Analysis of bronze artefacts from Mannersdorf am Leithagebirge, NÖ

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Drilled samples from 53 artefacts from 30 different graves from the La Tène Iron Age cemetery at Mannersdorf NÖ were submitted for composition analysis.

Analysis

The samples were hot-mounted in a carbon-filled thermosetting resin, ground and polished to a 1: m diamond finish. All samples were analysed by electron probe microanalysis (EPMA) with wavelength dispersive spectrometry (WDS), using a JEOL 8800 instrument operated by Oxford Materials Characterisation Services, Department of Materials, University of Oxford. I am grateful to Mr C.J. Salter for assistance with the analysis processs. Operating conditions were an accelerating voltage of 20 kV, a beam current of 30 nA and an x-ray take-off angle of 40E. Sixteen elements were analysed as set out in the table, using pure element and mineral standards, with a count time of 10s per element. Detection limits were 100–200 ppm for most elements with the exception (for bronze) of 300–400 ppm for gold.

From two to eleven areas, each 50x30:m, were analysed on each sample depending on the size and condition of the sample. The mean compositions for all the samples, normalised to 100%, are listed in Table 1 with all concentrations are in weight %. Experimental error ranges from about 1% for the major elements to 10% for impurities and larger values still for trace elements. Reproducibility between replicate analyses on the same area is rather better than this.

Comparative data

Two datasets are available for immediate comparison. The first is the comprehensive analysis of bronze metalwork, including fibulae, from the cemetery at Pottenbrunn NÖ[2], and the second is the analysis by laser-ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) of 75 typologically relevant fibulae from Switzerland, Austria and the Czech Republic[3] together with two from Mannersdorf and one from Pottenbrunn. One Mannersdorf fibula (60/6) provides a means of comparison between the two analytical methods. There are some other Iron Age datasets to which reference can be made but the most relevant are those from Bohemia[4], Slovenia[5] and some parts of the Alps[6].

The copper alloys

As might be expected for the central European Iron Age, no sample from Mannersdorf contained alloying levels of zinc. Virtually the entire sample set can be described as medium tin bronze, of which some only a very small number of examples can truly be described as leaded. The general pattern of alloying can be described by histograms for tin (Figure 1) and lead (Figure 2) and a scatter plot of lead against tin (Figure 3). With a modest population of observations as here the selection of the cell size and type of histogram can make a significant difference to its appearance. The choices made in Figures 1 and 2 give, sufficient clarity to the distribution without being misleading.

The distribution of tin contents is bimodal with two overlapping normal distributions, one with a peak at 8–9% and the other 10–11%. It could be argued that this division is an artifact of the way the histogram was drawn and that essentially it represents a single distribution. However, if the cell boundaries are shifted by 0.5% percentage points the division becomes much more marked. It should also be added that in prehistory control of alloy compositions could be very precise even when there was no functional need. At Pottenbrunn there was also a bimodal distribution of tin contents but it was shifted to lower values with the main peak at 8–9%, and a lower peak around 6% tin.

1 Material Science-Based Archaeology Group, Department of Materials, University of Oxford
2 Northover 2002.
3 Swoboda, Stingeder, Prohaska, this volume.
4 Frana et al. 1995, 1998.
5 Giumlia-Mair 1995.
6 E.g. Northover 1983; Schindler 1998.

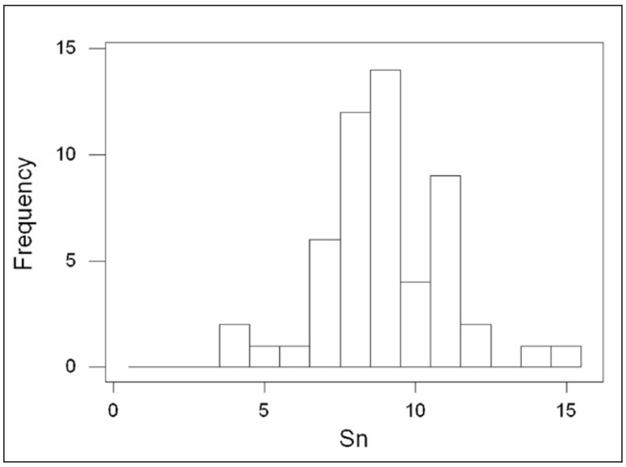

Fig. 1: Histogram for tin.

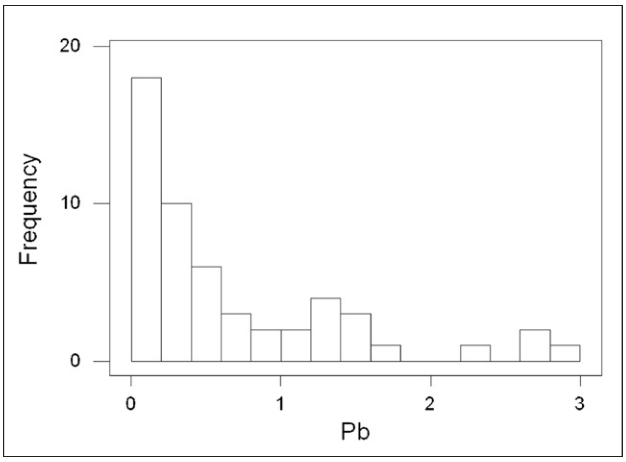

Fig. 2: Histogram for lead.

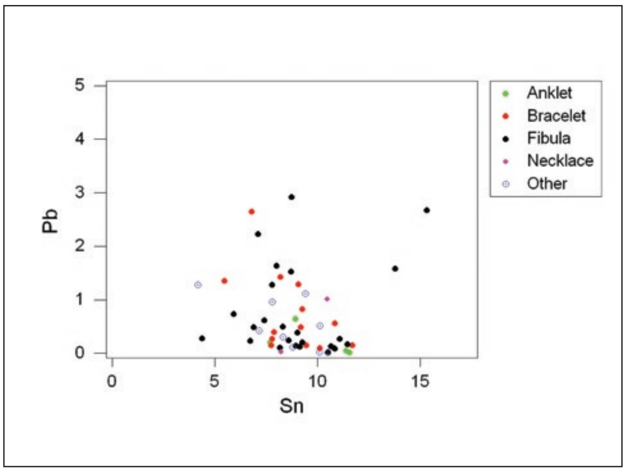

Fig. 3: Scatter plot of lead against tin.

Only four of the 53 samples (7.5%) have more than 2% lead (Figure 2) and could be regarded as unleaded. Although 2% lead will produce a useful reduction in the viscosity of a bronze melt[7] the improvement in overall casting properties was probably not enough for the majority of smiths using leaded bronze; an addition nearer 5% was a more likely minimum choice. The very small peaks in the distribution either side of 2% lead are insignificant and all the lead contents can be regarded as deriving from lead impurities in the copper or as residual from leaded bronze scrap, and none as alloys deliberately created for the object in question.

The plot of lead against tin in Figure 3 confirms these observations with a visible gap in the tin distribution. It also reveals a tendency for higher lead contents to be associated with lower tin contents. A similar plot for Pottenbrunn[8] shows a similar pattern, with the further observation that the highest lead contents could there be counted as marking truly leaded bronzes, with almost all dated to the LT B1 phase of that cemetery. The objects made from those leaded bronzes were almost all objects other than fibulae, and fragments of such pieces could be the sort of scrap incorporated in the fibulae at Mannersdorf which had the highest lead contents.

Impurity patterns

The statistical treatment of the bronzes from Pottenbrunn was made on 83 samples, of which 76 could be assigned to one of four rather arbitrarily defined impurity patterns, with the other seven belonging to three variants. The first purpose of such an exercise is to reduce the impurity pattern to a single, easily managed variable which can be correlated with other metallurgical features, and with typology and chronology, and it can be applied at Mannersdorf. The first step was to determine whether all the Mannersdorf analyses could be assigned to the Pottenbrunn impurity patterns, and it proved that only 77.3% could be so assigned. To accommodate the Mannersdorf data it was necessary to create two new groups, to give us:

IP 1	Ni, Sb <0.10%
IP 2	Ni > 0.10%, 0.10% < Sb < 0.20%
IP 3a	0.10% < Ni < 0.30%, Sb > 0.20%
IP 3b	Ni > 0.30%, Sb > 0.20%
IP 4	0.10% < Ni > 0.20%, Sb < 0.10%
IP 5	Ni, Sb < 0.10%, Zn > 0.10%

Of the two variant analyses at Mannersdorf, one matches a Pottenbrunn variant with Ni > 0.40%, Sb < 0.10%, while the second is like IP 2 but has Sb <0.20%. A principal components plot based on the major impurities of Ni, Zn, As, Sb, Ag, Pb (Figure 4) shows that these criteria give a reasonable separation between groups and supports their use as a measure of comparison. In Figure 4 it should be noted that the extreme values to the

[7] Staniaszek, Northover 1983.

[8] Northover 2002, Fig. 4.

right at the plot are connected with high values of Sb and NI, and at the left the cluster is of objects with low total impurities.

Comparing the distribution of these groups in the two cemeteries in percentage terms gives us:

		IP 2	IP 3a	IP 3b	IP 4	IP 5	Var
Pottenbrunn	25.3	31.3	25.3	9.6	0	0	8.4
Mannersdorf	20.7	34.0	17.0	5.6	11.3	7.5	3.8

The primary difference between the two sites is in the distribution of antimony contents, with Mannersdorf having both fewer members of high antimony groups (IPs 3a and 3b) and lower maximum antimony contents – 0.44% against 0.99% at Pottenbrunn. IP 1 and IP2 are present in similar proportions in both and can be regarded as rather typical of metal in circulation in Lower Austria in the Iron Age. The variation in antimony could be both a geographical trend and a chronological one. The Late Bronze Age and Early Iron Age in Switzerland and Slovenia produced some coppers with very high antimony contents indeed and these could be extering an influence, an influence which was decreasing eastwards. We do not, though, have enough data to say whether such copper was still being smelted well into the La Tène period, or whether we are looking at a residue of it still in circulation. It is also relevant to this geographical argument that one variant composition at Pottenbrunn which occurs in two fibulae, and that is one with Co > Ni, Sb <0.10%. This can be associated with the western Alps and copper produced in both Britain and Italy.

Although many of the analyses must reflect an important degree of mixing and recycling the extreme values as revealed by the principal components analysis (Figure 4) are an indicator of the types of metal going into circulation and, although potentially already recycled, are unmixed with metal of other types. In this plot one such input is represented by the objects with the lowest impurity contents are grouped at the left, i.e. IP 1 and, with the addition of zinc, IP 5. Indeed, since no other analyses have more than a trace of zinc, this group of four samples with low antimony and nickel (MD 6/16/45/48) has a very good claim to be unmixed. At the other extreme are the analyses with high antimony and nickel and some of these, too, may also be largely unmixed (e.g. IP 3b and MD1/2). The presence of IP 4 at Mannersdorf and its absence at Pottenbrunn suggests a different input in this eastern area, and that is a bronze with arsenic and nickel impurities but with only low antimony. This is a common pattern in Europe through much of prehsitory and its absence from Pottenbrunn is surprising.

Another metallurgical result of the grouping of compositions into impurity patterns is to look for correlations with alloy types as a further stage in identifying material with a common history. The plot of lead against tin from Figure 3 is re-drawn with the data-points grouped by impurity pattern in Figure 5a and compared with the data from Pottenbrunn[9] plotted on the same scale in Figure 5b. There are some remarkable similarities, such as the consistent association of IP 1 in both cases with higher tin contents, although, also in both cases, there are one or two exceptions. Similarly in both plots,

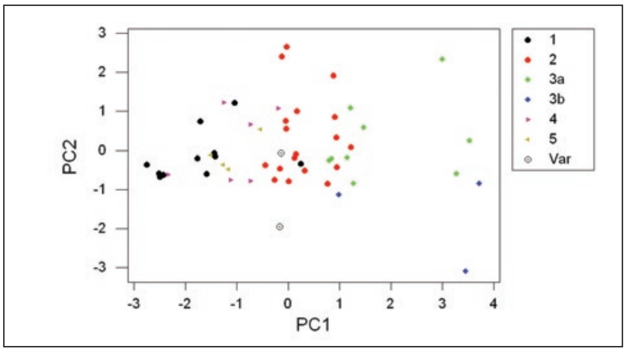

Fig. 4: Principal components analysis.

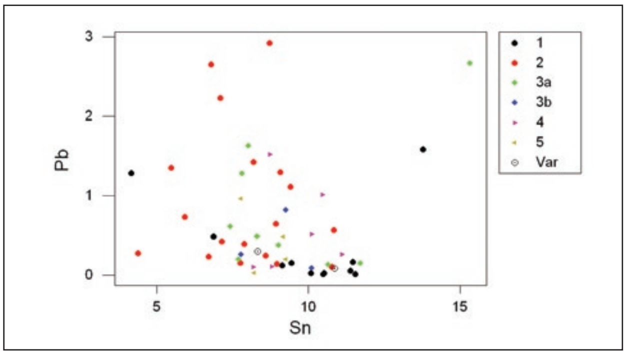

Fig. 5a: Lead against tin redrawnwith the data-points grouped by impurity pattern.

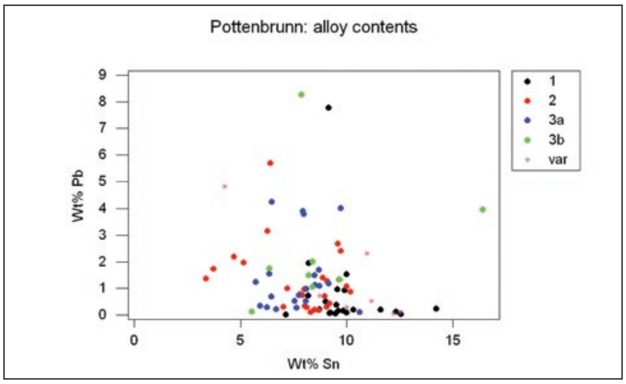

Fig. 5b: Comparison with Pottenbrunn.

[9] Northover 2002 Fig. 5.

IP 2 is associated with a lower range of tin contents, and also with higher lead contents but, as discussed above, this is much more marked at Pottenbrunn. Overall we can say that much of the metal at both Mannersdorf and Pottenbrunn was based on the same resources and used in a similar way. Also, as at Pottenbrunn, IP 3 compositions overlap with IP 1 and 2 in alloy content. Of the newly identified groups, IP 4 with As, Ni impurities is close to IP 1 in tin contents but has a little more lead, while IP 5 with its distinctive zinc content groups with the lower tin contents, showing that its zinc content is not the only difference in comparison with IP 1.

Sample	sf Nr.	Object	Period	Fe	Co	Ni	Cu	Zn	As	Sb	Sn	Ag	Bi	Pb	Au	S	Cd	Al	Si
IP 1: Ni, Sb <0.10%																			
MD 31	76/5	Omega pin	LT B1	0,12	0,01	0,04	89,20	0,01	0,04	0,00	10,50	0,00	0,01	0,01	0,02	0,00	0,00	0,00	0,02
MD 13	13/4	Fibula	LT B1	0,04	0,01	0,03	89,04	0,01	0,22	0,00	10,53	0,00	0,01	0,02	0,01	0,03	0,00	0,00	0,06
MD 10	10/19B	Anklet	LT B1	0,42	0,02	0,03	87,85	0,03	0,01	0,00	11,56	0,00	0,01	0,01	0,04	0,00	0,01	0,00	0,01
MD 30	74/1	Fibula	LT B1	0,40	0,02	0,05	89,98	0,03	0,16	0,01	9,14	0,01	0,01	0,12	0,03	0,02	0,00	0,00	0,02
MD 17	13/15C	Situla (bottom)	LT B1	0,09	0,01	0,00	89,68	0,00	0,01	0,01	10,09	0,02	0,01	0,02	0,02	0,01	0,00	0,00	0,04
MD 34	101/3C	Fibula	LT B2	0,39	0,03	0,07	87,56	0,01	0,23	0,02	11,47	0,00	0,02	0,16	0,02	0,02	0,00	0,00	0,00
MD 25	56/7B	Pendant	LT B1	0,04	0,01	0,05	94,22	0,01	0,11	0,02	4,15	0,00	0,01	1,28	0,03	0,01	0,00	0,00	0,07
MD 22	38/3	Fibula	LT A2/B1	0,09	0,01	0,05	92,10	0,02	0,19	0,03	6,88	0,00	0,01	0,48	0,01	0,06	0,00	0,01	0,06
MD 12	13/2A	Anklet	LT B1	0,09	0,00	0,01	88,38	0,01	0,01	0,03	11,39	0,00	0,00	0,05	0,01	0,00	0,02	0,00	0,01
MD 38	116/5B	Fibula	LT B1	0,18	0,02	0,09	83,86	0,02	0,20	0,04	13,79	0,00	0,07	1,58	0,02	0,12	0,00	0,00	0,01
MD 24	41/3B	Bracelet	LT B2/C1	0,07	0,02	0,09	89,53	0,01	0,48	0,07	9,44	0,00	0,01	0,15	0,01	0,06	0,00	0,00	0,06
IP2: Ni > 0.10%, 0.10%<Sb<0.20%																			
MD 47	153/5	Bracelet	LT B1	0,08	0,07	0,21	88,25	0,01	0,31	0,10	10,78	0,02	0,02	0,10	0,02	0,02	0,00	0,00	0,01
MD 32	79/2B	Bracelet	LT C1	0,09	0,01	0,12	92,41	0,00	0,17	0,10	5,47	0,07	0,04	1,35	0,05	0,06	0,00	0,01	0,04
MD 42	127/9	Fibula	LT B1	0,05	0,02	0,10	87,67	0,02	0,22	0,10	8,73	0,02	0,07	2,92	0,02	0,02	0,00	0,00	0,01
MD 35	101/4	Bracelet	LT B2	0,07	0,02	0,18	90,97	0,02	0,22	0,11	7,88	0,04	0,04	0,39	0,02	0,02	0,01	0,00	0,01
MD 39	124/1	Bracelet	LT B1	0,20	0,03	0,13	89,68	0,02	0,20	0,11	6,79	0,02	0,04	2,65	0,04	0,04	0,01	0,01	0,04
MD 19	22/6	Bronze fragment	LT B1	0,23	0,02	0,16	91,51	0,02	0,26	0,12	7,14	0,05	0,02	0,42	0,01	0,00	0,01	0,00	0,02
MD 18	22/4	Bracelet	LT B1	0,30	0,02	0,12	91,13	0,01	0,20	0,12	7,75	0,04	0,01	0,15	0,03	0,07	0,00	0,01	0,04
MD 5	4/1	Bracelet	LT B1	0,20	0,02	0,18	87,62	0,01	0,26	0,13	10,84	0,04	0,03	0,56	0,03	0,00	0,06	0,00	0,02
MD 49	180/1	Bracelet	LT B2	0,60	0,02	0,26	88,12	0,01	0,28	0,14	9,08	0,01	0,00	1,29	0,03	0,17	0,00	0,00	0,00
MD 43	139/7	Fibula	LT B2/C1	0,19	0,02	0,14	90,08	0,00	0,25	0,15	8,59	0,12	0,04	0,24	0,06	0,13	0,00	0,00	0,00
MD 41	124/5A	Anklet	LT B1	0,66	0,01	0,14	89,11	0,00	0,24	0,15	8,93	0,04	0,03	0,64	0,02	0,01	0,00	0,00	0,00
MD 33	94/7B	Fibula	LT C1	0,04	0,01	0,16	90,20	0,02	0,16	0,16	8,96	0,04	0,03	0,14	0,02	0,06	0,01	0,00	0,00
MD 9	10/7	Fibula	LT B1	0,19	0,01	0,13	89,66	0,02	0,23	0,16	7,09	0,08	0,05	2,23	0,02	0,00	0,08	0,00	0,04
MD 3	3/19	Fibula	LT B2/C1	0,10	0,02	0,28	92,04	0,02	0,22	0,17	6,71	0,08	0,02	0,23	0,06	0,01	0,02	0,00	0,01
MD 37	114/12	Bracelet	LT B1	0,15	0,03	0,18	89,41	0,00	0,26	0,17	8,19	0,07	0,03	1,42	0,03	0,05	0,00	0,00	0,01
MD 40	124/4B	Fibula	LT B1	0,10	0,00	0,14	94,63	0,02	0,15	0,18	4,38	0,09	0,02	0,27	0,02	0,00	0,01	0,00	0,00
MD 20	22/11	Fibula	LT B1	0,04	0,00	0,12	92,45	0,01	0,28	0,19	5,92	0,10	0,03	0,73	0,00	0,04	0,01	0,01	0,06
MD 15	13/15A	Situla (handle)	LT B1	0,03	0,02	0,21	88,63	0,02	0,27	0,20	9,41	0,05	0,01	1,11	0,01	0,02	0,00	0,01	0,01
Sample	**sf Nr.**			**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Sb**	**Sn**	**Ag**	**Bi**	**Pb**	**Au**	**S**	**Cd**	**Al**	**Si**
Sample	**sf Nr.**			**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Sb**	**Sn**	**Ag**	**Bi**	**Pb**	**Au**	**S**	**Cd**	**Al**	**Si**
IP3a: 0.10%<Ni<0.30%, Sb>0.20%																			
MD 26	56/8	Fibula	LT B1	0,05	0,01	0,18	89,95	0,01	0,26	0,21	7,80	0,10	0,01	1,28	0,04	0,06	0,01	0,00	0,04
MD 53	230/8	Fibula	LT B2	0,08	0,02	0,13	90,30	0,02	0,16	0,21	8,31	0,11	0,02	0,49	0,03	0,11	0,01	0,00	0,01
MD 7	8/14	Fibula	LT B1	0,10	0,04	0,24	88,14	0,01	0,25	0,21	10,66	0,10	0,00	0,13	0,03	0,00	0,06	0,00	0,03
MD 52	230/7	Fibula	LT B2	0,05	0,01	0,14	89,53	0,01	0,22	0,24	8,01	0,08	0,03	1,63	0,03	0,02	0,00	0,00	0,01
MD 11	10/27	Fibula	LT B1	0,14	0,02	0,15	89,53	0,01	0,34	0,25	9,02	0,04	0,05	0,38	0,04	0,01	0,00	0,00	0,01
MD 21	37/3	Bracelet	LT B1	0,36	0,02	0,12	86,97	0,01	0,26	0,28	11,71	0,05	0,00	0,15	0,02	0,01	0,00	0,00	0,05
MD 8	10/5	Fibula	LT B1	0,47	0,01	0,20	90,19	0,03	0,33	0,36	7,42	0,20	0,01	0,61	0,03	0,00	0,08	0,01	0,03
MD 44	143/3	Fibula (horse)	LT B2	0,11	0,01	0,22	80,72	0,00	0,38	0,37	15,34	0,07	0,04	2,67	0,01	0,04	0,00	0,00	0,01
MD 2	3/9	Anklet	LT B2/C1	0,07	0,01	0,23	90,57	0,03	0,37	0,44	7,69	0,11	0,03	0,20	0,01	0,17	0,05	0,00	0,02
IP3b: Ni>0.30%, Sb>0.20%																			
MD 36	106/5B	Bracelet	LT B2	0,13	0,02	0,43	90,74	0,04	0,25	0,15	7,78	0,07	0,00	0,26	0,05	0,05	0,00	0,00	0,01
MD 29	67/4	Bracelet	LT B1	0,06	0,03	0,59	88,32	0,02	0,37	0,27	9,26	0,16	0,03	0,82	0,04	0,03	0,00	0,00	0,01
MD 46	153/4	Bracelet	LT B1	0,15	0,03	1,26	87,59	0,01	0,39	0,28	10,11	0,02	0,01	0,09	0,02	0,01	0,00	0,00	0,02
IP4: Ni>0.10%, Sb<0.10%																			
MD 4	3/20	Fibula	LT B1	0,04	0,01	0,10	88,41	0,01	0,03	0,00	11,10	0,00	0,01	0,26	0,01	0,01	0,00	0,00	0,00
MD 27	56/12	Necklace	LT B1	0,94	0,02	0,12	87,05	0,03	0,16	0,05	10,46	0,02	0,04	1,01	0,00	0,06	0,00	0,01	0,03
MD 23	38/15A	Fibula	LT A2/B1	0,04	0,01	0,11	91,21	0,01	0,12	0,06	8,17	0,04	0,03	0,10	0,03	0,03	0,00	0,00	0,04
MD 51	230/2A	Bronze fitting	LT B2	0,98	0,02	0,16	87,79	0,01	0,24	0,08	10,11	0,02	0,04	0,51	0,02	0,02	0,00	0,00	0,01
MD 14	13/7	Wheel pendant	LT B1	0,06	0,03	0,17	90,47	0,01	0,22	0,08	8,78	0,01	0,03	0,11	0,01	0,00	0,00	0,00	0,01
MD 28	60/6	Fibula	LT B1	0,10	0,01	0,10	89,04	0,01	0,24	0,09	8,72	0,03	0,03	1,52	0,02	0,04	0,00	0,00	0,03
IP5: Ni, Sb < 0.10%, Zn > 0.10%																			
MD 6	8/6	Bracelet	LT B1	0,08	0,04	0,06	89,70	0,13	0,16	0,04	9,18	0,00	0,04	0,48	0,00	0,00	0,07	0,00	0,02
MD 48	165/1	Fibula	LT B1	0,09	0,01	0,03	89,80	0,22	0,19	0,02	9,25	0,03	0,01	0,20	0,03	0,09	0,00	0,00	0,01
MD 16	13/15B	Situla (attachment)	LT B1	0,14	0,01	0,07	90,35	0,11	0,29	0,02	7,78	0,03	0,13	0,96	0,03	0,05	0,00	0,00	0,01
MD 45	153/3	Necklace	LT B1	0,14	0,01	0,04	90,59	0,58	0,25	0,03	8,21	0,01	0,01	0,03	0,01	0,08	0,00	0,01	0,00
Misc.																			
MD 1	1/4	Fibula	LT B1	0,11	0,00	0,61	87,91	0,01	0,10	0,02	10,86	0,07	0,01	0,08	0,02	0,20	0,00	0,00	0,00
MD 50	197/3	Belt	LT B1	0,20	0,01	0,06	90,61	0,00	0,28	0,17	8,32	0,01	0,00	0,30	0,02	0,01	0,00	0,00	0,01

Fig. 6a, b: Data sets.

Chronology and distribution

The metalwork in the graves considered here runs from LT A2 to LT C1, a span of 200 years. The examples of Britain[10] and Denmark[11] suggest that changes in the compositions of bronze occurred rather slowly with time and in that context 200 years is not a long time. Consequently there might not be a great deal of chronological patterning in the data and the inclusion of the dating for each grave in the analysis table supports this. The dataset is dominated by material of LT B1 date; LT B2–C1 material is mainly associated with IP 2 but the correlation is probably not statistically significant. Consideration was also given to correlation with grave type, i.e. open or enclosed, but there were no sensible patterns.

Discussion

The review of the compositions of the Mannersdorf arteacts has been carried out in direct comparison with the data from Pottenbrunn because the latter provided the first structure for discussing the compositions of Iron Age bronze in Lower Austria, and because of the relative proximity of the two sites. Clearly there great similarities between the two suggest that many of the artifacts are products of a common technical culture and were made within the region. As we have seen, though, there are exceptions and some further insight into the provision of the grave goods can be obtained by studying them and perhaps the most distinctive is IP 5 with its zinc impurity. There are some examples of bronzes with a zinc impurity from both Bohemia and Slovenia, and tin two of the Swiss fibulae analysed for this project[12] but there are not sufficient to make any suggestions about their origins.

Another way of looking at Mannersdorf in a wider metallurgical context is to look for composition groups which are not there. It was noted above that two items characterised by an impurity pattern with Co>Ni were found at Pottenbrunn but none at Mannersdorf. This patten is common in Iron Age bronze in two regions of Europe, central southern England[13] and Italy and southern Switzerland[14]. It has also been identified in sheet metal vessels at La Tène itself with either Britain or Italy as a possible origin. It does not appear in either the Bohemian or the Slovenian data; although the latter come down only as far as the 4th century BC it is well represented in the Graubünden and Tessin at the same time[15]. As far as our present knowledge permits the two finds at Pottenbrunn would appear to represent the furthest penetration of this metal type in an easterly or northerly direction and that Mannersdorf lies beyond its reach.

Distributions of bronze compositions do not show us only how the copper is used, they also relate to the other alloying elements, tin and lead, and how they are viewed in different areas. Almost the first area where significant amount of Iron Age metalwork was analysed was in southern Britain where it became apparent that an area that had pioneered leaded bronzes in the Late Bronze Age abandoned the technology for much of the Iron Age until influence from the Roman world brought them to notice again. This avoidance of leaded bronze extended to cast as well as wrought products while but elsewhere there was a greater selection of alloys for particular products. In the Arbedo TI assemblage[16] Certosa fibulae are unleaded if made in one piece but have a leaded bronze bow if made in two pieces with the bow cast onto the spring/pin assembly. The same choice of leaded bronze for a cast product was made for the La Tène period beaded, hollow and other arm-rings in Bohemia, and for items such as bracelets at Pottenbrunn. As noted already the fibulae samples from Pottenbrunn tend to be unleaded although a small number of examples has up to 2–3% lead, and something similar is true at Mannersdorf with analyses up to 1–2% lead. The data on Swiss and Bohemian fibulae collected for this project[17] show that the majority were of unleaded bronze, with the only leaded alloys measured being from Mannersdorf (one example) and Switzerland, possibly in cast-on bows.

Broader comparisons of tin contents are constrained by the different methods used for analysis and the different treatments of corroded material in each of the projects cited. Perhaps the most useful comparisons beyond Mannersdorf and Pottenbrunn are the Bohemian data, which exhibit numerous parallels for both bands of tin contents seen at Mannersdorf. These are a subset of the full range of tin contents seen in European Iron Age bronze: although examples with tin contents above the highest seen at Mannersdorf are rare except in *Potinmünze,* there are some bronzes with very low tin contents, as low as 1–4%[18].

In summary, although we have emphasised the variation in both alloy and impurity contents of the fibulae from Mannersdorf, in reality the material is rather homogenous and in the smith's hands the most of the bronzes would appear to behave in a very similar manner. The compositions can be placed within general regional trends in the circulation of bronze but looking for specific correlations between typology, chronology and composition appeared fruitless.

[10] Northover 1991a, 1991b.

[11] Liversage 2000.

[12] Swoboda, Stingeder, Prohaska, this volume.

[13] E.g. Northover 1991a and 1991b.

[14] Schindler 1998.

[15] Schindler 1998.

[16] Schindler 1998.

[17] Swoboda, Stingeder, Prohaska, this volume.

[18] Schindler 1998.

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