INTRODUCTION

The Ljubljansko barje, located in the southern part of the Ljubljana basin, once was Europe’s most southerly high bog, with the Ljubljanica river flowing through its central part from Vrhnika towards Ljubljana. It became famous in Central European archaeology in the second half of the nineteenth century, when between 1875–1877 Dragotin Dežman excavated the first prehistoric pile dwellings north of the present village of Ig. A considerably larger number of settlements were found during later investigations, from the oldest dating to the first half of the 5th millennium BC to the last at the beginning of the 2nd millennium BC (at the end of the Early Bronze Age), when, as the plain became gradually swamp, settlement moved to the dry margins.¹

Dežman already recognised the importance of the pile dwellings at Ig as well as the copper artefacts and associated metallurgical implements discovered there. He reported his research currently in the professional journals of the time, but unfortunately he never published the entire material and his excavation notes. An extensive selection of the material only became available to a wider professional audience after the middle of the twentieth century (Korošec, Korošec 1969).

¹ Velušček 2004e.
since when the copper artefacts and metallurgical material have been the subject of frequent mention. The fact that the material was without stratigraphic data was overcome by new research. Careful comparative studies of the pottery from Dežman’s and other pile dwellings (Parzinger 1983), investigation of new related pile dwellings and, above all, the use of scientific methods have enabled more precise dating of pile dwellings as well as raised new chronological questions (Velušček, Čufar 2003; Velušček 2004a). It is thus generally believed today that Dežman excavated pile dwellings from different periods, most belonging to the late Eneolithic, or the third millennium BC, within the framework of the Vučedol culture. This also applies to the metallurgical material as well as to the copper artefacts (Velušček 2004a). The surprising number of metallurgical devices, the excellent state of preservation and persuasive technological evidence of Dežman’s metallurgical material which surpasses all similar finds discovered later, both on the Ljubljansko barje and elsewhere in Slovenia, still remains unique and worth new treatment (fig. 1).

This study deals with the metal composition of seven copper artefacts from Dežman’s pile dwellings by Ig and seven copper artefacts from the Ljubljanica, which were found by chance during work on the riverbed or deliberately collected by amateur divers. We added the latter in order to increase the number of finds analysed, which is relatively small and therefore not the most suitable for statistical processing. The chemical composition of the majority of the copper artefacts from Ig, and some from the Ljubljanica, was already investigated more than forty years ago within the framework of the Stuttgart project SAM.2 The results of these first spectral analyses were performed by the OES method and are still relatively often referred to, although rarely commented.3 It was for this reason that we decided on re-analysis using a more recent method (ICP-AES), since we wished to supplement data on the content of trace elements (arsenic, antimony, nickel and silver, and we also added lead). On the basis of the new, more accurate impurity pattern we tried

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Copper finds from the Ljubljansko barje (Ljubljana Moor) – a contribution to the study of prehistoric metallurgy

Table 1: Chemical composition of copper artefacts from the Ljubljansko barje (ICP-AES analyses). Analyses numbers (1–14) correspond to the object numbers in Plate 1. Analyses numbers from the SAM project are cited (SAM 2/3, 1968, 10–13, 56–57) and adjusted (paralleled) to actual analyses numbers: SAM 1060 = 5, SAM 1064 = 6, SAM 2483 = 7, SAM 1053 = 8, SAM 1055 = 9, SAM 1050 = 10, SAM 1054 = 11, SAM 1045 = 12, SAM 1047 = 13, SAM 1069 = 14. With the exception of two private finds (an. 1 and 2) all objects are kept by the National Museum of Slovenia in Ljubljana.

<table>
<thead>
<tr>
<th>An. No.</th>
<th>Inv. No.</th>
<th>Object Site</th>
<th>Elements %</th>
<th>Cu</th>
<th>Sn</th>
<th>Pb</th>
<th>As</th>
<th>Ni</th>
<th>Sb</th>
<th>Co</th>
<th>Bi</th>
<th>Ag</th>
<th>Fe</th>
<th>Zn</th>
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<tbody>
<tr>
<td>1 ZN 141/1</td>
<td>axe/sekira Ljubljanica</td>
<td>95</td>
<td>0.007</td>
<td>0.010</td>
<td>2.390</td>
<td>0.019</td>
<td>0.060</td>
<td>0.0010</td>
<td>&lt;0.003</td>
<td>0.021</td>
<td>0.0040</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 ZN 140/1</td>
<td>axe/sekira Ljubljanica</td>
<td>100</td>
<td>&lt;0.004</td>
<td>&lt;0.009</td>
<td>0.440</td>
<td>0.009</td>
<td>&lt;0.006</td>
<td>&lt;0.0005</td>
<td>&lt;0.003</td>
<td>0.013</td>
<td>0.0020</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 V 195</td>
<td>axe/sekira Ljubljanica</td>
<td>99</td>
<td>&lt;0.004</td>
<td>0.020</td>
<td>0.042</td>
<td>&lt;0.002</td>
<td>0.329</td>
<td>&lt;0.0005</td>
<td>&lt;0.003</td>
<td>0.295</td>
<td>&lt;0.0003</td>
<td>0.01</td>
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<td></td>
</tr>
<tr>
<td>4 B 5948</td>
<td>axe/sekira Ljubljanica</td>
<td>99</td>
<td>&lt;0.004</td>
<td>0.045</td>
<td>0.019</td>
<td>0.008</td>
<td>0.156</td>
<td>&lt;0.0005</td>
<td>&lt;0.003</td>
<td>0.064</td>
<td>&lt;0.0003</td>
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<td>0.010</td>
<td>&lt;0.002</td>
<td>0.010</td>
<td>&lt;0.0005</td>
<td>0.019</td>
<td>0.350</td>
<td>&lt;0.0003</td>
<td>0.01</td>
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<td></td>
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<tr>
<td>6 B 4776</td>
<td>axe/sekira Ig</td>
<td>99</td>
<td>0.013</td>
<td>0.327</td>
<td>&lt;0.008</td>
<td>0.014</td>
<td>0.172</td>
<td>&lt;0.0005</td>
<td>&lt;0.003</td>
<td>0.046</td>
<td>&lt;0.0003</td>
<td>0.02</td>
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<tr>
<td>7 B 5947</td>
<td>axe/sekira Ljubljanica</td>
<td>98</td>
<td>&lt;0.004</td>
<td>0.077</td>
<td>0.015</td>
<td>0.007</td>
<td>0.225</td>
<td>&lt;0.0005</td>
<td>0.028</td>
<td>0.063</td>
<td>&lt;0.0003</td>
<td>0.01</td>
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<tr>
<td>8 B 4777</td>
<td>dagg./bod. Ig</td>
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<td>&lt;0.004</td>
<td>0.025</td>
<td>0.011</td>
<td>0.011</td>
<td>0.013</td>
<td>&lt;0.0005</td>
<td>&lt;0.003</td>
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<td>&lt;0.004</td>
<td>0.333</td>
<td>0.007</td>
<td>0.005</td>
<td>0.003</td>
<td>&lt;0.0005</td>
<td>0.016</td>
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<td>0.049</td>
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<td>0.008</td>
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<td>&lt;0.003</td>
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<td>&lt;0.0003</td>
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</tr>
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<td>11 B 4779</td>
<td>dagg./bod. Ig</td>
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<td>&lt;0.004</td>
<td>0.075</td>
<td>&lt;0.008</td>
<td>0.012</td>
<td>0.132</td>
<td>&lt;0.0005</td>
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<tr>
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<td>0.019</td>
<td>0.006</td>
<td>0.009</td>
<td>0.084</td>
<td>&lt;0.0005</td>
<td>&lt;0.003</td>
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<td></td>
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<td>13 B 4786</td>
<td>awl/šilo Ig</td>
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<td>0.017</td>
<td>0.054</td>
<td>0.014</td>
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<td>0.072</td>
<td>&lt;0.0005</td>
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<td>14 B 5921</td>
<td>awl/šilo Ljubljanica</td>
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<td>0.124</td>
<td>&lt;0.008</td>
<td>0.014</td>
<td>0.018</td>
<td>&lt;0.0005</td>
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<td>0.203</td>
<td>&lt;0.0003</td>
<td>0.01</td>
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</tr>
</tbody>
</table>

nickel (Ni), antimony (Sb), cobalt (Co), bismuth (Bi), silver (Ag), iron (Fe) and zinc (Zn). The full sampling methodology, experimental procedure, instrumental conditions, spectral lines and limits of detection for each element of interest are published elsewhere.3

Some of these artefacts were analysed within the framework of the SAM project. The analyses were repeated mainly because the higher sensitivity and accuracy of the modern ICP-AES method allows the identification of a significantly lower content of some trace elements that do not appear in the first publication. The corresponding analysis numbers of the SAM project without results have been added to our analyses in Table 1. The concentration ratios of individual elements are shown graphically (Fig. 2). Some of the artefacts could not be re-analysed because the available surface of the object is unsuitable for taking a sample.

EXPERIMENTAL METHOD

Fourteen samples were analysed by the method of inductively coupled plasma atomic emission spectroscopy (ICP-AES). The results of the analyses are shown in Table 1. A Perkin Elmer simultaneous spectrometer, model OPTIMA 3100 RL, was used for the analyses. The elements analysed were copper (Cu), tin (Sn), lead (Pb), arsenic (As), nickel (Ni), antimony (Sb), cobalt (Co), bismuth (Bi), silver (Ag), iron (Fe) and zinc (Zn). The full sampling methodology, experimental procedure, instrumental conditions, spectral lines and limits of detection for each element of interest are published elsewhere.3

Some of these artefacts were analysed within the framework of the SAM project. The analyses were repeated mainly because the higher sensitivity and accuracy of the modern ICP-AES method allows the identification of a significantly lower content of some trace elements that do not appear in the first publication. The corresponding analysis numbers of the SAM project without results have been added to our analyses in Table 1. The concentration ratios of individual elements are shown graphically (Fig. 2). Some of the artefacts could not be re-analysed because the available surface of the object is unsuitable for taking a sample.

3 Trampuž Orel, Heath, Hudnik 1996, Trampuž Orel et al. 2004, 205–206. All samples were analysed by Z. Torkar and supervised by Dr. A. Kocijan and T. Dejlin MSc at the Institute for Metals and Technology, Ljubljana, Slovenia; we also thank D. Hren MSc for his assistance.

I would like to thank my colleague Ida Murugelj (National Museum of Slovenia) for the new drawings.
The fourteen copper artefacts analysed consist of an axe, four daggers and two awls from Dežman’s pile dwellings at Ig, and six axes and one awl from the Ljubljanica river (pl. 1). The finds have already been published and, despite the lack of relevant stratigraphic data, adequately defined chronologically.6

Two small, slender axes (pl. 1: 1,2) are the most recent finds discovered during diving in the Ljubljanica close to the Hočevarica eneolithic pile dwelling. Typologically, both axes are small flat axes of the Altheim type.7 They have been classified to the earlier horizon of copper finds and metallurgical implements in Slovenia, which places them in the fourth millennium BC. They probably belonged to the nearby pile dwelling, whose construction timber and seeds from the cultural layer have been absolutely dated to the 36th century BC on the basis of radiocarbon and dendrochronological analyses (Velušček 2004a; Velušček 2004b).

The remaining five axes are larger and thicker, but similarly belong to flat axes with enlarged blade (pl. 1: 3–7). Three of them fit well into the Altheim type in terms of the typical shape. It is interesting that two of the axes from the Ljubljanica (pl. 1: 4–5) are identical to the axe from Dežman’s pile dwellings at Ig (pl. 1: 6), from where clay moulds for casting Altheim axes are also known, as has already been noted several times.8 The axes belong to the late Eneolithic, the 3rd millennium BC, or the later horizon associated with the Vučedol culture (Velušček, Greif 1998).

The larger and narrower axe from the Ljubljanica (pl. 1: 3) differs from them in terms of shape, but similar specimens have been found among Altheim type axes in Austria.9 Axes of this type are common in Central Europe.

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6 Velušček 2004c, 55, fig. 3.1.35 and 3.1.36 ; Korosec, Korosec 1969, pl. 105: 1,2,6,7–9,11,13; Šinkovec 1995, 33–35, 118, pl. 2: 6–9, pl. 35: 237 and Šinkovec 1996, 146.
7 There are similar examples, e.g., from the Unterach pile dwelling settlement, Mayer 1977, pl. 115: 1–3.
9 There are similar examples, e.g., from the Attersee lake and pile dwelling, Mayer 1977, pl. 11: 142,143.
and a fairly wide time span is cited for them, the 4th and 3rd millennium BC. They mostly originate from lakeside settlements of the Mondsee group in Austria. They belong to the wider circle of flat, not very thick axes of trapezoid shape, which also appear in western and northern Europe as far as Spain and Denmark, and in the east extend to the Ukraine or northern Pontic region. The Griča type axe from the Ljubljana (pl. 1: 7) is commonest in the late Eneolithic in Bosnia.

Of the six daggers from the pile dwellings at Ig. four are presented here. Three of them are tanged daggers (pl. 1: 8-10) of type B according to Primas (1996). She reports of more numerous specimens not only on the Ljubljansko barje and in Greece, but mainly further to the east, in the region between the Dnieper and the Carpathians.

Similar daggers, related in terms of shape, are also known from western Europe, mainly from the Atlantic coast of France and the Iberian peninsula, where specimens from Almería on the Mediterranean coast are very similar to the artefacts from Ig. There are occasional specimens of a distant variant of such daggers in southern England, but there are similar specimens from northern Italy (Remedello type) and Hungary.

The fourth dagger (pl. 1: 11) is of leaf shape, without a tang and with a central rib, similar to a dagger of the Šebastovce type from Slovakia. Daggers of this type are located in the region of the Lažňany group in eastern Slovakia, and their distribution increases towards the east.

Only three of the awls have been treated: two with a rhomboid enlargement below the top from the pile dwellings at Ig (pl. 1: 12,13) and one from the Ljubljana with a chisel-shaped tip (pl. 1: 14). Similar awls have been found in the west of Slovenia in the Trentino (Italy) and in the Iberian peninsula, but also in the east in Trakia.

RESULTS AND DISCUSSION

Knowledge of the beginnings of metallurgy in Europe for the moment relies mainly on systematic chemical analysis of a large number of copper artefacts from the earliest period; from the Neolithic to the Middle Bronze Age inclusive. Mainly because of extensive German projects from the second half of the 20th century, which include material from a wide area of Central Europe, between northern Italy, the Carpathians and the Baltic, the data base was increased to approximately 27,000 analyses. The classification of so much data using multivariate analysis was carried out by Pernicka (1995), who proceeded from approaches that other researchers had used before him (Junghans et al. 1968; Rychner 1995). In determining copper groups, he took into account the impurities arsenic, antimony, silver, nickel and bismuth, which he arranged in order of decreasing absolute concentrations in particular compositional combinations. Using multivariate processing of the results, he chose 21 metallic groups (clusters), which in terms of the concentration ratios of impurities reflect five types of metallic copper (but not ore). Krause (2003) linked the results with an archaeological interpretation of the material, which showed that the copper types are chronologically significant and concentrated in specific geographic regions. He thus showed that three types of copper, antimony (type IV), arsenic (type V) and pure copper (type III) are only characteristic of the Neolithic or at least predominate in this period, while copper of the Fahlerz type (types I and II) is more characteristic of the Early Bronze Age and later periods.

In order to provide an easier overview, the metal composition of the artefacts, except in the analyses (tab. 1), is also presented in the form of concentration ratios As/Sb, Ag/Sb, Ag/Pb and Sb/Ni (fig. 2). It is clear from these that, except for samples 1 and 2, which differ in terms of a high level of arsenic (As 0.4 and 2.4 %), the majority of the samples show a relatively small quantity of arsenic (As < 0.05 %) and independence from the increasing content of antimony. There is a higher antimony content (Sb 0.13–0.33 %) in five samples (3, 4, 6, 7, 11). A considerable number of the samples (3, 5, 9, 14) have a relatively high silver content (Ag 0.20–0.35 %), which is comparable in samples 5, 9 and 14 with the lead content (Pb 0.12–0.33 %). This does not apply to sample 6 (Pb 0.33 %) which, despite higher lead, has a low silver content (Ag 0.05 %). Nickel is present in very low concentrations in the majority of samples (up to 0.01 %) or only as a trace. It is only higher in sample 10 (Ni 0.028 %).

As is clear from the analyses, the copper from the Ljubljansko barje contains a low impurity concentration, often only present on the trace level, which in any case differs from sample to sample. It
therefore seemed reasonable to identify the impurities and to classify the samples into suitable metallic groups and copper types in Europe. Compositional schemes of impurities were first made in terms of the concentration ratios of arsenic, antimony, nickel and silver, arranged by decreasing order (tab. 2).

The absolute content of these elements in each of the 14 artefacts was then compared with average values of the same elements in each of 21 European groups,17 weighted to maximum correspondence. We succeeded in classifying the samples into six European groups, respectively three copper types (fig. 3). Samples 1 and 2 were placed in groups Cl.34-3 and 20, which correspond to arsenic copper (type V). Samples 3, 4, 6–8 and 11–14 were placed in group Cl.34-7 and 11, corresponding to antimony copper (type IV). Samples 5 and 9 do not correspond to any of the 21 groups in terms of elemental compositions, being distinguished by a fairly significant silver content, together with a substantial content of lead. They were therefore provisionally (they have a very low concentration of As and Sb) classified as pure copper (type III), to which sample 10 also belongs. It is also clear from comparison of individual elements that the arsenic in these artefacts is for the most part higher than the average European level, antimony is close to the average, and silver and nickel are lower. These artefacts are also characterised by a relatively high presence of lead, which perhaps indicates a regional particularity of the copper.

If the frequency of appearance of individual types of copper is compared, it is clear that arsenic copper (V) only appears in the two oldest axes from the Ljubljanica by Hočevarica (tab. 2: 1,2; pl. 1: 1,2).18 This type of copper with a high arsenic content is most widespread on the Iberian peninsula, but appears in smaller concentrations over a wide area of Europe, including the Carpathian basin.19

The level of arsenic in the two axes (2.39 % and 0.44 %) raises the question of a possible alloy. Scientists today are sceptical about the deliberate use of copper with arsenic, or copper naturally polluted with arsenic in relation to artefacts from the Eneolithic with small quantities of arsenic (up to 4 %), because the mechanical advantages and different colour of such copper are insufficiently noticeable (Northover 1989, Rovira 2006). A small number of metallographic studies of copper axes also show that metallurgists at that time gave precedence to the mechanical working of artefacts, mainly forging, and not to the choice of copper, because it seems that the effect of arsenic in making the copper harder was not easily recognised (Kienlin et al. 2006).

Among the other artefacts from the pile dwellings at Ig and from the Ljubljanica, antimony copper (IV) predominates, which is possible to recognise in the majority of the artefacts (in four axes, tab. 2: 3,4,6,7, in two daggers and three

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17 Krause 2003, 91 ff, fig. 41.
18 The axes were also analysed by the XRF method, see Milić 2004, 73, tab. 3.5.1.
19 Krause 2003, 129.
Copper finds from the Ljubljansko barje (Ljubljana Moor) – a contribution to the study of prehistoric metallurgy

awls, tab. 2: 8.11–14). The single axe of the Griča type (tab. 2: 7) thus also belongs to this type of copper irrespective of the different, regionally limited distribution of other axes of Altheim type. The use of antimony copper with a higher content of antimony and silver, namely, is common in Central and Southeast Europe, especially between the Eastern Alps and the western edge of the Carpathians and is more typical of products from the Eneolithic than from the Early Bronze Age. Pure copper (III) can perhaps be ascribed to one of the axes from the Ljubljanica (tab. 2: 5) and two daggers from Ig (tab. 2: 9.10). This copper most often appears in artefacts from the Carpathian basin, from where it spreads towards the western Alpine area.20 There are no indications of the Fahlerz type copper with high arsenic and antimony concentrations (type II) among the artefacts in question. R. Krause, on the other hand, did find it. It is possible to recognize Ig on his distribution maps with artefacts made of the Fahlerz type of copper (Krause 2004, 156, fig. 123 and 120–122) while this site is missing on the map with artefacts from the antimony type of copper (id., 149, fig. 113). The reason for such a decision is not clearly evidenced. In our opinion, Fahlerz copper cannot be seen in the first Stuttgart analyses from the SAM project (see the analysis numbers in tab. 1) if he relied upon them. However, our view seems also in accordance with the chronological position of the finds which were identified as Late Eneolithic, while Fahlerz copper is more characteristic of the Early Bronze Age.

Despite the fact that we succeeded in classifying the artefacts from the Ljubljansko barje into some copper groups typical of the wider European area, the question still remains open of the possible use of local ore, to which researchers of eneolithic metallurgy on the Ljubljansko barje incline.21 Our research encountered specific differences in the

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20 Krause 2003, 122 ff., fig. 83, fig. 86.

metal composition in comparison with European metal groups, such as higher lead and/or antimony and silver in individual artefacts and a slightly higher concentration of arsenic in all the artefacts analysed. The question of the exploitation of local ore is thus relevant, although it goes beyond the scope of this study. It is therefore necessary to wait for the results of lead isotope analyses of local ore and copper in artefacts which, in combination with the trace element content, enable better differentiation among various ore sources (Pernicka 1999). Our research was restricted to determining the relationships among concentrations of trace elements in artefacts, and analyses of local ore are currently still in progress. It is thus not possible to say any more about the origin of the copper from the Ljubljansko barje. We are also aware that future comparative analysis of copper artefacts and the composition of local ore may not give positive results for the Copper age, since possible later mining activities may have removed all remains of the then ore layers. The oldest metallurgical remains from the Ljubljansko barje from the fourth millennium are unfortunately still too modest to prove the exploitation of local ore, even though they are analytically extremely well processed. In contrast, metallurgical instruments from the 3rd millennium convincingly demonstrate the flowering of copper metallurgy on the Ljubljansko barje, above all metal melting and perhaps even ore smelting. However, there is still a crucial lack of copper slag, which would directly prove that copper was obtained on the Ljubljansko barje.

CONCLUSION

The main reason for the incompleteness and deficiency of our conclusions is the relatively modest number of middle and late eneolithic artefacts in Slovenia that have been so far analysed. Statistically reliable data are not currently available on the frequency and average content of trace elements in copper from Slovenia. Therefore firm conclusions about differences from copper in other parts of Europe cannot be made, nor about local particularities of copper in the artefacts studied.

The arsenic type of copper thus only appears in the two oldest axes from the Ljubljanica from the middle of the 4th millennium BC. In addition to a difference in the type of copper there is also a chronological difference. The type of copper which is most often found in analysed artefacts from the Ljubljansko barje is antimony copper. It appears in the majority of artefacts connected with the period of the Vučedol culture in the 3rd millennium BC. This copper type is most widespread in the area between the western edge of the Carpathians and the Eastern Alps, which corresponds to strong archaeological links that settlements on the Ljubljansko barje show with settlements in the lower Danube region. One of the metallurgically important links is the two-part mould for a shaft-hole axe (fig. 1). Its appearance in the Balkans and the Carpathian basin in the second half of the 3rd millennium is linked with a new dissemination of copper metallurgy and a new technique of casting from Anatolia to the central part of Europe. The two-part moulds and numerous implements for melting copper convincingly demonstrate the appearance of the new metallurgical technique also in the Ljubljansko barje (fig. 1). They identify the pile dwellings in Ig as an important metallurgical location and very likely a starting point for ore prospectors, incomers from the middle Danube basin in search of copper ore in the eastern Alps and in the pre-Alpine regions in the 3rd millennium BC.  

Acknowledgements

The authors would like to thank the Slovenian Research Agency for financial support to the research program P 6-0283. For computer processing of the results we are grateful to Ivan Jerman, a researcher at the Institute of Chemistry in Ljubljana.

Translation: Martin Creegen

22 R. Urankar is researching ore within the context of his doctoral thesis at the University of Ljubljana, Slovenia.  
24 Parzinger 1993, 350.
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VELUŠČEK, A. 2004c, Terenske raziskave, stratigrafija in najde / Field research, stratigraphy and the material finds. - In: A. Velušček (ed.) 2004d, 33-55.


KROSEC, P. and J. KROSEC 1969, Najde v koliščarskih naselbin pri Iga na Ljubljanskem barju / Fundgut der Pfahlbausiedlungen bei Ig am Laibacher Moor. - Arheološki katalogi Slovenije 3.
Bakrene najdbe z Ljubljanskega barja – prispevek k študijam pragodovinske metalurgije

UVOD


Majhni in drobni sekirici (Parzinger 1983), rezultati novih sorodnih kolišč in nekaterih iz Ljubljanice, ki so bili naključno najdeni bakrenih predmetih z Dežmanovih kolišč pri Igu in v sedmih projekta vredno novih obdelav (Velušček 2004e). V primerjavi n. št. in v kontekst vučedolske kulture, tako tudi metalurški del od katerih večina sodi v pozni eneolitik v okvir 3. tisočletja pr. n. št. velja mnenje, da je Dežman odkopal več časovno različnih kolišč, natančnejše datacije nastanka kolišč, a tudi nova kronološka predvsem uporaba naravoslovnih metod odpirajo možnosti za kolišč (Parzinger 1983), raziskave novih sorodnih kolišč in natančne primerjalne študije keramike z Dežmanovih in drugih izdelkov vred (Velušček 2004e). V primerjavi z Velušček postavlja v 4. tisočletje pr. n. št. Verjetno je na}

Ostalih pet sekr je večjih in debelejših, vendar prav tako se je med ploščatim sekrima spadalo razdijerje rezilom (t. i. 3–7). Tri od njih so se značilniki obliko dobro uvrščali v tip Altheim. Zanimivo je, da sta dve iz Ljubljanske (t. i. 4, 5) iden-
tični sekri iz Dežmanovega kolišča na Igu (t. i. 6), od koder so znani tudi glineni kalupi za izdelavo sekr tipa Altheim, na kar se je bil vendar večkrat opozorjeno. Sekiri tovrstega tipa se v povzem ali enoličnik, v 3. tisočletje pr. n. št. oziroma v mlajših fazah bakrskih najdb, ki se povezuje z včedolskim kulturnim obrazom (Veluček, Gref 1998). Od oblik od njih ostaja večja in oja sekira iz Ljubljanske (t. i. 7) 8. Sekire sodijo v pozni eneolitik, v zaključku.
Sekire tovrstega tipa so sicer pogoste v Baltikom, se je podatkovna baza povečala na približno 27000 obširnih območij centralne Evrope med severno Italijo, Karpati vključno srednje bronaste dobe. Predvsem zaradi obsežnih nemških bakrskih izdelkov iz najstarejših obdobij – od neolitika pa do večinoma na sistematičnih kemijskih analizah velikega števila

9 Podobni primerki so npr. iz jezerja in kolišča Attersee (Mayer 1977, t. 11: 142,143).
10 Mayer 1977, 53 ss.
11 Žeravica 1993, 59 ss.
12 Primas 1996, 97 ss; sl. 7,7: 1,2–6,7–10–12.
13 Gerloff 1975, 5, 38.
14 Vidmar 1974, 3 ss, t. 1: 2.
15 Perini 1972, 17, sl. 10: 140–141; Primas 1976, 88.
16 Za nesimelke projekte Krause 2003, ss 16, 27.

odbelavo rezultatov je izbral 21 kovinskih skupin (klasterov), ki glede na razmerja koncentracij nečistoč odražajo pet tipov kovinskega bakra (ne pa rud). Rezultate je Krause (2003) povezal z arheološko interpretacijo gradiva, ki je pokazala, da so vrste bakra kronološko pomembne in skoncentrirane na določenih geografskih območjih. Tako se je izkazalo, da so trije tipi bakra – antimonov (tip V), arzenov (tip IV) in seker (tip III), značilni samo za neolitik ali pa vsaj prevladujejo v tem obdobju, medtem ko je bakr vrste Fählerz (tip I in II) bolj značilen za zgodnjo bronasto dobo in poznejša obdobja. Zaradi lažjega pregleda predstavljamo kovinsko sestavo naših predmetov razen v analizah (tab. 1) tudi v obliki koncentracijskih diagramov/ Sb, Ag/Sb, Ag/Pb in Sb/Pb (sl. 2, 3). Iz teh je razvidno, da razen vzorcev 1 in 2, ki izstopata zaradi visokega arzena (As > 0,4–2,4 %), večina vzorcev kaže relativno majhno vsebnost arzena (As < 0,05 %) in neodvisnost od rastuči vsebnosti antimonja. Visoki vsebnosti Sb (0,13–0,33 %) so po analizah (tab. 2) najbolj pogoste v srednji Evropi, zasebno v območjih centralne Evrope med severno Italijo, Karpati vključno srednje bronaste dobe. Predvsem zaradi obsežnih nemških bakrskih izdelkov iz najstarejših obdobij – od neolitika pa do večinoma na sistematičnih kemijskih analizah velikega števila

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žemo, da so toledanji metalurji dajali prednost mehanski obdelavi predmetov, predvsem kovanju, in ne izhibi bakra, ker se zdi, da vpliva arzena na večjo trdoto bakra niso zlahka prepoznali (Kienlin et al. 2006).

Med ostalimi izdelki s koliščem v sredini 4. tisočletja pr. n. št. so žal še preveč osebnih spomenov o izkoriščanju domače rude. Najstarejši metalurški ostanki s kolišč emulatajo vseh naših predmetov. Problem izkoriščanja lokalne rude je torej aktualen, vendar prerašča obseg te študije. Tako se arzenov tip bakra pojavlja le v dveh najstarejših sekerah iz Ljubljanske iz sredine 4. tisočletja pr. n. št. in poleg razlike v vrsti bakra predstavlja tudi kronološko razliko. Tip bakra, ki je najbolj pogost v analiziranih izdelkih z Ljubljanskega barja, pa je antimonov bakter. Pojavlja se v večini predmetov, ki se navedujejo na čas vučedolske kulture v 3. tisočletju pr. n. št. Ta tip bakra je sicer najbolj razširjen na območju, pri katerem pa se izmika možnost trdnih zaključkov o razlikah do bakra iz ostalih predelov Evrope in s tem o lokalnih posebnostih bakra v naših izdelkih.

ZAKLJUČEK

Glavni razlog za nepopolnost in pomanjkljivost naših zaključkov je relativno skromno število analiziranih predmetov iz srednjega in poznega eneolitika v Sloveniji. Zamenjamo se na voljo statistično zanesljivih podatkov o pogostosti in povprečni vsebnosti slednih elementov v našem bakru, zato se izmika možnost trdnih zaključkov o razlikah do bakra iz ostalih predelov Evrope in s tem o lokalnih posebnostih bakra v naših izdelkih.

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Pl. 1: Ljubljanica 1–5, 7, 14; Ig 6, 8–13. All copper. Scale = 1:2 (drawing: I. Murgelj).