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EARLY COPPER AGE SETTLEMENT WITH EVIDENCE OF COPPER SMELTING METALLURGY FROM HORNÁ MIČINÁ (CENTRAL SLOVAKIA)

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Keywords: *Slovakia, Western Carpathians, Early Copper Age, late Ludanice group, settlement, smelting pit, copper metallurgy, geophysical survey, elemental analysis, mineralogy, archaeobotany.*

Abstract: Early Copper Age settlement with evidence of copper smelting metallurgy from Horná Mičiná (Central Slovakia). *The presented paper shows the preliminary results of an archaeological and geophysical survey carried out in Horná Mičiná – Hájny diel (Central Slovakia). The site documents prehistoric settlement and is located outside the primarily agricultural area of the Zvolen basin. The magnetometric survey showed the existence of positive anomalies, suggesting the presence of settlement structures. The archaeological research revealed the existence of a settlement feature and a furnace pit. Elemental and mineralogical analyses witness the exploitation of local copper ores. On the basis of* ^{14}C *analysis, the settlement can be dated to early Eneolithic period. Further knowledge about the settlement are provided by archaeobotanical and osteological analyses.*

1 INTRODUCTION

In 2021 and 2022, the Frankfurt Archaeological Museum, in cooperation with the Slovak National Museum – Archaeological Museum in Bratislava (hereinafter "SNM – AM") and with organisation ArcheológiaSK, s. r. o., has conducted an archaeological research for scientific and documentary purposes in the cadastre of the municipality of Horná Mičiná (in the district of

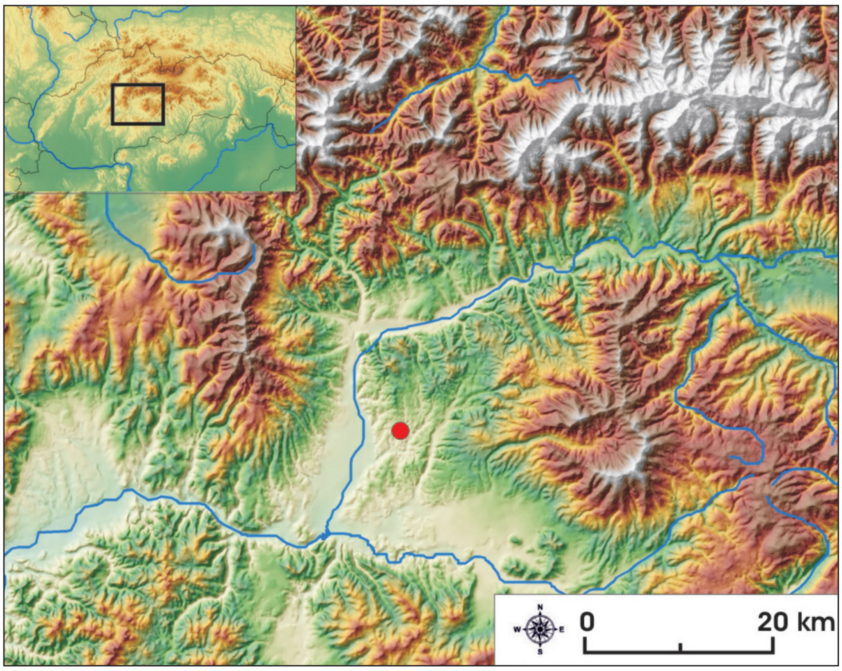

Fig. 1. Location of the Horná Mičiná site in Central Slovakia (source: www.stepmap.com, author: T. Zachar).
Obr. 1. Situovanie lokality Horná Mičiná na strednom Slovensku (zdroj: www.stepmap.com, autor: T. Zachar).

Banská Bystrica). The municipality is located in Central Slovakia, in the Zvolen basin. The studied site is named Hájny diel (542 m above the sea level) and it is located at the border between the Zvolen hilly area and the Banská Bystrica uplands. The Hron river flows around the surroundings of the site. The elevation with respect to the Hron river (constituting the axis of the Zvolen basin) measures about 170 m (Fig. 1). The first author to present Hájny diel as a site of findings of numerous lithic industry was G. Balaša (*1960*, 25). The lithic industry in this site was evaluated by M. Kvietok and Š. Ferenc (*2012*, 30). M. Solivajs and E. Kolton informed the authors of this article about the most recent findings documenting prehistoric copper metallurgy. The aim of the archaeological research was to clarify the character of the prehistoric settlement located outside the primarily agricultural area of the Zvolen basin (*Kvietok 2017*, 151, 152, obr. 1–3).

2 GEOPHYSICAL SURVEY

Vertical magnetometric gradiometry was selected as non-destructive prospection method in the studied site. Magnetometric survey belongs to the most important archaeogeophysical methods in practice (e.g. *Clark 1996*). Precise areal acquisition of Earth magnetic field was performed by means of the instrument SENSYS MXPDA with five fluxgate sensors. Distance between acquired lines was 0.25 m, sampling step along lines 0.1 m, accuracy of the measured magnetic field was ±1 nT. Determination of the measured points positions was performed directly in field by means of the instrument GNSS Trimble RS8 with applying of the SKPOS service. Acquired data were dumped from the instrument into a personal computer, median filter was applied to remove the so-called heading error, Gaussian low-pass filter was applied to remove the noise from the

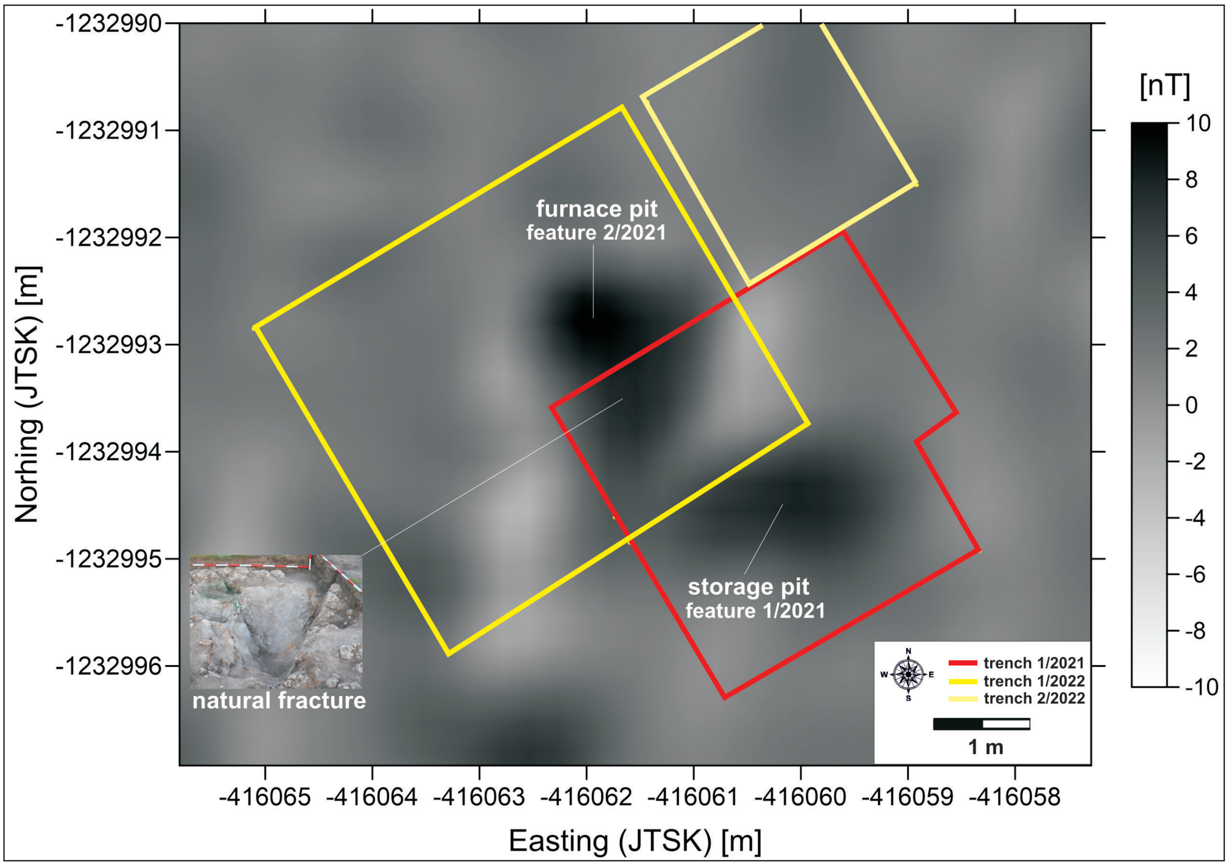

Fig. 2. Horná Mičiná – Hájny diel. Map of geomagnetic anomalies with plotted archaeological excavations and features (authors: R. Pašteka, T. Zachar).

Obr. 2. Horná Mičiná – Hájny diel. Mapa geomagnetických anomálií s vyznačenými archeologickými sondami a objektmi (autori: R. Pašteka, T. Zachar).

acquired data and finally the processed data were projected to a 0.2 m × 0.2 m grid in the coordinate system S-JTSK. Anomalous field of vertical gradient of the Earth magnetic field was then visualised in a form of areal image map with BW colour scale (Fig. 2), which was then qualitatively interpreted.

In the anomalous magnetic field, there are visible a relatively large amount of anomalies with small wavelength. Many of them have dipolar character (positive and negative parts in close vicinity), which are typical for recent iron (ferrous) objects. These were afterwards identified directly in field by means of a metal detector (iron nails, iron bottle covers, etc.).

Second category of anomalies was formed by relatively strong anomalies (several decades of nT) with almost monopolar character. These could be of natural objects, e.g. fillings with different character of soil, but also from man-made objects, like pits or thermal facilities (fireplaces, ovens, etc.). In the following interpretation and verification phase, we have focused on this type of anomalies and have selected some of them for the check by means of excavation. Archaeological survey from years 2021 and 2022 showed in the cases of intensive magnetic anomalies buried prehistoric settlement objects (storage pit and furnace pit), as also the existence of natural fracture filling in dolomites (Fig. 2). After analysing the whole map, we can expect in the surveyed part of the site more than 20 buried settlement objects.

Fig. 3. Horná Mičiná – Hájny diel. View of the uncovered storage pit (feature 1/2021; photograph: T. Zachar).

Obr. 3. Horná Mičiná – Hájny diel. Pohľad na odkrytú zásobnú jamu (objekt 1/2021; foto: T. Zachar).

3 ARCHAEOLOGICAL RESEARCH IN 2021–2022

The archaeological research in 2021 and 2022 focused on the uncovering of two significant geophysical anomalies (Fig. 2). The total studied surface was of 23,5 m^2.

The trench 1/2021 (size: 3 x 3 m) uncovered a pear-shaped storage pit with a mouth diameter of 140 cm and depth 125 cm. The storage pit was carved in a rocky dolomite subsoil (Fig. 3). The settlement pit contained pottery (Fig. 4), lithic and polished/ground stone artefacts (stone pads, a sharpener for arrow shafts), and various animal bones (54 pieces). Tentatively, we can conclude that domestic animals are dominating over wild fauna in the highly fragmentary osteological material. Sheep/goat and pig remains are predominant at the expense of bovine cattle. In the settlements of the Epilengyel groups in Central Europe, it is quite common to find similar storage pits (e.g. *Farkaš 1987*). The existence of above-the-ground habitations is documented by the presence of daub. The paleobotanical material is represented by charcoal. The archaeological research in 2021 and 2022 did not document house plans or stake pits. Feature 1/2021 shows a fragment of a metallurgical crucible and copper ore (Fig. 5: 1). In trench 1/2021 (around feature 1/2021), we also found a discontinuous cultural layer (thickness max. 20 cm). In the NW border of trench 1/2021, we have observed the margin of feature 2/2021 with a find of copper slag (Fig. 5: 3; *Zachar/Struhár/Bartík in print*). In 2022, trenches 1/2022 (4 x

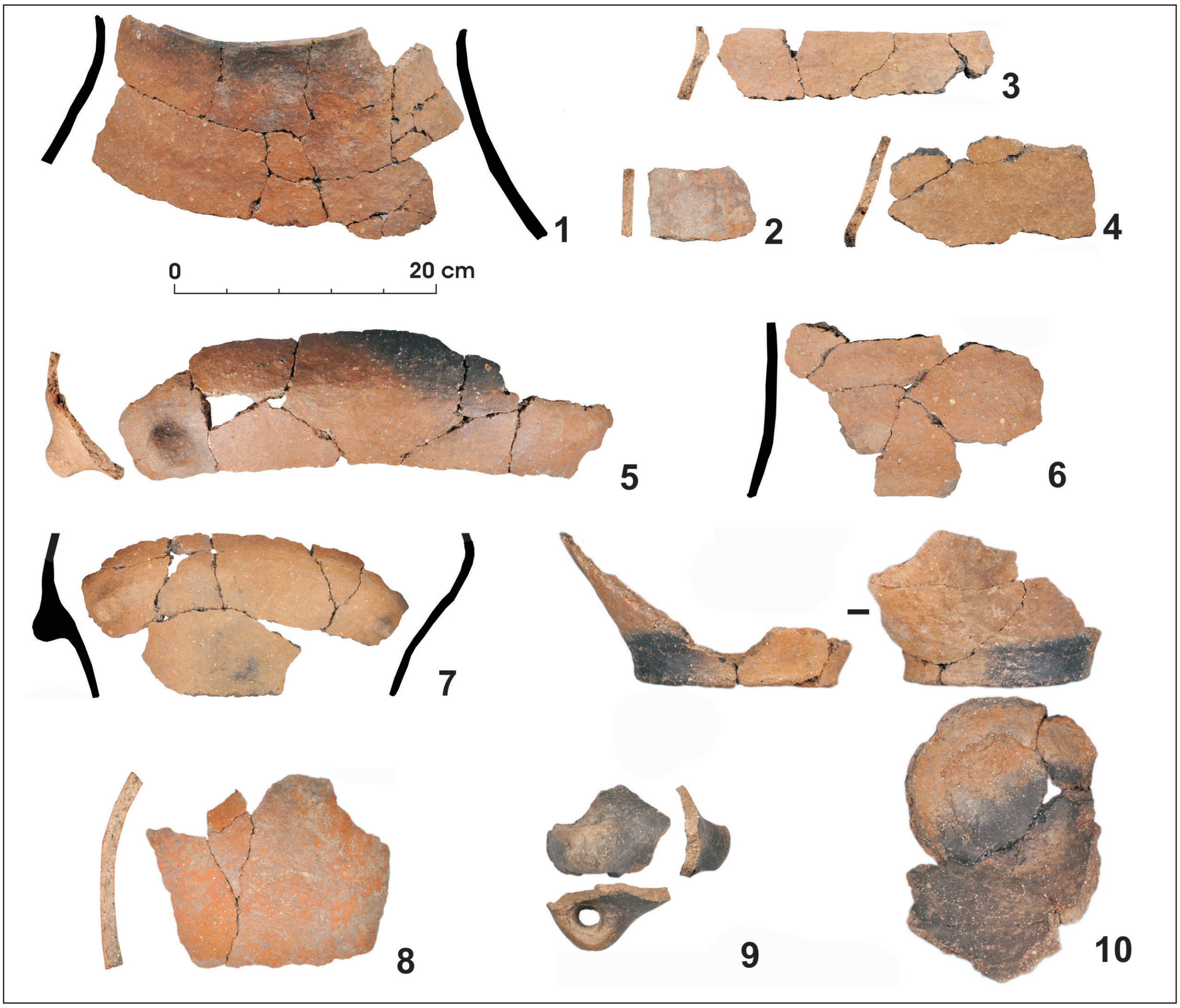

Fig. 4. Horná Mičiná – Hájny diel, trench 1/2021 and feature 1/2021. Selection of pottery (authors: T. Zachar, J. Bartík).
Obr. 4. Horná Mičiná – Hájny diel, sonda 1/2021 a objekt 1/2021. Výber keramiky (autori: T. Zachar, J. Bartík).

3,5 m) and 2/2022 (2 x 2 m) were demarcated. Trench 2/2022 contained a very small quantity of findings. In trench 1/2022, we have uncovered a furnace pit – feature 2/2021 (*Zachar/Bartík/Struhár in print*).

4 FURNACE PIT (FEATURE 2/2021)

The furnace pit (indicated as feature 2/2021) is an oval pit with size 80 x 70 cm and depth 40 cm. The pit contained melted copper ore (about 10 kg), a fragment of a metallurgical crucible containing copper ore, and some sporadic pieces of charcoal. The analysed pieces of charcoal come from unspecified coniferous (not pine) and deciduous wood (alder, willow or poplar). The feature was installed in a dolomite subsoil. The border of the pit was lined with smaller dolomite stones (Fig. 6). The smelting pit also included a so-called forehearth characterised by an irregular circular form, recessed in the gravel dolomite subsoil. Its diameter was 1,5 m and max. depth 50 cm. Apart from the remnants of the smelting pit, minute animal bones, and pieces of charcoal, the forehearth contained several fragments of pottery on the surface, with traces of copper slag. These elements can be interpreted as remains of larger vessels (diameter 30 cm) destined to metallurgical activities (Fig. 5: 4). Other metallurgical vessels with similar dimensions are known – for example – from

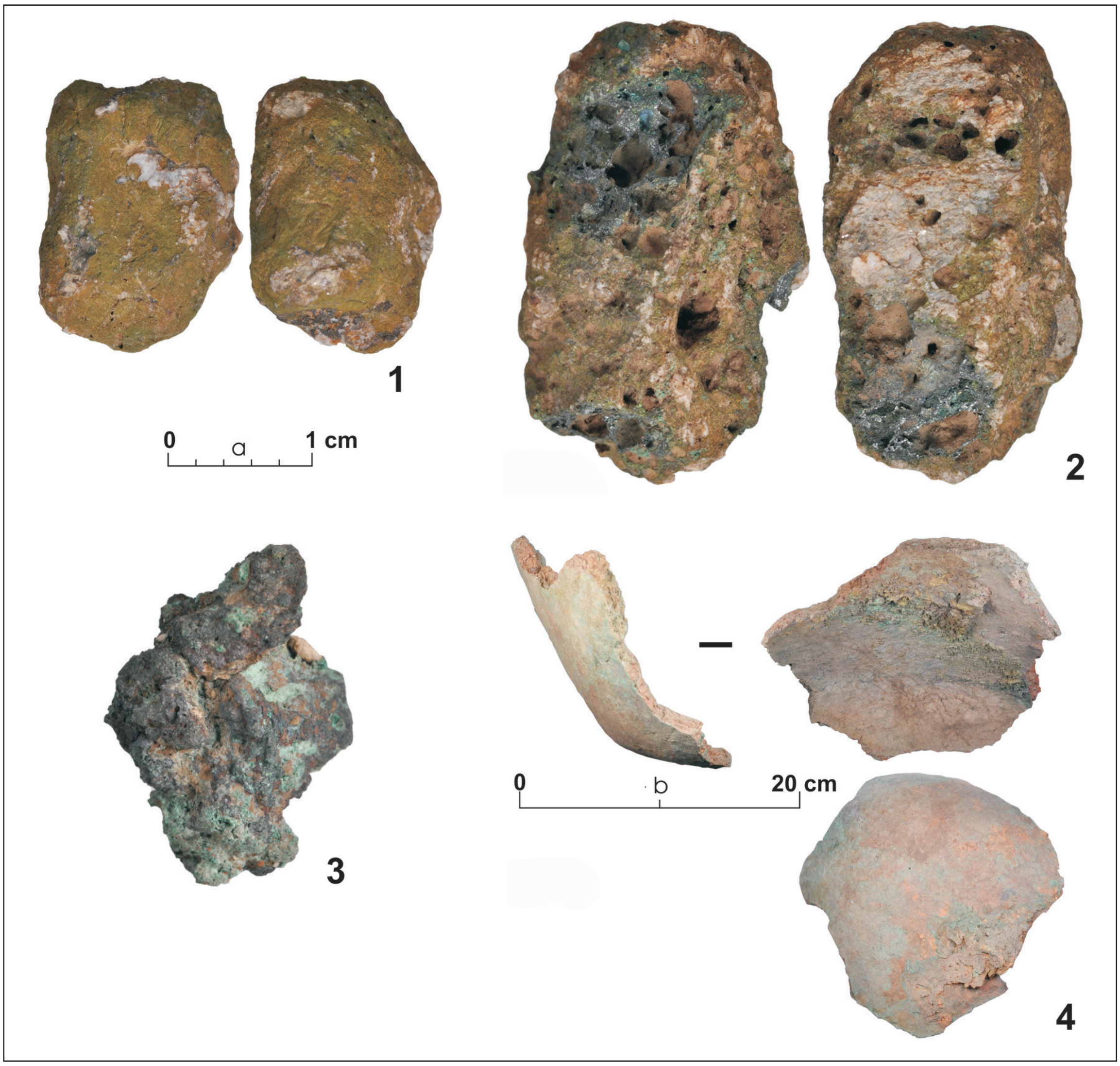

Fig. 5. Horná Mičiná – Hájny diel. Copper ore (1, 2) and slag (3) from trench 1/2021. Fragment of metallurgical vessel (4) from the furnace pit (feature 2/2021). Scale: a – 1–3, b – 4 (author: T. Zachar, J. Bartík).

Obr. 5. Horná Mičiná – Hájny diel. Medená ruda (1, 2) a troska (3) zo sondy 1/2021. Zlomok metalurgickej nádoby (4) z jamovej pece (objekt 2/2021). Mierka: a – 1–3, b – 4 (autor: T. Zachar, J. Bartík).

Copper Age in Spain (La Ceñuela). They are not defined as smelting crucibles, but they are known as smelting trays (*Rovira 2002*, 89, Fig. 3). In this site, they found no clay tips or blowpipe nozzles. Nevertheless, their existence at times of early Eneolithic period is witnessed in the territory of today's Slovakia with regard to the Ludanice group (*Beljak Pažinová/Beljak 2014*, 49, Fig. 44).

We can reconstruct the furnace pit as an excavated smelting pit with forehearth. Probably, copper ore was smelted in pottery vessels placed in the smelting pit by blowing into the ember (*Timberlake 2007*, 32–34, Fig. 5–8). So far, we are not able to explain in details the function of the forehearth. The findings' status corresponds to similar prehistoric metallurgical features known in Europe and the Near East (*Weisgerber 2004*). The function of simple furnace pit was checked even in an experimental manner (*de Zilva/Engelmann 2017*, 15, 16, Abb. 1, 2). We know several examples of extractive metallurgy from the times of early Eneolithic period in Central Europe (*Farkaš/Gregor 2013*); however, the furnace pit from Horná Mičiná represents a unique metallurgical feature for the time being.

Fig. 6. Horná Mičiná – Hájny diel. View of the excavated furnace pit (feature 2/2021; photograph: T. Zachar).

Obr. 6. Horná Mičiná – Hájny diel. Pohľad na odkrytú jamovú pec (objekt 2/2021; foto: T. Zachar).

5 DATING AND CULTURAL ASSIGNMENT OF THE SITE

For the purposes of absolute dating of the site, AMS ^{14}C was carried out on two selected samples. The sample no. 1 – in the shape of an animal bone (astragalus, sheep/goat) – comes from the filling of the storage pit (feature 1/2021). The second sample (charcoal) was lifted from the lower part (depth 35 cm) of the filling of the smelting pit (feature 2/2021). On the basis of the two calculated absolute dates (probability 95,4%), we can consider that the studied part of the settlement dates back to the years 3968 – 3708 cal BC (Fig. 7). The storage pit (feature 1/2021) and the furnace pit (feature 2/2021) are representative of one phase of the settlement and they might have been existed simultaneously.

In the first third of the 4th millennium BC, in the south-western part of Slovakia, we observe a cultural phenomenon known as pottery with furrowed incision (Bajč-Retz group). In Morava and in Lesser Poland, there are signs of settlements from the early phase of Funnelbeaker

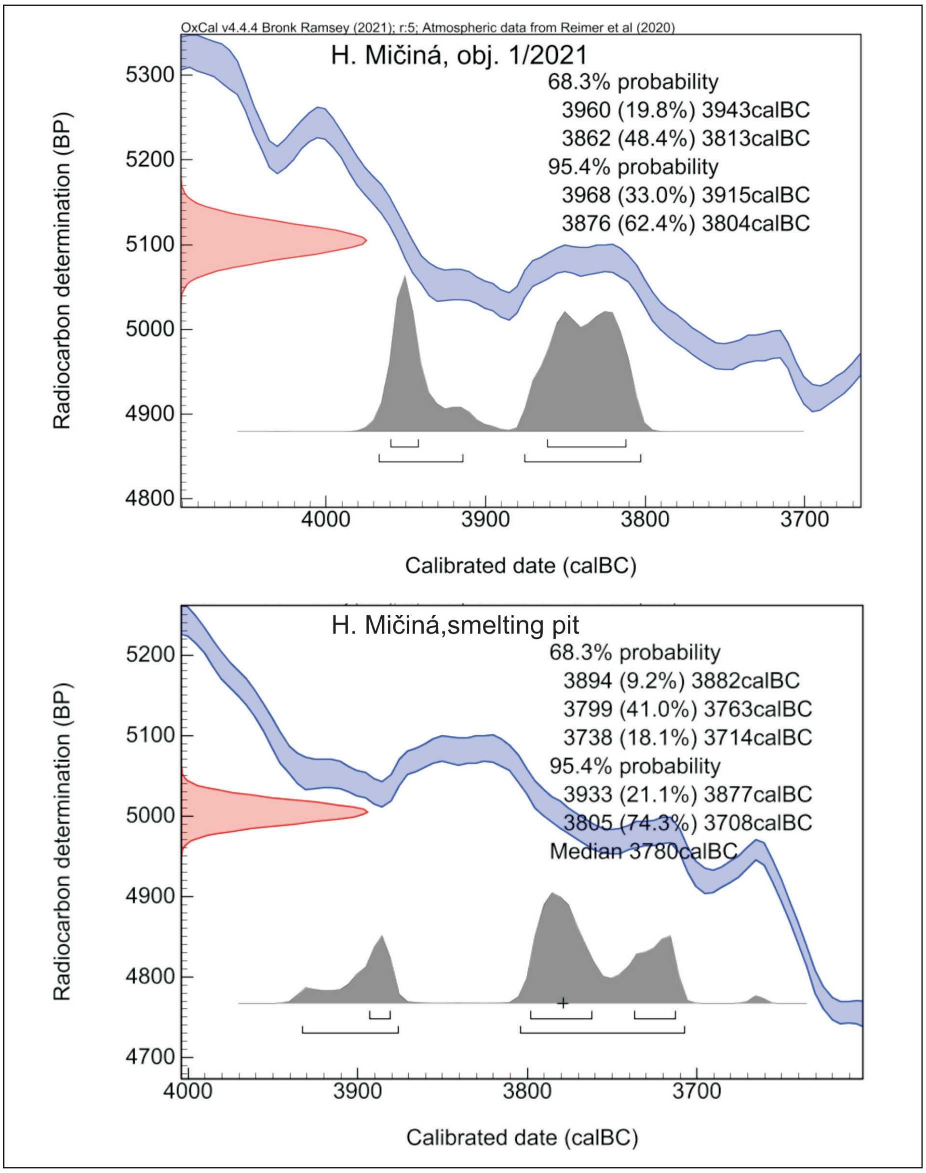

Fig. 7. Horná Mičiná – Hájny diel. Results of the ^{14}C analysis from feature 1/2021 and smelting pit (feature 2/2021; source: Radiochronology Lab C. E. N., Université Laval, Quebec, Canada).

Obr. 7. Horná Mičiná – Hájny diel. Výsledky analýzy ^{14}C z objektu 1/2021 a hutníckej jamy (objekt 2/2021; zdroj: Radiochronology Lab C. E. N., Université Laval, Quebec, Canada).

culture; their inhabitants moved from Southern Poland even to the bordering Liptov basin (Lisková; *Struhár 1999*). Influences of Funnelbeaker culture are also evidenced in the early phase of settlements in the nearby site of Slovenské Pravno. We connect this settlement with the late Ludanice group (*Nevizánsky/Šalkovský/Zachar 2017*, 39, 40, Fig. 2: 4). So far, with regard to pottery material, the archaeological research in Horná Mičiná did not show the presence of furrowed incision motifs or influences of Funnelbeaker culture. The pottery can be characterised as typical of the Epilengyel period (Fig. 4; *Gabulová et al. 2022*, 121–123, Fig. 42: A). For this reason, we link the Horná Mičiná settlement with the later stage of the Ludanice group. The cultural expression of these Epilengyel communities continued in the inner Carpathian basins – apparently unchanged – also during the time of pottery with furrowed incision in SW Slovakia (*Čambal et al. 2011*, 24–26).

6 ELEMENTAL ANALYSIS OF COPPER BASED FINDS

The elemental analysis of four samples was carried out in the conservation laboratory of the SNM – AM (measurement: B. Gábriková, samples no. 1 to 3; pXRF method) and in the CEZA centre in Mannheim (sample no. 4; ED-XRF[1]).

The sample no. 1 is a minute fragment of primary copper ore (feature 1/2021; Fig. 5: 1; Tab. 1: ID1). The sample no. 2 consists of a probably partially melted piece of copper ore (trench 1/2021; Fig. 5: 2; Tab. 1: ID2). The sample no. 3 is represented by copper slag (trench 1/2021; Fig. 5: 3; Tab. 1: ID3). The sample no. 4 represents the bottom part of the smelting pit (feature 2/2021; Fig. 6; Tab. 1: ID4). It shows compact dolomite gravel with traces of melted copper raw material.

The above-mentioned pXRF measurements of the Cu ore (samples no. 1 and 2) must be considered orientatively. Only the surface of the samples (surrounded by the relevant rock) was analysed. From the point of view of elemental composition, we could consider the origin of the four samples in a phenomenon called ore mineralisation, concerning a group of minerals of tetrahedrite. The factor that leads us to the above stated consideration is the dominance of Sb over As, as well as the contents of Ag and Bi. The basic metallurgical chain from ore to metal (*Hauptmann 2014*, 92, Fig. 5.1) can be reconstructed on the basis of the contents of As, Sb, and Cu. The highest amounts of As and Sb (max. 3.12% As; 9% Sb) are found in the two samples of primary copper ore (Tab. 1: ID1–2).

Significantly lower values (max. 0.094% As; 3.37% Sb) are found in the copper slag (Tab. 1: ID3). Compared to primary copper ore, the quantity of As and Sb (max. 0.2% As; 0.28% Sb) in the melted copper raw material from the bottom of the smelting pit shows very low values (Fig. 8; Tab. 1: ID4). These values correspond to the analyses of copper artefacts from early Eneolithic period in Central Europe (*Schreiner 2007*, 232–235).

For the above-mentioned reasons, it is evident that the contents of As and Sb are significantly reduced in the single metallurgical processes (*Pernicka 1999*, 169, 170, Tab. 1). At the same time, we observe an increase of the contents of Cu from primary ore (max. 26,29%) through slag (max. 61,58%) up to melted copper raw material

ID	Finds	Fig.	Method	Fe	Co	Ni	Cu	Zn	As	Ag	Sn	Sb	Au	Pb	Bi	Se	Te	Cd	In	Hg
1	Cu ore	5: 1	pXRF	11,287	<LOD	<LOD	14,623	0,098	2,894	0,162	<LOD	3,196	<LOD	<LOD	0,718	<LOD	n	<LOD	n	n
1	Cu ore	5: 1	pXRF	7,643	<LOD	<LOD	10,498	0,059	2,017	0,1	<LOD	3,413	<LOD	<LOD	0,495	<LOD	n	<LOD	n	n
2	Cu ore	5: 2	pXRF	5,012	<LOD	<LOD	8,808	0,123	0,908	<LOD	<LOD	6,396	<LOD	<LOD	0,229	<LOD	n	<LOD	n	n
2	Cu ore	5: 2	pXRF	7,579	<LOD	<LOD	26,297	0,377	3,121	<LOD	0,052	9,001	<LOD	<LOD	0,45	<LOD	n	<LOD	n	n
3	Cu slag	5: 3	pXRF	0,239	<LOD	<LOD	61,589	0,106	0,085	0,212	<LOD	3,361	<LOD	<LOD	1,014	<LOD	n	<LOD	n	n
3	Cu slag	5: 3	pXRF	1,13	<LOD	<LOD	44,5	<LOD	0,094	0,101	<LOD	3,37	<LOD	<LOD	0,388	<LOD	n	<LOD	n	n
4	Smelting pit	6	ED-XRF	0,27	<0,01	0,02	99	0,33	0,20	0,003	<0,005	0,288	<0,01	<0,005	0,01	<0,002	<0,005	0,002	<0,002	<0,01

Tab. 1. Results (%) of elemental analysis (pXRF, ED-XRF) copper-based finds from Horná Mičiná. Explanations: LOD – below detection limit; n – not analysed (author: T. Zachar).

Tabela 1. Výsledky (%) prvkovej analýzy (pXRF, ED-XRF) nálezov na báze medi z Hornej Mičinej. Vysvetlivky: LOD – pod detekčným limitom; n – neanalyzované (autor: T. Zachar).

[1] The sample is marked in CEZA Mannheim under number MA-225056.

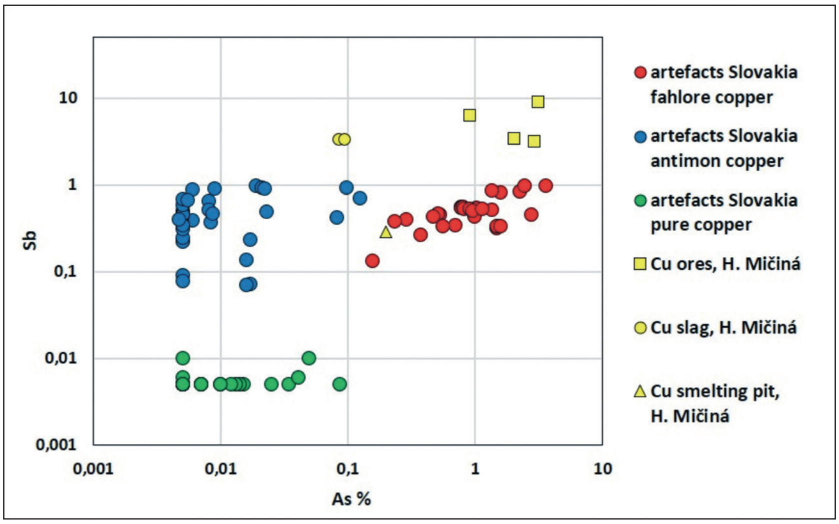

Fig. 8. A graphic comparison of the copper ores, slag and smelting copper from Horná Mičiná (yellow colour) to other artefacts from Slovakia, in terms of the As and Sb values (after *Schreiner 2007*; author: T. Zachar).

Obr. 8. Graf porovnania hodnôt As a Sb medenej rudy, trosky a vytavenej medi z Hornej Mičinej (žltá farba) s medenými artefaktmi zo Slovenska (podľa *Schreiner 2007*; autor: T. Zachar).

(99% Cu; Tab. 1: ID2–4). From the point of view of archaeological material groups (Fig. 8), the melted copper raw material (Tab. 1: ID4) belongs to the group of tetrahedrite copper (*Schreiner 2007*, 151), originally designated also as Handlová-type copper (*Schubert/Schubert 1999*).

7 MINERALOGICAL ANALYSIS

Sample 1: trench 1/2021, feature 1/2021 (Fig. 5: 1; 9C; Tab. 1: ID1; 2; 3): ore sample with tennantite and chalcopyrite, with intensively weather-worn mix of secondary predominant arsenate of olive-green colour. The most predominant amongst the non-metallic mineral is white quartz. Some various iron hydroxides are also present.

Sample 2: trench 1/2021 (Fig. 5: 2; 9D; Tab. 1: ID2): sample consisting in grey-black massive porous tennantite with green secondary minerals (mostly arsenate). The main rock is constituted by permian greywacke/arkose, where the main mineral is represented by white or grey-white quartz, with some portions of muscovite.

Sample 3: trench 1/2021, feature 2/2021, forehearth (Fig. 5: 3; Tab. 1: ID3): fragment of slag, with evident secondary green minerals, with predominance of malachite.

The samples of ore residues (Fig. 5: 1, 2) in the given site are made up of intensively altered tennantite-(Fe) or tetrahedrite-(Fe) (Fig. 9A), and further sulphides of copper – idaite (Cu_5FeS_6) and chalcopyrite ($CuFeS_2$). The chemical composition of minerals was studied by means of a Jeol JXA 8530FE electron analyser in the Earth Science Institute in Banská Bystrica. Within the chemical composition of minerals belonging to the tetrahedrite group – where single items can be expressed through the general formula $A_6(B_4C_2)D_4Y_{12}Z$ (*Biagioni et al. 2020*) – the studied samples always include the following elements (which are dominating in single positions):

– in position A: Cu
– in position B: Cu>Ag
– in position C: Fe>Zn
– in position D: Sb>As or Sb<As
– in position Y and Z: S

The dominance of elements in single positions identifies the mineral type. By considering the contents of single elements (Tab. 2, 3) and their ratios, it is possible to interpret the source area of the original raw material which was treated in the studied site. The average crystal-chemical formula of the tetrahedrite group minerals from Horná Mičiná is (n=14): $Cu_6[Cu_4(Fe_{1.50},Cu_{0.42},Zn_{0.18},Ag_{0.01},Mn_{0.01})_{2.12}]_{6.12}(Sb_{2.09},As_{1.93})_{4.02}S_{12.86}$. Here, amongst the mineral types, we find notably tennantite-(Fe) and – in lower amount – also tetrahedrite-(Fe). The chemical composition varies around the border between these two mineral types and it is relatively monotonous, which is reflected also during observation under electron microscope – where minerals are almost homogeneous (Fig. 9B).

The contents of the elements allowing some interpretations are notably Fe and Zn, but it is

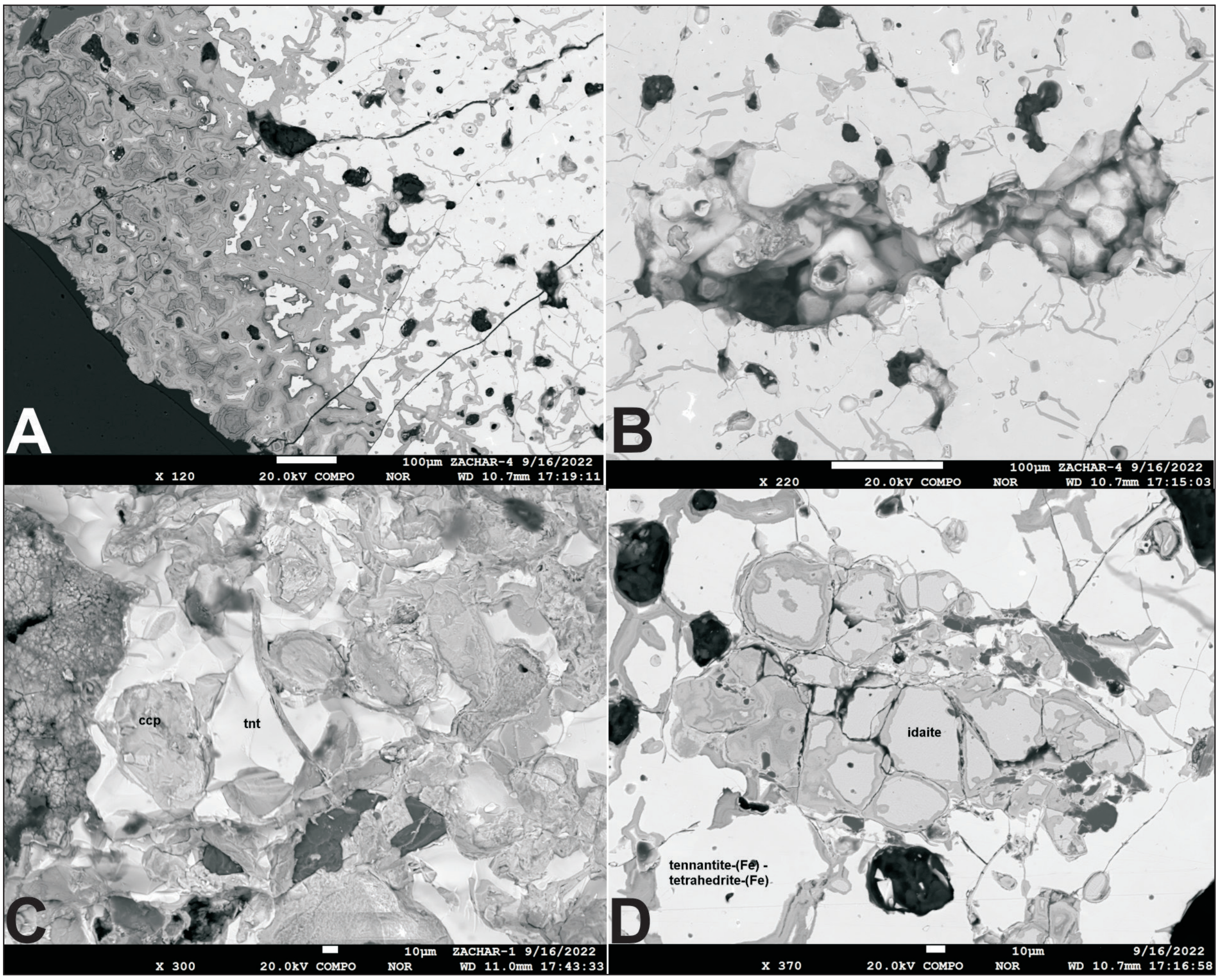

Fig. 9. Horná Mičiná. Mineralogical analysis. A (sample 1) – intensive process of alteration of porous tennantite-(Fe) (light grey, homogeneous). Secondary minerals (dark grey, zonal) push out the primary mineral and various mixed phases are formed, composed with Fe, Cu, Zn, As, Sb, S, O, and sometimes even P (BSE). B (sample 2) – mineral of the tetrahedrite group with more or less the same Sb/As ratio, from Horná Mičiná. The cavity is filled with unspecified secondary Cu-As mineral (BSE). C (sample 2) – photograph of the surface with electron microanalyser in backscattered electron mode (BSE). Tennantite-(Fe) (tnt) is white; besides it, on the left, there is chalcopyrite (ccp); the other parts are supergeneous minerals, predominantly copper. D (sample 2) – idaite (grey) in tennantite-(Fe) – tetrahedrite-(Fe) (light grey), intensively pushed along grain margins and along fissures by secondary copper minerals (darker grey, zonal). BSE (photograph: D. Ozdín).

Obr. 9. Horná Mičiná. Mineralogická analýza. A (vzorka 1) – intenzívny proces alterácie porézneho tennantitu-(Fe) (svetlosivý, homogénny). Sekundárne minerály (tmavšie sivé, zonálne) zatláčajú primárny minerál a vznikajú rôzne zmesné fázy zložené s Fe, Cu, Zn, As, Sb, S, O a niekedy aj P (BSE). B (vzorka 2) – minerál tetraedritovej skupiny s približne rovnakým pomerom Sb/As z Hornej Mičinej. Dutina je vyplnená bližšie neidentifikovaným sekundárnym minerálom Cu-As (BSE). C (vzorka 2) – fotografia povrchu z elektrónového mikroanalyzátora v režime spätne rozptýlených elektrónov (BSE). Tennantit-(Fe) (tnt) je biely, vedľa neho na ľavo je chalkopyrit (ccp), ostatné sú supergénne minerály prevažne medi. D (vzorka 2) – idait (sivý) v tennantite-(Fe) – tetraedrite-(Fe) (svetlosivé), intenzívne zatláčaný po okrajoch zŕn a po puklinách sekundárnymi minerálmi medi (tmavšie sivé, zonálne). BSE (foto: D. Ozdín).

also noteworthy to observe the absence of the most significant concentrations of elements such as Ag, Hg, and Bi. The most relevant for the provenance of samples of ore with minerals from the tetrahedrite group are notably the ratios of Fe/Zn and Sb/As (Fig. 10). The content of Fe varies in a range between 4.81 and 5.53 wt% (1.36–1.55 *apfu*) and Zn 0.29–1.03 wt% (0.07–0.25 *apfu*). The Sb/As ratio is in a range between 0.92–1.57 *apfu*, avg. 1.08 *apfu*. The

Element / Anal.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Average
Ag	0,12	0,16	0,12	0,08	0,12	0,08	0,09	0,11	0,09	0,11	0,10	0,09	0,10	0,07	0,10
Cu	41,59	42,13	42,32	41,96	42,15	42,01	42,11	42,17	42,55	41,87	41,89	42,12	42,45	42,18	42,11
Hg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Fe	5,43	5,40	5,37	5,17	5,30	5,13	5,44	5,39	4,81	5,43	5,43	5,28	5,25	5,53	5,31
Zn	0,74	0,91	0,60	0,80	0,53	0,60	0,93	1,03	0,93	0,57	0,78	0,29	0,86	0,68	0,73
Cd	0,02	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,01	0,00	0,02	0,01	0,00	0,01	0,00
Mn	0,00	0,04	0,02	0,00	0,00	0,00	0,01	0,04	0,05	0,04	0,03	0,00	0,01	0,01	0,02
Pb	0,04	0,02	0,01	0,02	0,03	0,07	0,06	0,04	0,04	0,05	0,01	0,04	0,06	0,10	0,04
Sb	15,81	16,64	16,72	16,11	16,39	16,72	15,18	15,02	15,22	16,80	16,47	18,85	15,25	15,04	16,16
As	9,34	8,68	8,91	8,75	9,15	9,05	9,66	10,11	9,69	9,02	9,25	7,39	9,97	10,04	9,21
Bi	0,05	0,00	0,00	0,16	0,00	0,01	0,08	0,00	0,00	0,00	0,03	0,00	0,00	0,00	0,02
S	25,64	26,86	26,13	26,23	25,69	26,48	26,13	26,18	25,94	25,95	26,05	26,30	26,78	26,83	26,23
Se	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,00	0,00	0,00	0,00
Te	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cl	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,01	0,00
Sum	98,77	100,85	100,19	99,28	99,37	100,15	99,68	100,08	99,33	99,84	100,09	100,36	100,72	100,48	99,94

Tab. 2. Electron microanalysis of tennantite from sample 1 in Horná Mičiná (in wt%; author: D. Ozdín).
Tabela 2. Elektrónové mikroanalýzy tennantitu zo vzorky 1 z Hornej Mičinej (v hm. %; autor: D. Ozdín).

Element / Anal.	1	2	3	4	5	6	7	8	Average
Ag	0,55	0,66	0,21	0,19	0,16	0,17	0,28	0,22	0,31
Cu	53,42	53,40	56,43	55,76	55,92	55,87	56,03	55,49	55,29
Hg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Fe	13,47	13,78	11,86	12,44	12,52	12,34	12,68	12,72	12,73
Zn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cd	0,00	0,00	0,01	0,00	0,02	0,00	0,00	0,02	0,01
Mn	0,00	0,00	0,00	0,02	0,00	0,02	0,00	0,00	0,01
Pb	0,02	0,05	0,05	0,01	0,04	0,07	0,06	0,08	0,05
Sb	0,12	0,18	0,14	0,10	0,13	0,11	0,05	0,10	0,12
As	0,01	0,00	0,00	0,00	0,02	0,02	0,02	0,11	0,02
Bi	0,38	0,40	0,30	0,41	0,51	0,48	0,51	0,52	0,44
S	30,71	30,18	29,62	29,79	29,50	29,72	29,52	30,22	29,90
Se	0,01	0,00	0,00	0,02	0,00	0,13	0,00	0,02	0,02
Te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00
Cl	0,00	0,00	0,02	0,03	0,02	0,00	0,03	0,01	0,01
Sum	98,67	98,65	98,63	98,75	98,81	98,92	99,17	99,51	98,89

Tab. 3. Electron microanalysis of idaite from sample 1 in Horná Mičiná (in wt%; author: D. Ozdín).
Tabela 3. Elektrónové mikroanalýzy idaitu zo vzorky 1 z Hornej Mičinej (v hm. %; autor: D. Ozdín).

Fe/Zn has a much higher dispersion of values and ranges between 6.08–21.32 *apfu* (avg. 8,50 *apfu*).

On the basis of so far published data about the chemical compositions of tetrahedrite group minerals from deposits and occurrences in the wider area of Banská Bystrica (*Ferenc et al. 2019*; *Luptáková et al. 2016*; *Majzlan et al. 2018*; *Michňová 2009*; *Michňová/Ozdín 2010*; D. Ozdín – private archive of unpublished analyses; *Sejkora/Števko/Macek 2013*), the following places can be excluded from the list of potential original sites: Polkanová, Staré Hory – Haliar, Staré Hory – Richtárová, Špania Dolina – Piesky,

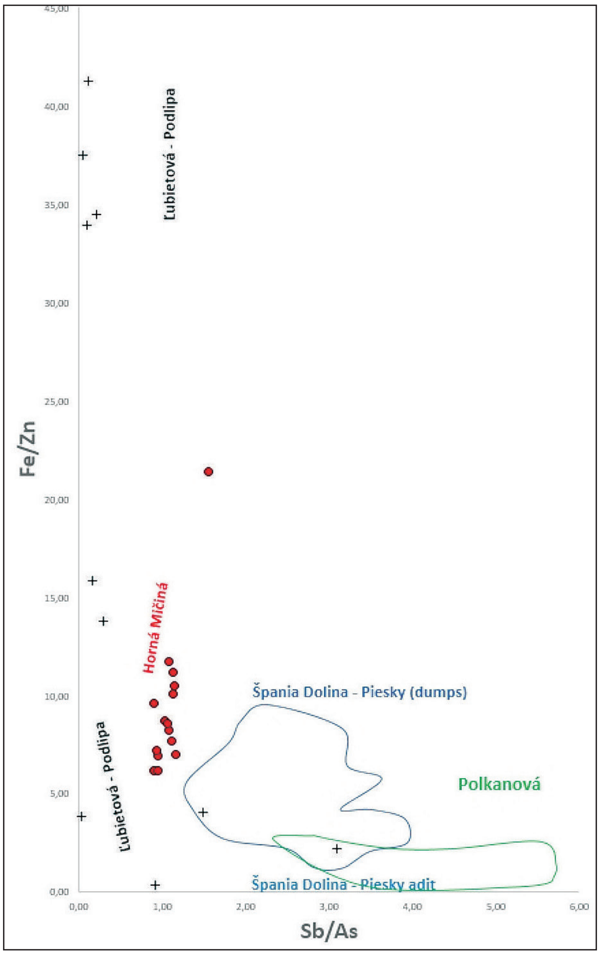

Fig. 10. Diagram of the Fe/Zn and Sb/As ratios (in *apfu*) regarding the minerals of the tetrahedrite from Horná Mičiná and some other Cu deposits and occurrences in the wider area of Banská Bystrica (author: D. Ozdín).

Obr. 10. Diagram pomerov Fe/Zn a Sb/As (v *apfu*) minerálov tetraedritovej skupiny z Hornej Mičinej a niektorých ďalších Cu ložísk a výskytov v širšom okolí Banskej Bystrice (autor: D. Ozdín).

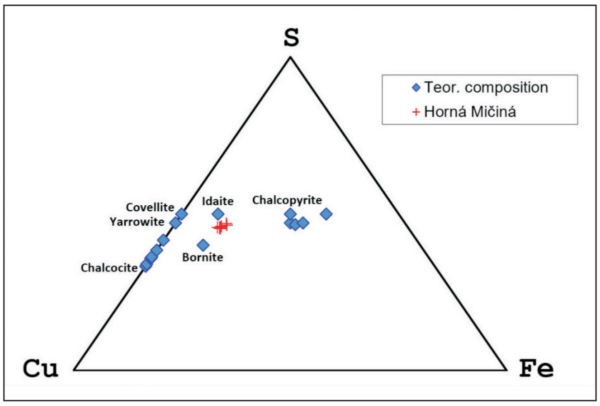

Fig. 11. Triangular diagram of idaite from Horná Mičiná and selected theoretical compositions of minerals in the Cu-Fe-S system (in *apfu;* author: D. Ozdín).

Obr. 11. Trojuholníkový diagram idaitu z Hornej Mičinej a vybraných teoretických zložení minerálov v systéme Cu-Fe-S (v *apfu;* autor: D. Ozdín).

Ľubietová – Podlipa, Ľubietová – Svätodušná and Kolba and Ľubietová (Brusno) – Peklo valley. Moreover, if the samples from Horná Mičiná were to come from the Ľubietová locations (Svätodušná and Kolba), they would have to contain Ni and Co; indeed, these minerals are very abundant in these deposits and the samples should have a different rock background. In other words, since the chemical composition of tetrahedrite group minerals excluded farther sites, the most probable sources of ore in the archaeological site close to Horná Mičiná would be the nearby sites of Poniky – Drienok, Poniky – Farbište or Ľubietová – Driekyňa. So far, from these sites, we do not have any data about the exact chemical composition of tetrahedrite group minerals; nevertheless, it is known that they are likely to be tennantites (*Ďuďa/Ozdín 2012*; *Koděra et al. 1986–1990*), which is evident also on the basis of the presence of secondary minerals – copper arsenates. Furthermore, the tennantites from Špania Dolina – Piesky are often characterised by chemical zonality, whereas the sample from Horná Mičiná is almost homogeneous.

Amongst other mineral, here we have identified chalcopyrite ($CuFeS_2$, Fig. 9C) and iron sulphide and copper – idaite, so fare quite rare in Slovakia (Fig. 9D). Idaite forms minute aggregates in the tennantite-(Fe). The average crystal-chemical formula of the idaite from Horná Mičiná (n=8) is: $(Cu_{5.12},Ag_{0.02})_{5.14}(Fe_{1.34},Sb_{0.01},Bi_{0.01})_{1.36}S_{5.49}$ or ideally $(Cu_{3.84},Ag_{0.01})_{3.85}(Fe_{1.01},Bi_{0.01})_{1.02}S_{4.12}$. The triangular diagram (Fig. 11) shows that the mineral is not ideally stoichiometric; however, the closest theoretical composition of this mineral is that of idaite.

The occurrence of porous ore (Fig. 5: 1, 2) as well as of idaite and intensively weather-worn Cu-Fe sulphides shows that the source of the raw material was constituted by surface parts of ore formation (quite probably in Permian rocks).

Taxon name	**Remains**	**Number of specimens**	**State of preservation**
Triticum monococcum	*s*	5	*ch*
T. monococcum	*g*	2	*ch*
T. monococcum vel T. dicoccon	*s*	2	*ch*
T. monococcum vel T. dicoccon	*g*	139	*ch*
Triticum dicoccon	*g*	1	*ch*
Cerealia	*c*	16	*ch*
cf. Cerealia (very small)	*c*	82	*ch*
cf. Cerealia	chaff	2	*ch*
Brassicaceae	*s/f*	1	*ch*
Bromus sp.	*c*	3	*ch*
Chenopodium sp.	*s/f*	3	*ch*
cf. *Polygonum convolvulus*	*s/f*	1 (4 fragments)	*ch*
Vicia	*s/f*	1	*ch*
Indet	*s/f*	10	*ch*
Indet	Testa	3	*ch*

Tab. 4. Plant remains found in the sample from feature 1/2021 from Horná Mičiná. Explanations: c – caryopsis; g – glume; s – spikelet; s/f – seeds and fruits; ch – charred (author: A. Stobbe).

Tabela 4. Rastlinné zvyšky nájdené vo vzorke z objektu 1/2021 z Hornej Mičinej. Vysvetlivky: c – zrno; g – pleva; s – klas; s/f – semená a plody; ch – zuhoľnatené; autor: A. Stobbe).

8 PRELIMINARY ARCHAEOBOTANICAL INVESTIGATIONS

During an excavation in 2021, a soil sample was taken from a pit (feature 1/2021) at a depth of 80 cm and handed over to the Laboratory for Archaeobotany of the University of Frankfurt in February 2023 for a screening.[2] The aim was to check whether plant material was present and in what condition. Before processing the sample, the displacement volume was measured (7,2 l). The sample was wet-sieved, with a finest mesh size of 0,315 mm. The botanical nomenclature follows E. Oberdorfer (*2001*).[3]

Besides charred plant remains, other material classes like bone fragments, a fish scale, molluscs and charcoal were present in the samples. A total of 271 botanical macro-remains was found. 249 of the remains were from cereals. These are caryopses, together with threshing remains. The poor preservation is responsible for the fact that a considerable proportion of the spelt wheat remains found could only be addressed as *Triticum dicoccon/Triticum monococcum* and that it was not possible to reliably specify the caryopses. Brassicaceae, *Bromus* sp., *Chenopodium* and *Polygonum convolvulus* were among the detectable wild plants (Tab. 4).

Archaeobotanical analyses of Copper Age sites in Slovakia are only available in a few cases. The Nitra, site Selenec about 100 km SW of Horná Mičiná is comparable, where emmer (*Triticum dicoccum*) and einkorn (*Triticum monococcum*) were also found as the main cereals (*Mihályiová 2022*). From an ash layer in the Lisková cave, about 50 km north of Horná Mičiná, the two types of spelt wheat were also found, but each with only one caryopsis (*Struhár 1999*, 205, tab. I). Overall, the state of research for the Copper

[2] For carrying out the archaeobotanical analysis we thank Apl. Prof. Dr. Astrid Stobbe z Archaeobotanical Laboratory, Institute of Archaeological Sciences, Johann Wolfgang Goethe University, Frankfurt am Main.

[3] The botanical identification was done by L. Rühl.

Age is also poor in neighbouring countries such as Romania, Hungary or Croatia (*Reed 2017*), but the occurrence of the two spelt wheats emmer and einkorn in the Horná Mičiná is documented.

9 CONCLUSION

The archaeological and geomagnetic research in Horná Mičiná (district of Banská Bystrica) documented the existence of a settlement from early Eneolithic period. The site and its close surroundings are located outside the agricultural area of the Zvolen basin, at the border between the Zvolen hilly area and the Banská Bystrica uplands (Fig. 1). Permanent settlement activities are witnessed by a storage pit (feature 1/2021) dug into dolomite subsoil (Fig. 2, 3). The storage pit and the settlement layer in its surroundings contained pottery of Epilengyel tradition (Fig. 4), lithic industry, daubs, and evidence of copper ore processing (Fig. 5: 1–3). Animal bones indicate the importance of sheep/goat and pig farming. The paleobotanical analysis has confirmed direct consumption of cereals in the given site. The most significant finding is represented by a furnace pit (feature 2/2021). It included a smelting pit and a forehearth (Fig. 2, 6). The storage pit and the furnace pit can be dated to 3968–3708 cal. BC (Fig. 7). Metallurgical vessels destined to processing of copper ore were found in the furnace pit (Fig. 5: 4). The results of the elemental analysis (Tab. 1) of copper ore, slag, and melted copper raw material from the smelting pit in Horná Mičiná document the production of tetrahedrite copper. The use of tetrahedrite copper is also documented by the analyses of some copper artefacts from the same period found in the area of Western Carpathians (Fig. 8). Even mineralogical analysis are in line with the above-mentioned findings. They confirmed that – in this site – they used to process copper ore from the group of tennantite minerals (Tab. 2, 3; Fig. 9). The origin of such copper ore can be found in local deposits in Central Slovakia. On the basis of a preliminary mineralogical analysis, we don't exclude ore deposits in the nearby municipality of Poniky (Fig. 10). The existence of a settlement in Horná Mičiná can be connected to later Ludanice group that was synchronous with pottery with furrowed incision, widespread in the mid Danubian region.

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SÍDLISKO S DOKLADMI HUTNÍCTVA MEDI Z OBDOBIA STARŠIEHO ENEOLITU Z HORNEJ MIČINEJ (STREDNÉ SLOVENSKO)

Tomáš Zachar – Juraj Bartík – Víťazoslav Struhár – Daniel Ozdín – Roman Pašteka – Miriam Nývltová Fišáková – Wolfgang David

V priebehu rokov 2021 a 2022 uskutočnilo Archeologické múzeum vo Frankfurte nad Mohanom v spolupráci s Slovenským národným múzeom – Archeologickým múzeom v Bratislave a organizáciou ArcheológiaSK, s. r. o. archeologický výskum v katastri obce Horná Mičiná (okr. Banská Bystrica). Význam lokality spočíva v špecifickej polohe sídliska na rozhraní Zvolenskej pahorkatiny a Bystrickej vrchoviny v nadmorskej výške okolo 542 m n. m. Prevýšenie voči rieke Hron ako hlavnému toku Zvolenskej kotliny, vzdialenom približne 2,3 km, tvorí asi 170 m (obr. 1).

Plošne obmedzenému archeologickému výskumu (23,5 m^2) predchádzal geofyzikálny prieskum, ktorý identifikoval na ploche lokality viaceré pozitívne anomálie (obr. 2). Okrem nesúvislej kultúrnej vrstvy (max. 20 cm), trvalejšie sídliskové aktivity dokladá sídlisková jama (objekt 1/2021 v sonde 1/2021) v podobe zásobnice zahĺbenej do dolomitového podložia (obr. 3). Z jej výplne a z okolitej kultúrnej vrstvy pochádza keramika epilengyelského charakteru (obr. 4), brúsená a štiepaná kamenná industria, mazanica, kostené šidlo/dierkovač, fragment metalurgického téglika, medená ruda (obr. 5: 1, 2), nepočetné zvieracie kosti (dominuje ovca/koza a ošípaná) a uhlíky. Paleobotanická analýza vzorky zo zásobnice doložila konzumáciu obilovín priamo na lokalite (tabela 4). Dôkazy nadzemných konštrukcií (kolové jamy, príp. žľaby) výskum v rokoch 2021 a 2022 nepriniesol, ich existenciu ale naznačuje mazanica.

Priestorové situovanie lokality umocňujú doklady spracovania medenej rudy v podobe termického objektu (objekt 2/2021 v sonde 1/2021 a 1/2022). Odkrytá jamová pec (obr. 6) pozostávala z oválnej hutníckej jamy (rozmery 80 x 70 cm, hĺbka 40 cm) a predpecnej jamy (priemer 1,5 m, hĺbka 50 cm). Výplň hutníckej jamy tvorila natavená medená ruda (spolu ca. 10 kg), fragment metalurgického téglika a sporadicky uhlíky. Z predpecnej jamy pochádza medená troska (obr. 5: 3) a fragmenty rozmernejších nádob (priemer dna ca. 30 cm) určených na hutnenie medenej rudy (obr. 5: 4). Odkrytú časť sídliska môžeme na základe metódy ^{14}C datovať medzi roky 3968 až 3708 cal BC (obr. 7).

Prvková analýza (pXRF; ED-XRF; tabela 1) medenej rudy (obr. 5: 1, 2), trosky (obr. 5: 3) a vytavenej medi z dna hutníckej jamy (obr. 6) ukázala, že na lokalite bola produkovaná tetraedritová meď, ktorá odpovedá medeným artefaktov z obdobia staršieho eneolitu z územia dnešného Slovenska (obr. 8). Tieto poznatky potvrdila aj mineralogická analýza (obr. 9; 11; tabela 2, 3). Pôvod spomenutého typu medi, v minulosti označený aj ako meď typu Handlová, môžeme hľadať v lokálnych (napr. Poniky; obr. 10) mineráloch zo skupiny tennantitu. S ohľadom na doterajšiu absenciu keramiky zdobenej brázdeným vpichom sídlisko môžeme nateraz priradiť nositeľom neskorej ludanickej skupiny.

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