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Change and stasis: the technology of Dark Age metalwork from the Carpathian Basin

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Summary This is a comprehensive technical study of the British Museum's important collection of material, principally from burials, belonging to the various groups who invaded and settled the Carpathian Basin of present-day Austria and Hungary. These include the Huns, various Germanic tribes, Avars/Kezsthely and the Magyars, dated to between the fifth and twelfth century AD, together with some exotic material from contemporary Byzantine, Italian Lombardic and Carolingian cultures.

The items include jewellery of gold, silver and copper alloy, and display a wide range of composition and metalworking techniques. It is instructive to compare these with the contemporary alloys used in Byzantium, western Europe and central Asia.

The gold and silver items were mainly hammered to shape, whereas the copper alloy objects were almost all cast, even quite tiny pins. The copper alloys are usually of leaded bronze, reflecting traditions in central Asia stretching back to the Iron Age and in marked contrast to the contemporary material from the Mediterranean and western Europe, which is usually of brass.

INTRODUCTION

The great plains of the Carpathian Basin have been regarded, geographically and environmentally, as the westernmost extension of the Eurasian steppe, Figure 1. This is certainly reflected geopolitically in the region's cultural history during the second half of the first millennium AD when periodic migrations, often originating from the Steppe, resulted in peoples passing through, invading or seeking sanctuary in the area. Most of these groups were, at least initially, pastoralists, for whom horses and all aspects of equestrian culture were very important, as reflected in the many fittings from harnesses and riders' belts in the grave goods that make up the bulk of the British Museum's collection.

These burials were often richly accoutered with items of precious metal, especially in the fifth and sixth centuries. This should come as no surprise considering that during the times of Atilla alone it is estimated that the Huns received upwards of 10 tons of gold from the Romans, with an annual tribute set at 668 kg [1].

The Huns and their principal successors spoke non-Indo-European languages as they, of course, still do in Hungary, and despite the far-reaching military campaigns of the mounted warriors from the Carpathian Basin into

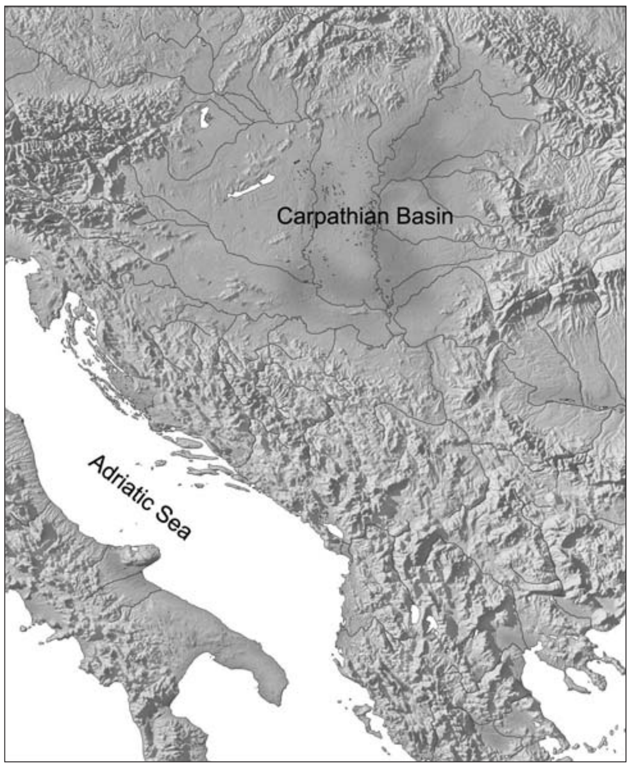

FIGURE 1. The geographical context of the Carpathian basin

western Europe and the Mediterranean, their interaction with their neighbours to the south and west seems limited. The region was probably the last major area of Europe to adopt Christianity; instead, their main cultural contacts seem to have remained with the Steppe. This is reflected in the metal technology, in which they certainly benefited from imports of metals, but seem to have preferred their own ways of working it.

ANALYTICAL METHODS

All the objects in the collection, numbering some hundreds in total, were analysed qualitatively by X-ray fluorescence (XRF) spectrometry to establish the nature of the metals present [2, 3], and a selection was quantitatively analysed by scanning electron microscopy (SEM), atomic absorption (AAS) [4] or inductively coupled plasma atomic emission spectrometry (ICP-AES) [5], Tables 1–4. Each object was examined by binocular microscopy to establish, as far as possible, how it was made and decorated and many items were further examined by SEM. Finally, some of the inlays of niello and garnet were identified by X-ray diffraction (XRD).[1]

GOLD

Composition

The analyses for the gold artefacts are reported in Table 1. During most of this period the main source of gold would have been Byzantium, very likely in the form of *solidi* (gold coins first minted under Constantine and used until the fall of the Byzantine Empire), although Bohemia and Transylvania were significant gold-producing regions in antiquity. Up to the eleventh century Byzantine gold was usually of high purity [6], as is evident from the coins from Constantinople recovered from Helgö [7], although *solidi* issued in Italy became progressively more debased through the seventh and eighth centuries [8]. The single piece of Byzantine goldwork included in this study, the clasp (1916,0211.2) of late sixth or early seventh century date, is of high purity with 99.6% gold and only traces of silver and copper.

The other gold objects are all quite early, either Hunnic work of the mid-fifth century or Avar pieces of the early sixth to seventh century. All are of good quality; the fifth century material includes, for example, the back plate of the Hunnic gold buckle (1900,0714.2) with 99.3% of gold, although most have between 4 and 13.7% silver and about 1% copper.

Goldwork from the Crimea of approximately the same date has a similar range of compositions, with silver contents lying between 4 and 20%, and copper contents lying between 0.5 and 5% [9].

TABLE 1. Analyses of gold artefacts

Registration No.	Culture	Description	Au	Ag	Cu
AF 510	Hunnic	Buckle: hinge	93.4	5.9	0.7
		Buckle: tongue	93.0	6.4	0.6
		Buckle: loop	93.0	6.4	0.6
		Buckle: sheet	93.8	5.7	0.5
		Buckle: rivet	94.4	4.9	0.7
1900,0714.1	Hunnic	Buckle: hinge	85.3	13.7	1.0
		Buckle: tongue	92.0	7.0	1.0
		Buckle: loop	92.0	7.1	0.9
		Buckle: back plate	85.8	12.2	2.0
		Buckle: rivet	89.6	9.5	1.0
1900,0714.2	Hunnic	Buckle: back plate/ hinge	99.3	0.7	<0.2
		Buckle: tongue	85.1	13.8	1.1
		Buckle: loop	90.7	8.1	1.2
1926,0511.2	Avar	Earring: loop wire	84.1	9.8	6.1
		Earring: sheet	97.7	1.9	0.4
		Earring: granule	94.2	4.2	1.6
		Earring: solder	80.5	10.0	9.5
1933,0405.12	Avar	Earring: loop wire	81.5	17.3	1.2
1933,0405.13	Avar	Earring: loop wire	83.1	16.6	1.3
		Earring: solder	54.5	28.2	17.3
1985,0301.1	Avar	Earring: loop wire	83.8	13.0	3.2
		Earring: sheet	83.7	13.6	2.7
1985,0301.2	Avar	Earring: loop wire	84.6	12.3	3.1
		Earring: sheet	83.9	12.7	3.4
1985,0301.3	Avar	Earring: loop wire	85.2	11.7	3.0
		Earring: sheet	84.2	12.5	3.3
1916,0211.2	Byzantine	Clasp: back sheet	99.6	0.2	0.2
		Clasp: solder	86.9	1.8	11.3
AF 3323	Germanic?	Mount: wall 1	95.4	4.3	0.3
		Mount: wall 2	95.7	3.9	0.4

Notes

All the analyses were made by SEM-EDX on cleaned surfaces; the detection limits for each element are variable but are typically 0.1–0.3% while the relative precision (reproducibility) is about 2% for the major elements, 10% for concentrations in the range 5–20% and deteriorates as the detection limits are approached.
The '<' symbol denotes that an element was not present above the quoted detection limits.

Fabrication

The majority of the artefacts are made from thin hammered components held together by gold solders. Two solders on the Avar metalwork were analysed by energy dispersive X-ray (EDX) spectrometry in the SEM. One contained around 10% each of silver and copper (1926,0511.2), and the other (1933,0405.13) 28% silver and 17% copper. Although the latter object was found to be rather base the gold colour is preserved quite well (the optimum silver:copper ratio for preserving the gold colour in a gold alloy is about 2:1). Where heavier wear or load was anticipated, such as for the tongues and loops on buckles, thicker pieces of gold were used that are of cast metal.

A few items incorporate gold wire, which seems mainly to have been made quite simply by hammering out thin rod to the required thickness. This is a primitive, although well-attested technique, perhaps used because only very short lengths of rather thick wire were required. The Byzantine clasp (1916,0211.2) has some short lengths of much finer strip- or block-twisted wire [10], which are soldered to the plate beneath, and borders of beaded gold wires made by rolling a shaped tool over the wire, Figure 2. Some of the Avar gold earrings have decorative elements of spiral beaded wire (Figure 3), produced by the simpler technique of rolling the wire beneath a thin hard edge to produce a running spiral [11]. Overall, the Byzantine piece stands out, therefore, for the quality of both its workmanship and materials.

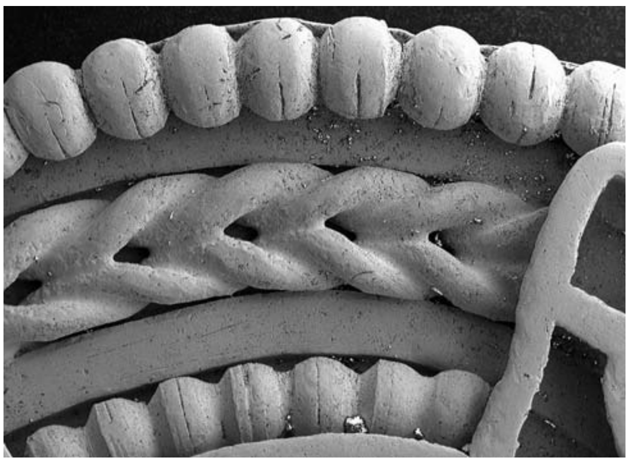

FIGURE 2. Byzantine clasp (1916,0211.2); SEM detail of the composite gold construction with beaded wire that shows characteristic equatorial seams. Note the double rope-twisted wires wound in opposite directions that are soldered together and onto the base sheet between the square-section strips. The width of the image is 12 mm

FIGURE 3. Avar gold earring (1933,0405.13); SEM detail with thin spiral beaded wire with decoration soldered in place. Note the extensive wear on the exposed regions of the gold. Scale bar: 5 mm

Four inclusions of platinum group elements (PGE) were observed in the limited selection of pieces examined here. They are generally of the common iridium/osmium/ruthenium type [12], and would seem to indicate a Mediterranean/Middle Eastern origin for the gold, via *solidi*, which often contain PGE inclusions [13]. Similar PGE inclusions were also observed in some of the gold items from the Crimea [9].

SILVER

Composition

The analysed material falls into three main cultural groups: Germanic, fifth to early sixth century; Avar/Keszthely, sixth to eighth century; and Magyar of the tenth to twelfth century. The silver from each group has a wide range of composition varying from 97% pure down to only 50%, the diluent being copper or copper alloy, Table 2. The obvious explanation would be that Byzantine or Islamic silver coins of good quality were being melted down and debased rather randomly by the various groups successively inhabiting the Carpathian Basin. However, this hypothesis falls down on closer inspection of the analyses of the silver from all three groups. Zinc, and to a lesser extent, tin are also often present in small quantities, and this suggests that the silver was being routinely debased with brass. Although this is a common phenomenon in other European silver of the first millennium AD [14], here it creates a problem in that the usual copper alloy in this region is bronze, not brass (Table 3), suggesting that the alloying/debasement may well have been done elsewhere. For example only 15% of the Magyar copper alloys in the qualitative survey contain zinc (almost always alloyed with tin as well), yet half the silver items contain the metal.

Broadly contemporary East Gothic silver brooches were much more debased with copper (18–88% silver) and once again the metal often contained zinc along with small quantities of lead, but only rarely contained detectable tin [15], in common with objects from Martynovka in the Ukraine [16], and from the Crimea [9]. It is perhaps significant that brass is much more prevalent in the copper alloy material from the Crimea, possibly suggesting that some of the silver used by the Carpathian cultures had come via the east.

Several of the silver objects have high gold contents. It is tempting to ascribe this to the presence of gilding, but none of the items with the highest gold content bear any obvious traces of gilding. It is more likely that the gold is in the body metal, and thus would have originated from the silver ore. It is highly unusual to find such high gold contents in the main sources of silver used in Europe at this period; Islamic coins, for example, contain only traces [17]. While the gold could perhaps be the result of gold-rich material being wastefully recycled into the silver, it should be noted that similar high gold contents have been reported for silver jewellery in the Kiev Hoard of the eleventh and twelfth centuries, suggesting

TABLE 2. Analyses of silver artefacts

Registration No.	Culture	Description	Ag	Cu	Zn	Au	Pb	Sn
1860,0609.12	Germanic	Brooch	50.1	42.7	2.7	2.1	2.5	tr.
1866,0815.8	Germanic	Brooch: body	75.8	19.1	2.3	2.0	0.8	
		Brooch: repair	88.0	11.4		0.2	0.4	
1921,0405.1	Germanic	Brooch	89.5	6.0	2.3	1.8	0.4	
1930,0409.2	Germanic	Brooch	86.5	7.2	2.6	1.7	2.1	tr.
1930,0409.3	Germanic	Brooch	76.0	19.5	0.6	1.3	2.7	tr.
1987,0308.1	Germanic	Sword chape	92.9	3.0	tr.	4.0	0.1	
1987,0308.1a		Binding strip	96.0	2.9		1.0	0.2	
1987,0308.1b		Binding strip	93.1	2.8		4.0	0.1	
1987,0308.2	Germanic	Sword chape	90.1	6.4		0.8	2.6	
1987,0308.2		Terminal knob	97.2	1.9		0.8	0.2	
1987,0308.2a		Binding strip	96.4	2.8		0.6	0.2	
1987,0308.2b		Binding strip	95.9	3.2		0.7	0.2	
1926,0511.17	Avar/Keszthely	Earring	74.3	20.0	2.6	2.0	1.2	tr.
1926,0511.18	Avar/Keszthely	Earring	75.2	22.4	tr.	1.5	1.0	tr.
1926,0511.21	Avar/Keszthely	Dress pin	94.7	3.9		1.1	0.3	
1933,0405.12	Avar/Keszthely	Composite earring	96.9	1.8		1.3		
1933,0405.13	Avar, Keszthely	Composite earring	97.3	2.7				
1933,0405.14	Avar/Keszthely	Earring	85.3	7.3		5.8	1.6	tr.
1933,0405.15	Avar/Keszthely	Earring	87.1	5.3		6.2	1.3	tr.
1987,0101.1	Avar/Keszthely	Box brooch: disc	97.7	1.4		0.9		
		Box brooch: wire	94.9	4.6		0.5		
		Box brooch: box	94.7	4.8	tr.	0.5	tr.	
1860,0609.9	Magyar	Armlet	54.9	31.6	9.4	4.0	0.2	
1976,0902.6	Magyar	Hair ring	84.1	14.6		0.2	1.0	
1976,0902.7	Magyar	Hair ring	92.7	5.6	3.0	1.4	0.3	
1976,0902.8	Magyar	Hair ring	96.2	2.8		0.9	0.1	

Notes

All the analyses were made by XRF on cleaned surfaces; the detection limits for each element are variable but are typically 0.1–0.2%, while the relative precision (reproducibility) is 1–2% for the major elements, 5–10% for concentrations in the range 5–20% and deteriorates to 50% at the detection limit. The entry 'tr.' denotes that a trace of that element was found by emission spectrography.

this may have been more common in silver from the Steppes [18].

Fabrication

The majority of the silver items were cast using two-piece moulds and then worked up, more or less extensively, by chiselling, hammering, etc. The Keszthely earrings are made of silver rod hammered to make thick wire loops, rather similar to the gold earrings. Some of the finer wires used on the filigree work are of strip- or block-twisted wires, Figure 4 (also see Ogden [10; pp. 46–52]). Some spiral beaded decorative wires are made in a similar way to the gold wires described above and illustrated in Figure 3. The pins seem to have been cast and then hammered with the openwork heads formed by splitting the rod with a chisel, in a manner analogous to that used for the stylistically similar bronze pins (see below).

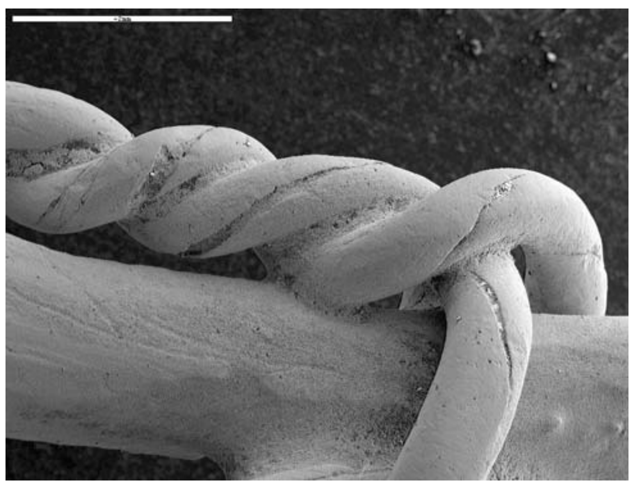

FIGURE 4. Keszthely silver earring (1933,0405.14); SEM detail of a pair of block-twist wires that are twisted and soldered together. Note the characteristic broad, shallow spiral seam running along the wires. Scale bar: 2 mm

TABLE 3. Analyses of copper alloy artefacts

Registration no.	Culture	Description	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Bi	Zn	S	Technique
1880,0501.15	Germanic	Radiate brooch	69.0	10.4	3.2	0.62	0.15	0.05	0.10	0	0.005	0.17	0.005	16.0		AAS
1973,0402.1	Germanic	Radiate brooch	73.0	7.8	18.4	0.06	0.08	0.05	0.04	0	0.008	0.13	0.01	0.54		AAS
1926,0511.22	Avar /Keszthely	Dress pin	86.0	5.9	5.4	0.37	0.15	0.12	0.04	0	0.005	0.25	0.003	2.35		AAS
1926,0511.23	Avar /Keszthely	Dress pin	92.0	0	7.8	0.07	0.06	0.35	0.15	0	0.01	0.2	0	0		AAS
1926,0511.24	Avar /Keszthely	Dress pin	81.0	7.7	8.5	0.36	0.12	0.15	0.06	0.004	0.005	0.17	0.005	1.7		AAS
1926,0511.25	Avar /Keszthely	Bracelet	85.0	5.2	7.6	0.85	0.04	0.11	0.07	0	0	0.14	0.005	0.035		AAS
1926,0511.26	Avar /Keszthely	Bracelet	91.0	3.3	4.6	0.21	0.12	0.10	0.05	0	0.005	0.16	0.005	1.2		AAS
1926,0511.27	Avar /Keszthely	Bracelet	82.0	9.9	5.9	0.37	0.12	0.12	0.06	0	0.01	0.18	0.005	2.0		AAS
1926,0511.28	Avar /Keszthely	Bracelet	88.5	5.7	4.7	0.90	0.04	0.13	0.07	0	0.007	0.12	0.015	0.32		AAS
1933,0405.16	Avar /Keszthely	Bracelet	86.0	5.4	5.1	0.63	0.10	0.24	0.07	0	0.006	0.27	0.008	1.0		AAS
1933,0405.17	Avar /Keszthely	Bracelet	85.0	7.7	5.7	0.60	0.05	0.33	0.06	0.01	0.003	0.2	0.005	0.8		AAS
1933,0405.18	Avar /Keszthely	Bracelet	85.0	7.1	6.2	0.45	0.10	0.15	0.06	0.003	0	0.07	0.005	1.1		AAS
1933,0405.19	Avar /Keszthely	Bracelet	85.0	7.6	6.2	0.07	0.03	0.15	0.03	0.002	0	0.12	0	1.1		AAS
1933,0405.20	Avar /Keszthely	Dress pin	88.0	5.4	4.7	0.49	0.10	0	0.07	0.001	0.01	0.03	0.005	0.52		AAS
1933,0405.21	Avar /Keszthely	Brooch	88.0	5.7	4.5	0.42	0.23	0.19	0.06	0	0.005	0.42	0.008	0.7		AAS
1876,1012.13	Avar	Brooch	75.0	6.6	10.3	0.25	0.11	0.07	0.08	0	0.007	0.22	0.005	7.6		AAS
1909,0717.2	Avar	Strap end	77.0	6.2	0.1	0.02	0.21	0.04	0.01	0	0	0	0.11	16.4		AAS
1926,0511.4	Avar	Strap end	86.0	7.9	3.7	0.24	0.11	0.12	0.04	0	0.005	0.14	0.003	1.75		AAS
1926,0511.5	Avar	'Propeller' belt fitting	79.0	13.3	4.4	0.26	0.23	0.25	0.05	0	0.005	0.15	0.005	2.9		AAS
1926,0511.6	Avar	Cast buckle	93.0	0.1	5.8	0.24	0.08	0.08	0.03	0	0	0.03	0.005	0		AAS
	Avar	Gilt belt fitting	89.5	0.14	8.8	0.25	0	0.08	0.02	0.003	0	0.01	0.005	0.003		AAS
1926,0511.7	Avar	Belt mount	84.0	8.8	3.5	0.65	0.13	0.10	0.04	0.001	0.003	0.1	0.005	2.45		AAS
1926,0511.8	Avar	Belt mount: pendant	84.0	8.9	3.9	0.26	0.13	0.16	0.04	0	0.002	0.13	0.008	2.6		AAS
1926,0511.9	Avar	Tinned strap end	86.0	0.5	11.3	0.04	0.20	0.15	0.55	0.008	0.03	0.35	0.003	0.05		AAS
1926,0511.10	Avar	Strap end	89.0	1.5	9.7	0.07	0.47	0.15	0.40	0.03	0.02	0.2	0	0.14		AAS
1926,0511.13	Avar	Belt hole guard	81.5	11.6	3.4	0.30	0.10	0.15	0.05	0	0.003	0.13	0.005	2.8		AAS
1926,0511.14	Avar	Belt hole guard	84.0	9.8	4.4	0.20	0.16	0.11	0.04	0	0.005	0.13	0.005	2.0		AAS
1926,0511.15	Avar	Tinned belt fitting	91.0	1.75	6.4	0.25	0.10	0.12	0.03	0.08	0	0.1	0.005	1.0		AAS
1926,0511.16	Avar	Tinned stud	83.0	8.5	6.5	0.11	0.14	0.14	0.08	0.027	0.003	0.11	0.005	1.1		AAS

cont'd

TABLE 3. Analyses of copper alloy artefacts *cont'd*

Registration no.	Culture	Description	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Bi	Zn	S	Technique
1987,1202.1	Avar	Buckle	83.3	11.6	4.01	0.09	0.21	0.04	0.052	<0.002	0.017	0.11	<0.01	0.56	0.31	ICP-AES
	Avar	Buckle: loop	79.5	0.19	0.28	0.007	0.21	0.02	0.129	<0.002	<0.002	0.04	<0.01	18.8	0.03	ICP-AES
	Avar	Buckle: plate	77.6	0.12	0.23	0.006	0.21	0.02	0.128	<0.002	<0.002	0.03	0.013	21.8	0.02	ICP-AES
1992,0603.22	Avar	Strap mounts	85.6	6.53	0.54	0.06	0.04	0.20	0.032	<0.003	<0.003	0.10	0.081	7.01	0.06	ICP-AES
1994,0606.2	Avar	Strap end	74.7	17.4	6.83	0.25	0.14	0.14	0.130	0.007	<0.007	0.22	<0.04	1.15	0.09	ICP-AES
1994,0606.3	Avar	Belt hole guard	60.5	28.4	9.91	0.35	0.16	0.07	0.038	0.010	<0.003	0.54	0.028	0.46	0.07	ICP-AES
1995,1105.1	Avar	Brooch	86.6	4.63	8.02	0.10	0.02	0.06	0.089	0.004	<0.004	0.10	0.023	0.65	0.02	ICP-AES
1997,0209.2	Avar	Suspension mount	79.4	12.4	5.53	0.17	0.12	0.43	0.175	0.003	0.008	0.15	0.018	1.77	0.14	ICP-AES
1997,0209.3	Avar	Belt end	75.8	8.38	12.8	0.28	0.08	0.13	0.063	0.006	0.004	0.11	0.015	0.59	0.06	ICP-AES
1997,0209.4	Avar	Strap end	87.8	2.31	8.86	0.33	0.02	0.11	0.048	0.018	<0.003	0.07	0.017	0.15	0.05	ICP-AES
1997,0209.6	Avar	Suspension mount	79.7	13.7	3.59	0.33	0.20	0.14	0.101	0.551	0.007	0.23	0.041	1.51	0.08	ICP-AES
1997,0209.10	Avar	Belt end	74.7	12.8	10.3	0.22	0.15	0.24	0.264	0.381	0.012	0.35	0.018	1.36	0.14	ICP-AES
1992,0102.11	Magyar	Belt mount	66.6	24.4	8.29	0.29	0.07	0.10	0.049	0.005	<0.002	0.46	0.102	0.04	0.03	ICP-AES
1992,0603.14	Magyar	Strap distributor	85.4	9.0	1.91	0.30	1.33	0.14	0.205	0.175	0.006	0.97	0.015	1.10	0.02	ICP-AES
1939,0704.2	Bulgar	Horseman pendant	70.0	2.6	1.9	0.05	0.38	0.15	0.03			0.16		24		XRF
1930,1024.23	Carolingian	Escutcheon	74.0	5.8	<0.1				0.1			1.1		19		XRF
1926,0511.11	Avar	Strap end	79.5	12.6	6.7							0.2		1.1		EDX
1926,0511.12	Avar	Strap end	82.6	8.8	4.2							0.2		4.2		EDX
1989,0110.1	Avar	Lion	94.0	0.5	3.7											EDX

Notes

The relative precision (reproducibility) for the AAS and ICP-AES analyses is about 1–2% for the major elements, 5–10% for concentrations in the range 1–20% and deteriorates to 50% at the detection limit.
The '<' symbol or a '0' denotes that an element was not present above the quoted detection limits. Mn, Cd, and P were also sought in the ICP-AES analyses but were not found to be present above their detection limits of *c.* 0.006, 0.002 and 0.02% respectively. The blanks on the XRF analyses were not quantified.

TABLE 4. Summary of main copper alloy types from both qualitative and quantitative analyses

Culture	Date (century AD)	Bronze	Brass	Mixed alloy
Slav	Seventh	4	1[a]	2
Avar/Kezsthely	Seventh to ninth	48	2[b]	15
Magyar	Tenth to eleventh	14	1[c]	3

Notes

The numbers in this table refer to single catalogue entries, but these may represent many individual objects.

a. Found in Bulgaria
b. One object was found in Italy and the other in south Russia
c. Found in Hungary but stylistically Carolingian

COPPER ALLOY

Composition

The objects studied here date from the seventh to the eleventh century (Table 3), with no earlier material. Overall, the most striking feature of the composition is that the pattern of alloys from the seventh to the eleventh century remains much the same, even though there was continual cultural change and considerable contact with, and movement into, areas that were using very different alloys, Table 4.

The predominant alloys are bronze or leaded bronze but there are also mixed alloys, containing both tin and zinc, which make up approximately 25% of the total; where quantified the zinc content was usually just a few percent. Finally, there are very few true brasses in which the copper is alloyed with substantial quantities of zinc, of the order of 15–30%. It should be noted that the few examples of high zinc brasses that were encountered here are usually not mainstream Carpathian material and they were either found in the region but are typologically from elsewhere (such as the Carolingian or Ottonian brooch, 1930,1024.23) or are typologically similar to material from the Carpathian Basin but were found elsewhere, usually in places where brass was prevalent (such as the Avar-style belt end, 1909,0717.2, found at Lake Trasimeno near Perugia in Italy).

In addition to the four brasses in Table 4 there is also a buckle (1987,1202.1) that is a stylistic oddity in which the loop and plate are of brass of identical composition, but the tongue is of leaded bronze.

The trace element content of the metalwork is not very distinctive, beyond a tendency towards relatively high silver contents; some European copper sources, including those in the Carpathians, have elevated silver contents [19]. From the twelfth century silver was removed from copper by liquation. In this process the copper was treated with molten lead, which absorbed the silver; these could be separated by oxidizing the lead, leaving metallic silver. With the single exception of the radiate-headed brooch found in southern Russia (1880,0501.15), it is also immediately apparent that the very few true brasses do not have this distinctive silver content, reinforcing the impression that the brasses have a different origin altogether. Conversely, the bronzes do not have the generally elevated contents of minor elements such as silver, nickel, arsenic and above all, antimony, that are found in much of later Medieval metalwork and are probably associated with sources in the Alps. This distinctive copper became very common in western Europe, particularly for heavier castings, during the twelfth and thirteenth centuries, but is encountered as early as the tenth century AD, for example in some of the objects from Faccombe Netherton, a small but high status settlement in Hampshire, near Winchester in southern England [20].

Other comprehensive analytical surveys of Avar copper alloy metalwork from the Carpathian Basin have been carried out on about 1500 artefacts from some of the major excavated cemeteries [21–23]. These were surface analyses by energy dispersive XRF and the results are broadly in line with those reported here, showing a preponderance of bronze. Avar and Slavic copper alloy material from Bohemia has also been analysed [24], and the results show an equally pronounced predominance of bronze over brass or mixed alloys. Of the 192 analyses reported, four were of brass, 60 were mixed alloys in which the zinc content was again typically low and the remainder were tin bronzes; lead was again prevalent in all the alloys.

Late Roman copper alloys generally contained a significant proportion of brasses or mixed alloys, as exemplified by the small study carried out on some brooches excavated from late Roman burials of the fourth century AD at Hegyeshalom in the far north west of present-day Hungary [25]. The 21 fibulae analysed included 11 of brass, six of mixed alloy and just four of bronze. After *c.*AD 350 brass became the usual alloy for fibulae in this region. The subsequent dominance of bronze over brass in the succeeding Migration Period is, therefore, somewhat surprising, and raises interesting questions concerning the sources of the metals [26].

The only other contemporary Migration Period European copper alloy material to have been analysed in any quantity hitherto has come predominantly from the Germanic regions, stretching from southern Scandinavia down through central western Europe to Italy and the Byzantine world [27–33]. These peoples were using brass quite extensively and production probably continued at centres such as Stolberg near Aachen from the Roman period onwards (and at other nearby sites in Flanders that were to become famous for brass making in the Medieval period [34]).

Based on these studies it seemed that, overall, there was a steady replacement of bronze by brass as the usual copper alloy through the first half of the first millennium AD, throughout the western part of the Old World, such that by the time of the Byzantine Empire and the Caliphates brass was universally prevalent [35, 36].

However, this picture considerably oversimplifies matters and it is now becoming clear that other groups in Europe, both German and non-Germanic, continued to use bronze. A qualitative analytical survey of metalwork from the Celtic west [2], similar in approach to that reported here, shows that bronze was the predominant alloy until the tenth century, when Ireland was taken over by Vikings from southern Scandinavia where brass had prevailed for centuries.

It is significant that these bronze-using regions, both in the east and west of Europe, had access to tin deposits. Present evidence concerning the working of tin deposits is scarce, but both of the main tin mining regions, south west England [37; pp. 237–245] and the Erzgebirge [37; pp. 71–78], have areas of alluvial tin at the surface that would have been easy to work.

The qualitative analyses undertaken on the more than 40 items from the Crimea are of some interest and significance [9]. Approximately half were of copper and although these were mainly small items such as rivets and backing plates to brooches, they also included some more substantial components of brooches, etc. Eleven objects were of brass, three were of a mixed alloy and only six were of bronze, clearly indicating that brass was much more significant here and suggesting that most of the metal for these items may have come from the Byzantine world across the Black Sea.

The clear implication is that there was not an extensive trade in copper alloy metals or artefacts between the groups inhabiting the Carpathian Basin, the Byzantine world to the south, the Germanic groups to the west, or possibly even to the east. This suggests an apparently isolated world, rather at variance with the usual perception of what, after all, is known as the Migration Period.

Fabrication

There was a great reliance on casting in two-piece moulds, even down to the tiny pins used to secure some of the belt fittings to the leather (Figure 5); seventh-century moulds from Maastricht for casting such tiny pins have been described by Dukman and Ervynck [38]. Leaded bronze possesses good casting properties as the lead, which does not enter into solution in the melt or in the alloy (but exists as discrete globules), lowers the melting point of the metal and renders the molten metal much more fluid than it would otherwise have been [39]. The metal can, therefore, flow more easily into small spaces and this allows tiny items such as the pins to be cast. However, these same globules of lead are very weak and behave as if they were voids, acting as crack propagation points if the structure is distorted; for this reason heavily leaded alloys cannot be extensively hammered. There is no hard and fast rule concerning the lead content above which the metal cannot be hammered as this depends on the distribution of lead in the casting; finely dispersed globules will present much less of a problem than a few, relatively large, globules. The detection of quite large quantities of lead in some of the armlets that clearly have been hammered to shape is, therefore, a little surprising. Similarly the split-headed Magyar pins are of leaded bronze that seems to have been cast as a rod then hammered and, finally, the split head created with a chisel.

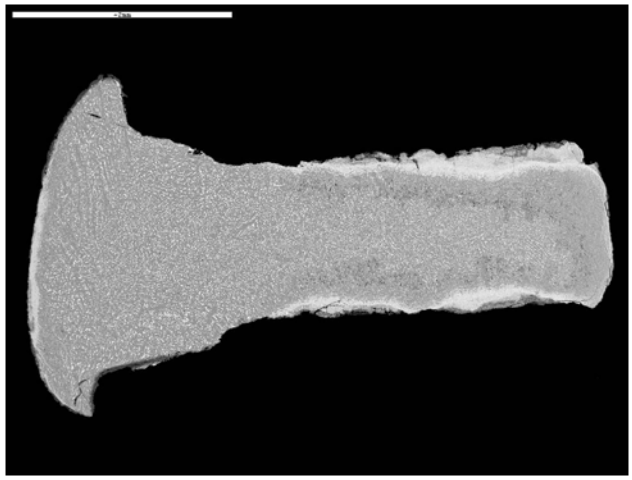

FIGURE 5. Avar strap mount (1992,0102.25); SEM detail of the cross-section of a cast leaded bronze pin used to secure the mount to leather. Composition: Cu 75%, Sn 7.2%, Zn 0.5%, Pb 17.3%. Note that this tiny pin is only 5.5 mm long. Scale bar: 2 mm

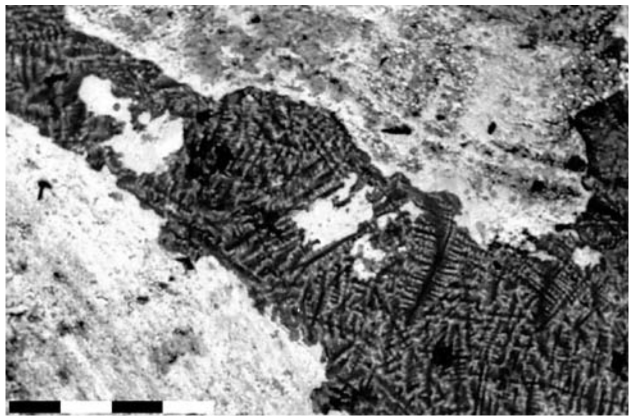

FIGURE 6. Example of a tinned bronze strap end (1926,0511.10); SEM detail of the surface, showing the tinned regions as light areas on the dendritic cast bronze strap end. Scale bar shows 100 µm divisions

Many of the ungilded pieces have very silvery-grey surfaces, which (in common with objects examined previously [40, 41]) have been identified as being tin rich. The problem here is to differentiate between deliberate tinning from the sweating of tin and lead from the alloy as the metal set and contracted in the mould [42, 43], and tin enrichment due to corrosion. Examples examined metallographically and by SEM showed evidence of deliberate tinning, Figure 6. Some of the bronze pieces look more silvery now than in antiquity because the more golden, low-tin, α phase has preferentially corroded from the surface leaving only the more silvery, higher-tin phases, such as on the radiate-headed brooch (1973,0402.1), Figures 7 and 8.

GILDING AND INLAYS

Many of the items from each of the cultures are gilded and, as mercury was often detected in the gilding, it is likely that mercury gilding was used for the majority, if not all,

FIGURE 7. Radiate-headed bronze brooch (1973,0402.1); note the silvery grey surface colour due to corrosion of the copper-rich phase from the surface, giving a tin-rich, silvery-grey appearance

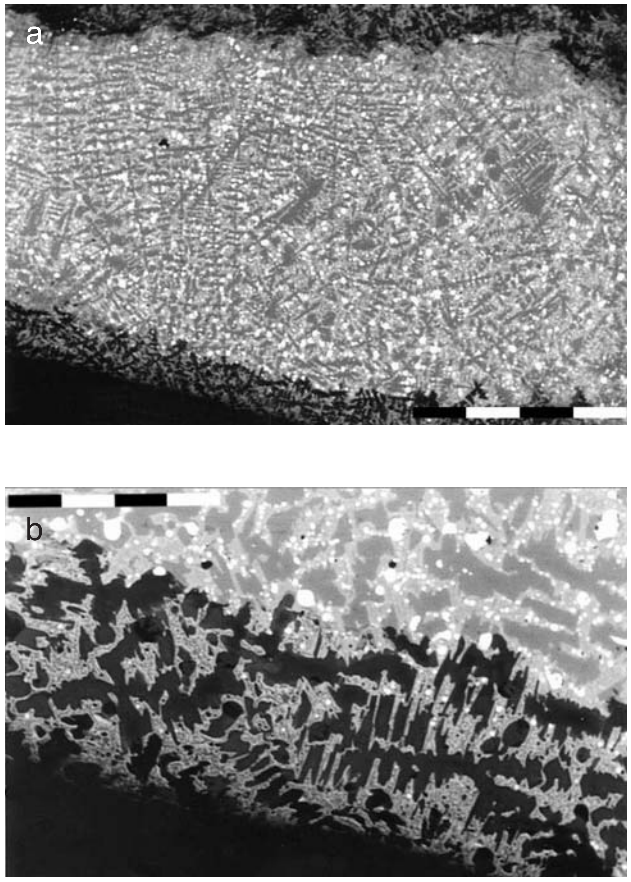

FIGURE 8. SEM images of the polished section of a corner of the brooch shown in Figure 7: (a) the whole cross-section with the dendritic cast leaded bronze core and the corroded surface, which appears darker: scale bar shows 100 μm divisions; (b) detail of the surface in section showing the dark mineralized (corroded) copper-rich phase and uncorroded high-tin bronze delta compound that gives the brooch its silvery grey appearance: scale bar shows 20 μm divisions

of these gilded pieces. Some pieces have niello inlays, of which the majority are of mixed copper–silver sulphides, common throughout Europe at this date [44].

Garnet was the favourite gemstone of late antiquity and the Migration Period especially for gold or gilt items [45]. Seven of the objects examined are inlaid with red gemstones, including three Hunnic gold buckles (1900,0714.1; 1900,0714.2 and AF 510), a Germanic gold buckle (1866,0815.8) and silver gilt radiate-headed brooch (1930,0409.2), a gilt silver disc brooch (1930,0409.3) and a silver gilt sword chape from a sword scabbard (1987,0308.1: Figure 9). In six of these, garnet alone was used, but in the Germanic buckle plate four out of the seven inlays are of glass, although in identical settings to the real garnets they were doubtless imitating.

Glass inlays are quite common, but often badly decayed. Analytically, the presence of lead in the setting shows the material was once a glass, while the presence of tin suggests that tin oxide was present as an opacifier and that, in the absence of colourants, the glass was presumably white. The gold Avar earring (1985,0301.1) and the gilt bronze Avar brooch both have green glass inlays; the sixth-century silver-gilt Keszthely culture earrings (1933,0405.14 and .15) have red glass inlays and the wire earrings (1933,0405.12 and .13) probably once had white glass inlays as suggested by the remains of tin oxides.

The silver chape (1987,0308.1) has a white inlay of the naturally occurring mineral magnesite ($MgCO_3$) within a gold strip collar in its quatrefoil centre, with a gold ring set in its middle (Figure 9); the use of magnesite as an inlay has been studied by La Niece [46].

CONCLUSIONS

The Carpathian Basin and the surrounding regions are very rich in metals, with a long history of exploitation stretching from the Bronze Age to the recent past. Although there is good documentary evidence for the mining of metals from the Medieval period onwards, the extent of exploitation in the Migration Period is unknown, not least because of the general absence of contemporary documentation.

The overall metals supply situation is quite interesting as gold, mercury and brass (treated here as the sum of its alloyed elements since zinc was then unknown as a sepa-

FIGURE 9. Silver-gilt sword chape (1987,0308.1) with garnet and magnesite inlays

rate metal) were likely to have been imported, while tin and copper were probably sourced more locally in central Europe. The origins of the silver are more problematic, but may well lie to the east.

The metalworking practices and the level of skills attained seem to be comprehensive and competent, especially for the precious metal working. The gold and silver items were mainly hammered to shape, whereas the copper alloy objects are almost all cast, including even quite tiny pins, usually utilizing a simple two-piece mould, but often with much subsequent working. The copper alloys are normally leaded bronze, reflecting traditions in central Asia stretching back to the Iron Age and in marked contrast to contemporary material from the Mediterranean and western Europe which is usually of brass.

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NOTE

1. Descriptions and some images of these objects can be found at www.britishmuseum.org/research/search_the_collection_database.aspx (accessed 24 August 2010).