

# Lead Isotope Analyses of Metal Objects from the Apa Hoard and Other Early and Middle Bronze Age Items from Romania

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## Abstract

Altogether 29 Early and Middle Bronze Age metal objects from Romania including six from the famous Apa hoard were analysed for their chemical compositions and lead isotope ratios. In order to determine the provenance of the copper, these geochemical signatures were compared with copper ores from geological deposits in central and southeastern Europe, which had been exploited in the Bronze Age. It can be concluded that the copper of the implements from the Apa hoard most likely derives from the east Alpine Mitterberg region while the other Middle and Late Bronze Age objects from Romania largely consist of Slovakian copper.

## Keywords

Apa hoard, lead isotope analysis, provenance of copper, Romania, eastern Alps, Slovakia.

## Zusammenfassung – Bleiisotopenanalysen von Metallobjekten aus dem Hortfund von Apa und anderen früh- und mittelbronzezeitlichen Gegenständen aus Rumänien

Insgesamt 29 früh- und mittelbronzezeitliche Metallfunde aus Rumänien inklusive sechs Objekten aus dem berühmten Hortfund von Apa wurden analysiert, um deren chemische Zusammensetzung und ihre Bleiisotopenverhältnisse zu bestimmen. Um die Herkunft des Kupfers zu ermitteln, wurden diese geochemischen Signaturen mit Kupfererzen aus Lagerstätten in Mittel- und Südosteuropa, die in der Bronzezeit ausgebeutet wurden, verglichen. Als Ergebnis kann festgestellt werden, dass das Kupfer der Objekte aus dem Hortfund von Apa sehr wahrscheinlich aus dem Mitterbergrevier in den Ostalpen stammt, während die übrigen mittel- und spätbronzezeitlichen Metallfunde aus Rumänien vorwiegend aus slowakischem Kupfer gefertigt sind.

## Schlüsselbegriffe

Depotfund von Apa, Bleiisotopenanalyse, Herkunft von Kupfer, Rumänien, Ostalpen, Slowakei.

## 1. Introduction

The Nebra Sky Disc hoard belongs to the late Únětice Culture, from around 1600 BC. This chronological position is confirmed by  $^{14}\text{C}$  analyses.<sup>1</sup> Of significant chronological and cultural-historical importance are typological parallels between the two Nebra swords and those of the Apa and Hajdúsámson hoards. In this context, it was interesting to investigate if the material composition of the Apa hoard would confirm this relationship or if a different material was used to produce them.

The Apa hoard from the Satu Mare district in northern Transylvania is one of the most significant bronze ensembles of the 2<sup>nd</sup> millennium BC. The first presentation of the find contained a detailed description of the objects<sup>2</sup> and the hoard has since become one of the best investigated finds, whose importance is evident by the large amount of archaeological literature that has been published about it.<sup>3</sup> It belongs to a larger group of hoards, which are characterised by assemblages of swords and axes. Besides weapons, carefully made spiral jewellery is also a common element;<sup>4</sup> together they constitute the structural elements of Apa-Hajdúsámson-type hoards in the Carpathian Basin from the beginning of the hoarding tradition onwards.<sup>5</sup>

<sup>1</sup> MELLER 2003. – LANDESAMT FÜR DENKMALPFLEGE n.d.

<sup>2</sup> POPESCU 1941.

<sup>3</sup> Cf. BADER 1991, 37–51. – SOROCEANU 2012, 18.

<sup>4</sup> HANSEN 2010, 80.

<sup>5</sup> HANSEN 2010, 81.



Fig. 1. Sword, Inv. no. 15914, samples MA-081310 and MA-081311 (Photo: M. Mehofer).



Fig. 2. Sword, Inv. no. 15914, the handle of the sword shows many fine decorations (Photo: M. Mehofer).

The ensemble was accidentally discovered by a soldier digging a trench in 1939. The find spot is located at the Jungreis estate, about 3 km to the west of the town Apa in the municipality of Medieșul Aurit. At a depth of c. 50 cm, six metal objects were discovered and, because other archaeological features were lacking, the find was considered to represent a hoard.<sup>6</sup> The hoard is dated to the FD III–MDI period according to Hänsel's southern European Bronze Age chronology,<sup>7</sup> and is hence well synchronised with the A2–B1 period of the Bronze Age in central Europe.<sup>8</sup> The dating to the beginning of the southern European Middle Bronze Age is verified by several closed finds in the Carpathian Basin.<sup>9</sup> However, several researchers prefer to date the Apa-type swords as well as the whole ensemble somewhat later.<sup>10</sup>

<sup>6</sup> BADER 1972, 85. – SOROCEANU 2012, 17.

<sup>7</sup> HÄNSEL 1968, 27–29 and Supplement 2.

<sup>8</sup> HACHMANN 1957, 108. – HÄNSEL 1968, 27–29 and Supplement 2. – WÜSTEMANN 2004, 118.

<sup>9</sup> BÓNA 1975, 56. – BADER 1991, 41. – KOVÁCS 1994, 58.

<sup>10</sup> MD I after HÄNSEL 1968, or Phase B1 in the southern German nomenclature. – See DAVID 2002, 210. – BARTÍK, FURMÁNEK 2004, 263.

## 2. The Finds and their Significance

Among the objects comprising the hoard is one well preserved Apa-type metal-hilted short sword (MA-081310 and MA-081311) with rich and characteristic spiral ornamentation on the hilt and the blade (Fig. 1). The hilt has five rivets of which two are functional (Fig. 2). The hilt ends in a pommel with five knobs, which is a unique feature in the Bronze Age. The sword was deposited completely intact. It has a length of 62 cm, weighs 1060 g and its balance point is positioned at 19.8 cm.<sup>11</sup>

The decorations, though partly destroyed due to corrosion, are still very well visible on both sides of the object (Fig. 3). A small hole (maybe a blow hole?), out of which a horizontal crack runs towards the sheath, is located in the lower third of the blade (Fig. 4/A).

The hammered and sharpened cutting edges (Fig. 4/B) show numerous damages, which supposedly were caused either by corrosion or during the excavation. A similar feature can also be found at another part of the sword's blade.

<sup>11</sup> Measured from the side of the pommel, OSGOOD 1998, 101–112. – JUNG, MOSCHOS, MEHOFER 2008. – JUNG, MEHOFER 2013, 177 and Fig. 4.



Fig. 3. Sword, Inv. no. 15914, spiral ornamentation is visible on the entire blade (Photo: M. Mehofer).

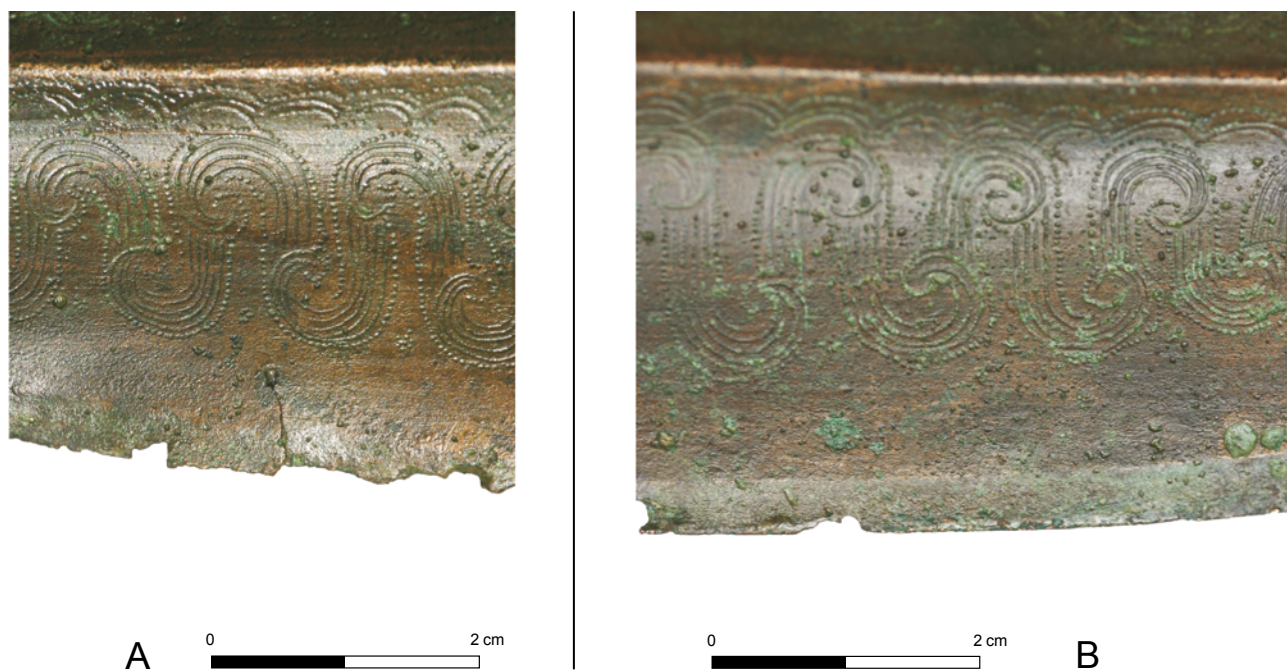


Fig. 4. Sword, Inv. no. 15914. – A. Detail of the lower part of the blade. A hole (shrink hole) is visible. – B. The photo shows that the cutting edges are hammered and sharpened (Photos: M. Mehofer).



Fig. 5. Sword, Inv. no. 15914, it can be recognised that the spiral ornaments, which are visible on both sides of the midrib, are slightly offset to one another (Photo: M. Mehofer).

The semicircular and spiral ornaments were composed of lines of dots engraved with a punch and worked in channels. These ornaments, visible at both sides of the midrib, are slightly offset to one another (Fig. 5).<sup>12</sup> Furthermore, the images show that the surface was polished in a final working step.

A second metal-hilted sword (MA-081312 and MA-081313), typologically belonging to the Oradea-Apa variant, is broken underneath the handle, but otherwise complete (Fig. 6). It has different, more geometric ornamentations, which do not cover the entire blade. The hilt has four rivets of which two have practical functions (Fig. 7). The decoration is discussed in detail elsewhere<sup>13</sup> and there is no need to repeat it here.

The sword has a length of 56.5 cm, weighs 681 g and its balance point is positioned at 19.1 cm (measured from the side of the pommel). Due to corrosion, the blade is severely damaged. The handle and the blade were not cast from the same metal charge, also indicated by a slightly different tin concentration.<sup>14</sup> The semicircular decorations visible on

the blade are of irregular shape, differing from each other, which is why the usage of a punch can be excluded. They are positioned at both sides of the centre rib and arranged not strictly parallel, but slightly offset to one another (Fig. 8).<sup>15</sup> Apparently no special attention was paid to make sure that the decorations of either of the two swords were at the same height – something which would have been easy to achieve, e.g. by pre-cutting the ornamentations.

Apa swords are considered to be the earliest metal-hilted bronze swords in continental Europe.<sup>16</sup> Bader has already comprehensively discussed their possible origin.<sup>17</sup> They have a wide distribution from the northern Carpathian Basin to Jutland. Their appearance in the Fårdrup Horizon or Period Ib in southern Scandinavia<sup>18</sup> therefore constitutes the earliest record of elaborate bronze objects in this region. Imports of swords from southeastern Europe are considered to have significantly contributed to the development of Nordic metal-hilted swords. However, local imitations were also produced,<sup>19</sup> which is well demonstrated by different manufacturing methods. Some Apa-type swords are cast in one piece. This appears to be the case with specimens found in the northern Carpathian Basin as well as in Jutland and northern Germany.<sup>20</sup> Other finds, such as the Apa-type swords from the Nebra hoard, have two-piece hilts fitted to the blade and held by rivets.<sup>21</sup> The Apa-type sword from Pella has yet another construction, where both hilt and blade are cast separately and attached with rivets.<sup>22</sup> On a sword found in the Topla River in modern day Slovakia, the handle and blade have the same composition, but the rivets are made of different materials.<sup>23</sup> Furthermore, the contents of copper and tin vary greatly at different locations on the sword.<sup>24</sup> It is striking that the Pella sword has similar variations in its composition.<sup>25</sup>

Carpathian Basin specimens are mainly found in eastern Hungary and northwestern Romania and they are closely related to earlier Hungarian daggers. It is therefore likely that their origin lies somewhere in this region.<sup>26</sup>

<sup>15</sup> DAVID 2002, Pl. 91/2.

<sup>16</sup> CHILDE 1929, 273. – HOLSTE 1953, 7.

<sup>17</sup> BADER 1991. – Also summarised by DAVID 2002, 369–371.

<sup>18</sup> HACHMANN 1957, 109. – LOMBORG 1959, 123–124.

<sup>19</sup> LOMBORG 1959, 95–96. – HUNDT 1978, 128–129.

<sup>20</sup> WÜSTEMANN 2004, 118. – HANSEN 2010, 79.

<sup>21</sup> HANSEN 2010, 79.

<sup>22</sup> HÄNSEL 2000, 37.

<sup>23</sup> OŽDIN 2004, 273–274.

<sup>24</sup> OŽDIN 2004, 275.

<sup>25</sup> HÄNSEL 2000, 37.

<sup>26</sup> KEMENZEI 1991, 2–3, 10. – KILLIAN-DIRLMEIER 1993, 127. – HARDING 1995, 71. – HÄNSEL 2000, 33–35. – See also BADER 1991, 40. – SICHERL 2004, 48–40 (with emphasis on the central Danube region).

<sup>12</sup> DAVID 2002, Pl. 90/1.

<sup>13</sup> DAVID 2002, 369–372.

<sup>14</sup> See Table 2.



Fig. 6. Sword, Inv. no. 15913, samples MA-081312 and MA-081313 (Photo: M. Mehofer).



Fig. 7. Sword, Inv. no. 15913, detail of the lower part of the handle richly covered with ornaments. Above the second rivet a shrink hole – remnant from the casting process – is visible (Photo: M. Mehofer).

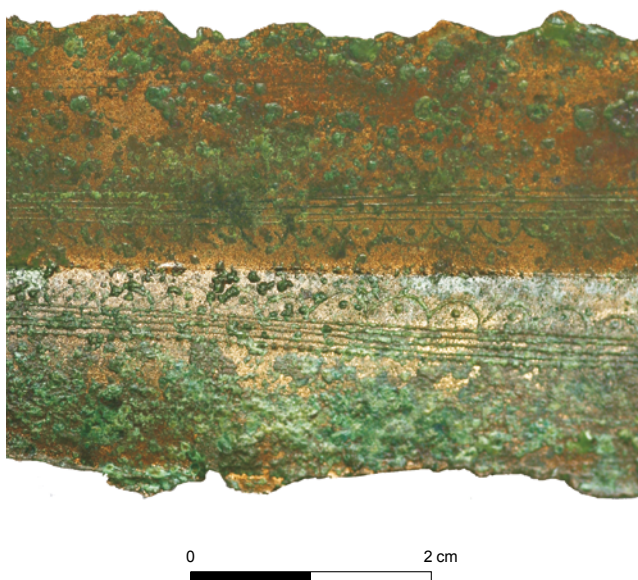


Fig. 8. Sword, Inv. no. 15913, the photo shows a detail of the lower section of the blade. The ornaments are of irregular, not strictly semi-circular shape (Photo: M. Mehofer).

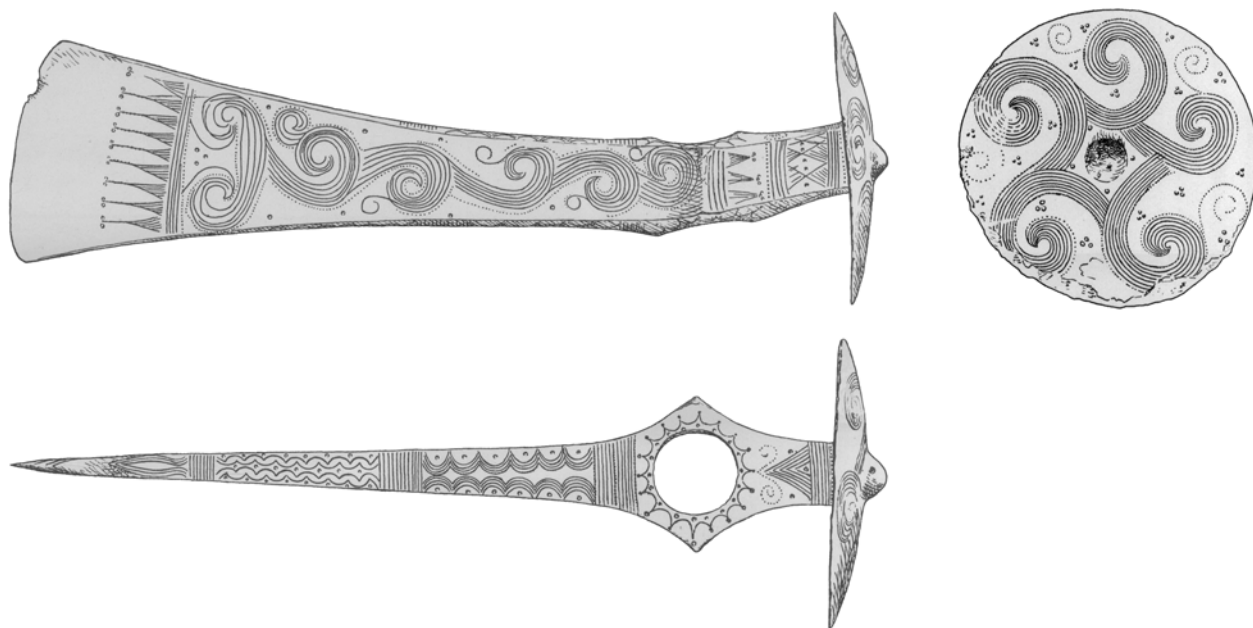


Fig. 9. Disc-butted axe, Inv. no. 15912, sample MA-155421 (after POPESCU 1941, Pl. III) (1:2).

Nevertheless, every Apa-type sword is a unique bronze item, as the ornamentation differs from piece to piece and the shape of blades and handles vary as well.<sup>27</sup> According to their functional attributes, Apa-type swords could have been used as slashing or stabbing weapons.<sup>28</sup> Since most of them, however, do not have traces of battle activities, they mainly appear to have had a representative function, or were employed as prestige objects.

In addition to the two swords, three axes belong to the hoard. One is a disc-butted axe type A2 after Nestor<sup>29</sup> (MA-155241; Fig. 9), a typological designation that is still in use with minor modifications.<sup>30</sup> The axe does not have a shaft tube, the disk is flat except for a central small protruding knob,<sup>31</sup> and it has a slim and slightly curved body. The axe is adorned with typical and carefully made spiral decorations, which cover every part of the body, except the rounded cutting edge. Finds of A2-type axes are confined to northwestern Transylvania and Hungary.

Similar ornamentation elements are also present on the crest-butted axe of the Apa-Nehoiu type (MA-081316; Fig. 10). Like the Apa-type swords, every axe of this par-

ticular type is a unique bronze item.<sup>32</sup> Their ornamentation is never identical and the shape varies from piece to piece. Elongated, thick and curved ridges with rounded cutting edges characterise Apa-Nehoiu-type axes.<sup>33</sup> The ornamentation on the axe from the Apa hoard has a more geometric character compared with other specimens of this type.

The artefact was cast and its surface was ground and polished so that no traces of the fabrication process are visible. The triangles at the ridge are framed by dotted lines and filled with parallel engraved lines. The ornaments on the shaft and on the blade were produced by the same technique. Apa-Nehoiu-type axes first appeared in the early phase of the Middle Bronze Age in the Carpathian Basin and were at least in use until the late phase of the same period.<sup>34</sup> Crest-butted axes in general, but specifically those with carefully made ornamentation, are often interpreted as prestige weapons,<sup>35</sup> although their actual use in battles is considered possible.

The third axe in the hoard is a shaft-tube axe of the Křtřenov type (MA-081317). After casting, its surface was smoothed. Due to heavy corrosion, it is not possible to obtain further information on the manufacturing techniques of the ornaments and decorations. These axes are characterised

27 E.g. BARTÍK, FURMÁNEK 2004, 260. – VACHTA 2008, 9.

28 BADER 1991, 40.

29 NESTOR 1938, 183. – The item is missing (SOROCEANU 2012, 19).

30 E.g. HÄNSEL 1968, 61–65. – KROEGER-MICHEL 1983, 46–48. – BO-ROFFKA 1999, 67.

31 VULPE 1970, 67.

32 VULPE 1970, 53.

33 VULPE 1970, 53.

34 VULPE 1970, 55–56.

35 VULPE 1970, 55.



Fig. 10. Crest-butted axe, Inv. no. 15910, sample MA-081316 (Photo: M. Mehofer).



Fig. 11. Crest-butted axe, Inv. no. 15909, sample MA-081317 (Photo: M. Mehofer).

by ribbed shaft-tubes with end-discs and very narrow bodies with linear ornamentation, which follow the silhouettes. Hájek first defined the Křtěnov type,<sup>36</sup> which after several additions,<sup>37</sup> is now usually divided into three variants.<sup>38</sup> Variant A represents the actual Křtěnov type to which the Apa axe belongs (Fig. 11). Axes of variant A are frequently found in hoards, while the types B and C are commonly found in graves. Therefore, finds in closed, well-dated contexts support the chronological position of the axes at the

transition from the Early to the Middle Bronze Age. The distribution of these axes is as wide as the Apa-type swords. They appear in more than 50 sites between the Carpathian Basin and southern Sweden,<sup>39</sup> but the core area of their distribution is clearly located in Hungary, Slovakia and Romania.

As the cutting edges of all three axes seem to have been ground and polished, in principal they would actually be usable. Whether the analysed axes served as representative or prestige objects or had another function, cannot be reconstructed based on observable technological features.

<sup>36</sup> HÁJEK 1950.

<sup>37</sup> MOZSOLICS 1967, 24–28. – HÄNSEL 1968, 55–58. – MAYER 1977, 34–38. – STUHLÍK 1988, 320–321.

<sup>38</sup> NEUGEBAUER-MARESCH, NEUGEBAUER 2000–2001, 338–339.

<sup>39</sup> NEUGEBAUER-MARESCH, NEUGEBAUER 2000–2001, 341–342.



Fig. 12. Arm-spiral, Inv. no. 15915, sample MA-081315 (Photo: M. Mehofer).

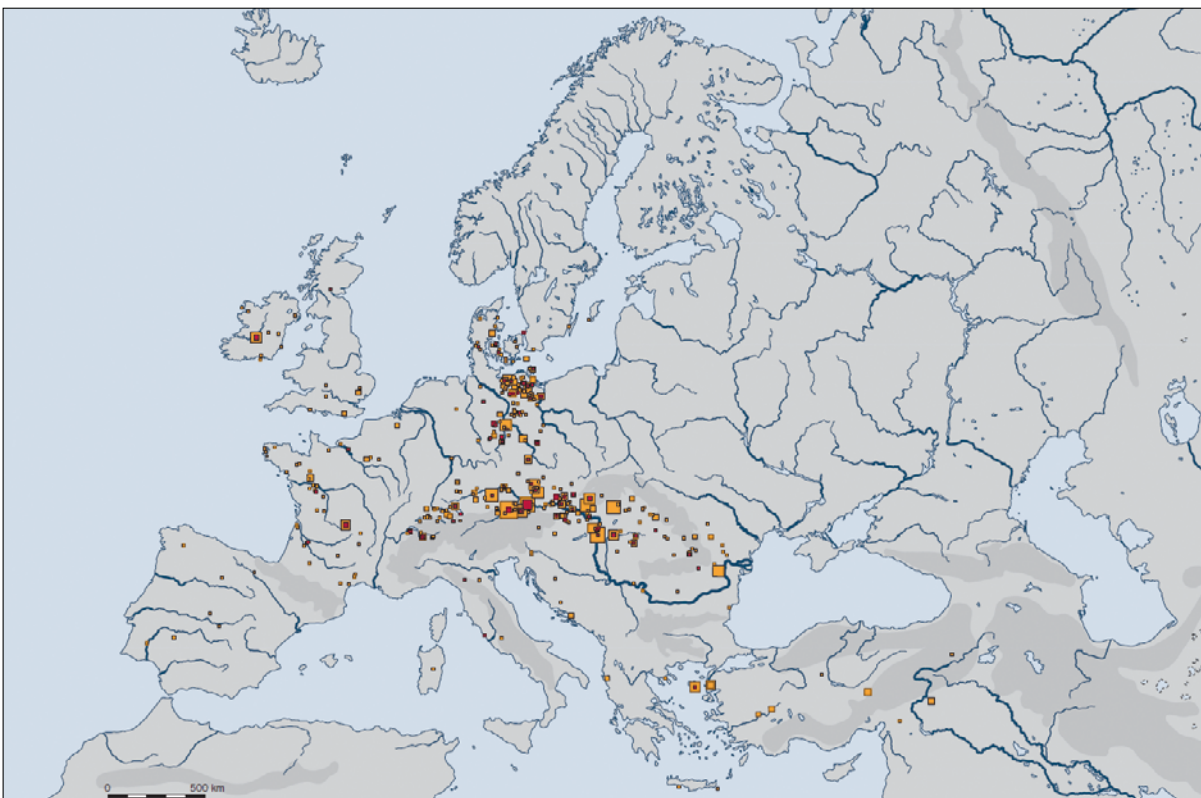


Fig. 13. Geographical distribution of contemporary Bronze Age metal finds with similar concentrations of As, Sb, Ni and Ag as the Nebra hoard. The size of the symbols relates to the number of finds at one location. Dark symbols relate to objects that are similar with Nebra metal within a factor of  $\pm 2$ . Light symbols relate to similar compositions with a factor of  $\pm 4$ . It is obvious that this metal type has a wide distribution along the northern piedmont of the eastern Alps and reaches into the Carpathian Basin (after PERNICKA 2010, 725 and Fig. 5).



Besides the weapons, an Apa-type arm spiral also belongs to the find (MA-081315; Fig. 12). It is made of tin bronze with 6.2 % tin and consists of good quality copper with very few impurities.<sup>40</sup> These spirals are characterised by a lack of ornamentation and central knobs. Another distinguishing trait is their rectangular cross section and three to four turns of the large spiral.<sup>41</sup> The Apa spiral is made from a thick bar, which becomes thinner towards the ends, one ending in a large spiral, while the other end forms a small spiral in a vertical position in relation to the large one.

Its surface shows no traces of production, e.g. remnants from the casting or forging process. One can assume that it was carefully ground and polished before it was shaped into its final form and e.g. the spiral was rolled up.

Several different spiral types of typological and chronological significance have been established.<sup>42</sup> The distribution of Apa-type arm spirals is largely limited to northeastern Hungary and northwestern Transylvania,<sup>43</sup> but a few finds are also known from the region around Arad. In general, arm spirals are characteristic bronze items for the Danube-Carpathian region and the Pontic area. They appear mostly in hoards and rarely in graves.<sup>44</sup> Apa-type spirals are normally dated to the beginning of the Middle Bronze Age,<sup>45</sup> but some researchers have emphasised that they could also belong to a later phase of the Early Bronze Age in the area.<sup>46</sup> Arm spirals are usually interpreted as defensive equipment. Nevertheless, it cannot be ruled out that they served purely decorative functions. Several researchers have therefore assumed that the spirals have a symbolic meaning, which denotes the wearers as warriors or individuals in high social positions.<sup>47</sup>

The objects of the Apa hoard are early examples of a new elaborate style and new techniques in bronze working. The find shares stylistic similarities with materials from the Aegean and northern Europe, which have been extensively discussed in the literature. The absolute date of the hoard between 1600 and 1500 BC falls into a period when significant changes in the material culture occurred in a number of European regions.

### 3. Methods

The hypothesis that trace element concentrations can be a guide to the provenance of ancient metals was formulated more than one hundred years ago. One early example is F. Göbel, who drew his conclusions from the geographical distribution of about 120 analysed objects and ascribed them to seemingly well-defined ethnic groups, as it was customary in those times.<sup>48</sup> As soon as appropriate analytical methods became available in the 1930s, very large analytical programmes for ancient metal objects were carried out along these lines. The largest one was undertaken by the Württembergisches Landesmuseum in Stuttgart<sup>49</sup> with more than 20,000 analyses of prehistoric metal objects from all over Europe. They were classified according to their chemical composition, and the distribution of these metal groups was studied in time and space based on a frequency analysis of the concentration of As, Sb, Ag, Ni and Bi. These data can now be used to study the geographic distribution of certain compositional copper types from central European bronzes, which are contemporary with the Apa hoard (Fig. 13).

All objects of the Apa hoard were sampled<sup>50</sup> (Tab. 1). The material was analysed by energy-dispersive XRF in the laboratories of the Curt-Engelhorn-Zentrum Archäometrie in Mannheim. Details of the procedure were described by Lutz and Pernicka in 1996.<sup>51</sup> Lead isotope analysis was accomplished by Multiple-Collector Inductively-Coupled Plasma Mass Spectrometry (MC-ICP-MS). The samples were dissolved in dilute HNO<sub>3</sub> and lead was separated with ion chromatography resin from the matrix, essentially following the procedure of Niederschlag and colleagues.<sup>52</sup>

### 4. Results and Discussion

#### 4.1 Apa Hoard

With the application of lead isotope analysis to copper-based alloys,<sup>53</sup> chemical analyses of ancient metal objects seemed to have become obsolete. Lead isotope analysis provided a new set of parameters, which are not changed by chemical processes that take place during smelting or corrosion.

40 JUNGHANS, SANGMEISTER, SCHRÖDER 1968b, 242–243, No. 8707.

41 BADER 1972, 88.

42 For a compilation of the literature see: PETRESCU-DÎMBOVIȚA 1998, 30.

43 BADER 1991, 42.

44 PETRESCU-DÎMBOVIȚA 1998, 29.

45 For references see: PETRESCU-DÎMBOVIȚA 1998, 34.

46 E.g. HÄNSEL 1968, 103–105.

47 BADER 1972, 90. – KRISTIANSEN 2002, 326–327.

48 GÖBEL 1842.

49 JUNGHANS, SANGMEISTER, SCHRÖDER 1960. – JUNGHANS, SANGMEISTER, SCHRÖDER 1968a,b. – JUNGHANS, SANGMEISTER, SCHRÖDER 1974.

50 As mentioned above, the disc-butted axe Inv. no. 15912 is missing, but remaining sampling material from the archive of the SAM project was used for lead isotope analysis.

51 LUTZ, PERNICKA 1996.

52 NIEDERSCHLAG et al. 2003.

53 GALE, STOS-GALE 1982.

Tab. 1. Objects from the Apa hoard.

Lab. no.	Object	Site	Museum inventory no.	SAM no.
MA-081310	sword, sample from the blade	Apa	15914	8706
MA-081311	sword, sample from the hilt	Apa	15914	8705
MA-081312	sword, sample from the blade	Apa	15913	8704
MA-081313	sword, sample from the hilt	Apa	15913	8703
MA-155421	disc-butted axe	Apa	15912	8702
MA-081315	arm-spiral	Apa	15915	8707
MA-081316	crest-butted axe	Apa	15910	8701
MA-081317	crest-butted axe	Apa	15909	8700

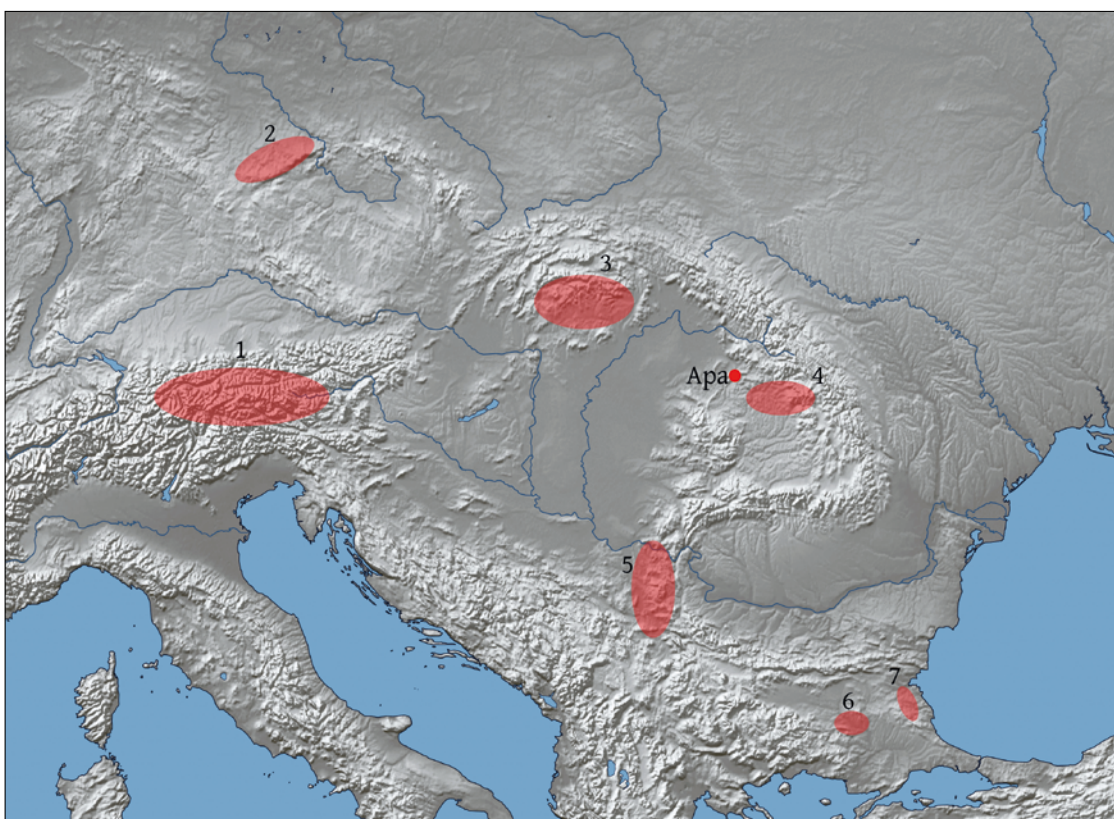


Fig. 14. Location of Apa and major copper mineralisation in central and southeastern Europe together with one minor one (Aibunar) that was already exploited in the 5<sup>th</sup> millennium BC (Graphics: B. Nessel).

However, it is necessary to assume that the lead in the copper or copper alloy derives as impurity from the used copper ores. Furthermore, it must be assumed that neither ores nor metals from different sources were mixed. The latter condition of course also applies to the chemical composition, which carries some geochemical information of the original ore source and can thus be used as an independent parameter set for the discussion of provenance. Although ore deposits can in principle be distinguished by these two parameter sets, they are, however, not unique for a single ore deposit like a human fingerprint. Therefore, the larger the area that

is considered as possible source region (e.g. all of Europe), the larger the number of ore deposits and overlapping geochemical characteristics, resulting in geographically unrelated ore deposits which may have the same lead isotope and/or chemical signature. In addition, there are copper ore deposits that are relatively poor in lead, but contain relatively high concentrations of uranium and thorium which can lead to a highly variable lead isotope signature. Such lead is usually called radiogenic and increases the possibility of overlapping lead isotope characteristics of different ore deposits. A useful approach is to first exclude those ores that

Tab. 2. Chemical composition of the Apa samples as determined with energy-dispersive XRF. All values are given in mass percent. Zn and Se were below the detection limit of 0.01 % and Te and Bi below 0.005 % in all samples.

Lab. no.	Cu	Sn	Pb	As	Sb	Ag	Ni	Fe	Co
MA-081310	90	8.9	<0.01	0.39	0.13	0.019	0.33	0.10	0.013
MA-081311	90	9.0	<0.01	0.16	0.17	0.008	0.16	0.23	<0.01
MA-081312	89	9.4	0.05	0.52	0.08	0.019	0.45	0.08	0.017
MA-081313	90	8.4	<0.01	0.56	0.18	0.037	0.42	<0.02	0.037
MA-155421	93	5.6	<0.01	0.68	0.055	0.017	0.38	0.05	0.01
MA-081315	91	8.0	<0.01	0.45	0.12	0.021	0.54	<0.02	0.022
MA-081316	92	7.2	<0.01	0.51	0.04	0.012	0.46	<0.02	0.013
MA-081317	92	7.0	<0.01	0.39	0.02	0.019	0.25	0.04	0.028

Tab. 3. Lead isotope ratios in the samples from the Apa hoard. One sample (MA-081315) was too small for lead isotope measurement. The precision of measurement is less than  $\pm 0.01$  % for ratios with  $^{206}\text{Pb}$  in the denominator and up to  $\pm 0.03$  % for  $^{206}\text{Pb}/^{204}\text{Pb}$ .

Lab. no.	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{208}\text{Pb}/^{204}\text{Pb}$
MA-081310	2.0474	0.81861	19.198	15.716	39.306
MA-081311	2.0423	0.81646	19.249	15.716	39.312
MA-081312	2.0604	0.82897	18.909	15.675	38.960
MA-081313	2.0741	0.83275	18.851	15.698	39.099
MA-155421	2.0421	0.81611	19.249	15.709	39.309
MA-081316	2.0524	0.82423	19.046	15.698	39.090
MA-081317	2.0671	0.82106	19.135	15.711	39.554

do not match the archaeological artefacts isotopically, and then check if the remaining (isotopically overlapping) ore deposits can be discriminated by their trace element patterns.

Indeed, it is often stated that chemical analyses alone will not allow copper-alloy artefacts to be matched to their parent copper ores. Although this is in principle correct, there are cases where the trace element pattern may be more indicative of an ore source than lead isotope ratios. Some copper ore deposits are chemically rather homogeneous, but show wide variations in their lead isotope ratios. This occurs more often than initially thought so that it is obvious that a combination of both sets of data – lead isotope ratios and trace element concentrations – will provide a better discrimination between different sources. In this study, we are facing such a situation.

Although copper mineralisation exists in Transylvania, no lead isotope ratios of copper ores have so far been available. Therefore, the results of the Apa hoard can only be compared to three mining regions in central Europe, where

prehistoric mining has been confirmed or at least seems likely. Of course more copper deposits and small occurrences are known in the wider surrounding area of the find location, but they cannot be considered here, because the trace elements used for provenance discussion are often not reported in the geological or geochemical literature. In addition, very few geological reports contain any information on ancient or 'old' mining. In Figure 14 the regions are outlined where conditions for a reasonable discussion of the provenance of copper are fulfilled. It can be safely assumed that the substantial amount of copper, which was produced in the developed Early Bronze Age could only be supplied by larger deposits. The mining region of Baia Mare is included, although it mainly consists of a group of lead-zinc deposits; local accumulations of copper ores can, however, not be excluded.

The results of the chemical and lead isotope analyses are summarised in Tables 2 and 3. As expected, all samples consist of tin bronze with no other alloying components, especially no addition of lead, which is important for the

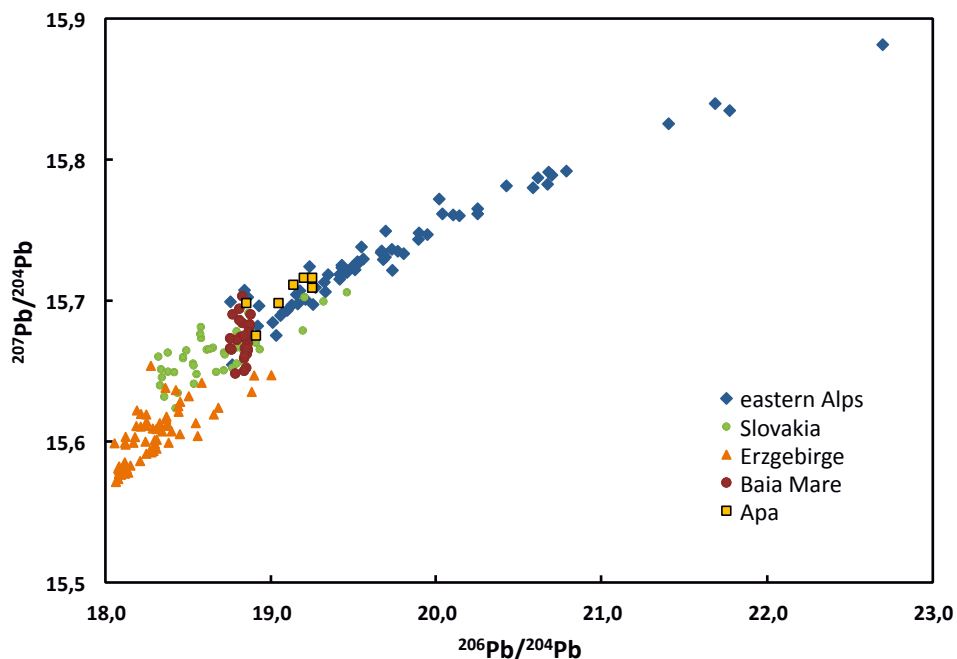


Fig. 15. Lead isotope ratios of the analysed archaeological objects (red symbols) and of copper ores from the eastern Alps, the Slovak Ore Mountains, and the Saxo-Bohemian Ore Mountains (data are taken from MARCOUX et al. 2002. – NIEDERSCHLAG et al. 2003. – SCHREINER 2007). The data for the eastern Alps are as yet unpublished. The analytical errors are smaller than the symbols (Graphics: E. Pernicka).

discussion of the lead isotope ratios in relation to the possible provenance of the copper and is the major question here. The chemical compositions agree well with the results for these elements.<sup>54</sup>

When producing long objects with a relatively thin cross-section, e.g. a sword, it is important that the bronze used is poor in certain alloying elements, such as lead, which can negatively influence the mechanical properties.<sup>55</sup> The investigated objects comply with these conditions, as they contain no other alloying element than tin, except for the trace elements, which originate from the used copper ore. The tin concentrations of both swords and their single components respectively lie between 8.4 % and 9.4 % (Tab. 2) and are therefore close to the ideal mixing ratio of 1:9. The analysed axes have lower tin concentrations than the swords, but still enough to change their colour and enhance their quality.

Figure 15 shows the lead isotope ratios of the analysed artefacts and the ore deposits marked in Figure 14. Not shown are the data for Majdanpek in eastern Serbia and Aibunar in Bulgaria, which would plot around  $^{206}\text{Pb}/^{204}\text{Pb} = 18.5$  and  $^{207}\text{Pb}/^{204}\text{Pb} = 15.6$  so that they can safely be excluded as possible sources for the objects under study. The

Chalcolithic copper mine at Aibunar in Bulgaria can be excluded as well, because its ores only contain arsenic at similar concentrations as the objects from the Apa hoard, but have much lower nickel concentrations.<sup>56</sup> Although the copper ores from the Medni Rid region in Bulgaria are also rich in radiogenic lead and thus exhibit an extremely large variation of their lead isotope ratios, they are rather pure and contain about an order of magnitude less arsenic and antimony than the objects from this study,<sup>57</sup> so that they are also not included in the discussion. Majdanpek in Serbia is one of the largest copper deposits in Europe and was already exploited in the 5<sup>th</sup> millennium BC,<sup>58</sup> but it also seems to have produced rather pure copper in prehistoric times and can be clearly distinguished from the eastern Alps by lead isotope ratios.<sup>59</sup> This leaves only the central European ore regions, of which the Slovak Ore Mountains are geographically the closest. From Figure 15 one can also conclude that the copper ores from the Saxo-Bohemian Ore Mountains are an unlikely source for the copper of the Apa hoard. Furthermore, the Baia Mare region is an unlikely source of copper as well, since the major mineralisation is dominated

<sup>54</sup> JUNGHANS, SANGMEISTER, SCHRÖDER 1968a, b.

<sup>55</sup> SPERBER 2004, 329. – SCHUMANN 2005. – MEHOFER 2011, 127.

<sup>56</sup> PERNICKA et al. 1997.

<sup>57</sup> Unpublished data.

<sup>58</sup> PERNICKA et al. 1993. – RADIVOJEVIĆ et al. 2010.

<sup>59</sup> HÖPPNER et al. 2005.

by lead and zinc sulphides with gold and silver. A typical example is the principal vein at Baia Sprie with more than 1000 m depth that contained Au-Ag mineralisation in its upper part, Pb-Zn sulphides in the lower part, and Cu mineralisation at great depth.<sup>60</sup> Furthermore, the lead isotope ratios define trends in the lead ores that are clearly different from the copper-based artefacts. There are two copper deposits in the southern Apuseni Mountains, also known as 'Metaliferi Mountains', but these are so-called porphyry copper types with disseminated copper, i.e. large amounts of low-grade copper ore that can only be economically exploited with modern mining and beneficiation technology. Accordingly, we need only to distinguish between the remaining two regions that are not so clearly separated in the lead isotope diagram, namely the eastern Alps and the Slovakian Ore Mountains.

Although only a few elements are really useful for provenance discussions, because they behave in a similar way during the smelting processes, they can now provide the necessary information to discriminate between those two regions, which are difficult to differentiate by lead isotope ratios alone. Of these elements, the most indicative are silver and nickel, which are plotted in Figure 17 together with the analysed artefacts. Although there is still some overlap between the two ore regions, the fit of the Apa hoard with copper ores from the Mitterberg area near Salzburg is much better. Incidentally, this is also true for the typologically similar, contemporary hoard of Hajdúsámson in eastern Hungary,<sup>61</sup> from which five axes have been analysed (Fig. 16).

Pernicka already discussed the trace elements that are useful for establishing a possible relationship between copper ores and smelted copper.<sup>62</sup> It is obvious that a better differentiation of ore deposits can be achieved if the number of elements considered is increased. This can be shown at the Mitterberg area, where different lode systems can be differentiated with the concentrations of seven elements.<sup>63</sup> One can compare these patterns with the analysed objects in Figure 18, which plot along the trend of the Mitterberg ores from the main lode, and perhaps to the Brander and Buchberg lodes, which have a similar pattern.

The number of chemically analysed ore samples from the Slovakian Ore Mountains is still limited, but using the data provided by Schreiner,<sup>64</sup> the silver concentrations seem

to be systematically higher than in the copper ores from the eastern Alps (Fig. 17). The Slovakian ores are mostly polymetallic in character, but in Figure 17 only ore samples are plotted that would produce copper rather than lead. Most of these also contain more than 10 % copper so that copper could have been smelted from them in the Bronze Age. Of course one must also assume that some beneficiation of the ores was practiced. Another diagram of antimony and bismuth concentrations (Fig. 19) confirms the difference between the two regions and corroborates the association of the copper of the Apa finds with the eastern Alps.

If the lead isotope ratios are plotted in a different type of diagram, we see that the copper ores from Mitterberg and Slovakia define different trends, which overlap in the upper right hand corner (Fig. 20). Such wide variations of the lead isotope ratios are characteristic for copper deposits that have low lead concentrations combined with relatively high uranium concentrations, which results in so-called radiogenic lead.<sup>65</sup> They are often more homogeneous in their trace element patterns than in their lead isotope ratios. However, if one can assume that a number of samples derive from the same deposit, either from the archaeological context or similar trace element patterns or both, as with the objects of the Apa hoard, then a differentiation is possible if the associated trend lines have different slopes, such as demonstrated in Figure 21. It is evident that the slope of the combined samples from the Apa hoard is identical to the Mitterberg region, which differs from the Slovakian copper ores of the Hron valley.

The match with the ore samples from the Mitterberg main lode is not perfect, as the  $^{208}\text{Pb}/^{206}\text{Pb}$  ratios are somewhat lower in the analysed samples. On the other hand, the slag samples from the Mitterberg region plot more closely to our samples, which may be explained by a slight alteration of the lead isotope ratios in the ores by the smelting process, in which a certain amount of lead from the host rocks is bound to be included. These rocks may have had lower Th/Pb ratios than the ores. This would result in lower  $^{208}\text{Pb}/^{206}\text{Pb}$  ratios. Confirmation for this hypothesis has recently been provided by the lead isotope ratios of copper ingots from the Middle Bronze Age metal hoard of Moosbruckschrofen in the Upper Inn Valley in the Tyrol,<sup>66</sup> which show a similar trend in their lead isotope ratios. Again, the combined trace element and lead isotope characteristics are consistent with copper ores from the Mitterberg region.

60 LANG 1979.

61 ZOLTAI 1908. – MOZSOLICS 1967, 139–140 and Pl. 9. – DANI et al. 2013. – For results of LIA see PERNICKA 2013.

62 PERNICKA 1999.

63 LUTZ, PERNICKA, PILS 2010.

64 SCHREINER 2007.

65 See PERNICKA et al. 1993 for a more detailed explanation.

66 LUTZ 2016.



Fig. 16. Analysed objects from the Hajdúsámson hoard in Hungary (Photos: A. Jurás, Déri Museum, Debrecen)

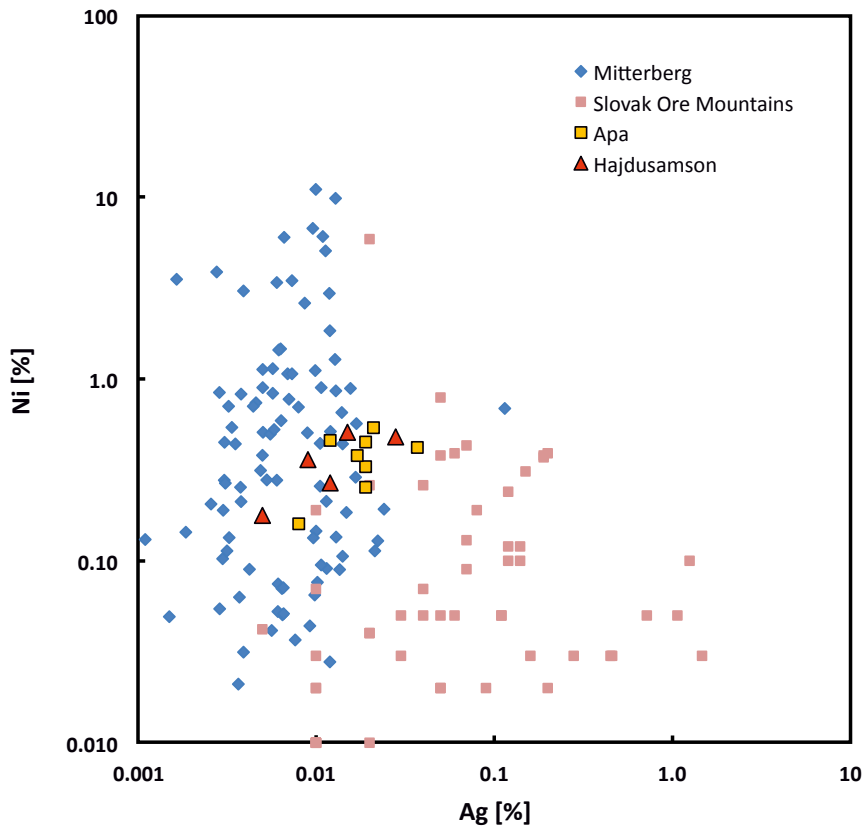


Fig. 17. Concentrations of silver and nickel in the analysed archaeological objects compared with copper ores from the eastern Alps and the Slovak Ore Mountains (data are from SCHREINER 2007. – PERNICKA, LUTZ, STÖLLNER 2016). The analytical errors are smaller than the symbols. Note that the detection limits for both elements were about 0.01 % in the data set of the Slovak Ore Mountains (Graphics: E. Pernicka).

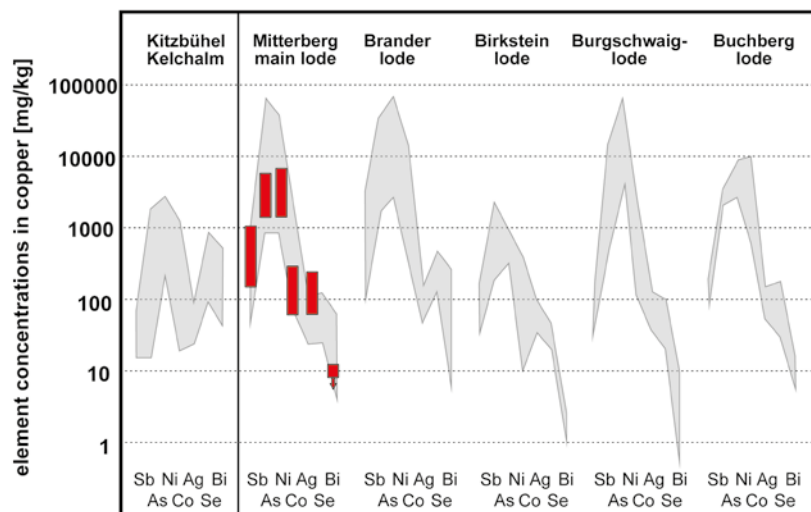


Fig. 18. Trace element patterns of copper ores from Kitzbühel, Tyrol, and from different lodes in the Mitterberg area in Salzburg, Austria (LUTZ, PERNICKA, PILS 2011). The objects analysed in this study (red) match the pattern of the main lode almost perfectly (Graphics: E. Pernicka).

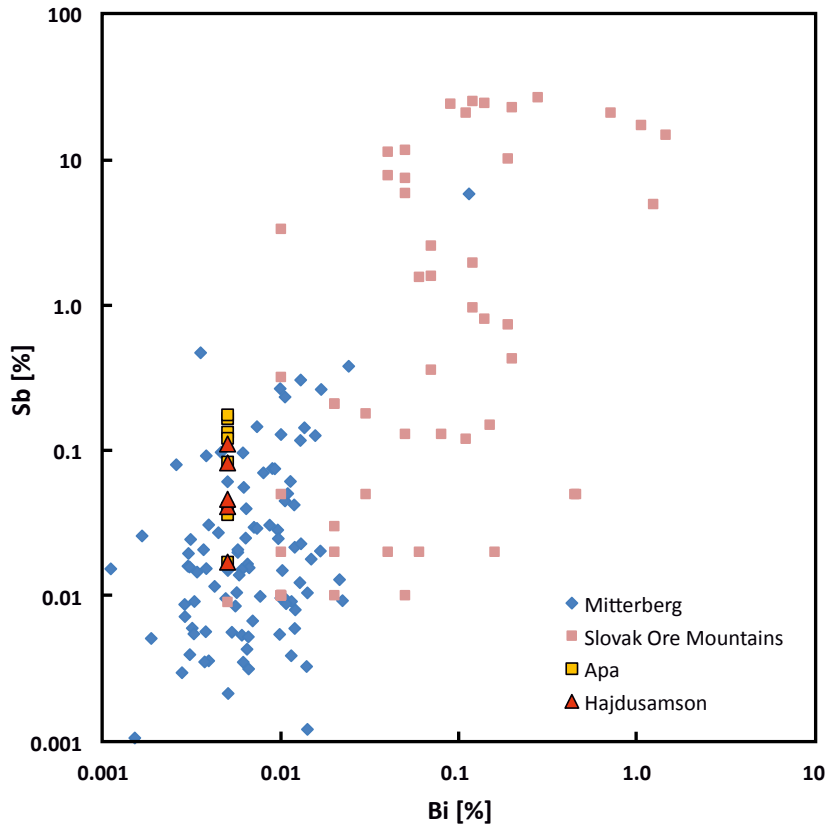


Fig 19. Concentrations of bismuth and antimony in the analysed archaeological objects compared with copper ores from the eastern Alps and the Slovak Ore Mountains (data are from SCHREINER 2007. – PERNICKA, LUTZ, STÖLLNER 2016). The analytical errors are smaller than the symbols. Note that the detection limits for both elements were about 0.01 % in the data set of the Slovak Ore Mountains (Graphics: E. Pernicka).

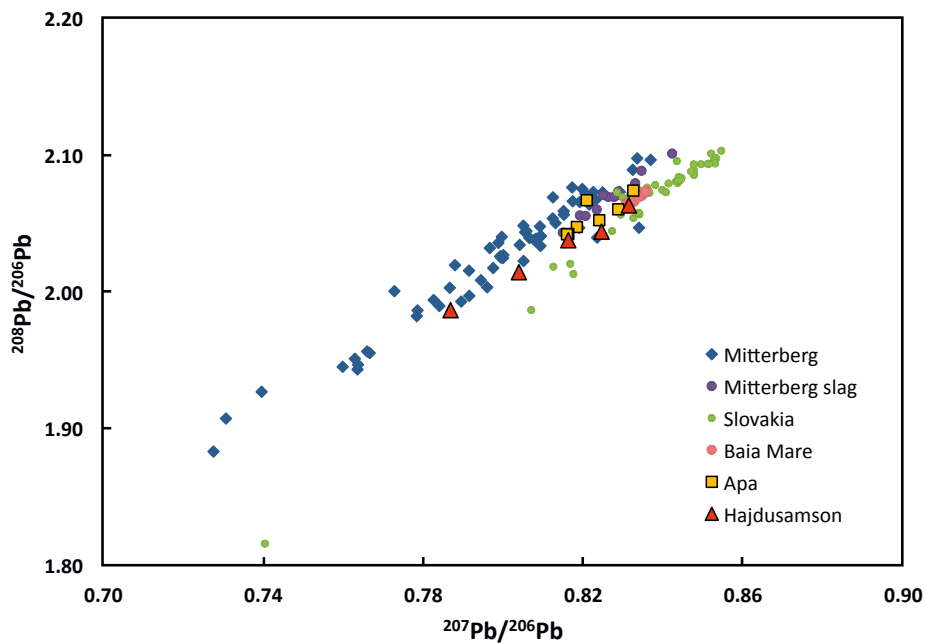


Fig. 20. Alternative presentation of the lead isotope ratios of the objects from Apa (orange symbols) and of copper ores from Mitterberg, the Slovak Ore Mountains and lead ores from Baia Mare (data from MARCOUX et al. 2002. – SCHREINER 2007; unpublished data for Mitterberg). The analytical errors are smaller than the symbols (Graphics: E. Pernicka).



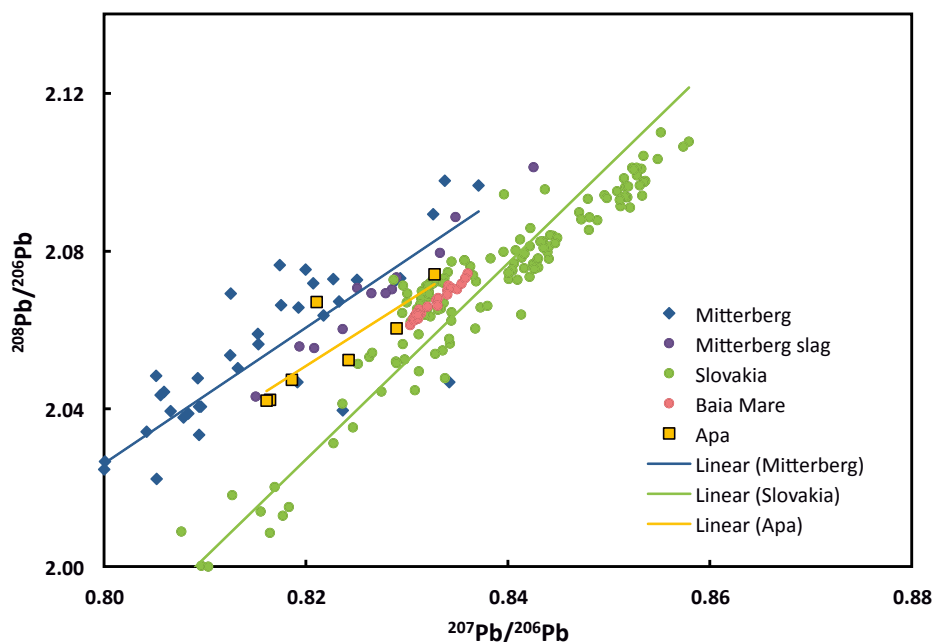


Fig. 21. Magnification of the most relevant part of Figure 20 with linear regression lines of copper ores from Mitterberg and Slovakia as well as from the Apa hoard (Graphics: E. Pernicka).

The lead ores from the Baia Mare district cannot have provided the copper for the objects from the Apa and Hajdúsámson hoards, but they are nevertheless included to show that also the small range excludes them, even though the slope is similar to the Mitterberg ores. Lead isotope ratios of prehistoric copper slags from the Italian part of the eastern Alps<sup>67</sup> generally indicate higher geological model ages and would plot in the upper right hand corner of Figure 21 and are thus not consistent with the samples considered here. There is a substantial overlap of the Slovakian ore data with copper ores from the Valais region in Switzerland,<sup>68</sup> but these cannot be included in the discussion here, because no information is provided on their chemical compositions. In conclusion it seems almost certain that based on the combined evidence of trace element patterns and lead isotope ratios, the copper for the objects of the Apa hoard predominantly derives from the Mitterberg area in Salzburg, Austria.

#### 4.2 Other Bronze Age Finds from Romania

In addition to the Apa hoard, a number of other Early, Middle and Late Bronze Age copper-based finds from various, mainly south-central Romanian locations were analysed as

well (Tab. 4), including a disc-butted axe from Tărian, jud. Bihor (MA-081314; Fig. 22), which belongs to type B1 after Nestor and has a very similar decoration (Fig. 23) to the bronzes from the Apa and Hajdúsámson hoards. Although this axe is a single find and information regarding the circumstances of its discovery are lacking,<sup>69</sup> it can be assumed to be contemporary with the two hoards.

Six Ösenringe from the middle Bronze Age hoard of Maglavit, jud. Dolj (MA-092903 to MA-092908) were analysed. It has been proposed that four significantly younger spiral arm rings and three hair rings might also be part of the hoard. But as it is highly likely that the ensemble was bought from antiquarians, its composition cannot be determined. Therefore, a secure dating of the find is not possible.<sup>70</sup> However, at least a chronological position of the Ösenringe as belonging to the early Middle Bronze Age in Romania can be assumed.

Five sampled Ösenringe from the hoard of Predeal, jud. Prahova (MA-092909 to MA-092913) possibly occupy a similar chronological position. Originally, the find consisted of six objects, but one ring has been missing for several decades.<sup>71</sup> Ösenringe are distributed widely between northern Italy and the Baltic Sea, with a specific find concentration

67 JUNG, MEHOFER 2013, – ARTIOLI et al. 2015.

68 CATTIN et al. 2011.

69 VULPE 1970, 71, No. 303 and Pl. 55.

70 SOROCEANU 2012, 141–142 (with older literature).

71 ȚÂRLEA, FLOREA, NICULESCU 2009, 314 (with older literature).



Fig. 22. Disc-buttet axe of Tărian, jud. Bihor (Photo: M. Mehofer).



Fig. 23. Decorations on the axe from Tărian, which are comparable to those of the Apa bronzes (Photos: M. Mehofer).

noticeable to the north of the eastern Alps. Most researchers tend to interpret them as a type of ingots, although only a few finished objects consist of this copper composition.

Three bronzes from the settlement of Odaia Turcului, jud. Dâmbovița were also analysed for this study. The sickle fragment (MA-092915), the axe fragment (MA-092914), and the chisel (MA-092916) were found in a level with ceramic sherds from the Glina Culture. None of the items are decorated.<sup>72</sup> The sickle and the axe from Odaia Turcului have analogies from contemporary sites in the Carpathian Basin.

One sampled triangular dagger with four rivets and a mid-rib was found in an Early Bronze Age settlement at Crivaș, jud. Călărași (MA-092900). It was accompanied by

a flanged axe and a shaft-hole axe of the Veselinovo type. The information on the circumstances of their discovery varies. The pieces have been published either as part of a deposition<sup>73</sup> within the settlement or as stray finds from the surface.<sup>74</sup> The mentioned flanged axe was also added to the samples (MA-092894).

Another sampled dagger (MA-092895) was found in a settlement of the Glina Culture. It has a flat, leaf-shaped blade with a lenticular section, a rounded tip and prominent shoulders.<sup>75</sup>

One of the remaining axes from the first hoard of Ostrou Corbului (MA-092897) is included in the sample set as

<sup>72</sup> BĂJENARU 2006.

<sup>73</sup> BERCIU 1966, 529.

<sup>74</sup> VULPE 1975, 64, No. 326.

<sup>75</sup> BĂJENARU, POPESCU 2012, 375, No. 16.

Tab. 4. Early, Middle and Late Bronze Age metal objects from Romania (EBA = Early Bronze Age, MBA = Middle Bronze Age, LBA = Late Bronze Age).

Lab. no.	Object	Site	Mus. inv. no.	SAM no.	Date	Published figures
MA-081314	disc-butted axe	Tărian, jud. Bihor	–		MBA	VULPE 1970, Pl. 55/303a
MA-092894	flange axe	Crivăț, jud. Călărași	14045		EBA	VULPE 1970, Pl. 65G/2. – VULPE 1975, Pl. 36/326
MA-092895	dagger	Glina, Bucharest	14055	8667	EBA	BĂJENARU, POPESCU 2012, Fig. 6A/3
MA-092896	dagger	Sărata Monteoru, Merei, jud. Buzău	74951		LBA	BĂJENARU, POPESCU 2012, Fig. 9/9
MA-092897	axe	Ostrovul Corbului I, jud Mehediniți	14047		EBA	VULPE 1970, Pl. 4/45. – SOROCEANU 2013, Pl. 59/2
MA-092898	axe	Poiana, jud. Galați	15918	8694	LBA	VULPE 1970, Pl. 12/198
MA-092899	dagger	Sărata Monteoru, Merei, jud. Buzău	73467	8598	LBA	BĂJENARU, POPESCU 2012, Fig. 9/8
MA-092900	dagger	Crivăț, jud. Călărași	13914		EBA	VULPE 1970, Pl. 65G/3
MA-092901	borer	Branet, Gem. Bârza, jud. Olt	63275		EBA?	BĂJENARU 2014, Fig. 66B/7
MA-092903	Ösenring	Maglavit, jud. Dolj	14063	8776	MBA	SOROCEANU 2013, Pl. 56/3
MA-092904	Ösenring	Maglavit, jud. Dolj	14062	8780	MBA	SOROCEANU 2013, Pl. 57/3
MA-092905	Ösenring	Maglavit, jud. Dolj	14061	8779	MBA	SOROCEANU 2013, Pl. 57/2
MA-092906	Ösenring	Maglavit, jud. Dolj	14060	8777	MBA	SOROCEANU 2013, Pl. 57/1
MA-092907	Ösenring	Maglavit, jud. Dolj	14058	8778	MBA	SOROCEANU 2013, Pl. 56/1
MA-092908	Ösenring	Maglavit, jud. Dolj	14059	*	MBA	SOROCEANU 2013, Pl. 56/2
MA-092909	Ösenring	Predeal, jud. Prahova	12065	8770	MBA	ȚÂRLEA, FLOREA, NICULESCU 2009, Pl. 2/3
MA-092910	Ösenring	Predeal, jud. Prahova	12063	8774	MBA	ȚÂRLEA, FLOREA, NICULESCU 2009, Pl. 2/5
MA-092911	Ösenring	Predeal, jud. Prahova	12066	8768	MBA	ȚÂRLEA, FLOREA, NICULESCU 2009, Pl. 2/4
MA-092912	Ösenring	Predeal, jud. Prahova	12064	8771	MBA	ȚÂRLEA, FLOREA, NICULESCU 2009, Pl. 2/2
MA-092913	Ösenring	Predeal, jud. Prahova	12067	8775	MBA	ȚÂRLEA, FLOREA, NICULESCU 2009, Pl. 2/1
MA-092914	axe fragment	Odaia Turcului, Mătășaru, jud. Dâmbovița	–		EBA	BĂJENARU 2006, Fig. 1/3. – BĂJENARU 2014, Fig. 66A/3
MA-092915	sickle	Odaia Turcului, Mătășaru, jud. Dâmbovița	–		EBA	BĂJENARU 2006, Fig. 1/4. – BĂJENARU 2014, Fig. 66A/4
MA-092916	point	Odaia Turcului, Mătășaru, jud. Dâmbovița	–		EBA	BĂJENARU 2006, Fig. 1/5. – BĂJENARU 2014, Fig. 66A/5

\* In the ‘Studien zu den Anfängen der Metallurgie’ (SAM, JUNGHANS, SANGMEISTER, SCHRÖDER 1968b) the analysis numbers were tied to the old Muzeul Național de Istorie a României (MNIR) inventory numbers. Certain information from the re-evaluation of the composition of the Maglavit hoard by SOROCEANU (2013, 142) is not consistent with identity numbers used by the SAM-project. Soroceanu uses the old MNIR Inv. no. III 5971 for the Ösenring with the new MNIR Inv. no. 14059. However, Inv. no. III 5971 is not part of the SAM-dataset. Instead, there is Inv. no. III 5973, which might be the Ösenring in question. But the mentioned attributes (*Ring, offen, dreikantig*; see JUNGHANS, SANGMEISTER, SCHRÖDER 1968b, 244) do not match well Ösenring Inv. no. 14059. It is also possible, that the Ösenring with Inv. no. I 5971 is the one sampled. Since there is no drawing of the item in the SAM publication, it is impossible to definitely connect the ring with Inv. no. 14059 to the SAM-project sample.

Tab. 5. Chemical composition of the Early Bronze Age metal objects of this study as determined with energy-dispersive XRF. All values are given in mass percent. Zn and Se, were below the detection limit of 0.01 % in all samples and Te below 0.005 %.

Lab. no.	Cu	Sn	Pb	As	Sb	Ag	Ni	Fe	Co	Bi
MA-081314	87	11.1	0.052	0.47	0.79	0.018	0.61	0.13	0.03	<0.005
MA-092894	99	0.007	<0.01	0.38	0.006	0.039	0.11	<0.02	<0.01	<0.005
MA-092895	99	0.078	0.059	0.21	0.026	0.040	0.19	<0.02	<0.01	<0.005
MA-092896	96	3.2	0.032	0.54	0.017	0.16	0.035	<0.02	<0.01	<0.005
MA-092897	99	<0.005	0.35	0.31	0.009	0.006	0.021	<0.02	<0.01	<0.005
MA-092898	93	6.7	0.014	0.15	0.022	0.019	0.080	<0.02	<0.01	<0.005
MA-092899	98	1.02	0.063	0.27	0.036	0.094	0.061	0.083	<0.01	<0.005
MA-092900	97	<0.005	0.065	2.8	0.032	0.068	0.025	0.13	<0.01	0.030
MA-092901	100	<0.005	0.080	0.041	0.026	0.053	0.10	<0.02	<0.01	<0.005
MA-092903	95	5.1	<0.01	0.043	0.029	0.030	0.079	<0.02	<0.01	<0.005
MA-092904	96	<0.005	<0.01	2.3	1.19	0.90	0.012	<0.02	<0.01	0.075
MA-092905	95	<0.005	<0.01	2.2	1.51	0.71	0.018	<0.02	<0.01	0.096
MA-092906	95	<0.005	<0.01	2.0	1.35	1.06	<0.01	<0.02	<0.01	0.21
MA-092907	97	<0.005	<0.01	1.7	1.31	0.33	0.031	<0.02	<0.01	0.040
MA-092908	93	4.4	0.18	0.56	0.51	0.029	0.92	0.066	0.035	<0.005
MA-092909	93	5.5	0.62	0.24	0.22	0.033	0.52	0.031	0.021	<0.005
MA-092910	93	5.6	0.62	0.23	0.22	0.035	0.53	<0.02	0.015	<0.005
MA-092911	93	5.3	0.44	0.20	0.19	0.036	0.47	0.015	<0.011	<0.005
MA-092912	93	5.9	0.54	0.19	0.23	0.035	0.54	<0.02	0.021	<0.005
MA-092913	93	5.8	0.59	0.23	0.22	0.039	0.54	<0.02	0.013	<0.005
MA-092914	100	0.020	0.060	0.19	0.022	0.038	0.061	<0.02	<0.01	<0.005
MA-092915	98	<0.005	0.63	1.58	0.043	0.052	0.050	<0.02	<0.01	0.019
MA-092916	98	0.034	0.12	2.03	0.024	0.052	0.11	<0.02	<0.01	0.031

well. The hoard was found in a clay vessel in a settlement, but most of the items of the hoard have been missing for a long time. It was often described as related to a Glina III layer but pottery of the Coțofeni-Kostolac and Vučedol groups were also discovered on the site.<sup>76</sup> The axe belongs to the Corbasca type, which does not occur very often in the Carpathian Basin.<sup>77</sup>

The small 'bronze point' from Branet (MA-092901) has a pyramidal head, followed by an opposed section with a truncated pyramidal shape. The find is associated with Glina- or Coțofeni-Culture<sup>78</sup> contexts in the settlement. How-

ever, no similar finds are known from other contemporary sites.

A much younger axe of the Monteoru type, variant III after Vulpe, was found in a settlement in Poiana (MA-092898). It shows the characteristic prolonged neck and three parallel ribs on its shaft. The circumstances of its discovery do not indicate a more specific date within the Monteoru Culture. However, axes of that variant are usually found in contexts of the second phase of the Monteoru Culture.<sup>79</sup> They can therefore be dated to the latest Middle Bronze Age and the early Late Bronze Age in Romania.

<sup>76</sup> VULPE 1970, 30, Nos. 44–47.

<sup>77</sup> DANI 2013, Fig. 3.

<sup>78</sup> BĂJENARU 2014, 40–41, No. 77 and Fig. 66B/7.

<sup>79</sup> VULPE 1970, 43, 47–48, No. 198.

Tab. 6. Lead isotope ratios in the samples from Early, Middle and Late Bronze Age copper-based finds from various, mainly south-central Romanian locations. Samples MA-092903, MA-092904, MA-092906, MA-092907 and MA-092911 did not yield enough lead for isotope measurement, because the sample mass was either too small and/or the lead concentration of the sample was exceedingly low. The precision of measurement is less than  $\pm 0.01$  % for ratios with  $^{206}\text{Pb}$  in the denominator and up to  $\pm 0.03$  % for  $^{206}\text{Pb}/^{204}\text{Pb}$ .

Lab. no.	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{208}\text{Pb}/^{204}\text{Pb}$
MA-081314	2.0958	0.85263	18.378	15.670	38.517
MA-092894	2.0704	0.83354	18.842	15.706	39.010
MA-092895	2.0845	0.84472	18.588	15.702	38.747
MA-092896	2.0846	0.84481	18.540	15.663	38.648
MA-092897	2.0713	0.83739	18.675	15.638	38.682
MA-092898	2.0752	0.84039	18.610	15.640	38.619
MA-092899	2.0806	0.84091	18.611	15.650	38.722
MA-092900	2.0736	0.83633	18.755	15.685	38.890
MA-092901	2.0791	0.84024	18.641	15.663	38.757
MA-092905	2.0894	0.85072	18.400	15.653	38.445
MA-092908	2.0976	0.85249	18.380	15.669	38.554
MA-092909	2.0985	0.85419	18.335	15.662	38.476
MA-092910	2.0986	0.85419	18.335	15.662	38.478
MA-092912	2.0984	0.85423	18.340	15.667	38.485
MA-092913	2.0983	0.85421	18.338	15.665	38.479
MA-092914	2.0767	0.84270	18.519	15.606	38.458
MA-092915	2.0680	0.83250	18.846	15.689	38.974
MA-092916	2.0680	0.83275	18.856	15.702	38.994

The two other daggers in the sample set have different attributes. Both are from Sarata-Monteoru. The first was found in Grave 27 at the Sarata-Monteoru cemetery 1 (MA-092896). It is of the Costișa type variant C after Băjenaru and Popescu and has a slim blade with a rhombic shaped end, which is followed by a slim rectangular handle. The grave is dated to the Late Bronze Age phase IIb of the Monteoru Culture.<sup>80</sup> The fourth dagger (MA-092899) is much smaller and has a triangular shaped blade with a rhombic cross section. It is of the Costișa type variant B. At least on some sites similar daggers are associated with Late Bronze Age Noua-Culture pottery.

The results of the chemical analyses are listed in Table 5 and the lead isotope ratios in Table 6. Four out of six Ösenringe from Maglavit consist of fahlore copper, which has its major distribution area in central Europe and contains

around 2–4 % arsenic, the same amount of antimony, and about 1 % silver.<sup>81</sup> Fahlore is usually found in Ösenringe, which appear mostly in hoards and occasionally in graves.<sup>82</sup> They have a high degree of standardisation in shape and weight and are usually less frequently associated with other types of ingots. Initially they were mainly considered as ingots themselves or as semi-finished products intended for transport and further use. However, as Krause and Pernicka have shown, the metal composition in question is almost exclusively found in Ösenringe and not in other objects, which presumably would have been produced from them, if they indeed were ingots.<sup>83</sup> This raises questions about the function and the role of these metal rings.<sup>84</sup>

<sup>80</sup> BĂJENARU, POPESCU 2012, 395–396.

<sup>81</sup> JUNGHANS, SANGMEISTER, SCHRÖDER 1968a, b. – BUTLER 1979.

<sup>82</sup> INNERHOFER 1997.

<sup>83</sup> KRAUSE, PERNICKA 1998.

<sup>84</sup> Cf. LENERZ DE WILDE 1995.

The presence of Ösenringe south of the Carpathian Basin near the Danube corroborates contacts to central Europe, which were already suggested above from the provenance of the metal in the Apa hoard. However, it is difficult to identify the source of the metal of the Romanian Ösenringe made from fahlore copper. In this case, the concentrations of arsenic and antimony are most likely not indicative of the source, as has been shown previously,<sup>85</sup> and there are few lead isotope ratios available for fahlore and prehistoric objects made of it, because these ores usually have exceedingly low lead concentrations. Nevertheless, one study of Ösenringe from Gammersham in southern Bavaria seems to suggest that they derive from the Inn Valley in Austria.<sup>86</sup> In our sample suite we have lead isotope ratios for only one Ösenring with fahlore metal composition, which does not match the fahlores of the Inn Valley.<sup>87</sup> Furthermore, the low but measurable nickel concentrations in these rings do not favour an Austrian origin. Accordingly, Ösenringe seem to have been produced in more than one single region or production centre.

The same is true for the complete sample suite of Early and Middle Bronze Age metal objects from Romania including the disc-butted axe from Tărian (MA-081314), as Figure 24 suggests. The east Alpine copper deposits can virtually be ruled out as sources. Although the object is similar in appearance with the disc-butted axes from the Apa-Hajdúsámson horizon, it is made of copper from an entirely different source than the items of the two eponymous hoards (Tabs. 6, 9). This could indicate that the choice of manufacturing materials in the Carpathian-Danube region is not specifically tied to the function or the social meaning of an object, at least when it comes to copper. We have to evaluate other, probably socially and economically motivated mechanisms for the use of specific ore sources. In any case, the Mitterberg region can safely be excluded from the further discussion of the provenance of the metal.

The remaining alternatives are data from the Slovakian Ore Mountains, the Saxo-Bohemian Erzgebirge, the Baia Mare region and the Apuseni Mountains in Romania, although one has to keep in mind that the data for Romanian ores were measured mainly on galena (PbS) samples and are not directly comparable with copper-based objects. Furthermore, neither the occurrence of copper ore nor any indication for prehistoric mining and/or smelting has so far been reported.<sup>88</sup> However, since these deposits are mostly

polymetallic it is in principle possible that copper was also produced. In this case, one can safely assume that the lead isotope ratios in the copper would be the same as in the lead ores. Figure 25 shows that the *Erzgebirge* can be ruled out as a source region for the copper and that the best option for the origin of the metal still is the Slovakian Ore Mountains. Although there is some overlap with the Baia Mare region and the Apuseni Mountains, the wide scatter of lead isotope ratios in the objects is also observed in the copper ores from the Hron valley in Slovakia. This is also corroborated by their trace element pattern (Fig. 26).

## 5. Conclusion

After discussing the different results and possible parameters for their interpretation, it can be concluded that more than one copper source was used to produce bronze items at the end of the Early and the beginning of the Middle Bronze Age in the Carpathian-Danube region. While the copper for the objects from the Apa hoard most likely derived from the Mitterberg main lode, possibly from the same smelting episode, the copper of other contemporary bronzes was mined in the Slovakian Ore Mountains. Similar results were reported in the above mentioned study of the Hajdúsámson hoard (Tabs. 7–9) and contemporary bronzes from Hungary.<sup>89</sup> In both instances copper from the eastern Alps was chosen to manufacture technically challenging objects, such as swords and arm spirals. The material analyses suggest that the items of the Apa and Hajdúsámson hoards respectively, were manufactured and deposited as ensembles belonging together. The bronzes were not collected over a longer period of time and they do not derive from different areas.

On the other hand, there is obviously no direct relationship between the choice of metal and the type of object or its attached symbolic meaning, as evidenced by the disc-butted axe from Tărian. Variants of bronzes from both hoards, of related typological characteristics, were usually made of copper from nearby sources, such as the Slovakian Ore Mountains. The typological and stylistic roots of all sampled objects undoubtedly lie in the Carpathian Basin.<sup>90</sup> We have to consider other reasons than just the quality of the material for the use of copper from one source and not another. The Carpathian Basin was participating in more than one exchange and contact network. One of them was definitely characterised by the import of copper from the eastern Alps, an area which supplied major parts of central

<sup>85</sup> PERNICKA 1999.

<sup>86</sup> HÖPPNER et al. 2005, 309–310.

<sup>87</sup> HÖPPNER et al. 2005.

<sup>88</sup> KACSÓ 2013.

<sup>89</sup> PERNICKA 2013.

<sup>90</sup> DAVID 2010.

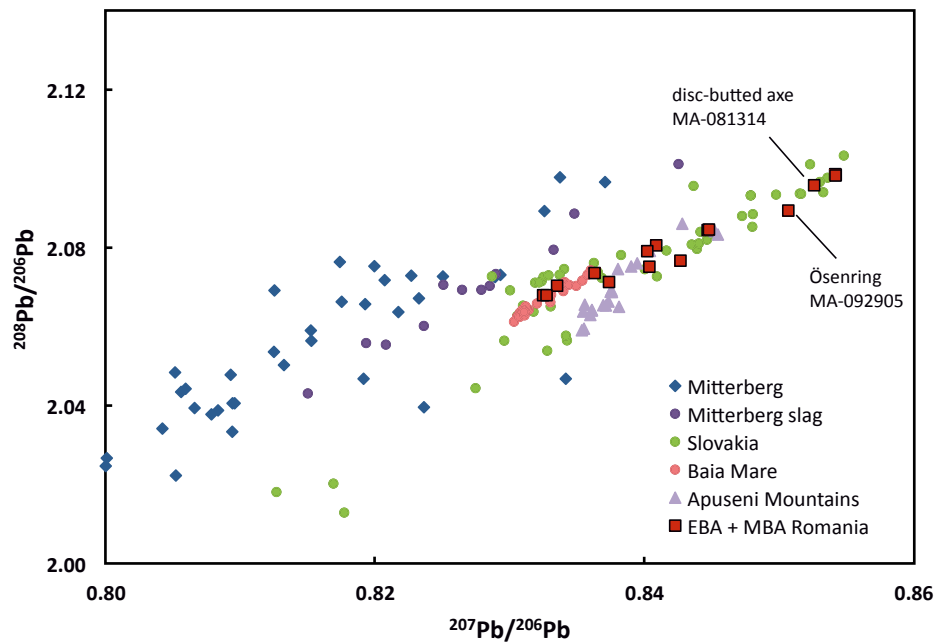


Fig. 24. Comparison of lead isotope ratios of the Mitterberg region (PERNICKA, LUTZ, STÖLLNER 2016) and copper ores from Slovakia and lead ores from northwest Romania (MARCoux et al. 2002. – SCHREINER 2007) with Early and Middle Bronze Age metal finds from Romania (Graphics: E. Pernicka).

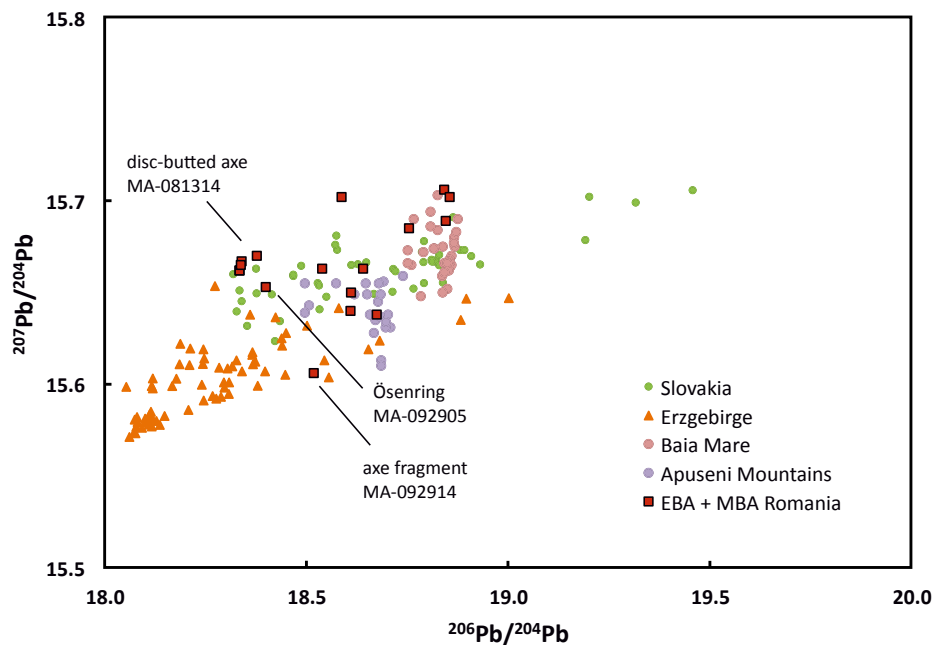


Fig. 25. Comparison of lead isotope ratios of copper ores from Slovakia and the Erzgebirge (NIEDER-SCHLAG et al. 2003) as well as lead ores from northwest Romania (MARCoux et al. 2002) with Early and Middle Bronze Age metal finds from Romania (Graphics: E. Pernicka).

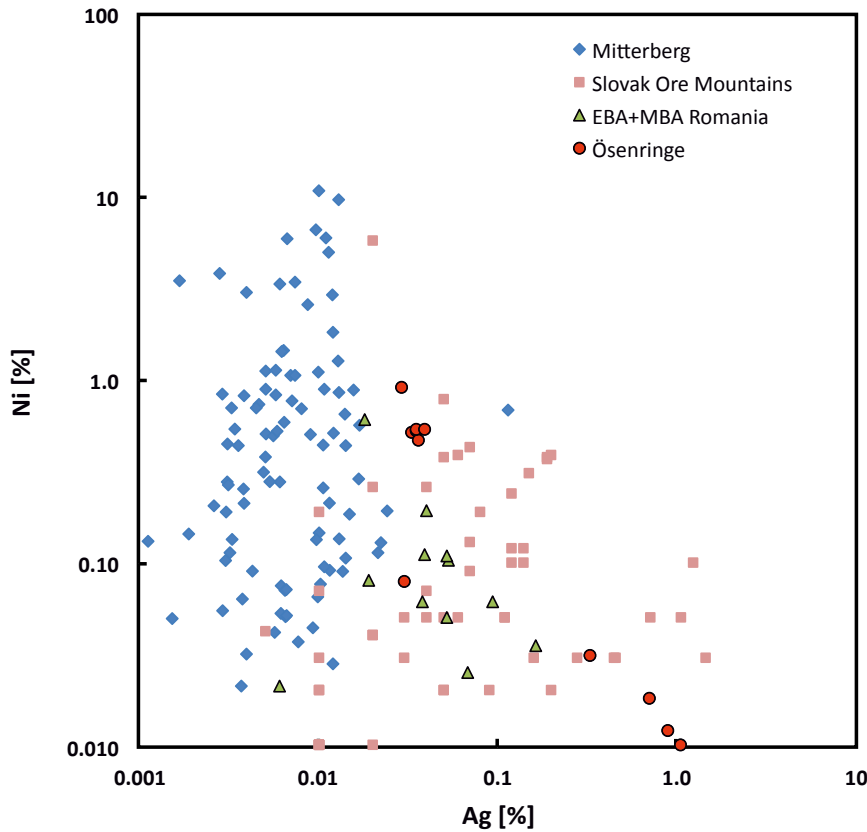


Fig. 26. Silver and nickel concentrations in copper ores from the Mitterberg region in Austria (PERNICKA, LUTZ, STÖLLNER 2016) and in copper ores from Slovakia (SCHREINER 2007) with Early and Middle Bronze Age metal finds from Romania (Graphics: E. Pernicka).

Tab. 7. Objects from the Hajdúsámson hoard (after PERNICKA 2013).

Lab. no.	Object	Site	Mus. inv. no.
FG-030622	disc-butted axe	Hajdúsámson	D 2; 1907.1206
FG-030623	disc-butted axe	Hajdúsámson	D 3; 89.5.1
FG-030624	shafthole axe	Hajdúsámson	D 4; 1907.1210
FG-030625	shafthole axe	Hajdúsámson	D 5; 1907.1216
FG-030626	shafthole axe	Hajdúsámson	D 6; 1907.1214

Tab. 8. Chemical composition of five axes from the Hajdúsámson hoard as determined with energy-dispersive XRF (after PERNICKA 2013).

Lab. no.	Cu	Sn	Pb	As	Sb	Ag	Ni	Fe	Co
FG-030622	94	7.0	0.02	0.60	0.082	0.028	0.48	< 0.05	0.021
FG-030623	94	7.0	0.09	0.27	0.041	0.012	0.27	< 0.05	< 0.005
FG-030624	96	3.6	0.03	0.23	0.017	< 0.005	0.18	< 0.05	< 0.005
FG-030625	94	5.1	0.03	0.52	0.111	0.015	0.51	0.09	< 0.005
FG-030626	97	2.1	0.02	0.30	0.046	0.009	0.36	< 0.05	< 0.005



Tab. 9. Lead isotope ratios in samples from the Hajdúsámson hoard (after PERNICKA 2013).

Lab. no.	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
FG-030622	2.0440	0.82478	19.009
FG-030623	2.0633	0.83167	18.804
FG-030624	1.9863	0.78685	20.089
FG-030625	2.0142	0.80405	19.523
FG-030626	2.0377	0.81646	19.246

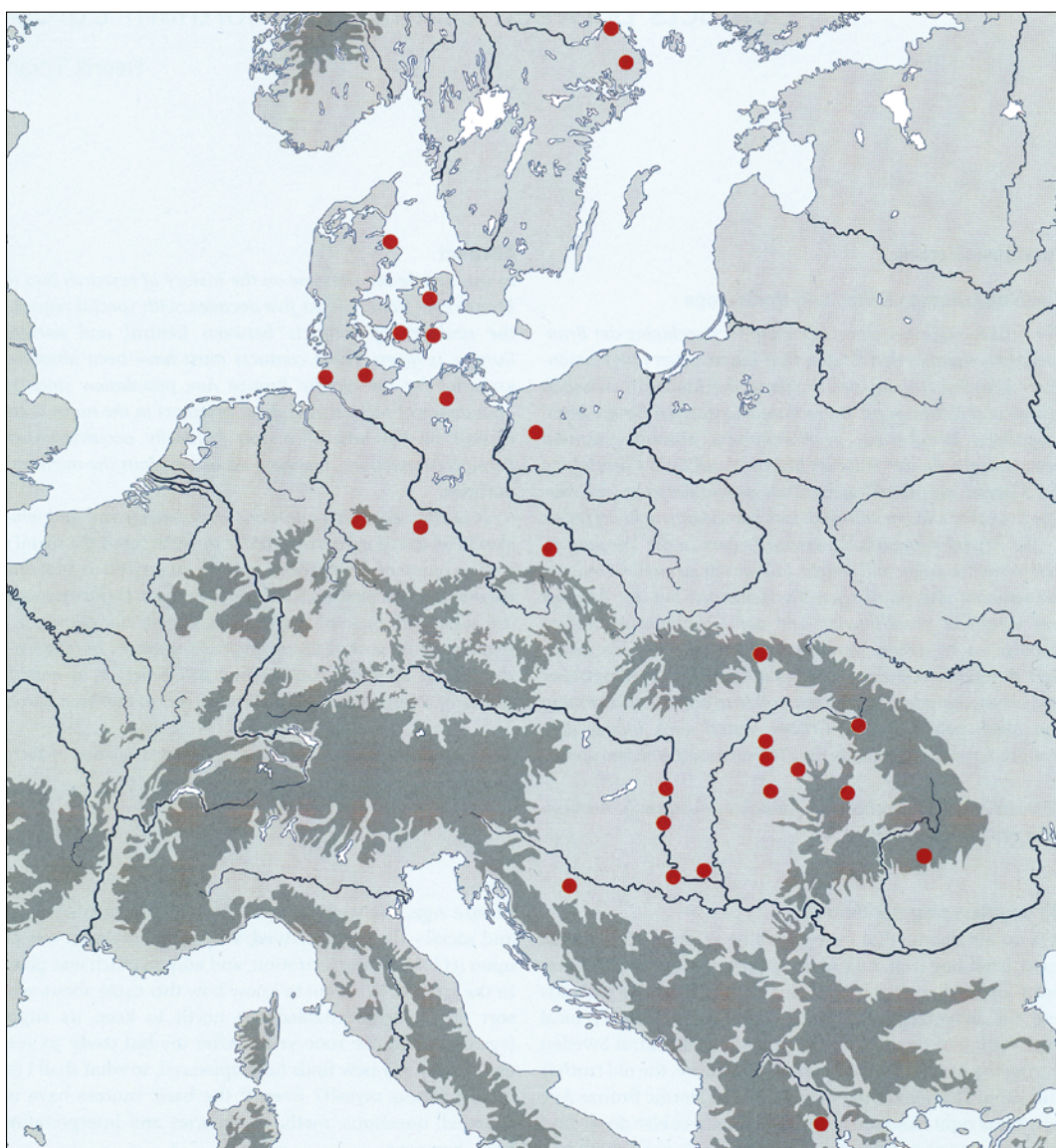


Fig. 27. Distribution of Apa-type swords in Europe (after THRANE 2010, with additions).

and even northern Europe with raw material. This exchange network is particularly visible in all participating regions through finds of certain ingot forms such as Ösenringe.<sup>91</sup>

Besides this long distance trade network, the establishment of regular contacts with middle range regions, such as the Slovakian Ore Mountains, were also important for communities in the Carpathian Basin. As more and more studies of material composition of bronzes show, copper was constantly imported from this area as well. In contrast, this network is not visibly manifested in a specific type of object like ingots. Since this copper was used to produce indigenous types of objects in both areas in question, it can usually only be identified by metal analyses.

Interestingly enough, there is only a small number of items where there is a possibility that copper from the Baia Mare or Apuseni Mountains was used to manufacture the investigated bronzes. These objects represent a regional contact network, where local ore was used for production. This may suggest the presence of a single or perhaps a group of linked workshops, which used a specific metal source, probably from a small scale supplier, during a certain period of time. Future research will focus more on this question, especially regarding bronzes from the Carpathian-Danube area.

These major and minor copper exchange networks functioned differently from and manifested themselves in other ways than networks of high ranking persons or groups, who exchanged unique luxury items or objects of great value such as weapons. The Apa- and Hajdúsámson-type swords make connections between the Carpathian Basin and southern Scandinavia visible (Fig. 27). Similar assumptions can for example be made about two axes from Sösdal in Sweden<sup>92</sup> and Grave 7 in the cemetery of Gemeinlebarn F.<sup>93</sup> There are no further analogies and they therefore show a direct connection between the Alpine area and Nordic Bronze Age elites. Several other finds with their distribution limited to the same areas could be mentioned, and it is important that these contacts, once they had been established, were influential in both directions throughout the Bronze Age. To some extent, this makes it highly likely that communities in the north and in southern areas close to the Alpine sources participated in the same raw material exchange networks. Different suppliers for specific regions should, on the other hand, be considered as well. Further investigations of raw material compositions of bronzes are needed to solve these questions.

91 E.g. INNERHOFER 1997. – KRAUSE, PERNICKA 1998. – HENSLER 2014.

92 LINDQUIST 1925, 36 and Fig. 16/a–b.

93 NEUGEBAUER 1991.

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