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Raw material trade and/or itinerant artisans? Data for a diachronic study of the trade in copper raw materials and finished products in the Carpathian Basin

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ABSTRACT

Copper is one of the most important raw materials in the Carpathian Basin, and its extraction, processing and trade can be traced at least from the Bronze Age to the Middle Ages and beyond. Drawing on a variety of sources and research methods, the authors explore the patterns of distribution of this raw material in Europe. The aim of the diachronic analysis is to uncover the networks of connections – commercial, cultural, and migratory – that can be traced over the long term in the Central European region. It also draws attention to other, less stable links in the Carpathian Basin, which have also influenced the history of the region in certain periods.

KEYWORDS

Bronze Age, Middle Ages, Carpathian Basin, copper production, copper trade, diachronic investigation

INTRODUCTION

One of the determining factors in the development of crafts is the raw material, its type, availability, and transport. In the Carpathian Basin, the presence of metalworking can be traced back to very early times. The importance of this was recognised by Ferenc Pulszky when, at the Eighth Congress of Prehistory and Anthropology held in Budapest in 1876, he suggested that the triple division of the European prehistory – Stone, Bronze, and Iron Ages – should be supplemented by the Copper Age.¹ The great importance of the raw material resources of South-Eastern Europe in the fifth to fourth millennia BCE is demonstrated by the spread of large copper tools from the Carpathian Basin to present-day Bulgaria, and the absence of copper artefacts in the contemporaneous western European areas beside the spread of jade axes.²

In the archaeological and historical periods mining and metallurgy, although to varying degrees, were always present in the region, thanks to the numerous mineral resources of the Carpathian Basin (Fig. 1). From the point of view of copper, the Roman period and the late Middle Ages and Early Modern period stand out alongside the Copper and the Bronze Ages, when this raw material played a particularly important role in the economy of the study area.

¹Pulszky (1883); Horváth and M. Virág (2003); Siklósi and Szilágyi (2019).

²Dominguez-Bella et al. (2016) Fig. 1.

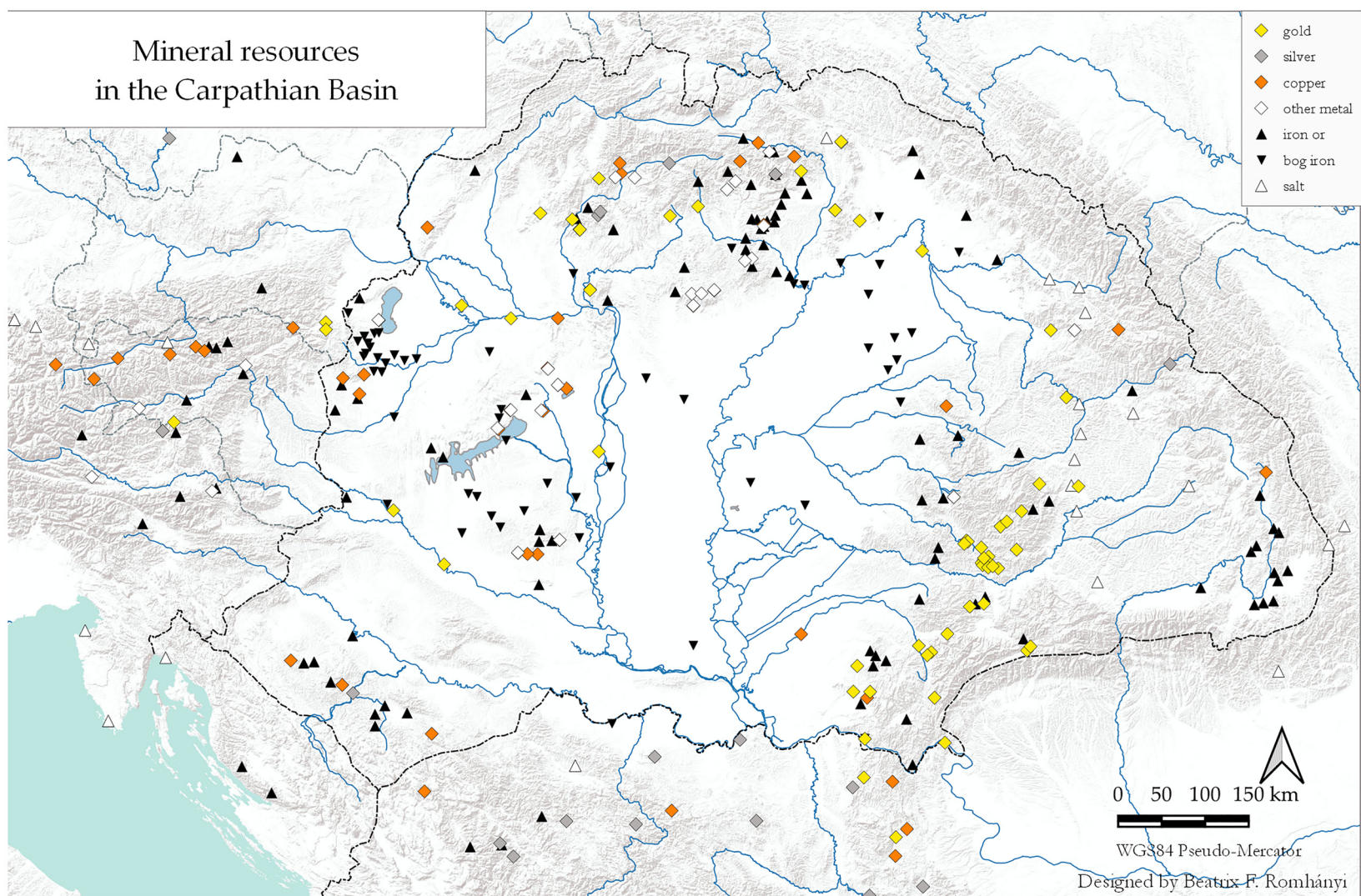


Fig. 1. Mineral resources in the Carpathian Basin.

Map signs are not proportional to volume. The exploitation of each mineral resource has varied over time. Some deposits could only be exploited economically in modern times others were abandoned because of technological progress

In the wider region of Central Europe (e. g., in the Saxo-Bohemian Ore Mountains, the Eastern Alps, the Northern Carpathians, the Vihorlat-Gutin Mountains, the Transylvanian Ore Range and the Timok Massif),³ the analysis of the distribution of objects and their raw materials in the prehistoric periods⁴ is supported by the bioarchaeological data of human remains, while in later periods written sources provide further information. For example, using bioarchaeological methods (DNA and stable isotope analyses), it has become clear that metalworking in the British Isles around 2500 BCE – contemporaneous with the dawn of the Bronze Age in the Carpathian Basin, and 2000 years after the spread of the first copper jewellery found in the Great Hungarian Plain(!) – can be linked to communities migrating from the continent.⁵ This multidisciplinary approach provides an insight into the complex system of movement of people, objects, and technologies.

We have very few raw material analyses for the Middle Ages.⁶ Written sources, on the other hand, can shed direct light on relationships that can only be examined indirectly in periods without written sources. The copper trade was of particular importance between the fourteenth and sixteenth centuries, so it is worth comparing the medieval system of mining districts and trade networks with prehistoric patterns. Although our research has focused mainly on these two periods, in some cases we have also included data from the Roman Age, to demonstrate that the knowledge of the raw material deposits was not lost, even if their cultivation was not continuous.

In this study, we use archaeological and historical data to outline the possible periods of cultivation of some of the most important ore deposits (mainly copper), the presumed routes of transport of the raw material and the networks of its commercial circulation.

³Czajlik et al. (2012a, 2012b); Radiivojević et al. (2019). In addition to the better-known regions, research on the Apuseni Mountains has also recently been revived (Papalas, 2008; Duffy, 2014; Quinn et al., 2020).

⁴In the 1960s and 1970s, a large-scale metal analysis programme was started in Stuttgart (*Studien zu den Anfängen der Metallurgie* – SAM; Junghans et al., 1968; Junghans et al., 1974). With the addition of later analyses, there are now more than 35,000 analytical data from the European prehistoric period (Pernicka, 1995; Krause, 2003).

⁵Fitzpatrick (2011); Olalde et al. (2018).

⁶One of the rare exceptions is Benkő and Barkóczy (2017). According to the results of the material analysis, the corner pieces and other decorative elements of the book bindings found in the area of the Pilis Abbey came from the South German regions not only in terms of style and parallels, but also in terms of their material. Actually, even prehistoric research only in the earliest period of metal use, mainly before the Late Bronze Age, expects that compositional analysis of bronze objects can be used to determine the origin of the copper raw material. D. Liversage states that the tin content of bronze objects in the period of the appearance of tin bronzes is on average quite high (between 5 and 10%). This suggests that the mixing of copper and bronze objects was not common (Liversage, 1994, 77). Recently, the analysis of recycled raw materials has also started (Berger et al., 2022; Bray, 2022). In later periods, e. g. in the Roman Age, it is known from written sources that copper and bronze objects were repeatedly melted down and recycled (Sey, 2015, 21).

THE BEGINNINGS OF METALWORKING AND RESEARCH OF PREHISTORIC COPPER PROCESSING IN THE WIDER CARPATHIAN BASIN

The use of metals in Central Europe developed mostly along the geology of ore deposits. Accordingly, the first ores used were those of the crop zone and the near-surface zone containing oxides-carbonates (cuprite, malachite, azurite). In the mountains weathering of the rock surface allowed the ores to be brought to the surface, so that, in addition to the 10 kg ore 'flakes' of native copper, 10–30 cm of cuprite (Cu_2O), formed by oxidation of the native copper, and spectacular green and blue crystals of malachite ($\text{Cu}_2\text{CO}_3(\text{OH})_2$) and azurite ($\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$), could be collected at the surface or accessed by rudimentary mining. Copper can be recovered from oxide-carbonate copper ores by direct smelting, that is, by heating the ore in a reducing medium (charcoal), so it is no coincidence that this type of ore was the first to be metallurgically processed.⁷ Further down, at groundwater level, in the so-called 'cementation belt', the most metal-rich zones of ore deposits were created. As reduction increases, secondary sulphide minerals are formed with a high copper-sulphur ratio. In addition to the most commonly used chalcopyrite (CuFeS_2) and arsenic- and antimony-bearing fahlore tennantite: $\text{Cu}_{12}\text{As}_4\text{S}_{13}/\text{Cu}_6[\text{Cu}_4(\text{Fe,Zn})_2]\text{As}_4\text{S}_{13}$, tetrahedrite: $\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$, enargite-luzonite: Cu_3AsS_4 minerals in the primary sulphide ore zone (Fig. 2), many other sulphide ores occur, containing silver, bismuth, nickel, antimony, and arsenic. These are often found in such close association with copper minerals that their separation is difficult even with modern techniques. The composition of the metallic copper may therefore be indicative of the ore deposit used as raw material.⁸ However, as the research currently stands, lead isotope analysis is needed for a more accurate provenance determination.⁹

Research into early metalworking has shown that the first copper objects appeared in the Middle East (between 10000 and 8000 BCE) and the Balkans (around 6200 BCE).¹⁰

⁷Szakáll (2001); Molnár (2008).

⁸Liversage (1994); Molnár (2008); Kiss (2009); Kiss (2020).

⁹Several international debates have touched on the evolving lead isotope analyses (Gale and Stos-Gale, 2000; Northover et al., 2001; Niederschlag et al., 2003; Ling et al., 2014; Radiivojević et al., 2019) for bronze objects, in part due to the realisation that not only copper but also tin, other component of bronze, may contain minor amounts of lead (Krüger et al., 2012), which may lead to the misinterpretation of the results of lead isotope tests for bronze. However, since the presence of less than 10% tin in bronze is very low, the very low lead content of the latter, which is an order of magnitude lower than the lead content of copper, has only a negligible effect on the results of the measurements to determine the origin of copper, which can therefore be considered reliable, see Pernicka et al. (2016a).

¹⁰Roberts et al. (2009); Radiivojević et al. (2021).



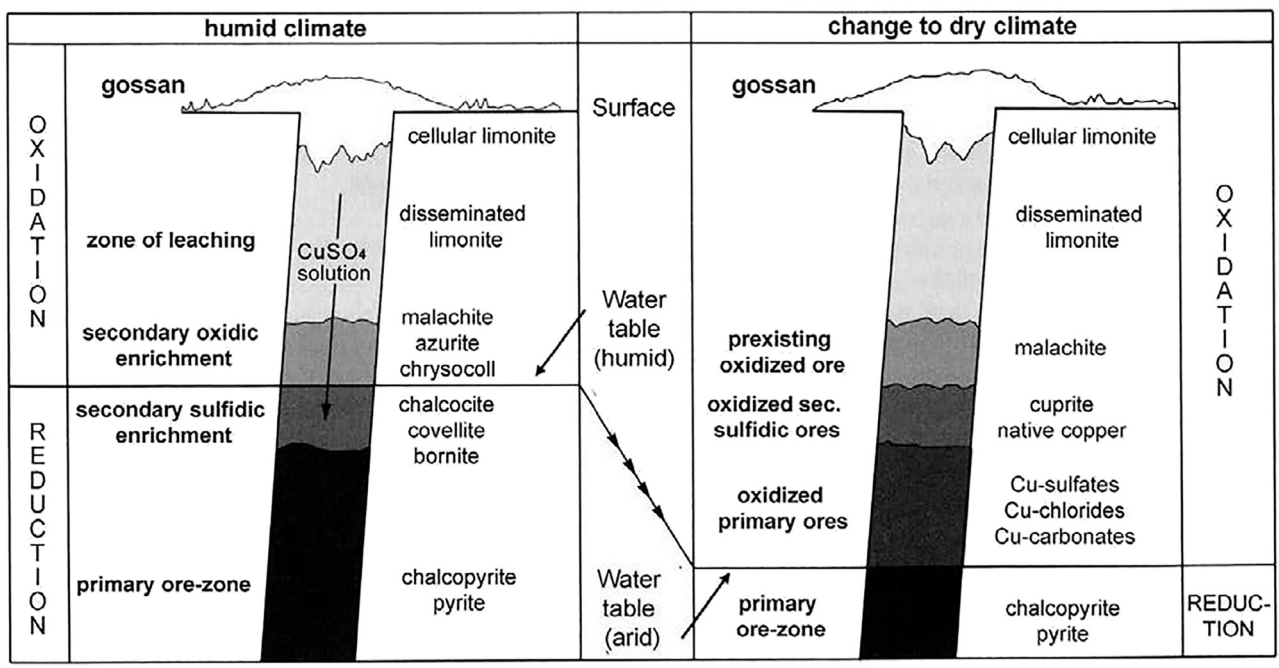


Fig. 2. Scheme of an ore deposit in humid and arid climate zones (after Strahm and Hauptmann, 2009)

The earliest Late Neolithic and Copper Age metal objects were made of high-purity copper, most likely from copper ore or oxide ores.¹¹ In the late Neolithic ore-mine at Rudna Glava (Serbia) the grooves, which are a few metres deep, are mainly evidence of near-surface mining, but there were also shafts 20–30 m deep.¹² After the near-surface resources were exhausted, mining was abandoned in some places, while in others the extraction of deep-cultivated sulphide ores and fahlores began. From this, the research has suggested a clear correlation between the use of different ores and archaeological chronology; however, this may vary from place to place due to different ore deposits or environmental influences (e. g., changes in groundwater levels in relation to climate).¹³

Although mining activities of later periods have often largely destroyed traces of prehistoric extraction at important sites, there is now evidence of prehistoric copper ore exploitation in several mining districts in the wider region of Central Europe: Rudna Glava and Majdanpek (Serbia) on the southern edge of the Carpathian Basin, Špania Dolina in present-day Slovakia, the well-known and well-studied Mitterberg in the Austrian Alps, and many other sites.¹⁴ Although no specific mining site has yet been proven, prehistoric copper deposits suitable for cultivation can also be

found in the Dobšina area, in Rudabánya and perhaps also in the Mátra Hills.¹⁵ The use of the latter in the late Middle Ages cannot be confirmed, but in the Árpadian period, for example, the construction of the county castle in Gyöngyöspata may have been connected with mining there. On the other hand, Smolník, on the northern side of the Dobšina ore deposit, appears in the sources as an important mining centre as early as the beginning of the fourteenth century.¹⁶ The main block here is up to 40 m thick, and its quality was a benchmark in Central Europe in the fifteenth century (Figs 3–5).

In the Carpathian Basin, the earliest copper artefacts were found in the layers of Late Neolithic settlements from eastern Hungary (dating from 4700 to 4500 BCE). The elemental composition and lead isotope analysis of the high-purity, small copper jewellery excavated at Polgár-Csőszhalom and Berettyóújfalu-Herpály show that the raw material of these pieces is related to mines in Serbia and Bulgaria, including the Aibunar area. At this time, no evidence of metalworking is known from these settlements, thus the objects may have arrived in finished form.¹⁷ The next, Early and Middle Copper Age period, the spread of the so-called large copper implements (hammer axes, adze-axes) all over the Carpathian Basin, has been linked to the emergence of local metalworking.¹⁸ However, the lead isotope analyses

¹¹Summarised by Kiss (2012a); Siklósi et al. (2017).
¹²Jovanović (1999); Borić (2009); Kienlin (2010) 16–17.
¹³Strahm–Hauptmann (2009) Fig. 5; O’Brien (2014).
¹⁴Czajlik (2012b); Radivojević et al. (2019) Fig. 1; Artioli et al. (2013); Artioli et al. (2017).

¹⁵Sánta (2011); Czajlik (2012b); Siklósi et al. (2017).
¹⁶Hronček et al. (2021).
¹⁷Kasztovszky et al. (2010); Siklósi et al. (2015); Siklósi et al. (2017).
¹⁸Kalicz (1992); Siklósi et al. (2017).



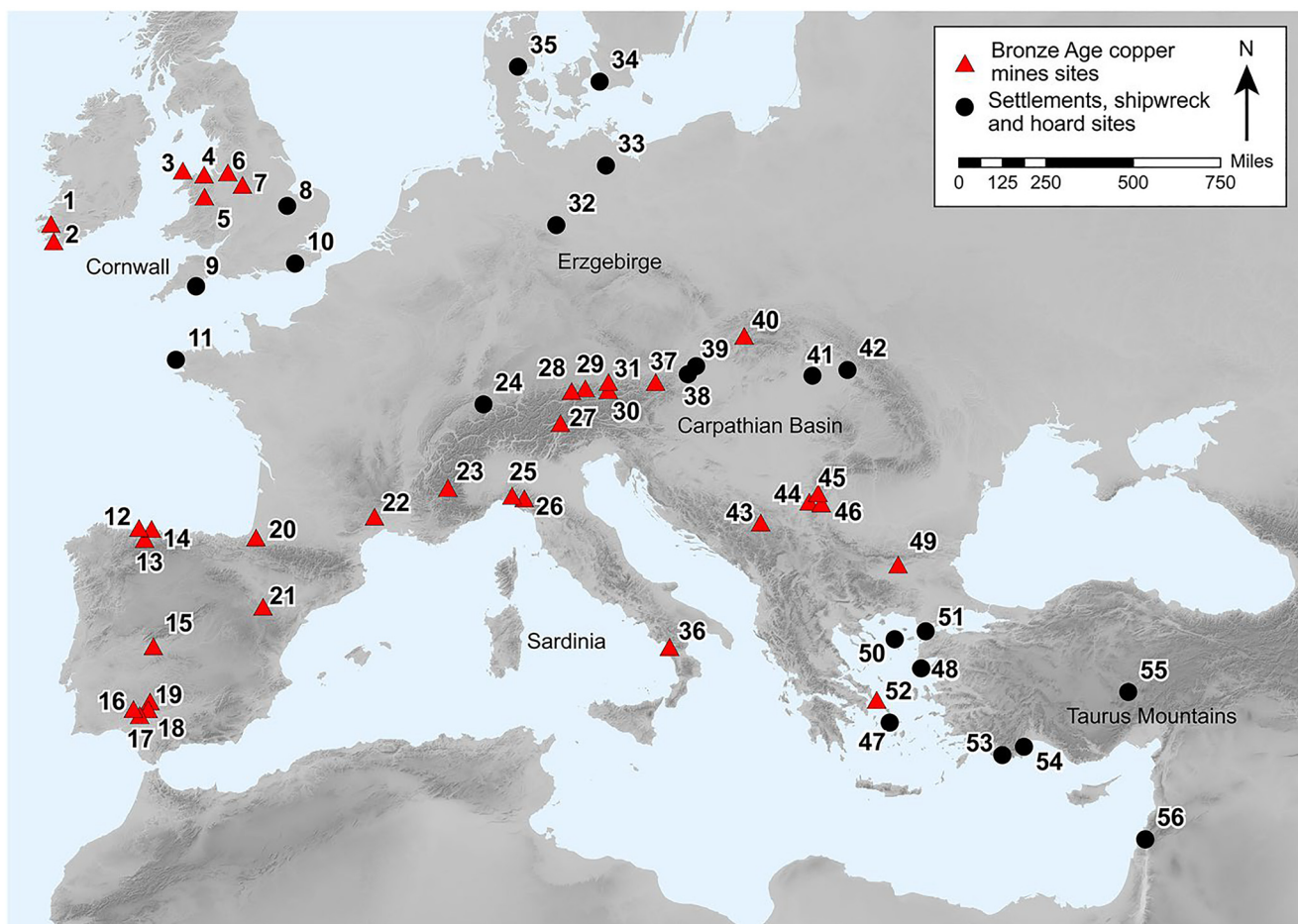


Fig. 3. Overview of Copper Age and Bronze Age mines with additional significant finds, such as ship finds and hoards (after Radivojević et al., 2019, Fig. 1).

1: Ross Island; 2: Mount Gabriel; 3: Parys Mountain; 4: Great Orme; 5: Cwm Ystwyth; 6: Alderley Edge; 7: Ecton; 8: Must Farm; 9: Salcombe; 10: Langdon Bay; 11: St Renan; 12: El Aramo; 13: La Profunda; 14: El Milagro; 15: San Cristóbal de Logrosán; 16: Cuchillares; 17: Chínflón; 18: La Loba; 19: Berrocal; 20: Causiat; 21: Loma de la Tejería; 22: Cabrières; 23: St. Véran; 24: Sursee-Gammainseli; 25: Libiola; 26: Monte Loreto; 27: Trentino; 28: Schwaz-Brixlegg; 29: Glemmtal; 30: St. Veit; 31: Mitterberg-Bischofshofen; 32: Nebra; 33: Tollense; 34: Pile; 35: Egtved; 36: Grotta della Monaca; 37: Eisenerz; 38: Mannesdorf; 39: Hainburg; 40: Špania Dolina; 41: Hajdúsámson; 42: Apa; 43: Jarmovac; 44: Ždrelo; 45: Majdanpek; 46: Rudna Glava; 47: Kastri; 48: Thermi; 49: Aibunar; 50: Poliochni; 51: Troy; 52: Lavrion; 53: Uluburun; 54: Cape Gelidonya; 55: Kanesh; 56: Nahal Mishmar

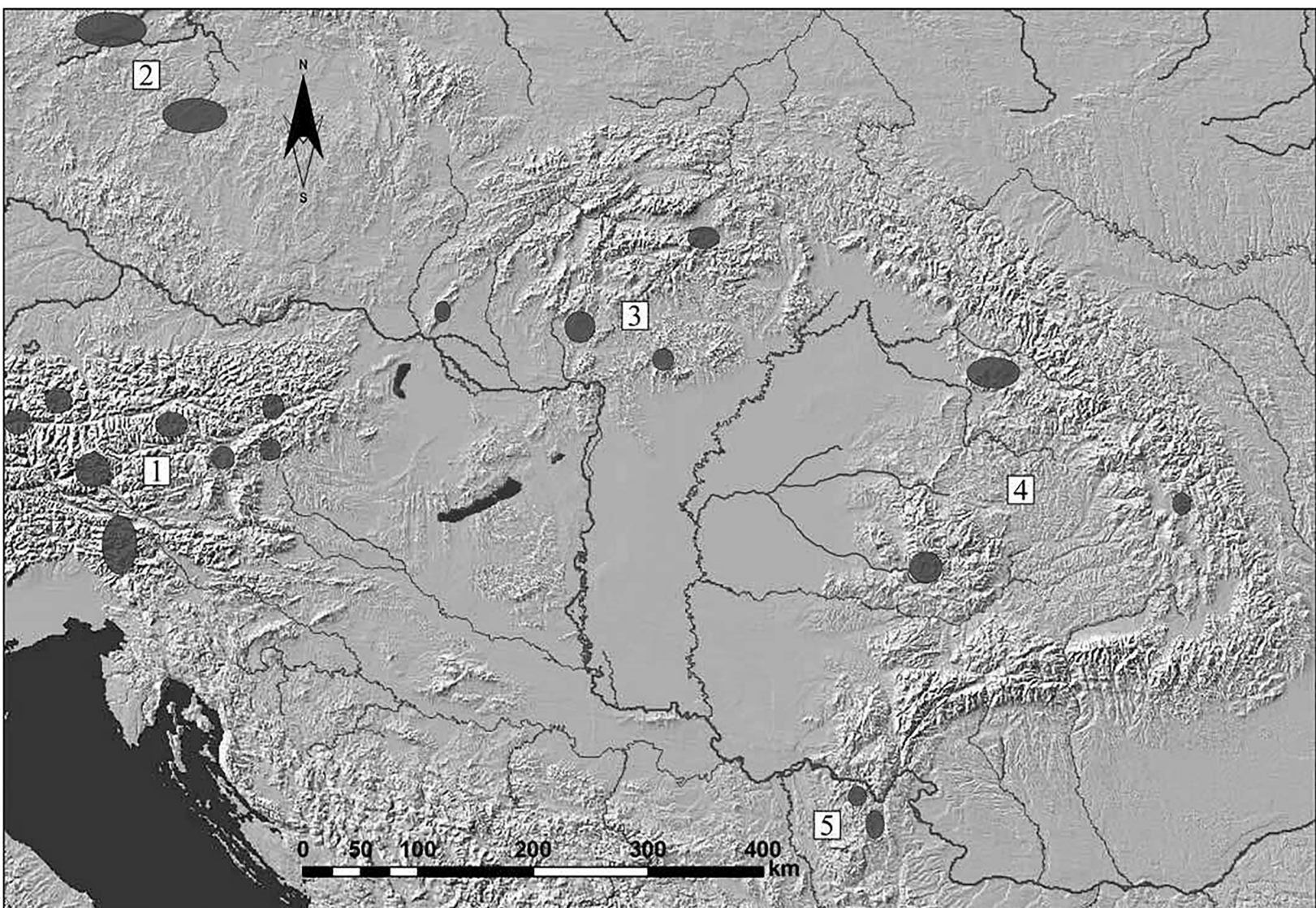


Fig. 4. Prehistoric copper mining sites in the Carpathian Basin and its surroundings (after Czajlik, 2012b, Fig. 2).

1: Eastern Alps (Kitzbühel, Schwaz-Brixlegg, Mitterberg, Schladming, Trieben, Ramsau, Rax, Adige valley); 2: Saxo-Bohemian Ore Mountains, Bohemian Massif; 3: Northern Carpathians, mainly Pezinok, Špania Dolina, Dobšiná, and the zone of the Mátra Hills(?), 4. Eastern Carpathians, mainly around Baia Mare, Bălan and Roșia Montană, 5. Bor and Majdanpek (Rudna Glava)

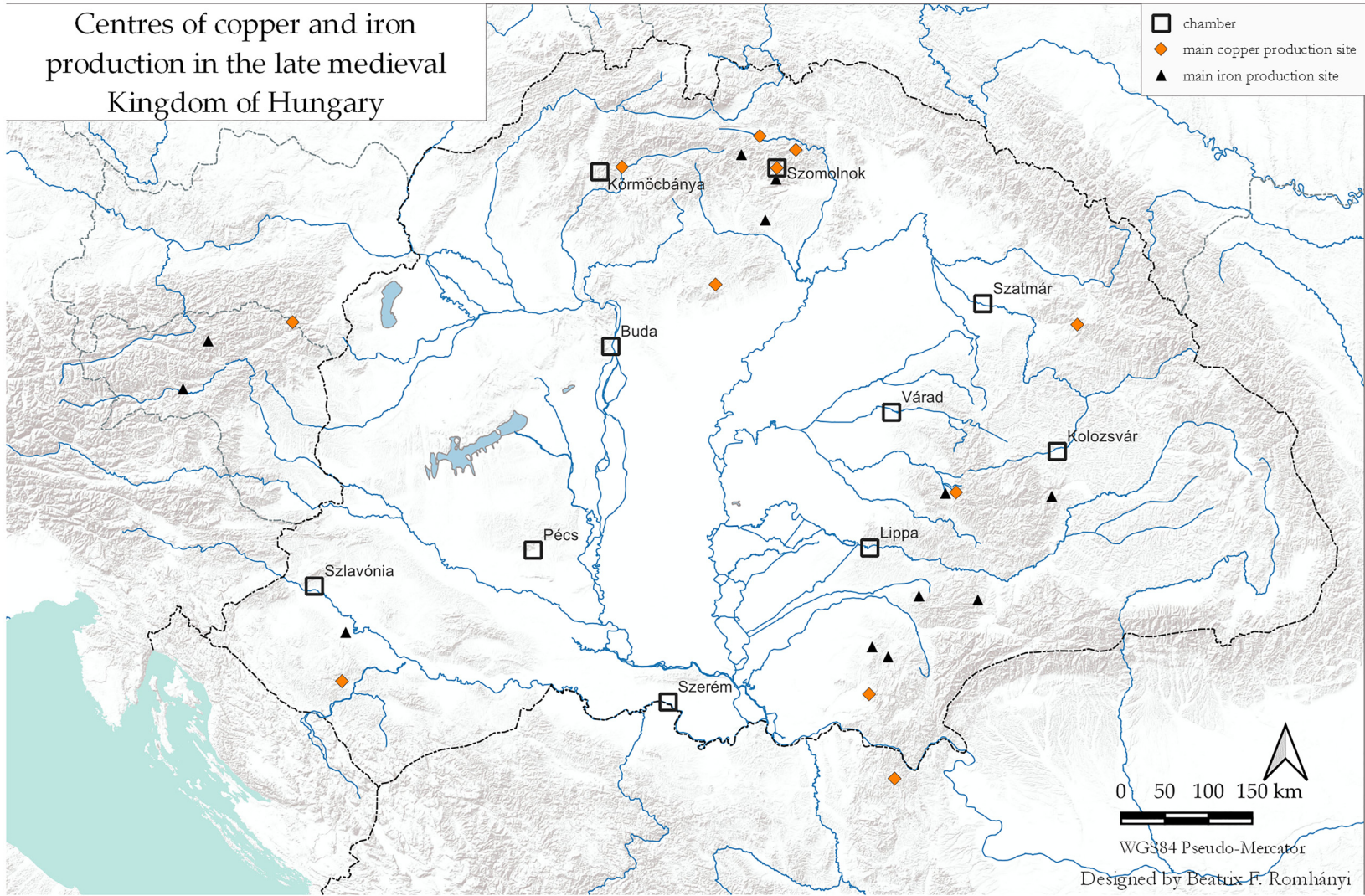


Fig. 5. Centres of copper and iron production in the late medieval Kingdom of Hungary



carried out so far confirm the predominance of Balkan copper sources even in this period.¹⁹ In the case of the Early-Middle Copper Age cemetery at Rákóczi-falva (4300–4200 BCE), the copper raw material may have come from the Majdanpek and Aibunar regions. The fact that no finds indicating metal production have so far been found in the settlements of the period in the Great Hungarian Plain suggests that the trade in finished objects continued.²⁰

One of the most important questions for the region's metallurgy is when the ore deposits in Slovakia or Romania, in the Alps, and the resources found in the area of today's Hungary, in the Northern Hill Region (Recsk, Rudabánya, Telkibánya) and several other places were exploited.²¹ Among the most important of these are the Gemer-Spiš ore-mining area and the Špania-Dolina copper deposit (both in Slovakia). The latter one is on the border between the Low Tatras and the Great Fatras, and its earliest use is attested by the 150 ore-producing stone hammers found there and attributed to the Ludanice culture dating from the first half of the Middle Copper Age (ca. 4300–3800 BCE) and the Űnĕtice culture of the Early and Middle Bronze Age of the Carpathian Basin (2200–1600 BCE).²² The ore-roasting site at nearby Slovenské Pravno is also associated with the Ludanice culture, which represents the earliest ore-processing workshop in the whole Carpathian Basin. The antimony content of the Copper Age Nĕgrádmárcal-type copper hammer axes identified by Maria Novotná and the arsenic-copper raw material of the Handlová copper axes, which she associated with the fahlores in the region containing antimony and silver, or arsenic, also point to the Copper Age ore mining.²³ Despite this, until recently the lead isotope analyses carried out so far have not confirmed the origin of the raw material for Copper Age tools in the region. In many cases, even the analysis of raw material of objects dating to the beginning of the Bronze Age suggested a Balkan origin. This is explained by the fact that, according to recent research, the unequivocal determination of the origin of the raw materials is made difficult because the results of analyses of lead isotope ratios in ores from geologically similar mountain ranges give overlapping values.²⁴ However, a study on the metallurgical analysis of the Middle Copper Age Magyaregres hoard published at the end of 2022

provides more convincing evidence than hitherto that a specific metallurgical tradition, different from that of South-Eastern Europe, may have been established as early as the fifth-fourth millennium BCE on the basis of the ore sources of Špania Dolina and L'ubietová near Banská Bystrica in Slovakia. The 700 artefacts in the hoard probably reached the communities of the Balaton-Lasinja culture settled in southern Transdanubia as finished products²⁵ from the workshops of the Ludanice culture, located near the mines of the Slovakian region.²⁶

In the Late Copper Age (from 3500 BCE) and the Early Bronze Age copper objects containing arsenic appeared alongside pure copper objects made from native copper or oxide ores. Clay crucibles from this period attest to the local metalworking activities of groups living south of the Mecsek (at the settlement sites of Lánycsók and Zók).²⁷ The material of the typical shaft-hole axes of this period,²⁸ as well as daggers used by the communities of the Bell Beaker culture in the Budapest area, also indicate the use of regional sources.²⁹

The copper artefacts used by the communities living in western Hungary at the end of the Early Bronze Age (between 2200 and 2000 BCE) are associated with the fahlore types of high (2–4%) antimony, similar or slightly lower arsenic and silver (0.5–1%), and low bismuth content, typical in the Central European region.³⁰ After the spread of tin bronzes (2000 BCE), the jewellery used by Middle Bronze Age groups in the West-Hungarian region was also made of this material, alloyed with 5–10% tin.³¹ This metal type is the main raw material for neck rings (*Ösenring*), which are also interpreted as a symbol of status and power and as a form of raw material (ingot; Fig 6.1) and is therefore also known as the classical *Ösenring* copper type. Its origins have been traced to the distribution of neck rings in Slovakia and in the Inn Valley in Austria, or in Transylvania according to former

¹⁹Höppner et al. (2005); Schreiner (2007); Siklósi et al. (2017).

²⁰Siklósi and Szilágyi (2019); Siklósi et al. (2022a).

²¹Novotná (1955); Durman (1983); Ecsedy (1977); Ecsedy (1990); Pernicka et al. (1993); Boroffka (1994); Schalk (1998); Krause (2003); Kiss (2012a); Czajlik (2012a); Czajlik (2012b); Szabó (2013). The ore deposits of Recsk, Rudabánya and Telkibánya were worked in the Middle Ages, but there is no evidence of their earlier use. The possibility of the use of these ores in prehistoric period, as well as ores from the Mecsek or Velence Hills is still debated and subject of recent scientific projects (Siklósi et al., 2017; Bondár, 2019).

²²Točík and Žebrák (1989); Žebrák (1995); Czajlik (2012a).

²³Novotná (1955); Junghans et al. (1968); Ferenc and Rojkovič (2001); Heeb (2014).

²⁴Schreiner (2007); Modarressi-Tehrani and Garner (2015); Modarressi-Tehrani et al. (2016) 110.

²⁵Siklósi et al. (2022b).

²⁶Točík and Žebrák (1989); Horváth and M. Virág (2003).

²⁷Ecsedy (1990); Ecsedy (1994); Bondár (2019). A further contribution to the raw material trade of the period is the lead isotope analysis of the axe of Ötzi, a glacial mummy found on the border of the Austrian and Italian Alps. This shows that the high-purity copper axe of the 'ice man', who died between 3350 and 3000 BCE in the Alpine passes, did not come from the Balkans or from the many known copper sources in eastern Austria and northern Italy, but from present-day Tuscany (Artoli et al., 2017).

²⁸Junghans et al. (1968); Shalev et al. (2012); Dani (2013); Szeverényi (2013).

²⁹For the possible local copper sources of the shaft-hole axes Durman (1983); Durman (1988); Ecsedy (1990); Liversage (1994); Dani (2013). Previous studies suggest that the material of the objects from the eastern areas of the Bell Beaker culture is more heterogeneous than the uniform Bell Beaker metal (98% copper with arsenic, antimony, and nickel components) found in Western European communities (Merkel, 2010; Needham, 2011). Analysis of artefacts from Hungary has revealed varying proportions of silver, arsenic, and antimony in the raw material (Endrődi et al., 2003; Kulcsár et al., 2016).

³⁰Schubert and Schubert (1967); Liversage (1994); Krause (2003); Somogyi (2004); Költő (2004).

³¹Schubert and Schubert (1967) Abb. 38; Kiss (2012a); Kiss (2012b); Kovács et al. (2019).





Fig. 6. Copper raw material types 1: neck ring; 2: axe; 3: rod (1-2: after Krenn-Leeb and Neugebauer, 1999; 3: after Spangenberg, 2017)

hypotheses. More recent research has linked it to copper ore occurrences in the triangle of the Eastern Alps, Slovakia, and the Saxo-Bohemian Ore Mountains.³² The importance of this raw material is illustrated by the fact that it spread as far as Scandinavia during the Central European Early Bronze Age (contemporaneous with the Middle Bronze Age in the Carpathian Basin, 2000/1900–1600 BCE).³³

Around the transition from the Middle Bronze Age to the Late Bronze Age of our study region (around 1600 BCE, coinciding with the beginning of the Middle Bronze Age in Central Europe), a metal type with a high arsenic and nickel content appeared, and quickly became dominant.³⁴ Regarding elemental composition analyses, this so-called eastern Alpine copper is associated with fahlores known from the copper mines in the Mitterberg area south of Salzburg, dated between the eighteenth and fourteenth centuries BCE.³⁵ Based on the depth of the mine parts, reaching 120 m, and the amount of

slag preserved as a trace of the smelting operations carried out near the mine, it is estimated that some 18,000 tonnes of crude ore were extracted from the Mitterberg mine workings during the Bronze Age centuries concerned. The possibility of a Transylvanian origin for a variant of this metal type has been raised,³⁶ as well as the possibility that the chalcopryrite and fahlore associations of the Dobšina region of the Slovakian (Gemér-Spiš) Ore Mountains may be the source of this raw material, in connection with the occurrence of arsenic- and nickel-rich gersdorffite (NiAsS).³⁷ However, the lead isotope analyses carried out so far support the identification of this metal type with ores from the Mitterberg mine.³⁸

Near the mining regions, depot finds containing identical objects are often found, which are interpreted as raw material ingots, e. g. dozens or even hundreds of neck rings (*Ösenringbarren*; Fig. 6.1), ribs (*Spangenbergbarren*; Fig. 6.3) spread in the eastern Alps, axes (Fig. 6.2) more common in

³²Junk et al. (2001); Höppner et al. (2005).

³³Vandkilde (2005); Norgaard et al. (2019).

³⁴In the SAM database, fahlore containing arsenic and nickel is the most common, with 6500 data (Krause, 2003, Abb. 39, Cluster group 4).

³⁵Pittioni (1957); Neuninger et al. (1969) Karte 2; Liversage (1994) 72–73: ‘AsNi’; Romanow (1995) 266–272; Krause (2003) 166–169.

³⁶Liversage (1994) 73–75 ‘dasni’; Krause (2003) 166–169, Abb. 138: Variant III.

³⁷Sánta (2011).

³⁸Pernicka et al. (2016a); Radivojević et al. (2019); Nessel and Pernicka (2020).

the area of present-day Germany, or the more widespread casting cakes (planoconvex ingots). Both their roughly uniform weight (e. g., around 150–230 g for ring and axe ingots, 80–170 g for rib ingots) and the fact that they are sometimes found in ‘packages’ of several pieces, rarely with traces of organic material indicating that they are bound together (Fig. 6, Fig. 9) support their evaluation as semi-finished products.³⁹

The number of lead isotope analyses from the Bronze Age of the Carpathian Basin, that allow a more precise provenance determination than elemental composition data, is still small. So far, beside lead isotope analyses (LIA) of 32 objects from two sites in Eastern Austria (Hainburg, Mannheim) and 29 samples from Western Romania (from the Apa treasure and several other objects of similar date), only nine data of swords and axes from Hungarian sites (from Hajdúsámson, Téglás and Vámospércs) are published. The bronze objects from cemeteries in present-day Eastern Austria, dating between 2000 and 1600/1500 BCE (Central European Early Bronze Age, contemporaneous with the Middle Bronze Age in Hungary), could be associated with the *Ösenring* metal type on the basis of compositional data; the lead isotope analysis of the same objects most probably indicates an origin from ore sources in the Slovakian Ore Mountains (located in the Garam/Hron valley).⁴⁰ The analysis of the lead isotope ratios of samples from the Romanian region beside the use of ores from east Alpine (Mitterberg) and Slovakian mines suggest that other local raw materials (e. g. from Baia Mare and the Apușeni Mountains) cannot be excluded.⁴¹ The lead isotope analyses published so far for present-day Hungary are limited to the analysis of the five axes of the Hajdúsámson hoard and the ornamented swords and axes of the Téglás and Vámospércs hoards. According to the elemental composition, the examined axes of the Hajdúsámson hoard, the Vámospércs axe and the handle of the Téglás sword show a good agreement with the elemental composition (Fig. 7) and lead isotope ratios of the ore recovered from the Mitterberg mine. However, the axe and blade of the sword from Téglás were made of a different raw material; this higher silver and antimony content of copper could have come from the copper mines of the Slovakian Ore Mountain deposit, supported by the lead isotope analysis.⁴² Based on the different

raw materials and the uniform ornamental patterns, we can state that the weapons and jewellery belonging to the Upper Tisza Metalworking Circle (or to the Hajdúsámson hoard horizon) did not arrive as finished objects from the eastern Alpine region but were made by local bronzesmiths.⁴³

During the Late Bronze Age, the dominance of chalcopryrite ores continued, reaching the peak of copper production in the east Alpine region (present-day Austria and Italy). In the Hallstatt B period (1100–800 BCE) an increase in the proportion of fahlores was observed; analyses indicate the use of Slovakian and Alpine sources.⁴⁴ After the Bronze Age period the study of Late Iron Age bronze bracelets have distinguished several types of raw materials and different manufacturing techniques.⁴⁵

DATA ON ORE PRODUCTION AND TRADE IN ARCHAEOLOGICAL AND HISTORICAL PERIODS (ROMAN, MEDIEVAL, EARLY MODERN)

Pliny the Elder mentions two types of copper ore: *cadmea*, found on and near the surface, and *chalcitis*, found deep underground. *Cadmea* can be a mixture of copper and zinc oxides, hydroxides and carbonates, water-bearing carbonates (cuprite, tenorite (CuO), malachite, azurite, hydrozincite ($\text{Zn}_5(\text{CO}_3)_2(\text{OH})_6$), smithsonite (ZnCO_3), etc.). *Chalcitis* is not a single mineral either but is composed of three parts. These components have been defined as a mixture of copper and iron sulphide and their oxides, so that the term *chalcitis* probably refers to a weathered chalcopryrite-pyrite (FeS_2) mineralised rock.⁴⁶

The raw materials of the Carpathian Basin may also have been attractive to the Romans, even if they did not occupy all the areas where they occurred. It is well known that one of the important reasons for the Roman occupation of Dacia was the exploitation of the gold deposits there (Abrud, Roșia Montană, Zlatna). However, other raw materials, such as salt and other ores, including copper and iron ores, may also have played a role in the province's economy. The use of copper deposits in Pannonia and Moesia in the Roman period is illustrated, for example, by the mints of Sirmium (329–370), Siscia (262–423) and Viminatium (239–258). The first was probably established and only intermittently used because of its role in the late imperial administration of the Roman Empire, while the latter two were in the immediate vicinity of mines (Sisek, Majdanpek).⁴⁷ The Viminatium mint, according to the inscriptions on the reverse of

³⁹Lerner-de Wilde (1995); Vandkilde (2005); Krenn-Leeb (2006); Krenn-Leeb (2010); Czajlik (2012b); Lutz et al. (2019); Cavazzuti et al. (2021) S4 Fig. These ingot were also interpreted as commodity money, see Kuijpers and Popa (2021).

⁴⁰Duberow et al. (2009); Radivojević et al. (2019).

⁴¹Czajlik (2012b) 46, 2. ábra; Pernicka et al. (2016a) Fig. 15, Fig. 17, Figs. 24–25; Radivojević et al. (2019) Fig. 7; Nessel and Pernicka (2020). The mining area of Baia Mare was first mentioned in written sources in 1329 (Wenzel, 1880, 111), but based on the development level of the region in the 1330s, the mines were started decades earlier (F. Romhányi et al., 2023, 45–47). The area remained one of the most active districts till the mid-eighteenth century, and even beyond. Mining declined only after 1989.

⁴²Dani et al. (2013); Pernicka (2013); Pernicka et al. (2016b); Radivojević et al. (2019).

⁴³Kovács (1977) 32; Dani et al. (2020). For a different interpretation see Nessel and Pernicka (2020).

⁴⁴Czajlik (2012b); Czajlik (2013); Szabó (2013); Nessel (2014); Pernicka et al. (2016) Fig. 20; Mödinger and Trebsche (2020).

⁴⁵Molnár et al. (2012).

⁴⁶Forbes (1964) 8; Mayhoff (1870) 162–163 (*liber* XXXIV, *cap.* 1–2); Sánta (2011).

⁴⁷Petković (2009) Fig. 4.



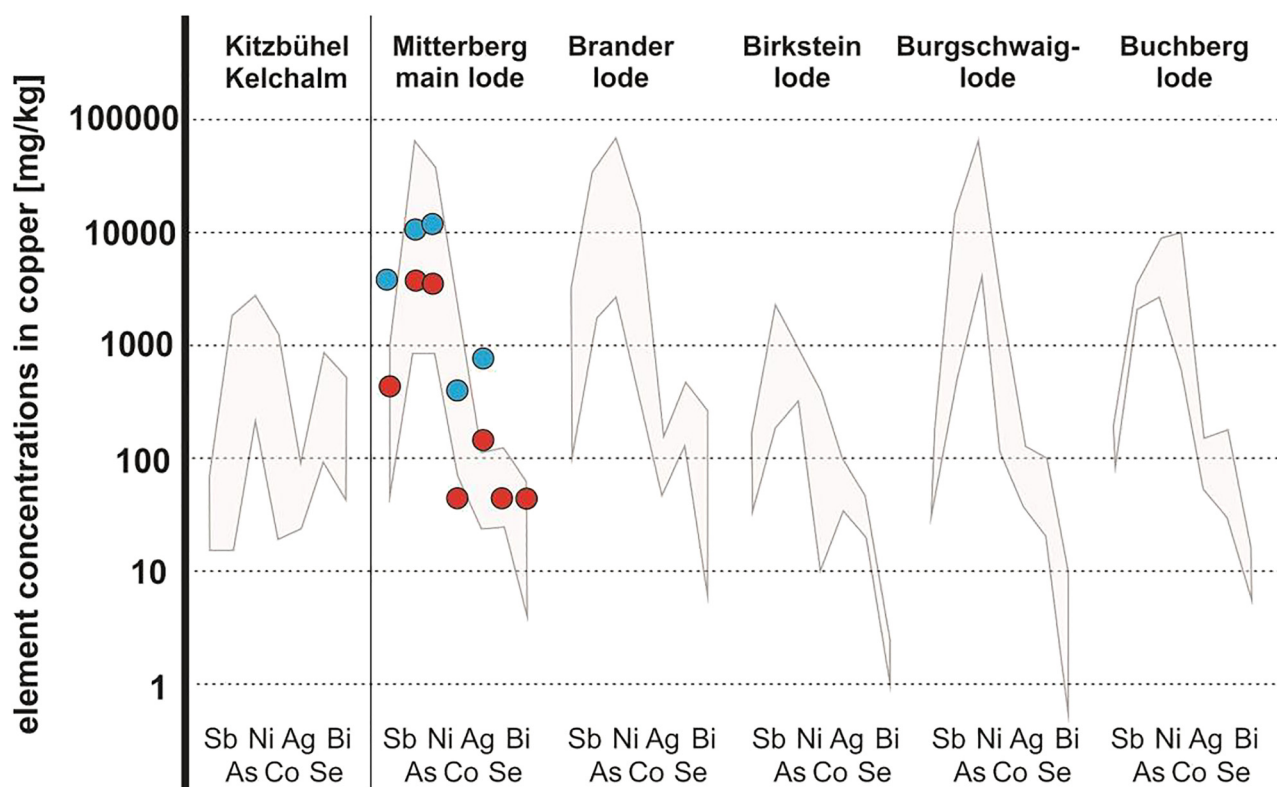


Fig. 7. The elemental composition of the objects from the Hajdúsámson hoard (red) and the Téglás hoard (blue) compared to the elemental composition of the eastern Alpine ore deposits (after Pernicka, 2013, Fig. 4)

the bronze coins recovered from it, worked for both Moesia Superior and Dacia.⁴⁸ Although not a mint, evidence of Roman copper working has also been found in Neunkirchen, at the foot of the Rax in Austria.⁴⁹ However, it is also true that no Roman bronze ingots have been found in the Pannonia area, and only the accumulation of recycled objects can be identified.⁵⁰ Finds indicating the processing of copper have been found north of the Danube in the area of Bratislava and along the road to Trenčín (Zohor, Stupava, Pác, Pobedin). In Stupava, the workshop itself has been found, but it is not known whether the raw material was obtained from the mines in the eastern Alps or in the Northern Carpathians.⁵¹

Although we have no direct evidence, it is likely that the mining and trade of copper ores from the Gelnica mines in Smolník is behind the association of the valuable Roman objects in the Vandal royal burial in Ostrovany, including the large onyx fibula.⁵²

After the fall of the Roman Empire, in the centuries of the Migration Period, there is no evidence of any major exploitation of ores, including copper ores, from the

Carpathian Basin. The first written records of mining date back to the end of the eleventh century, after the Kingdom of Hungary had been established. Archaeological evidence in the area of the former Zvolen Forest confirms that at least some mining sites were worked. A ¹⁴C dating of a timber found at Šturec, north-west of Dolný Harmanec, yields a date of around 1050,⁵³ though the mines cannot be dated before the twelfth century.⁵⁴ The trade in copper to the west was confirmed as early as the twelfth and thirteenth centuries by the Stein and Hainburg customs (Lower Austria, 1192, 1243).⁵⁵ It should be noted that the Stein customs also list other metals (tin, lead, iron) and salt, some of which may have come from the Carpathian Basin.

The real boom in the copper trade, however, did not come until the fourteenth century. The privileges of Venetian merchants were regulated by King Charles I as early as in 1318,⁵⁶ and in 1349 King Louis I granted the privileges of Venice to Genoese merchants, coming to Buda from Orşova and Timișoara, in the copper-merchant's trade.⁵⁷ In 1376, the Florentines also requested – and, on the basis of subsequent developments, obtained – the right to participate in

⁴⁸Fitz (1995).

⁴⁹Gassner (2015).

⁵⁰Sey (2015) 21.

⁵¹Kušik (2015) 7.

⁵²About the grave and its finds see Prohászka (2004).

⁵³Kušik (2015) 8.

⁵⁴Garner (2021) 41.

⁵⁵CDH (1831) VII/1., 282; Knittler (1978).

⁵⁶Benda (1983) 195.

⁵⁷Wenzel (1880) 158

the copper trade, with the restriction that they could buy up the excess of copper to be delivered to the Low Countries.⁵⁸ These privileges show all three important trade routes: on the one hand, Italy, originally Venice, which had long been linked to the Kingdom of Hungary and enjoyed trading privileges, but from 1376 Florence was also involved in the business, and on the other, Genoa, which became interested mainly through its Black Sea colonies. As a third buyer, the German Low Countries (indirectly the Rhine area), to which the goods initially reached only by the Vistula and by sea, but later, from the time of King Sigismund of Luxembourg, also by land, partly through the intermediary of southern German merchants, mainly from Nuremberg. Ragusa was a partner of Florence in this network,⁵⁹ and its trade links extended to the Adriatic and the Balkans. The copper mined in the Carpathian Basin could be traded through these channels over an extremely large area (Fig. 8). Venice's special interest was shown by the fact that in 1384 it regulated the refining charges for copper from the new deposit at Banská Bystrica, and at the end of the century it sought to channel as much of the copper from Hungary as possible into the Venetian trade network by means of a series of contracts.⁶⁰

In this context, the role of Ragusa and Genoa also points to a further trade link. In the region from the Adriatic to the Black Sea, Ragusa and its backbone Florence had already had considerable interests from the thirteenth century, and trade in the Pontus region was to a large extent in the hands of Genoa.⁶¹ During the reign of King Louis I, the Kingdom of Hungary sought to join this network by expanding into the Balkans. Of particular interest from the copper point of view is the area of the Vidin province occupied in the 1360s (Vidin itself is just opposite Calafat, a Genoese colony engaged in ship repair), which includes the mines of Majdanpek, known and worked since prehistoric times. It is perhaps no coincidence that King Louis, after failing to organise the Vidin Banat, settled the Bulgarians loyal to him

on the eastern edge of the Temesköz (today Banat Montan, Romania), essentially in the present-day Reșița mining district. Iron mining in this area appears only a few decades later in the otherwise sparse sources.⁶²

In the early fifteenth century, the German financier Mark of Nuremberg (in the office of *comes tricesimarum*), in the service of King Sigismund, forged closer links with Nuremberg, one of the most important copper centres of the period. The importance of these economic ties is shown by the fact that at the end of the fifteenth century one of the most important patrician families of Nuremberg, the Haller family, moved to Hungary. For decades from the turn of the fifteenth to the sixteenth century, the family played a role in the East–West trade, one of the most important commodities of which was copper (in which they also competed with the Turzó-Fugger company).

Copper mining gained momentum in the last decades of the fifteenth century. The earlier mines had by then been partly exhausted and partly in serious difficulties due to water ingress. The latter problem was solved by the water extraction structure *Wasserkunst* by John Turzó.⁶³ Thanks to this technical innovation, working mines were able to produce more safely, and even previously abandoned mine sites could be brought back into production. John Turzó himself reopened several old mines, not only in Upper Hungary (today Western Slovakia), but also in Rézbánya (meaning copper mine, today Băița, Romania) in the bishopric of Várad. Equally important was the establishment of the mining company founded in 1494 in partnership with the Fugger company of Augsburg.⁶⁴ The company's capital strength and John Turzó's outstanding technical knowledge enabled the first Banská Bystrica Seiger smelter to be started up a year later. The technology was used to further refine the copper and extract the residual silver. The location of the smelter was not a coincidence, as the copper ore from the Špania Dolina valley near Banská Bystrica was rich in silver. Previously, the technology could only be used in Venice, so the silver extracted from the copper bought in from Hungary also enriched the Serenissima.

⁵⁸Teke (1995) 129. At this time, the overland route to Flanders through southern German territory was not used, but the goods were transported via the Dunajec and the Vistula Rivers to the Baltic Sea and then on to Flanders by sea Divéky (1905) 7, 10–11. For a summary of the trade in Gemer-Spiš copper in the early fourteenth century and its market via Poland, see Štefánik (2017).

⁵⁹Florentine merchants regularly used ships of Ragusa to transport their goods to the Levant. The complexity of the relationship is illustrated by an incident in 1379 when two merchants from Florence, who also had links with Hungary, and a further merchant from Genoa had their goods (including 19 bundles of tin and 800 copper ingots) carried on ships of Naples and Catalonia confiscated by the Venetians. However, Ragusa merchants were also linked to Venice, e. g., two Ragusa merchants had offered Hungarian copper for refining in Zecca before 1378 (Teke, 1995, 131).

⁶⁰Paulinyi (1933) 33; Teke (1995) 136–138.

⁶¹Heyd (2020) 97. It was in the second half of the fourteenth century that Genoa began to expand intensively on the western shores of the Black Sea, not only gaining a foothold in the Danube Delta but also controlling several Danube ports. The easternmost of these was Calafat on the left bank of the Danube, named after the workers who repaired the ships (*calfati*).

⁶²Iron mining was already possible in the area in the Árpáadian period (Ilidia), but it only became more important in the fourteenth and fifteenth centuries. The importance of the mines here is shown by the fact that King Sigismund, when he took over the castle of Kövesd from the Csáki family, specifically mentioned the iron mine (which was identical to the present-day Bocșa Montana) among the castle's appurtenances. In the fifteenth century, other mines were also documented in written evidence (F. Romhányi, 2019). The iron mines continued to operate during the Ottoman occupation, and after the reconquest the Habsburgs almost immediately settled Styrian miners in the area (Stájerlakanina, today Anina). The importance of the raw material resources is shown by the fact that during the Monarchy the region developed into one of the most important industrial areas in Europe, and the Reșița ironworks was one of the most important industrial enterprises in Romania until the regime change.

⁶³Paulinyi (1978) 322–323.

⁶⁴Zsámboki (2005) 14. At the beginning of the sixteenth century, the average annual copper production in Banská Bystrica was estimated at 2,000–2,500 tonnes.



By the end of the fifteenth century, the Fugger company was the largest copper producer and trader in Europe. Their interests also included the mines of Tyrol and Thuringia in Saxony. The Turzó-Fugger consortium brought another huge source of raw materials into the Fugger interest, and copper mined in Hungary was traded throughout Europe through their own network.⁶⁵ In the Hungarian company, which Jakob Fugger the younger founded together with the Turzós and which the Fuggers ran independently from 1526 to 1546, John Turzó brought not only his interests in Hungary but also the Polish contacts he had built up in the preceding decades. The result was a production and trading network covering much of Europe that was truly capable of dominating the continent's copper trade. Through the Fugger company, copper from Banská Bystrica reached the Spanish territories of the Habsburg Empire and even played a role in the emerging world trade.⁶⁶

POSSIBLE PERIODS OF EXPLOITATION OF COPPER ORE DEPOSITS IN THE CARPATHIAN BASIN, PRESUMED TRANSPORT ROUTES OF THE RAW MATERIAL AND THE DIRECTION OF ITS TRADE

In summary, pure copper jewellery and weapons were imported into the Carpathian Basin communities in the first half of the fifth millennium, in the Late Neolithic and Early Copper Age, and, as far as we know, even in the Middle Copper Age, as a result of contacts with groups in the Timok Massif (Serbian Carpathians) and the Balkan Mountains.⁶⁷ The study of mining and metallurgical tools, mining sites, and the raw material and lead isotopic analysis of prehistoric artefacts all confirm that the population of the Northern Carpathians discovered mineral associations with high metal content, with near-surface outcrops, mainly of fahlore, and that regional ore mining and local metallurgy may have developed by the turn of the fifth-fourth millennia, during the Middle Copper Age.⁶⁸ In the two millennia from the Late Copper Age to the end of the Middle Bronze Age (3500–1600/1500 BCE), the exploitation of ore deposits in the Gemer-Spiš Ore Mountains (perhaps as far west as the Little Carpathians) may have been significant. Some data suggest that mining of ore sources on a much smaller scale in the Transylvanian ore range, as well as in the Vihorlat-Gutin Mountains may also have begun.⁶⁹ From the communities living near the ore sources, the copper and, from 2000/1900 BCE, the – probably alloyed – tin-bronze raw

material reached the people living further away from the mining areas in the form of cast ingots, including the Middle Bronze Age settlements in Transdanubia and the Scandinavian areas.⁷⁰ Around 1600/1500 BCE, a change took place, and the most typical *Ösenring* metal type, containing arsenic, antimony and silver, and less frequently some nickel (suggesting a fahlore mixture in its origin), was replaced by the so-called East Alpine copper type, probably derived from chalcopyrite ore, with a high arsenic and nickel content. At present, it is questionable whether this phenomenon can be explained by changes in the raw material preparation process or by changes in ore sources and possibly in exchange trade relations. Lead isotope analyses suggest the latter, i. e., that the main site of extraction shifted from Slovakia to the eastern part of the Alps, to the copper sources known from Mitterberg, which were active between 1700 and 1300 BCE.⁷¹ In the Late Bronze Age, the dominance of chalcopyrite ores continued, followed by an increase in the proportion of fahlores from the Hallstatt B period (1100–800 BCE), due to the growing importance of the Slovakian sources again.⁷² Analyses of Iron Age copper raw materials have distinguished several different raw materials.

Roman metalworking probably continued to use local resources in the Northern Carpathians, the Serbian Carpathians, and in Transylvania. After the centuries of the Migration Period (fifth–tenth century), written sources referring to mining are available from the eleventh century onwards. There are records of western copper exports from the early-thirteenth century onwards, which intensified in the fourteenth and fifteenth centuries.

By projecting the network around 1500 CE on a map and comparing it with the map of the Bronze Age contacts based on quite different data (mostly from 2000 to 1500 BCE), we can observe interesting coincidences (Figs 9 and 10). It is not only that the exploited copper ore sites coincide – this can be considered a natural feature – but also that the cultural and commercial links that emerge are largely overlapping. The transport corridors that developed in Central Europe in prehistory and appear to have been very active in the Bronze Age show a similar pattern in the late Middle Ages and in the early modern period. It is also striking that mining was carried out, albeit not continuously, on a sustained basis in the ore deposits (in the Northern Carpathians, the Eastern Alpine region and Thuringia) that were most easily integrated into this trade network. Raw material from the Balkan deposits, on the other hand, could only intermittently appear in this supply, with copper from the Balkans largely reaching the market through other channels, especially in South-Eastern Europe and the Black Sea region, where the circulation of raw material from the Carpathian Basin appears to be episodic. The trade relations of the Kingdom of Hungary,

⁶⁵Monostori (2020).

⁶⁶Monostori (2021).

⁶⁷Siklósi et al. (2015); Siklósi et al. (2017); Siklósi et al. (2022a); Siklósi and Szilágyi (2019).

⁶⁸Siklósi et al. (2022b).

⁶⁹Liversage (1994); Czajlik (2012b); Bondár (2019); Quinn et al. (2020).

⁷⁰Lenerz-de Wilde (1995); Vandkilde (2005); Czajlik (2012a); Czajlik (2012b); Kiss (2012b); Nørgaard et al. (2019); Ling et al. (2023).

⁷¹Schubert and Schubert (1968); Krause (2003); Kiss et al. (2012b); Pernicka et al. (2016); Ling et al. (2019).

⁷²Czajlik (2012b); Pernicka et al. (2016) Fig. 20.



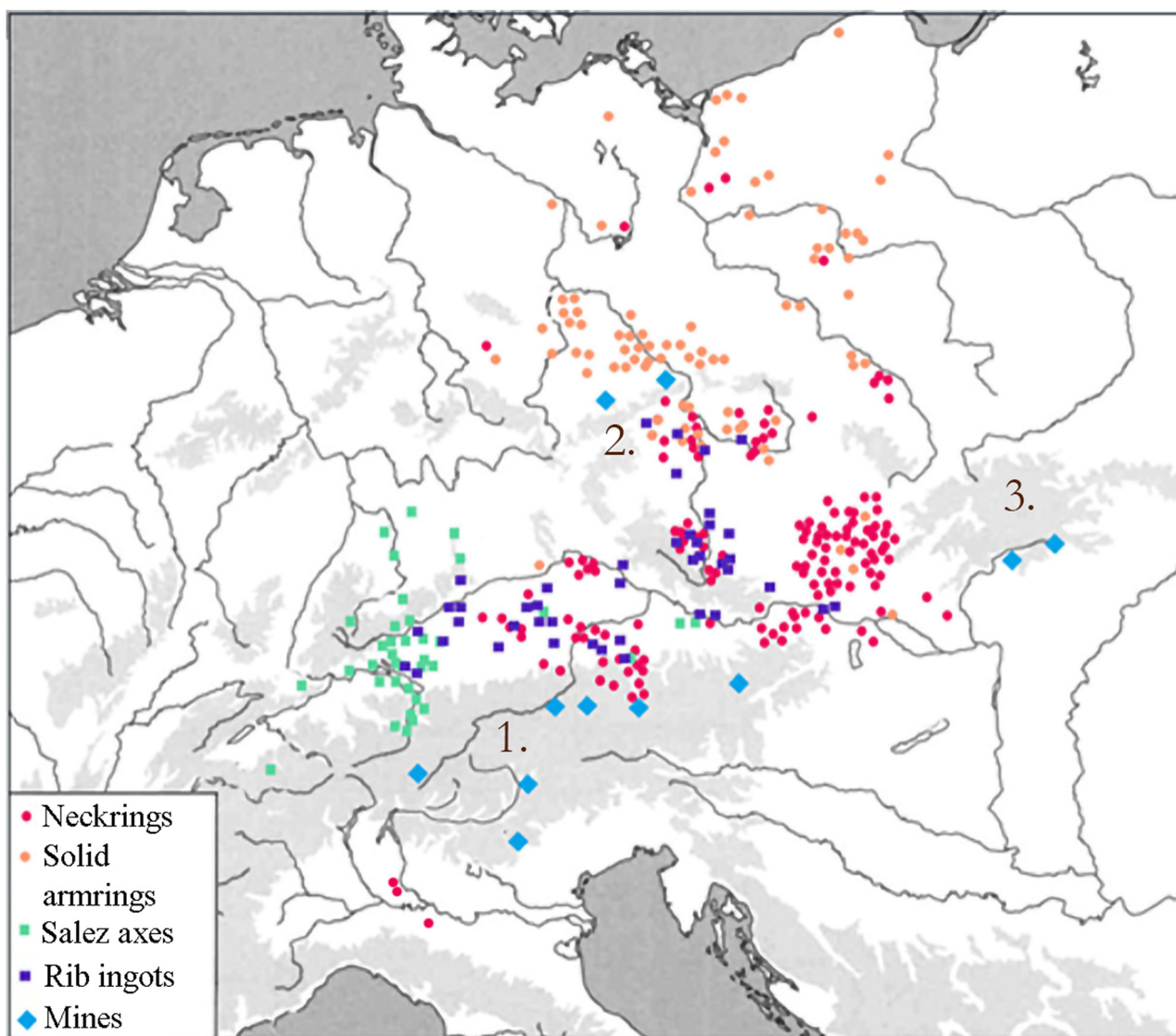


Fig. 9. The distribution of Early and Middle Bronze Age ingots (after Innerhofer, 1997; Krenn-Leeb, 2010). Indicated mining regions: 1: Eastern Alps; 2: Saxo-Bohemian Ore Mountains; 3: Northern Carpathians (see also Fig. 4)

which emerged in the second half of the fourteenth century but withered after the Ottoman conquest (Fig. 8), can be seen as one such episode.

The available evidence suggests that the most important copper deposits in the Mountains were regularly and extensively worked in the Early and Middle Bronze Age (cca. 2200–1600/1500 BCE), the Late Roman period, and the Middle Ages (from the twelfth century at the latest). In addition, copper ore mining in the Mátra and around Rudabánya can be attested in several periods, but these appear to have been of local importance. In the Apușeni Mountains and Szatmár County there is evidence of copper mining in the late Middle Ages and early modern period, but the products of these mines were not included in international trade. The mining of the ores of the Banat Mountains and the continuation of the ores of the Serbian Carpathians south of the Danube presents a particular picture. In the latter area, mines have probably been in continuous

operation since prehistoric times, but the former's minerals were much less exploited until the nineteenth century. The ore deposits here appear to have been exploited intermittently in the Roman period and in the late Middle Ages, in shorter periods. In the fourteenth century, the copper production of this region, which includes the south-eastern part of the Banat and the Serbian Carpathians, was probably destined for the Black Sea markets held by the Genoese colonies, but further research is needed to understand this trade network.

The question posed in the title – whether we are talking about trade in raw materials and finished products or also about itinerant craftsmen – cannot be answered with a clear answer, at least for the time being. What is certain is that in Central Europe, since the Bronze Age, there has been a network of trade covering a large part of the continent's important copper deposits and trading the metal in the form of semi-finished products. Although we cannot identify the

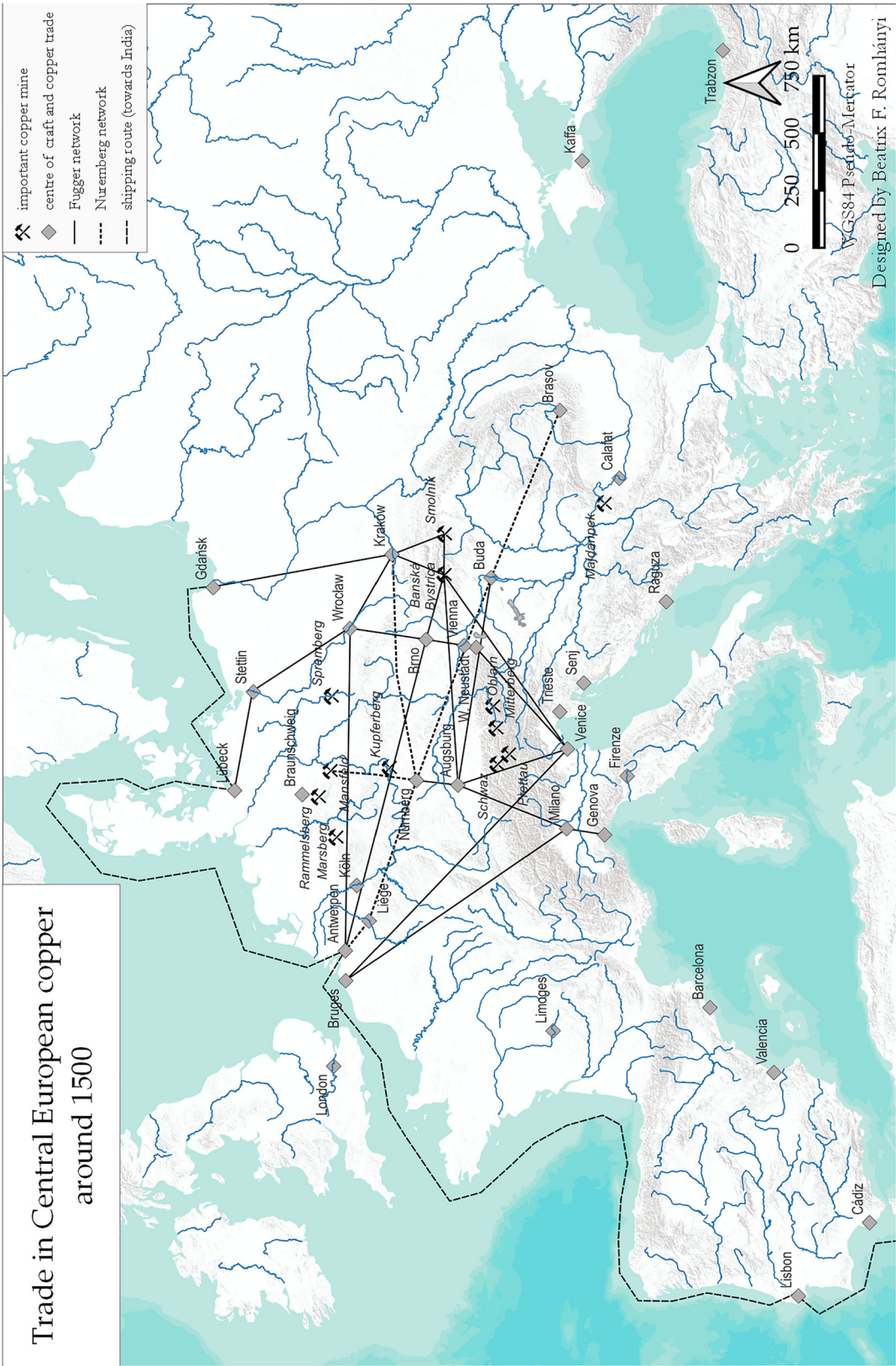


Fig. 10. Trade in Central European copper around 1500

counterpart of this commodity (the returned goods), we can be certain that there was a product available in commercial quantities to the buyers of copper. Nevertheless, the movement of craftsmen and, in certain periods, of artisans engaged in mining and metallurgy can also be traced in rare cases, partly on the basis of the techniques used to make the objects and partly on the basis of written sources.⁷³

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