

Copper shaft-hole axes and early metallurgy in south-eastern Europe: an integrated approach

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Abstract

Although the copper axes with central shaft-hole from south-eastern Europe have a long history of research, they have not been studied on a transnational basis since the 1960s. What has also been missing is an integrated or holistic approach, trying to use as many methods as possible and better understand the production, use and context of these enigmatic objects. This present research therefore approaches the axes from different angles. A database was compiled in order to find answers on questions such as the patterns of distribution, context, fragmentation and deformation of axes. For the distribution of axes in general as well as different attributes like fragmentation and typology, the content of the database was imported into GIS software and analysed. Aspects of production were considered through experimental archaeology, metallographic analysis and a re-discovered axe blank with missing shafthole. Especially the missing moulds make it difficult to fully understand the production sequence. The typology was re-evaluated and modified to ensure comparability across modern national boundaries. The context and background was developed through a thorough review of the literature and combined with theoretical considerations. The integration of all these approaches yielded some interesting results. The great variability in shape combined with the results of metallographic analyses clearly shows that a variety of production techniques were used, but it is as yet difficult to relate these to specific geographic areas or even cultural groups. In fact the typology as well as the practice of marking the axes indicate that traditional archaeological 'cultures' rarely correspond to the distribution of a type or to the practice of marking the axes. They show instead that there were different spheres of influence, some even more localised and others much larger (like the Carpathian Basin) than specific ceramic traditions. These different levels of belonging, as well as the increasing visibility of the individual in the archaeological record, show that it was a period of complex cultural patterns and interactions. The axes were a part of these networks of the daily life on many different levels from the strict utilitarian to the ritualised placement in burial contexts.

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Accompanying material:

1 CD with Appendices V-X (see table of contents)

1 Introduction

The topic of this research is the first large cast copper objects in the Old World, namely the axes with central shaft-hole from south-eastern Europe. They appear at a time when the dynamics in south-eastern Europe are changing dramatically from a Neolithic way of life with hardly any hierarchical differentiation, to a Bronze Age which sees the development of stratified society. It is during this transitional stage, known as the Copper Age that metallurgy began to develop within south-eastern Europe. Whether this development was independent of the Near East is still a topic of debate (Radivojević *et al.* 2010).

1.1 The innovation of metallurgy in the old world

It is generally accepted that copper metallurgy developed due to the bright colours of native copper and its oxidised ores which would have been noticed whilst prospecting for other raw materials already in use (Chapman and Tylecote 1983, 373; Coghlan 1975, 21-27; Hamlin 1996, 12-17; Ottaway 1994, 13; Parkinson 2004, 318). In the Near East as well as in south-eastern Europe, a period can be identified in which coloured minerals were not used for their metallic properties, but as pigments and ornaments, produced and made in the already known lithic traditions (Radivojević *et al.* 2010, 2776; Roberts *et al.* 2009, 1013; Strahm and Hauptmann 2009, 118-119). This ‘preliminary stage’ begins in the Near East already between the 11th and 9th millennium BC (Moorey 1994, 255; Roberts *et al.* 2009, 1013; Solecki *et al.* 2004, 96; Strahm and Hauptmann 2009, 118; Yalçin 2000, 19) and starts in south-eastern Europe about 6500 BC (Borić 2009, 237; Radivojević 2007, 8). Early finds have been made in Serbia, Bulgaria and Romania, belonging to the earliest Vinča, Karanovo, and Criş groups respectively (Ottaway 1994, 231). The two early finds from Romania have been hotly debated as the context of the awl from Balomir, and the date of the entire horizon of a copper fragment from Iernut have been questioned (Luca 1999, 282-283). However, as mentioned above the ‘cold’ working of copper mineral is now accepted to have started in Europe around 6500 BC so these two examples from Romania could well have such an early date (Borić 2009, 237; Radivojević 2007, 8).

The first evidence in the Near East for the use of annealed native copper in the form of beads, awls and other amorphous fragments dates to the late 9th and early 8th millennium BC (Pernicka 1995a, 29; Pernicka *et al.* 1997, 46; Maddin *et al.* 1999, 38; Özdoğan and Özdoğan 1999, 14-15; Yalçin and Pernicka 1999, 46). However, this initial annealing

was not carried out at high temperatures, and is still part of the so-called ‘cold’ working of metallic objects classed as being part of the lithic industry (Radivojević *et al.* 2010, 2776). It is only with the first evidence for smelting and/or casting that one can talk about ‘hot’ metallurgical processes (Radivojević *et al.* 2010, 2776). The smelting of copper possibly occurs for the first time during the 7th or 6th millennium BC in Anatolia although the evidence, two melting or smelting crucibles from Çatalhöyük, is contentious (Borić 2009, 237; Roberts *et al.* 2009, 1013). Interestingly the first conclusive evidence for the smelting of copper comes from Belovode (Serbia) and Tal-i Iblis (Iran) around 5000 BC (Borić 2009, 238; Radivojević 2007; Roberts *et al.* 2009, 1014). The evidence from Iran comes from a layer with a very long time window, from the late 6th to the late 5th millennium BC, making the Serbian evidence the earliest not only in Europe but probably in the old world (Radivojević *et al.* 2010, 2778). This early evidence for smelting confirms the early dates for some large cast axes from Pločnik which have been dated to the first centuries of the 5th millennium BC. Mining activities at Rudna Glava can now be dated to at least the mid 6th millennium BC, maybe even to the late 7th millennium BC (Borić 2009, 237).

The picture emerging at the moment is that the first use of copper minerals as well as the manufacture of small hammered copper objects using the known lithic techniques clearly happened in the Near East. The first evidence for ‘hot’ or ‘real’ metallurgy (smelting and the casting of large objects) actually comes from south-eastern Europe. The early occurrence of large cast axes under study was one of the arguments Renfrew used for the autonomous development of metallurgy in south-eastern Europe (1969). This premise is favoured particularly in south-eastern Europe itself, indeed Todorova even speaks about “ex balkanae lux” when talking about the origin of developed metallurgy (Todorova 1978, 1). However, in recent years, an increasing number of scholars are again postulating a single origin in time and space for metallurgy in Eurasia and diffusion to south-eastern Europe possibly at the same time as the introduction of agriculture (Borić 2009, 237; Pernicka *et al.* 1997, 48; Roberts *et al.* 2009, 1014; Strahm and Hauptmann 2009, 125-126). In a recent paper on the ‘development of metallurgy in Eurasia’ the authors use the two earliest sites with definitive evidence for the smelting of copper, at Belovode in central Serbia and Tal-i Iblis in south-eastern Iran, as an argument for a single invention of smelting that happened somewhere in Anatolia (Roberts *et al.* 2009, 1014). Although the oldest copper finds do come from this region, it seems somewhat simplistic to use the midway point between the two

earliest occurrences of copper smelting as the centre of origin for this innovation, especially as one of them is still contested. The authors do say that the debate is not settled, and more scientific research is necessary to clarify the situation once and for all (Roberts *et al.* 2009, 1014).

In a recent paper on the first extractive metallurgy in Europe, the Near Eastern impulse or origin is postulated also (Radivojević *et al.* 2010). The authors argue that the distinction between ‘cold’ and ‘hot’ metallurgy is vital in understanding the transmission and origin of metallurgy (Radivojević *et al.* 2010, 2784). They argue that the knowledge of ‘cold’ metallurgy came to Europe with the ‘Neolithic package’ from the Near East (Radivojević *et al.* 2010, 2784). This would fit the evidence for the first small copper and malachite artefacts from south-eastern Europe around 6500 BC which were all made using the known lithic techniques. The advent of smelting and casting, however, was an independent discovery within south-eastern Europe, in an area extremely rich in copper deposits (Radivojević *et al.* 2010, 2784). Although this hypothesis does sound plausible to a certain extent, it is difficult to make such statements about the transmission of ‘cold’ metallurgy, when we are only dealing with a handful of finds from across all of south-eastern Europe. As south-eastern Europe was full of easily accessible and visible copper deposits, it might not have needed an impulse from the Near East to explain the few known finds, especially as they can all be produced using the known lithic techniques. An impulse might also have come at a slightly later date, after the very first introduction of farming to Europe. A distinction should also be made between working copper ore into beads or pigments and the hammering of native copper. The former really is using lithic techniques, as the qualities of ore are very much like stone. The hammering of native copper, however, is different as it takes into account the different properties of an entirely new softer and more malleable material. Another problem with the transmission of the so called ‘cold’ metallurgy with the ‘Neolithic package’ is the complete absence of copper and copper ore artefacts from the rest of Europe at the time of the introduction of farming. In fact the earliest copper objects from southern Germany date to the second half of the 5th millennium BC, over one millennium after the introduction of farming (Schier 2010, 30)

Despite these problems this hypothesis is worth keeping in mind for the debates on the origins of metallurgy in the future which are still very much in progress. The second part of the theory, concerning the independent development of the ‘hot’ metallurgy

(smelting and casting) in the Balkans is in my opinion probable, especially due to the downright explosion of metallurgy shortly after the first evidence for mining and smelting in the form of the heavy copper axes. The reason for this explosion in metallurgical expertise in the Balkans was probably a combination between the highly developed pottery repertoire, controlling high temperatures in purpose built furnaces (Sherratt 1994, 169), the presence of rich copper deposits throughout south-eastern Europe and, of course, the ‘readiness’ on the part of (some) Copper Age persons not only for the invention, but also for the uptake of these new techniques and skills.

1.2 The copper axes with central shaft-hole

Besides their importance in the debates on the origin of metallurgy, the copper axes with central shaft-hole were chosen as a topic of study due to the many unanswered questions which arise when looking at the assemblage in more detail. The assemblage consists mainly of hammer-axes and axe-adzes, although some pick-axes and adzes as well as double-axes and adzes have also been found. The hammer-axes have a hammer-end and an axe-end, and the axe-adzes, as the name suggests, consist of an adze – and an axe-end. The characteristic, which stands out most, is their weight. Compared to other metal artefacts in circulation at the time, the vast majority of copper axes weigh between 600 and 1500gr., although some hammer-axes weigh up to 3785gr. (see database ID 676). However, to use this as an argument for the ‘special status’ of all these axes is not tenable, as quite a number, especially the most common Jászladány – type axes, weigh often less than 1kg, and have a very light and practical ‘feel’ to them.

Most of these axes have been published as part of the series ‘Prähistorische Bronzefunde’ (Antonović 2010; Mayer 1977; Novotná 1970; Patay 1984; Říhový 1992; Todorova 1981; Vulpe 1975; Žeravica 1993). At the heart of these PBF volumes is a catalogue of the finds, including drawings. The contextual and technological aspects of the copper axes are only covered in a short introduction. Although essential for any scholar working with these objects, the PBF volumes do not go much beyond listing the axes under consideration and many questions therefore remain unanswered. There are invaluable examples of published material, (Coghlan 1961; Kienlin and Pernicka 2009; Pittioni 1957; Ryndina and Ravich 2000, 2001), both old and new, which have tried to look closer at the production of these axes, but the last significant contextual overview was written in the 1960s (Schubert 1965). It is also, so far, the only work looking at the axes on a transnational basis. The PBF volumes cover the axes on the basis of modern countries, making it difficult to interpret trends and patterns in the data for the entire

distribution area of the axes. The scientific studies concentrating on the production are highly specialised in terms of space and/or numbers of specimens (Coghlan 1961; Kienlin and Pernicka 2009; Pittioni 1957; Ryndina and Ravich 2000, 2001). Although they are exceptionally important sources of data, specifically for answering questions regarding their production, they are not useful for large scale contextual studies of the copper axe assemblage as a whole. It was therefore a necessity to approach these axes afresh, ignoring national interests and borders.

The main aims of this thesis were to better understand how the axes were made and used, what the overall context and place of them was within the cultures and settlements of the Copper Age, and how the production and context might relate to the living experiences of the individuals in the Copper Age. The overall approach can be described as holistic, using different methodologies as well as putting the axes in their wider context. So far, such an integrated analysis has been missing in any of the publications on these axes. They were considered within their overall environment looking at all aspects of Copper Age life directly relevant to the axes. This was important as most of them are isolated finds, and are therefore often considered as a ‘stand alone’ class of material culture. The second meaning involves using as many available research methods as possible suited to answering the relevant questions (see Chapter 2).

To begin with, a theoretical framework had to be established, in order to define the relationship between humans and their environments, and how, through the interactions, artefacts come into being and change. In archaeology, change is often taken for granted within all theoretical frameworks; they merely describe changes in settlement patterns and material culture over time without looking at how and why the changes occurred in detail (van der Leeuw 1989, 300). This is true for traditional cultural-historical, processual and indeed post-processual archaeology (Chapman 1997; Ciugudean 2000; Bailey 2000; Kalicz 1998b; Pavúk 1998). Although post-processual archaeology acknowledges that individual and group actions are responsible for the changing cultural landscapes (Bailey 2000, 190; Chapman 1997, 138), the time frames used are often far too long for any real analysis of individual action. The long accepted tendency from a so-called “communal” Neolithic to a more “individual” Bronze Age (Bailey 2000, Hodder 1990) is a generalisation which would not have been perceived by the people in the past. It is only with hindsight that we can define these broad patterns in material culture. This is why a reversal of approach can be useful, as it tries to

understand the techniques and skills involved in production from the point of view of the artisan (van der Leeuw 2008). It is also from this perspective that the dichotomy between the natural and social world can be overcome, as in any material engagement the two mingle and are combined in an extensive *meshwork* of relations and associations between materials, ideas, humans, gestures and traditions to name but a few (Ingold 2000; Latour 2005; van der Leeuw 2008).

Besides this theoretical framework and a thorough review of the available literature, there are two core approaches of data collection that are essential to this dissertation. The first is the database and the second the use of experiments, together with the metallographic analysis of the results (see Chapters 7, 8 and 10). The database is an important tool for managing large quantities of information and searching for patterns within the data, which can then be put into the wider context. The experiments, as well as the metallographic analyses were the only ways to try and further the debate on the production of the copper axes. One could say that the database was used to investigate the contextual patterns in the data on a larger scale, whereas the experiments helped to engage with the specifics of how the axes were made. The results of both approaches were combined and integrated into the larger picture as obtained through the literature.

Besides these two main approaches, other aspects were also considered. While investigating and thinking about these axes and the related questions in more detail, it was seen to be vital to re-appraise the typology used to categorise them (see Chapter 9). The debate about the methods of production was reinvigorated through the re-discovery of a possible axe blank (see Chapter 6 and Fig. 9). The axe blank did not have a shaft-hole and had a very rough outline of an axe-adze. It had been lying in the storerooms of the Museum für Vor-und Frühgeschichte Berlin since the early part of the 20th century without having been recognised for what it is, until now. Unfortunately, I only came across it after I had finished the experiments otherwise I might have concentrated more on the questions raised by this unique find.

Through these different approaches, I tried to illustrate the place and importance of the copper axes with central shaft-hole from south-eastern Europe within the relevant cultural groups, as well as on an individual level of production and use. Be it the potential magico-religious aspects of mining and smelting or the individual choices made during the production process, understanding all aspects from the level of the individual to the level of archaeological groups and cultures has been the aim. It is in

the larger scale developments that change is most visible, although it was always started by an individual action. The question is whether the larger changes seen by archaeologists, like the change in burial practices leading to an increasing archaeological visibility of the individual in the Copper Age, happened fast enough to be actually experienced as a dramatic shift by the people in the past. I hope that this investigation of the Copper Age axes will help to understand this interesting time period a little bit better.

2 Methodology

Although the copper hammer-axes and axe-adzes from south-eastern Europe have been the topic of numerous publications (Kienlin and Pernicka 2009; Novotná 1970; Patay 1984; Říhovský 1992; Ryndina and Ravich 2000; Schubert 1965; Todorova 1981; Vulpe 1975; Žeravica 1993), many questions regarding their production and function still remain unanswered. Two reasons for this are the lack of experimental archaeometallurgy and studies investigating the entire assemblage on a transnational basis. In order to address these issues, the methodology of this research is not linear, but more like a spider's web; the copper hammer-axes and axe-adzes were approached from as many different angles as possible in order to obtain an integrated or holistic picture. As the majority of axes are isolated finds, a re-integration with the daily lives of past people is especially important when trying to understand their function and meaning. A transnational database of the entire known assemblage helped to identify significant patterns and trends in the data, which were illustrated using graphs, charts and digital GIS mapping. This chapter will introduce the methods used, and look at their potential and limitations.

2.1 Background

The starting point of any research is the review of the available literature. In this case, not only the literature relating directly to the axes was covered, but almost all issues of daily life throughout the Copper Age were looked at as well as the theoretical background regarding sociological and anthropological issues of network-theory and the entanglement of humans with their environments during the processes of making and using (Ingold 2000; Latour 2005). This was necessary to set the scene and appreciate the first large metal objects in Europe in their context and understand the production and use of these axes from the point of view of the individual. Chapters 3 and 4 are therefore discussions of the theoretical frameworks used, as well as the actual environments (natural/social/cultural) of the hammer-axes and axe-adzes from south-eastern Europe. Only the literature regarding the axes directly (Chapter 5) was reviewed as a traditional history of research.

2.2 Terminology

Before starting to discuss the methodology in more detail, a terminological problem will be considered in order to clarify the use of the term 'Copper Age' throughout this thesis.

Already at the end of the 19th century, the term Copper Age was used in some parts of Europe, particularly in Hungary for the period between the Neolithic and the Bronze Age (for a detailed discussion see Chapter 5). This was due to the presence of large numbers of copper artefacts in south-eastern Europe especially the copper axes under consideration in this present research. Alternative terms for the same period are Chalcolithic and Eneolithic. These three terms are often used interchangeably, but do have specific regional areas of use. Whereas in Hungary the term Copper Age is most commonly used, scholars from Romania and Bulgaria tend to use Eneolithic to describe the same period. The term ‘Chalcolithic’ is used mostly in Greece and Turkey (Parzinger 1993, 355). However, there is not only a difference in terminology between the different countries in south-eastern Europe, but also one of chronology (see Table 1). The discrepancies do reflect to a certain extent the variation in the regional developments. However, there are copper finds from the Carpathian Basin, which are as early as copper finds from Bulgaria as well as evidence for the exploitation of copper ores from Serbia, which is at least as early as similar evidence from Bulgaria. It is therefore as much a matter of national definition of when the use of copper warrants the beginning of a ‘new age’ as it is a reflection of true differences in the uptake of copper metallurgy.

Table 1: The different terminologies on a national level from the Neolithic to the Bronze Age in south-eastern Europe. (after Parzinger 1993, p. 355, Fig. 16)

Hungary	Western Balkans	Romania	Bulgaria
Middle Neolithic	Middle Neolithic	Middle Neolithic	Late Neolithic
Late Neolithic	Late Neolithic		Early Eneolithic
Early Copper Age	Early Eneolithic	Late Neolithic/Eneolithic	Late Eneolithic
‘High’ Copper Age			Transition Period
Late Copper Age	Middle Eneolithic	Copper Age (Transition Period)	Early Bronze Age
Early Bronze Age	Late Eneolithic	Early Bronze Age	
		Early Bronze Age	Middle Bronze Age

During a symposium with the title ‘The Copper Age as a historic period’ the definition, meaning and usefulness of the term ‘Copper Age’ was discussed and problems in terminology exposed (Lichardus 1991). In agreement with Lichardus (1991, 14), I will

use the term Copper Age to describe a period, which lies chronologically between the Neolithic and Bronze Age, and can be defined not only through the beginnings of metallurgy, but also through changes taking place in the way people lived their everyday lives. The extent to which all these changes have cause and effect relationships will be discussed in the concluding chapters, as many new discoveries have changed the picture considerably since the publication of the symposium mentioned above. The alternative terms for the description of the Copper Age (see Table 1) sprung up due to the lack of definition of the term Copper Age, and have themselves never been defined properly (Lichardus 1991, 14). Without a proper definition, all terms can be used interchangeably, which confuses the picture and is one of the reasons why I will use the term Copper Age only, also when writing about the areas in which the term is not commonly used. Another reason for the development of alternative terms was the argument that the period in question is not dominated by copper as a material, as stone was still very much part of the everyday lives of people. However, as the same can be argued for the Bronze Age, and the definition of the Copper Age includes all aspects of daily life, it can be used without hesitation, especially as it does have a long tradition, going back to the 19th century.

2.3 The collection of data

The majority of axes used for this study were published in the ‘Prähistorische Bronzefunde’ volumes (Antonović 2010; Mayer 1977; Novotná 1970; Patay 1984; Říhovský 1992; Todorova 1981; Vulpe 1975; Žeravica 1993), which is a great foundation and starting point. A number of newer and unpublished finds were also taken from a PhD thesis on the copper objects from Romania (Mareş 2002). The rest of the axes come from articles in various local journals, and some have never been published before. Although I tried to collect data on all known copper hammer-axes and axe-adzes to date, this was impossible. Many museums in eastern and south-eastern Europe have unpublished axes that they are not willing to show (although there were some exceptions), which means that the database is incomplete. I visited a number of museums which own copper axes in order to record macro-morphological features in more detail. This was important as it might help unravel the production sequence. Although most axes are accompanied by good drawings when published, it is important to handle as many objects with one’s own hands as possible. The number of museums visited was limited by the available time and financial resources, as many are in local museums, distributed over the whole of south-eastern Europe.

To create distribution maps using ArcView GIS, the latitude and longitude values had to be obtained for all axes with known findspots. Each findspot had to be found on Google Earth to obtain the geographic coordinates. A large number of sites were not marked on Google Earth. In this case, other online maps like Multimap were used, as well as Wikipedia, to find the correct spot on Google Earth. However, the findspots of most axes are just given as the name of a village. The axe might have been found anywhere within the village or indeed in the surrounding fields. It was therefore decided to use the coordinates of the centre of the village whose name is given as the findspot, unless more exact details were known. The collection of data for the different tables of the database (composition, context, axe marks, deformation, dimensions), will be discussed in more detail below (see 2.7).

2.4 Experiments

When traditional methods of research are exhausted, experimental archaeology can be used to come one step closer to the past through replicating objects and processes at a 1:1 scale. Especially for better understanding processes of production, the direct engagement with the material becomes invaluable. It is therefore evident that an experimental approach should be part of a holistic methodology. As is the case with most subjects, the deeper one engages with a question the wider the scope for more research becomes. The number of questions one would like to answer is often far too optimistic, as many questions will have to be broken down into separate experiments and are always much more time-consuming than expected.

With this in mind, an experimental approach to the copper axe-adzes and hammer-axes from south-eastern Europe could be seen as a never-ending story unless some priorities are set by taking into account previous research, the morphological qualities of the objects themselves, as well as related archaeological evidence or, in this case, the lack thereof. As mentioned before, there is as yet no clear agreement about the exact production sequence and skills used for the copper axe-adzes and hammer-axes. Were they cast in open or closed moulds? Were they made from clay or sand? However, the reconstruction of the mere production sequence is not the end in itself but rather the beginning of a more integrated analysis and interpretation of the technical choices made by the people in the past. Being able to show changes, differences and similarities in the production over space and time will allow a more nuanced approach to innovation and tradition.

Further considerations applicable to all experiments are issues of the experimenting environment. Experiments should be as actualistic as possible, meaning the materials and environment should be as close to the original as possible. Depending on which part of a process is tested experimentally, this need not apply to the entire procedure. If, for example, the aim of an experiment is the testing of different moulds, the means by which the metal is melted does not directly affect the end result and need not necessarily be actualistic. If, on the other hand, the object being cast itself is under study, the environment and method of casting might indeed influence the results, as it might alter the microstructure of the metal.

Metallography is by far the most reliable means by which to ascertain the production techniques used, but it is rarely possible to sample archaeological specimens, due to the strict conservation policies of museums (being a PhD student with no published results makes this an even greater difficulty). It was therefore important to design experiments, which would create both metallographic as well as macro-morphological data, which can easily be compared to archaeological specimens without destructive sampling.

Three partial axe-adzes were cast in a closed mould using materials and methods in line with Copper Age materials. However, the lack of experience on my part as well as time constraints meant that the main experiments had to be carried out using a modern gas furnace. It was decided to investigate the production of the shaft-hole. For this purpose, 18 axe blanks were cast using an open sand mould. Three shaft-hole production techniques were tried: casting around a clay core, punching the shaft-hole while the metal was still soft and drilling the shaft-hole into the solid metal. Three axes of each method were air cooled and the other three were water quenched. This meant that three axes were produced using the same variables in order to have a certain control over random or unforeseen factors, which cannot otherwise be kept constant.

2.5 Metallography

When carrying out metallographic analysis it is important to understand which variables directly affect the formation of the microstructure. Samples were taken from all experimentally produced axes cast as part of this study, and from a privately owned original Jászladány axe-adze. The privately owned axe has been in the same collection for well over 50 years, which means it does not come within the scope of the 1970 Convention of illicit antiquities (Harding 2011). The casting environment does have an

impact on the microstructure, which has to be taken into account when looking at the micrographs of the axes cast actualistically, and using the gas furnace.

For the metallographic analysis, the axes cast using the actualistic furnace, were sampled at the cutting edge and on one side. The axes cast using the gas furnace, were only sampled along the shaft-hole. It is important that the microstructure of the metal is not altered through heat, while the samples are taken and prepared (Scott 1991, 61). The samples were therefore removed using a fine jeweller's saw with slow back and forth movements. For the preparation of the samples, a cold mounting resin was used. The samples were then ground using disc grinders with sandpaper between sizes 80 and 1000. For polishing the samples, diamond paste of 6, 3 and 1 micron diamond was used on rotating polishing cloths. The finished samples were analysed using reflected light microscopy at a magnification of x50 and x200 both in an unetched state as well as after etching with alcoholic ferric chloride.

2.6 Typology

Typological differences can be defined intuitively (being led by the material) or characteristics can be predefined with different levels of importance according to which the assemblage is then sorted. Early typologies of the copper hammer-axes and axe-adzes were all created intuitively (Novotná 1970; Patay 1984; Schubert 1965; Todorova 1981; Vulpe 1975). After the first typology based on a large assemblage of axes from the entire distribution area was published by Schubert (1965), the authors of the PBF volumes on Slovakia, Romania Bulgaria and Hungary (Novotná 1970; Patay 1984; Todorova 1981; Vulpe 1975) used this typology, but added new types and variants named after local findspots. These new types and variants were devised by looking only at assemblages from within a specific modern country. Therefore Schubert was the last scholar to look at the entire assemblage on a transnational basis. The problem with creating new types of an object group, with a distribution area covering various modern countries, based only on a national assemblage, is that the typologies become difficult to use and a similar type might have three different names, depending on which country they come from.

In 1992 Říhovský made an attempt to get around this confusion, when he published his PBF volume on the axes from Moravia (Říhovský 1992). He defined some characteristics, and gave each characteristic a different weighting and a number or letter. He then sorted the axes according to his pre-defined characteristics, creating types such

as ‘Group IId, Type 3c, Variant E/E’. This method might seem more objective but it is extremely user-unfriendly and, as we shall see, it is difficult to ascribe fixed levels of significance to specific characteristics. The number of axes has increased considerably since Schubert devised his typology, and the large number of new local types and variants has confused the picture increasingly, making a renewed engagement with, and ‘disentanglement’ of, the material a necessity. The situation is thus in dire need of being looked at again on a transnational basis.

All images available (just under 1000) were scanned and printed out, in order to look at the entire assemblage and create a new typology without taking into account the origin of the objects. Both the types and subtypes were described in detail, in order to allow replication and consistency in classification. A number of the axe images were not clear enough, so only 868 axes were classified using the new typology (see Chapter 9).

2.7 Database/GIS

A further important step to overcome the often nationalised nature of research into the hammer-axes and axe-adzes was the creation of a database in order to analyse the data and extract patterns and trends of the entire known assemblage to date. A total of 1313 axes were added to the database. This is, of course, only a small proportion of the axes in circulation during the Copper Age, but it should be a large enough sample size to represent some of the real trends applicable to the past. Six tables were set up in a Microsoft Access database. A unique ID number was given to each axe, which was repeated in each table as it was the field through which all tables were linked. The database was structured as follows:

Base: ID, PBF Nr, Axe shape, New Type, Old Type (PBF), Place, County, Country, Period, Present location, Inventory Nr, Latitude, Longitude, Source

Composition: ID, PBF Nr, Analysed by, Sample Nr, Sn, Pb, As, Sb, Ag, Ni, Bi, Au, Zn, Co, Fe

Context: ID, PBF Nr, In situ, Secure context, Possible context, Landscape context, Related finds

Axe marks: ID, PBF Nr, Decorated, Side decorated, Arm decorated, Deco codes, Notes

Deformation: ID, PBF Nr, Fragmented, Complete axe present, Place of fracture, Type of fracture, State of fracture, Arm present, Deformation

Dimensions: ID, PBF Nr, Length (cm), Weight (gr), Shaft-hole diameter (cm), Shaft-hole diameter bottom, Shaft-hole shape

Before going into more detail on the different topics tackled through the analysis of the database, some issues regarding the use of GIS have to be dealt with. Distribution maps in general can be invaluable in archaeological research but have to be used carefully. The density of known finds might not always portray the real picture. It often depends on the personality of specific collectors and archaeologists. Vulpe mentions, for example, that the tradition of collectors and museums is older in Transylvania than in southern Romania and that there was greater collecting activity around Sibiu and Oradea (Vulpe 1975, 14).

For the distribution maps and spatial analysis of specific topics, ArcGIS Desktop version 9.2 was used. The base map ‘shaded relief’ was downloaded from the ESRI resource centre¹, which offers a number of maps and layers free of charge.

2.7.1 Composition

The data on the chemical composition of the copper hammer-axes and axe-adzes were taken from the database ‘Stuttgarter Metallanalysendatenbank’, which combined the results of three projects² and was published as part of a *Habilitationsschrift* (Krause 2003). In the case of the copper hammer-axes and axe-adzes from south-eastern Europe, the majority of analyses were carried out as part of *Studien zu den Anfängen der Metallurgie* (SAM), which has been criticised both for the sampling techniques and the way the results were categorized into groups. Slater and Charles (1970, 208) argued that due to the segregation of bismuth during cooling, it is not enough to take one sample per object, as was done for the SAM analyses. One sample, they claimed, cannot be representative for the composition of the whole object. Data published by Craddock (1976, 101) and Pernicka (1984, 524) indicates, however, that although there is indeed some variation, it is not significant enough to influence the results. The categorization of compositional groups created as part of the SAM has been criticised for not taking into account archaeological findings, and relying wholly on statistics (Budd et.al. 1995; Slater and Charles 1970, 207). This argument has been partly refuted, as the SAM

¹ <http://resources.esri.com/arcgisdesktop/index.cfm?fa=content>

² Studien zu den Anfängen der Metallurgie (SAM), Stuttgarter Metallanalysenprojekt (SMAP) and Frühe Metallurgie im zentralen Mitteleuropa (FMZM) (see chapter 5 and 12 for more details)

groups have been largely confirmed, with only minor adjustments, both through archaeologically obtained categorizations as well as modern cluster analyses (Krause 2003, 23; Pernicka 1995a, 89). However, the impossibility of trying to relate a specific compositional cluster to a specific ore deposit has been widely accepted for almost 20 years (Budd et. al. 1995; Pernicka 1995a,b).

The specific trace element values were added to the database to complete the dataset as a whole rather than carrying out my own cluster analysis, as that has been done already (Krause 2003). It was only the presence and absence of bismuth, which was used during the analysis of fracture patterns (see Chapter 10). The enlarged dataset of all analyses from the European Neolithic and Bronze Age was investigated using multivariate cluster analysis by Pernicka in the 1990s, resulting in 34 clusters (Pernicka 1995a). These 34 clusters comprising the complete dataset were added in my database to the relevant objects. However, as they are based on analyses from all of Europe, the 34 clusters turned out to be not very effective for investigating patterns specific to the copper hammer-axes and axe-adzes from south-eastern Europe. Despite these problems, they were included and discussed, as it is a valuable dataset (see Chapter 10 for more detail).

The missing archaeological meaning of these 34 clusters was also acknowledged by Krause (2003, 122), who established new levels of clusters, by analysing regional datasets only. Unfortunately only one of the regional sets has some significance for this present PhD research, namely the collection of analyses from the Middle Danube and Western Carpathians. However, they were not part of the published data, but Prof. Rüdiger Krause kindly sent them to me, which meant I could add these new clusters to the relevant axes in my database. As the set was regionally restricted, only 44 axes of my database could actually be related to one of the new clusters (see Chapter 10 for more detail).

2.7.2 Context

Most axes are isolated finds and therefore come from unknown contexts. An isolated find is usually a single object for which the find circumstances are unknown. It can also mean that the knowledge of the find circumstances simply did not survive. It is often difficult to distinguish between a hoard and an isolated find, but when just one object is found without intentionally modified surroundings the find will be classified as an isolated find. It cannot be guaranteed, however, that both hoard and burial finds are

sometimes classed as isolated finds, if the find circumstances are too vague. The axes coming from known find circumstances have been found either in hoards, settlements or graves. Although their number is small compared to the entire assemblage, it was large enough to be analysed and interpreted. Settlements are defined in this study as permanently or seasonally occupied places by at least one (extended) family, with architectural remains like postholes and pits. A grave or cemetery is the place where human remains are buried with a specific ritual, which can include grave goods. Hoards are places where groups of items are deposited intentionally, although the reason why the objects are deposited is not included in the definition.

With GIS, it might have been thought possible to analyse the axes with known coordinates in their landscape setting. However, due to the vagueness of the find spot description mentioned above, this is somewhat difficult. Only one landscape aspect was thought to be worth investigating further using ArcView. A buffer of 1km was created around the main rivers; and the number of axes lying within and without this buffer was compared. It was realised that many axes were clearly lying near rivers, which were not on the digital layer used for creating the buffer. A further layer was therefore created, digitising all rivers visible on the base map used³, manually, which had one or more axes lying close to it. The results have to be interpreted with due caution, as streams and rivers have regularly changed their course in the last six millennia. The size of the buffer (1km) is thought large enough to allow for some river movement, and small enough to exclude most axes, which in reality were not deposited (accidentally or on purpose) in direct relationship to a river.

2.7.3 Axe marks

Some axes are marked with small circles or other motifs. They are often described as decoration, but in this study the term ‘mark’ will be used instead as it does not imply a function. The presence and absence as well as the type of marks were recorded in the database. Some of the elements are recurring, like the circles, whereas others only occur on one or two axes. A code list was created in order to simplify the entry of the data into the database. Only axes with the same number of marks in the same places were given the same code (see appendix II). Spatial variation as well as the relationship of the marks to other features like axe type and axe shape were analysed using database queries and GIS.

³ <http://resources.esri.com/arcgisdesktop/index.cfm?fa=content>

2.7.4 Deformation

Complete fractures as well as wear and deformation of the copper hammer-axes and axe-adzes fall into this category. A fairly large number of axes were found in a fragmented state, most of them broken at the shaft-hole. The places of fracture as well as the pieces still present were recorded. In order to analyse the wear three terms were used, as a finer distinction would have only been possible on axes which were actually photographed or seen. The three categories ('none' 'slight' 'heavy') could also be used on axe drawings. As with any arbitrary division, it was not always easy to decide which category the 'borderline' cases belonged to, especially as the quality of the drawings is quite variable. However, due to the large sample size, the divisions should indicate actual trends and patterns in the data. The possibility of use wear analysis in combination with the experimental use of copper axes was quickly abandoned as almost all axes are far too corroded to show traces of use on the cutting edge. The original surface is, in many cases, completely corroded away. The potential relationships of the fragmented and deformed axes with other features recorded, like context and type, were analysed as well as their spatial distribution.

2.7.5 Dimensions

The length, weight, and shaft-hole diameter of the axes was recorded when possible. Not all axes published in the PBF volumes had been measured and/or weighed. The axes seen by the author in the museums were recorded in full, although some smaller museums did not have a scale, a problem which had not been anticipated. The published axes without information on their dimensions, were measured using the scaled drawings, but could, of course, not be weighed. It is unfortunate that this information will remain incomplete for many axes. Possible relationships between the length and/or weight as well as other features were investigated.

2.8 Summary and conclusion

As outlined during this chapter, the copper hammer-axes and axe-adzes from south-eastern Europe were approached holistically. Different methods and theories were applied to try and better understand the production, function and possible meaning of these objects. Experimental archaeology helped to understand the practical processes of production from an 'a priori' perspective (van der Leeuw 2008) and was used to create reference samples for comparison with the original axes regarding their macro-

morphology and microstructure. The existing typology was modified and changed to better suit the transnational nature of the assemblage. The creation of an extensive database was an important prerequisite for the study of these axes. It will be made available on CD so that future researchers may add to and complete the data. However, besides using a multitude of methodologies, I have attempted to put the axes into their prehistoric context and relate them to lived experiences during the Copper Age. The production was studied and thought of as a composite web of different materials and actions, much like Ingold's taskscape (2000).

3 Theoretical perspectives

As this thesis studies the Copper Age axes from south-eastern Europe, it is their production and use for which a theoretical framework has to be established. How do objects come about? How were they used? What brings about the many changes we can see in the archaeological record? A vast array of theories exist on how to deal with these questions both in archaeology and other disciplines like anthropology, economy and of course the social sciences (eg. Pinch and Bijker 1984; Pfaffenberger 1992, Arthur 2009; Ingold 2000; Latour 2005; Dolwick 2009; van der Leeuw 2008).

Traditionally, the production, use and change of material culture has been explained through various concepts of technology and technological change. Although the concept of technology has changed over time and is in fact a fairly recent invention (Ingold 2000, 321-22), it still is used in many discussions on change and innovation (Pinch and Bijker 1984; Pfaffenberger 1992). Most of the papers dealing with technological change and innovation written in the second half of the last century have helped to better understand the dynamics of change by firmly integrating them within society (Pfaffenberger 1992; White, 1962). There is no 'technology' without the 'social' as in the 'Social Construction of Technology' or SCOT (Pinch and Bijker 1984).

When engaging with these questions in more detail, terms like 'technology' and 'social' have to be discussed and re-defined. This inevitably leads to a discussion of the recent debates on Actor-Network-Theory (ANT) (Dolwick 2009; Latour 2005) and Ingold's 'dwelling' and 'meshwork' perspective (2000, 2007, 2010). Traditional dichotomies like nature/culture, body/mind and technical/social are being de-constructed or dissolved by various scholars (Latour 2005; Ingold 2000, 2007, 2011; Knappett 2008). These topics seem, at first sight, not directly relevant to the questions laid out above, concerning a theoretical framework for the production and use of the copper axes in question. However, it is essential to understand the relationships and connections between human agents and the material they engage with, and what drives the processes of change, before these insights can be applied to archaeology. This is why, after briefly introducing some 'social' approaches to technology and innovation, their limitations will be explained through charting the development of ANT (Latour, 1988, 2005) and Ingold's *meshwork* (2008, 211) in some detail. It is with these almost philosophical world views in mind as well as van der Leeuw's (1989, 1990, 2008) theories and studies of invention and innovation and Ingold's concept of 'taskscape' (1993) that a theoretical framework is outlined. The discussions will show that it is only in combination with an

experimental methodology, that these concepts can be applied to the archaeological record. This chapter does not strive to give a complete overview of the many approaches to change and material/human entanglements. It is a summary of the theories which are necessary to better understand the questions and developments in this field and the approaches which seem most helpful to Archaeology in general and this study in particular.

3.1 Social technologies

Although early accounts of technological change were mostly linear and positivist, technology and innovation are seen in the social sciences as part of society and embedded in culture, for at least the last 50 or so years (Bruun and Hukkinen 2003; Dupree 1969; Layton 1973; Pfaffenberger 1988; White 1962). The danger of seeing each technological development as following a linear almost rational path from simple to complex was already a topic of discussion during the 1960s, when White states that “a novel technique merely offers opportunity; it does not command” (White, 1962, 490). Technical innovations are developed and taken up by people depending on their social and cultural context, which also gives different meanings to the same inventions (White 1962, 497-498). Pfaffenberger (1988, 244) comes to a similar conclusion as he acknowledges the dynamic relationship between all spheres of existence in shaping technology, summarising it as the sociotechnical system. These sociotechnical systems come into being when all factors of the network are working in harmony, but a successful system is not necessarily successful because it has used the optimal choices. It merely works because the choices made do the job satisfactorily, as a number of other choices might have done also (Pfaffenberger 1992, 499).

In the 1980s Pinch and Bijker (1984, 406) use a similar argument to launch their theory of the social construction of technology (SCOT). The authors argue that new ideas are adopted not because they objectively work better, but that their functionality is socially constructed and determined (Pinch and Bijker 1984, 406). The linear, positivist approach to studies of technological change is criticised and explained through a bias in studying only successful innovations (Pinch and Bijker 1984, 405-6). Instead SCOT proposes that “the developmental process of a technological artefact is described as an alternation of variation and selection”, resulting “in a 'multi-directional' model” (Pinch and Bijker 1984, 411). The identification of problems and therefore the selection of specific variants of inventions is driven by the relevant social groups (institutions and

organisations or sub-groups thereof) (Pinch and Bijker 1984, 414-5). These have an interpretative flexibility, meaning that a solution to a problem can have multiple different causes for implementation (Pinch and Bijker 1984, 422). When the relevant social groups see a problem as being solved, SCOT authors talk about the stabilisation of an artefact, or the closure of a controversy (Pinch and Bijker 1984, 426-7). As the norms and values of the relevant social groups are shaped by “the sociocultural and political situation”, the meanings of artefacts are socially constructed (Pinch and Bijker 1984, 428).

3.2 Overcoming dichotomies

There are three main problems with social constructionist approaches to technology. Firstly, the terms ‘technology’ and ‘social’ are used uncritically, even though they are laden with multiple and often positivist meanings (see below) (Dolwick 2009, Ingold, 2000). The second problem is the neglect of the natural environment and its materials for the development of artefacts. The last problem is the lack of understanding change on the level of the individual, in the everyday context of the (prehistoric) craftsperson.

3.2.1 ‘Technology’ and the ‘social’

Ingold (2000, 295-298) has discussed the philosophy and history of technology in great detail, beginning his discourse with the Greek origin of the term itself. The classical Greek words *tekhnē* (practical skill) and *logos* (application of reason) were only seldom combined in antiquity and meant ‘the art of reason’ (Ingold 2000, 295). Nowadays technology is better described as the ‘reason of art’ (Ingold 2000, 295). However, to define technology as ‘the reason of art’ would not take into account the actual modern use and history of the term, as it is traditionally opposed to ‘art’ and indeed the social sphere as a whole (Ingold 2000, 289), although anthropological and sociological approaches have tried to overcome this dichotomy as mentioned above (Ingold 2000, 189; Pfaffenberger 1988, 244; Pinch and Bijker 1984, 406). The dichotomy between technology and society arose with the automatising of production processes during the industrial revolution as the individual skill of the artisan became increasingly expendable (Ingold 2000, 295-297). The “objectification and externalisation of the forces of production” (Ingold 2000, 321-22) gave rise to the modern “disembedded” meaning of the term technology. The term technology is laden with industrial concepts of production and it is difficult to apply these directly to prehistoric contexts. In fact Ingold (2000, 314) goes as far as to say that “there is no such thing as technology in pre-

modern societies”. He proposes instead to use the word technique or skill (Ingold 2000, 289-291, 314). The divide between the social and technical activities can thus be overcome when looking at technology as “skilled practices of socially situated agents” (Ingold 2000, 289). In his view, technique is therefore one aspect of the social sphere

Similar problems come with using the term ‘social’. Three broad categories of meaning can be defined. The most constricted meaning of ‘social’ is that it is an independent entity in itself, determining the actions of individuals through macro-scale forces (Dolwick 2009, 22). A more common understanding of ‘social’ is that it refers to anything which is related to humans or human-human and human-non-human relationships (Dolwick 2009, 22). Many concepts in archaeology use this meaning, including some approaches on agency, temporality, and phenomenology, which invariably implies a human/thing dichotomy, with humans being the primary agents (Dolwick 2009, 22). What is probably the widest meaning of the word is seeing ‘social’ as associations between everything, including materials, plants, animals and humans (Dolwick 2009, 21). The most notable proponents of this view of the social are supporters of ANT. In fact the actual re-definition of ‘the social’ into an all-encompassing ‘associations between anything’ was, according to Latour (2005, 106), the birth-moment of ANT. “Social is *nowhere* in particular as a thing among other things but may circulate *everywhere* as a movement connecting non-social things” (Latour 2005, 107). (Social) associations and actions make up the actor-network of materially heterogeneous elements (Dolwick 2009, 36).

A similar view is put forward by Ingold. At first glance it appears to have more in common with the second definition of ‘social’ (see above Dolwick 2009, 22), as it is mostly used in connection with human beings. Although sentences like “the technical is one aspect of the social” (Ingold 2000, 318) overcome the divide between technique and the social, it seems to be firmly situated within the human environment. However, just as the technical is only one part of the social, so social relations are only one part of ecological relations in general, although there can be no clear distinction between the two (Ingold 2000, 60).

“If human beings on the one hand and plants and animals on the other, can be regarded alternately as components of each others’ environments, then we can no longer think of humans inhabiting a social world of their own, over and above the world of nature in which the lives of all other living things are contained. Rather, both humans and the

animals and plants on which they depend for a livelihood must be regarded as fellow participants in the same world, a world that is at once social and natural". (Ingold 2000, 87)

By putting the people back into nature, he diffuses the boundaries of what is social, making the term itself redundant. Everything is connected without clear boundaries between humans, animals, plants and materials (Ingold 2000, 318).

3.2.2 'Network' and 'meshwork'

The second problem with the social constructionist approaches touched on above is their neglect of the natural world. Both ANT and Ingold's understanding of the term 'social' have already touched on a solution for the social/nature dichotomy and do, at the same time, fully acknowledge the important part played by all aspects of the environment. Within ANT it is called the levelling of the 'natural' and the 'social', or the creation of symmetry (Dolwick 2009, 37). Latour argues against two separate universes and states that by symmetry between the social and nature he means "not to impose a priori some spurious asymmetry among human intentional action and a material world of causal relations" (Latour 2005, 76). This means that for both Ingold and Latour, there is just one world, as the social and the natural cannot be separated.

Whereas ANT theorists talk about a 'network' when describing the associations and interactions between humans, animals, plants and materials in this all encompassing world, Ingold is using the term *meshwork* (2008, 212; 2010, 11). Ingold criticised the concept of the 'network' most notably in his humorous essay 'When ANT meets SPIDER: Social theory for arthropods' (2008). The two main problems he saw with ANT were firstly that the network was made up of materially bounded entities and secondly that agency is distributed equally amongst all connections of the network (Ingold 2008, 210-11). Ingold's *meshwork* differs to the network as there are no connections between heterogeneous entities, but a tangle of threads and pathways, where animate and inanimate things are not bounded but have trailing ends and are immersed in a force-field of energy (Ingold 2008, 211; 2010, 12). However, Ingold acknowledges that the predominant ANT view of a network of connected points is of a linguistic nature (Ingold 2010, 12). Latour himself has said that the centres of things are "surrounded by many radiating lines, with all sorts of conduits leading to and fro" (Latour 2005, 177).

The ANT 'network' has therefore become more like a 'meshwork', but the question of agency still remains unresolved. Although the degree and quality of agency varies (Malafouris and Knappett 2008), and Latour makes a distinction between human action and the agency of objects when he clarifies that objects cannot determine a course of action, but are participants thereof (Latour 2005, 71), ANT proponents quite clearly believe that objects have agency (Latour 2005, 63). Ingold on the other hand claims that agency is an unhelpful construct, which obscures the fact that things happen because they are alive (Ingold 2010, 7). "...action is not so much the result of an agency that is distributed around a network, but emerges from the interplay of forces that are conducted along the lines of the meshwork" (Ingold 2008, 212). When things are called objects and treated as such, they are taken out of the currents of life, leaving them isolated and motionless (Ingold 2010, 7). In order to bring them back to life, Ingold accuses proponents of ANT, of using agency as a 'sprinkling of magic dust' (Ingold 2008, 213). Instead of ascribing the potential for agency to all entities in a network, Ingold argues that if things are left within the current of the environment (fish in water, kite in wind), there is no need for the term agency as they move and grow due to "the very circulation of materials that continually give rise to the forms of things" (Ingold 2010, 7).

3.2.3 The paradox of archaeological research

If change happens continually through the very process of life, how can we then detangle it, in order to study the material remains of the past? Although Ingold's *meshwork* or world view can overcome every dichotomy and is an important foundation for looking at the world as a totality, it is not directly helpful to the study of the past. This is due to the fact that when archaeologists study the material remains of past people, the artefacts *are* removed from the currents of their environment. In fact when we study something it is automatically detached from its context. A recent discussion on the difference between *things* and *objects* can illustrate this problem further. *Things* are poly-interpretable, ambiguous and still embedded in their environment (Knappett 2008 and 2010; van der Leeuw 2008). When they are named or studied by humans they become *objects*, requiring a framework or world view, which detaches them from their contexts (Knappett 2008 and 2010; van der Leeuw 2008). Ingold also acknowledges this problem when he notes that in order to study the world, a person has to detach himself from being-in-the-world (Ingold, 2000, 417). And it is only from this detached

perspective, which Ingold (2000, 417) and van der Leeuw (2008, 232) both link to western scientific discourse, that *things* can become *objects*.

Accepting that we have to remove ourselves from ‘dwelling’ in the world in order to study it, both past and present, how can we understand change, if it happens continually through the very process from which we as researchers are removed? Van der Leeuw (2008) offers some useful tools by adopting his cognitive approach to innovation and combining it with (a slightly changed version of) ANT in order to study change and invention at the level of the individual. In addition he tries to overcome the problem of the detached researcher by proposing a reversal of approach in order to study invention ‘as it happens’ in the past. (van der Leeuw, 2008, 217).

3.3 Change, invention and innovation

Invention is the term for the very inception of change at the level of the individual. Innovation on the other hand happens, when an invention is adopted by a population (van der Leeuw 2008, 225). This distinction is important, as studies of innovation have often left the process of invention to one side, concentrating instead on ‘a posteriori’ accounts of successful innovations (van der Leeuw 2008, 225; Pinch and Bijker 1984, 405-6). The dangers of ‘a posteriori’ accounts of innovation have already been stressed by social constructionists as each new development seems to be inevitable (Pinch and Bijker 1984, 406; Pfaffenberger 1992, 499). As mentioned above, van der Leeuw (2008, 218) links this ‘a posteriori’ perception of the detached researcher to the western positivist tradition of the natural sciences, as everything is explained in terms of chains of cause-and-effect. Instead an ‘a priori’ approach to invention is proposed, in which the researcher should look forward with the individual of the past in order to understand why certain choices were made and ultimately why change happened (van der Leeuw 1989, 302; 1990, 92).

When the act of invention was the topic of study, it was, in its early days, characterised by a dichotomy of describing early men and women as conservative and habit-ridden while at the same time grappling with the need for a second type of person with a more inventive mind, thus disregarding the tenet of “universal human nature” (McGee 1995, 774; White 1962, 487). Allen writes about ‘stochasts’ and ‘cartesians’ as being necessary for innovations to take place, the former having an open and creative mind, and the latter being prone to adhering more to tradition (Allen 1989, 276).

Van der Leeuw has used results from scientific research carried out on the brain structure to argue that the two kinds of approaches or perceptions (detached/a posteriori and embedded/a priori) are an integral part of every person (van der Leeuw 1989, 309-310). Results show that the right brain hemisphere perceives “with an intuitive grasp equal to understanding” (van der Leeuw 1989, 310). The left brain hemisphere on the other hand perceives “with a rational grasp equal to explanation” (van der Leeuw 1989, 310). Although both types of perception seem to be inherent in all humans, some occupations can be said to foster one type of perception more than the other. As already mentioned the ‘a posteriori’ approach or perception can be linked to rational, mainly theoretical or laboratory research (van der Leeuw 2008, 218). That means there is no direct engagement with the world, and if there is the variables are controlled so that experiments are repeatable (which life never is). A skilled craftsman on the other hand works in a direct engagement with the environment, using his ‘know-how’ to deal with problems and new situations as they arise in the task of creation. The perception used by persons who engage directly with the world and its materials is mainly ‘a priori’ (van der Leeuw 2008, 218).

This means that an ‘a posteriori’ outlook is more common when people study life and an ‘a priori’ outlook when people live life. It does not mean that there is an absolute dichotomy between these two kinds of perceptions, as people can switch from one to the other, both consciously and unconsciously. Van der Leeuw argues that as both types of perception seem to be inherent in humans, they are also inherent in the process of invention itself (van der Leeuw 1989, 310). For him invention is “enabled and constrained by the structure and dynamics of the scaffolding structure that maintains the link between ‘things’ and ‘objects’” (van der Leeuw 2008, 229). The ‘scaffolding structure’ is the world view or mind-map an individual uses to create *objects* out of *things* (see above Knappett 2008 and 2010; van der Leeuw 2008). Van der Leeuw (2008, 229) describes this scaffolding structure as the “total configuration of relationships among all elements in the network”. With network he does refer to the network of ANT, although he clearly states that the relationship between humans and non-humans is not symmetrical as “humans create the link between ‘things’ and knowledge that transforms these ‘things’ into ‘objects’ (van der Leeuw 2008, 229). To summarise, van der Leeuw thinks that change and invention are shaped by the network which humans use to understand the world. His network can include humans, non-human entities, the weather as well as theoretical concepts, ideas and knowledge but in

contrast to ANT, his networks are not symmetrical. It is the same all encompassing world we find in ANT and Ingold's publications, but as "humans are the medium through which action occurs" (van der Leeuw, 2008, 246) he has adapted ANT, making it asymmetrical.

3.3.1 Unconscious and conscious change

If inventions are enabled and constrained by a network of our ideas, memories and all other material and non-material elements in the environment, what are the actual mechanisms for change in the everyday lives of people? Ingold (2010, 7) thinks that change happens constantly through the very process of life. Van der Leeuw (2008, 232) argues that change happens constantly through the engagement of humans with the material world or the interplay between our ideas (*objects*) and the world of materials (*things*) due to human action. Although this is similar to Ingold's view, van der Leeuw (2008, 228) uses a cognitive approach in order to explain change in more specific terms. He argues that "moving from the material to the world of ideas reduces the number of dimensions in the hyperspace associated with each artefact, whereas implementing ideas increases the number of dimensions in hyperspace" (van der Leeuw 2008, 222). In other words, when creating an object, the solutions or know-how are present in the world of ideas as a reduced number of dimensions. When the object is then made, the engagement with the material world increases the dimensions and the memory and perception has irretrievably changed so that an artisan can never truly make the same object twice. "Material culture is not replicated, it is re-created" (van der Leeuw 2008, 228). This sort of change, which happens constantly during the everyday production of artefacts, is obviously mostly unconscious and therefore if it does lead to archaeological visible inventions, they are only inventions from an 'a posteriori' perspective. The artisan himself, being fully immersed in the creation, does not necessarily see it as making a change. It just happens.

This unconscious change is firmly connected to the nature of the human memory. "It is in society that people normally acquire their memories. It is also in society that they recall, recognise and localise their memories" (Halbwachs 1992, 38). Memories are based on perceptions. However, one does not need a new perception for every single change to take place. The memory itself changes, as every time a person remembers something it is only a re-interpretation of the original experience or perception (Olick and Robbins 1998, 123). The memory is never constant, and is manipulated by changes

in circumstance (Olick and Robbins 1998, 127). But repetition based on ever changing memories in the everyday manufacture of artefacts is unconscious and cannot be called innovation. To illustrate let us look at archaeological typologies of artefacts. There are usually some broad categories, which I think are due to conscious decisions. However, when splitting these broad categories there usually comes a point when the variables are just too manifold and the differences so small that the boundaries are often blurred. It is these changes and differences that are due to the inherent changeability and subjectivity of memory. This unconscious change, which can happen through the subjective and often incomplete remembering of the finer details of an artefact, might also account for the vast variability in hammer-axes and axe-adzes from south-eastern Europe under consideration (see Chapters 7 and 9).

Besides these unconscious changes, which are due to changing memories and the interaction with the material world, there are also conscious decisions which can lead to changes, inventions and innovations. Arthur (2009) summarises conscious changes as a chain of links. At one end stands the need or problem and at the other the solution (Arthur 2009, 110). Innovations can start from either end. The discovery of a new principle sets into motion the search for an application of the principle in question or a perceived problem sets into motion the search for a new principle (Arthur 2009, 110). There is no absolute dichotomy between conscious and unconscious changes as they are both part of a whole spectrum of different changes and inventions. What all these changes have in common is that they are enabled and constrained by the world view or scaffolding structure of the people who are active participants in these changes as well as by their environments. In short by the *meshwork* that connects all the participants of a change.

3.3.2 Approaches to the ‘a priori’ construction of past change

This means that in order to study change we have to try and re-construct the specific *meshwork* in place at the time the actual change occurred. Van der Leeuw (2008) uses ethnographic examples of pottery making to illustrate his approach. In his case it is possible to re-construct a fairly complete *meshwork* from an a-priori perspective. But how do we go about studying past changes, when all we have as archaeologists are detached objects? Looking at something from an a priori perspective does not necessarily mean that one has to be there at the moment the object of study ‘happens’, as it is as much an attitude or specific mindset we have to get into. Nevertheless the

more we know about the original context of a change or work process in the past, the better we can understand the enabling and constraining elements and the choices made by the people in the past. This is rarely the case within archaeological research, as the contexts are always, to varying degrees, fragmentary or even non-existent. The copper axes studied in this thesis fall under the latter category, as the vast majority are isolated finds.

In order to better understand the production of specific artefacts archaeologists often use the *chaîne opératoire*. The term was coined by Leroi-Gourhan and built on work done by Mauss (Schlanger 1994, 144). In essence the *chaîne opératoire* or operational sequence is the equation of artefact production to social actions and/or gestures (Schlanger 1994, 145). Coming from a network or meshwork perspective, the *chaîne opératoire* can sometimes be too simplified, merely describing gestures which would have been necessary to carry out a certain activity. Schlanger approaches the problem from a cognitive angle, by analysing and re-fitting flint flakes (Schlanger 1994, 146-147). In his conclusion he merely states that the steps involved had to have been pre-planned, using complex cognitive processes (Schlanger 1994, 148-149). The danger of such applications of the *chaîne opératoire* is that the results sometimes seem to suggest that we should be amazed at the mental capacities of prehistoric people.

But how can the *chaîne opératoire* be applied to the archaeological record in a more integrated way, which really engages with the multiplicity of dimensions present in a specific task? In her book on *Technology and Social Agency*, Dobres (2000, 170) reminds us that artefacts are not produced by merely skilful hands in a social context, but by knowing agents. In her example on lithic re-fitting she goes beyond stating that complex cognitive processes were involved. Her case study shows that it is possible to use a *chaîne opératoire* approach to bring out routines of knapping, different levels of skill and many other aspects (Dobres 2000, 171). However, lithic technology is unique, as it really does give the archaeologist the opportunity to see every single action in the reduction technology of a core which happened thousands of years ago. The same cannot be said for metallurgy or pottery. This means that it is often ethnographic production sequences, which are examined, like in van der Leeuw's study of pottery making in Mexico (van der Leeuw 1994, 138). The problem with using the *chaîne opératoire* is that it focuses too much on the human agent, and that it is often too linear.

I prefer Ingold's (1993, 158) term 'taskscape' when studying the processes of engagement between humans and their environment. The taskscape is "the entire ensemble of tasks, in their mutual interlocking" (Ingold 1993, 158). In a more recent paper, Ingold argued that the concept of, and the literature on materiality is completely lacking any real understanding of materials. Objects are often seen as static and entirely abstract and a clear bias towards consumption is a widespread phenomenon (Ingold 2007, 9), as the social life of things probably begins in many people's minds only when the object is being used. Ingold asks whether a direct engagement with the material and processes of formation like 'knapping a stone' might not bring us closer to understanding the properties and qualities of a certain material. Of course it will, and it is this practical engagement with the materials we study, which is the most important tool we have for achieving van der Leeuw's 'a priori' perception of the past. This is a clear call to experimental archaeology. By actually creating the artefacts we study afresh, we are able to identify parts of the *meshwork* and the choices made, which would have remained unknown through purely theoretical approaches. It is through the creation of a taskscape (never identical to the one in the past) that we are able to better understand past *meshworks*.

However, experimental archaeology itself combines both a more *detached* and a more *engaged* world view. On the one side there are the formal experiments, with well formulated hypothesis, carried out under controlled conditions. They belong to the western positivist tradition of the natural sciences in which the researcher tries to be as objective as possible. The results cannot be overestimated in their importance to archaeological research if they are put into an overall context. The other mindset, which also offers great opportunities, is that of creative engagement with the material. It is in particular the reduction and increase of dimensions in hyperspace through switching between 'things' and 'objects' (see above van der Leeuw 2008, 222), which makes such an engagement with the material at a 1:1 scale so important. The duality of cognition could be called the interface between humans and non-human entities, as it is through the engagement with the world that we are constantly made to switch between 'a priori' and 'a posteriori' perceptions (van der Leeuw, 2008, 232). During the first part of any practical act, the indefinite number of possibilities and constraints of the environment are mentally reduced into one solution or conceptualisation (van der Leeuw 1994, 135-6). The second part of this cognitive duality is the execution of the idea. It is during this stage that one often encounters unforeseen problems, as the conceptualisation has

simplified the variables of reality (van der Leeuw 1994, 135-6). It is these unforeseen problems that arise when our theoretical models are tested in the material world that we realise their limitations.

3.4 Conclusion

This process can then open up whole new research avenues, as well as uncovering many areas of the *taskscape*. This in turn will lead to a more complete understanding of the wider *meshwork*, and the changes, both conscious and unconscious, which take place all the time. If we combine the *meshwork* and the *taskscape* with the understanding of conscious and unconscious change we can create a powerful analytical tool for all artefacts in the archaeological record. Accepting that change is constant, the everyday creation of artefacts is actually the very place where innovation and change happens, and where it is made visible through the choices of craft specialists.

4 Context and background of the copper hammer-axes and axe-adzes from south-eastern Europe

The main distribution area of the copper hammer-axes and axe-adzes lies in the modern countries of Hungary, Slovakia, Romania, Bulgaria and Serbia. Some isolated pieces have also been found in the Czech Republic, Ukraine, Austria, Switzerland and even as far North as the Baltic Sea coast in northern Germany. The cultural landscape and topography of this area is diverse although the Danube runs through the centre of the region, connecting one landscape with another, and one ‘culture’ with the next.

Although it is impossible to separate between the natural and the social environment or context, as stated in Chapter 3, in order to describe the background in a systematic and understandable way, it has to be detangled. This chapter will start with describing the topography and climate of the study area before discussing the key areas of human engagement with their environment. These include the first visible human impact as seen in environmental records, the plants, animals and natural resources exploited during the Copper Age as well as a short summary of the so-called second product revolution. The last part of the chapter will deal with the temporal and spatial variation in settlement and burial customs amongst the different cultural groups within south-eastern Europe.

4.1 Topography and climate

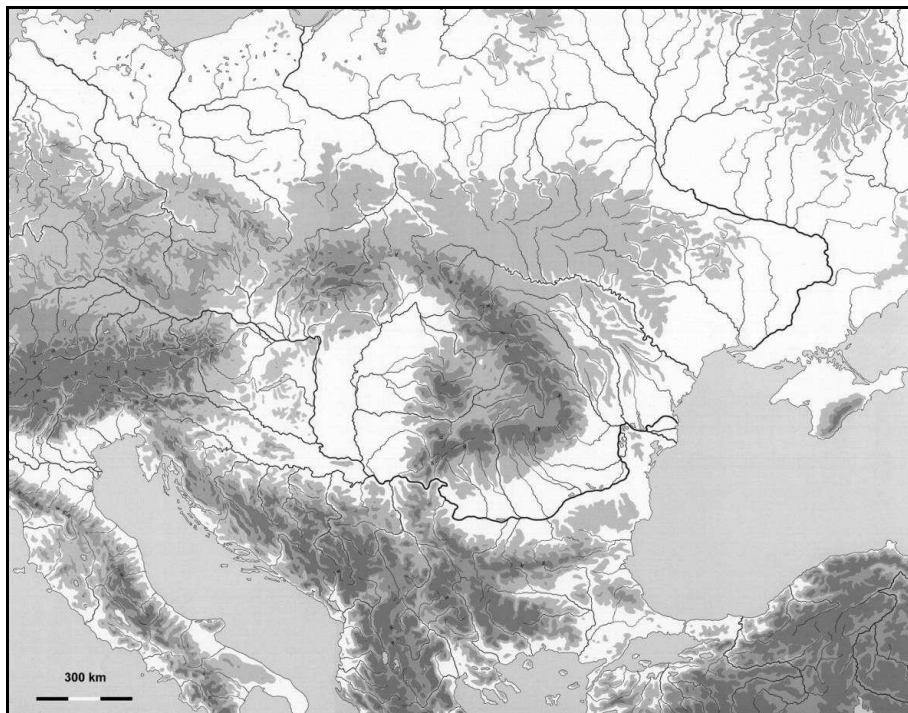


Fig. 1: Physical map of the study area (source: Museum für Vor-und Frühgeschichte Berlin)

4.1.1 Topography

As can be seen on Fig. 1, the study area is dominated topographically by the Carpathian and Balkan mountain ranges and the fertile lowlands around the middle and lower Danube. Taking into account the topography and the archaeological cultural groups, seven regions can be loosely defined (see Fig. 2). Before making its way through the Iron Gates, the Danube divides the hilly landscapes of *Transdanubia* (western Hungary, northern Croatia and western Slovakia) from the Great Plain or *Alföld* (eastern Hungary, western Romania and northern Serbia). To the North of these two regions lie the *Slovakian Carpathians*. The eastern and southern Carpathians divide *Transylvania*, a higher lying hilly landscape, from the *Lower Danube Basin* (southern Romania and north-east Bulgaria) and the *western Pontic Steppe* region (eastern Romania, Republic of Moldova and Ukraine). The last region can be described as the *central and western Balkans*, which are dominated by the Dinaric Alps in Croatia, Bosnia and Herzegovina, the Kapaonik Mountains in Serbia and Montenegro and the Rhodope Mountains in Bulgaria.



Fig. 2: The seven regions defined using the topography as well as the archaeological groups (source: M. Kacner)

As mentioned above the Danube is the most important river in the area under consideration and also the one feature, which connects all the different *Lebens- und Kulturräume*⁴. Almost all other major rivers lying within the main distribution area of the copper hammer-axes and axes-adzes join the Danube on its way to the Black Sea. In Transdanubia, the main water features are Lake Balaton and the rivers Drau/Drava and Save/Sava, who originate in the Alps and the Dinaric Alps respectively. The Alföld is dominated by the Tisza and its numerous tributaries. The two rivers connecting Transylvania with the Alföld Plain are the Szamos/Someş in the North, and the

⁴ The word 'Lebensraum' can be loosely translated as 'living spaces', which would not be appropriate in the current context. Lebensraum basically means the same as habitat means in biology, but it incorporates the human component as well. Lebensräume can be separated geographically and culturally, although the geographic elements are more important. 'Kulturräume' on the other hand means 'cultural spaces/habitats', and is used to describe areas of homogeneous cultural/social phenomena and are not necessarily linked to geographical characteristics.

Maros/Mureş in the South. The easternmost area of where the copper hammer-axes and axe-adzes are found is the fertile area around the Siret/Cepem, Prut/Pruth and Dniester/Nistru, the former two flowing into the Danube, and the latter directly into the Black Sea. The Lower Danube Basin is separated from the western Pontic Steppe by the Danube, Siret/Cepem and the Făgăraş Mountains or Transylvanian Alps, which are the southernmost part of the Carpathians. The only direct passage connecting Transylvania and the lower Danube Basin is the narrow river valley of the Olt, which is also one of the major rivers in the Lower Danube Basin. Other major rivers include the Argeş, and the Ialomiţa on the northern side of the Danube, and the Isker and the Osŭm on the southern side. There are only two major rivers in the mountainous region of the central and western Balkans with comparatively narrow fertile valleys. In Central Bulgaria the Maritza originates in the Rhodope Mountains and flows into the Aegean Sea and the Morava/Velika Morava originates in the Kapaonik Mountains in Kosovo, making its way through Serbia where it joins the Danube east of Belgrade.

4.1.2 Climate

The climate of south-eastern Europe, both in the past and the present is as variable as the landscape itself. There is not only the difference between low-lying plains and mountainous regions, but also the distinction between the more Mediterranean southern Balkan regions, and the northern and eastern regions, which are dominated by a continental climate (Willis 1994, 770). The important issue for this study is, however, what the climate was like approximately 6000 years ago when copper hammer-axes and axe-adzes were made and used.

Although somewhat cooler temperatures than today were the general trend at the time when the copper axes were in circulation (Cheddadi *et al.* 1996, 7; Jacomet *et al.* 1995, 54; Davis *et al.* 2003, 1713) some short-term climate events have also been recorded. Cold periods are noted around 6000 BC, between 4850-4450 BC, and 3150-2850 BC (Feurdean *et al.* 2008, 500; Onac *et al.* 2002, 324). Although Onac *et al.*'s study confirms the cold periods seen in Feurdean *et al.*, they write about the 'Holocene Climate Optimum' with slightly warmer temperatures than today being placed at around 4850-2850BC, interrupted by a cold period around 3200 BC (2002, 324). Although the longer term climate trends are somewhat unclear, the cold periods recorded in various studies seem to match. What can be said with some certainty is that the period around 4000 BC was not part of a cold period, but the decline of the copper hammer-axes and

axe-adzes happened around the same time as the cold period in the 4th millennium BC. According to the dates obtained by Feurdean et al. (2008, 500), the time when most heavy copper axes were in circulation was preceded by a colder period (see above 4850-4450 BC) although some early hammer-axes appeared during this time already.

The studies on climate in south-eastern Europe are as yet too tentative to be used with certainty in an archaeological context. They can nevertheless be used as possible factors when thinking about the development of settlement patterns, population dynamics and possibly the emergence of new technologies.

4.2 Vegetation, plants, animals and natural resources of the Copper Age in south-eastern Europe

4.2.1 Vegetation

Although climate reconstruction in south-eastern Europe is only in its beginnings the vegetation history during the Holocene is somewhat better understood. An increasing number of pollen cores are being published, which are used to reconstruct the vegetation in both mountainous regions and low-lying areas (Bjorkman *et al.* 2003; Bodnariuc *et al.* 2002; Edwards *et al.* 1996; Marinova and Atanassova 2006; Tantau *et al.* 2006; Tonkov 2003; Willis 1997; Willis *et al.* 1995). In the 6th to 5th millennium BC, there seems to be a major shift happening in the woodland vegetation of south-eastern Europe. Hazel (*Corylus*), hornbeam (*Carpinus*), and beech (*Fagus*) increase dramatically (Bjorkman *et al.* 2003, 101; Tantau *et al.* 2006, 55; Willis 1994, 783-4). In mountainous regions, pine (*Pinus*) and fir (*Abies*) are also on the increase (Willis 1994).

Human impact as seen in pollen records is often problematic and especially the spread of agriculture has been a frequent topic of debate (Willis and Bennett 1994). The problem is that it is difficult to define what indicates anthropogenic disturbance in pollen sequences. Some scholars take the increased abundance of beech as a clear indicator for the spread of agriculture (Küster 1997), whereas others explain this phenomenon through competition and other natural factors (Gardner and Willis 1999; Küster 1999). An interesting paper by Gardner (2002) on a palaeoecological sequence from north-east Hungary suggests that the changes in the forest canopy seen in the Hungarian Late Neolithic and Copper Age, is linked to woodland management like pollarding and coppicing. Despite the differences in opinion the dates given for the first human impact onto the landscape can be used to identify some trends.

Table 2: Early human impact as seen through pollen data from south-eastern Europe (source: Author)

Source	Place	Nature of impact	Date (BC)	Topography
Gardner 2002	NE Hungary	Woodland management	4900	Low/flat
Bodnariuc <i>et al.</i> 2002; Jalut <i>et al.</i> 2003	Central Romania	Human impact	5800-5400	Mountainous
Bodnariuc <i>et al.</i> 2002; Jalut <i>et al.</i> 2003	Central Romania	Deforestation and agriculture	4800	Mountainous
Willis 1997	Hungary	Anthropogenic disturbance (burning, cleared ground)	7000-6000	Low/flat/hilly
Lazarova and Bozilova 2001	NE Bulgaria	Human impact	5000	Low/flat

Table 2 shows some of the earliest dates for a human impact on pollen sequences in south-eastern Europe. The early signals are very subtle, and most palynological studies only detect clear signs of agriculture in the form of cereal pollen in the Bronze and Iron Ages. In three pollen cores from Hungary, Willis states that early changes in charcoal levels and clearance at around 6000BC are not necessarily connected with widespread cultivation, but could be due to animal husbandry or the driving of wild game (Willis 1997, 202). At Kis-Mohos Tó in northern Hungary the pollen sequence suggests that a second period of intense burning and clearance in the middle and late Copper Age indicates the intensification of cultivation (Willis 1997, 203).

4.2.2 Plants

In order to have as complete a picture as possible about the living conditions of the people who made the copper hammer-axes and axes-adzes, the plant macro and faunal remains can be used to reconstruct past diet, agricultural and hunting activities and issues of economy. There are, however, not enough sites with detailed analysis of such remains to enable one to draw comparative conclusions over space and time. Especially the plant macro-remains have only been studied and retrieved in a very small proportion of excavations carried out in south-eastern Europe (Schier and Draşovean 2004, 218). Table 3 is adapted from the paper by E. Fischer und M. Rösch (Schier and Draşovean 2004) and serves therefore as an indication only, illustrating the variety of species which were exploited, cultivated and consumed.

Table 3: Plant species from Copper Age sites within south-eastern Europe (after: Schier and Draşovean 2004, p. 211-212, Table 11)

Einkorn	<i>Triticum monococcum</i>
Wild Einkorn	<i>Triticum boeoticum</i>
Emmer	<i>Triticum dicoccon</i>
Sanduri-wheat	<i>Triticum cf. timophevii</i>
Barley	<i>Hordeum vulgare</i>
Naked barley	<i>Hordeum vulgare</i> var. <i>nudum</i>
Six-row hulled barley	<i>Hordeum vulgare</i> var. <i>vulgare</i>
Two-row barley	<i>Hordeum distichon</i>
Bread wheat	<i>Triticum aestivum/durum</i>
Broomcorn millet	<i>Panicum miliaceum</i>
Rye	<i>Secale cereale</i>
Spelt	<i>Triticum spelta</i>
Oat	<i>Avena</i>
Flax	<i>Linum usitatissimum</i>
Poppy	<i>Papaver somniferum/Papaver</i>
Pea	<i>Pisum sativum</i>
Lentil	<i>Lens culinaris</i>
Bitter vetch	<i>Vicia ervilia</i>
Grass pea	<i>Lathyrus sativus/cicera</i>
Chickpea	<i>Cicer arietinum</i>
Common vetch	<i>Vicia sativa</i>
Broad bean	<i>Vicia faba</i>
Cornelian cherry	<i>Cornus mas</i>
Vine	<i>Vitis</i>
Sloe	<i>Prunus spinosa</i>
Hazelnut	<i>Corylus avellana</i>
Winter cherry/bladder cherry	<i>Physalis alkekengi</i>
Blackberry	<i>Rubus fruticosus</i>
Acorn	<i>Quercus</i>
Pistachio	<i>Pistacia</i>
Wild strawberry	<i>Fragaria</i>
Dwarf elder	<i>Sambucus ebulus</i>
Common elder	<i>Sambucus nigra</i>
Dogwood	<i>Cornus sanguina</i>
Apple	<i>Malus</i>
Dewberry	<i>Rubus caesius</i>
Rosehip	<i>Rosa</i>
Red-berried elder	<i>Sambucus racemosa</i>
Fig	<i>Ficus carica</i>
Beech	<i>Fagus sylvatica</i>
Walnut	<i>Juglans regia</i>
Plum	<i>Prunus insititia</i>
Wild cherry	<i>Prunus avium</i>
Raspberry	<i>Rubus idaeus</i>
St. Lucies cherry	<i>Prunus mahaleb</i>
Water chestnut	<i>Trapa natans</i>

4.2.3 Animals

As is the case with the analysis of plant macro remains, sites with high quality evaluations of the zooarchaeological material are rare in south-eastern Europe. It is therefore impossible to discern any significant patterns. The following species are known from Neolithic to Bronze Age settlement contexts.

Domestic: Cattle, pig, sheep/goat and dog

Wild: Aurochs, European bison, boar, red deer, roe deer, wolf, bear, horse, fox, badger, lynx, hare and other small mammals, beaver, birds, turtle, freshwater mussels and snails

(Bankoff and Winter 1990, 181; Bolomey and El Susi 2000, 160-161; Greenfield 1991, 172; Legge 1990, 217; Parkinson *et al.* 2002, 116-7; Tringham *et al.* 1985)

One of the few zooarchaeological assemblages, to have been analysed and published in great detail is from the tell settlement Selevac. Selevac dates from the Late Neolithic to the Copper Age. Measurements of both pig and cattle bones show that both wild and domesticated animals were being butchered. The slaughtering pattern of cattle in Selevac indicates a concentration on meat production (Legge 1990, 230). The same can be said for sheep and goat, where it is not possible to see any specialisation for wool or dairy exploitation (Legge 1990, 234). The analysis of deer bones from Selevac has shown that they were primarily hunted during the winter months when the agricultural activities were largely on hold (Legge 1990, 235). Deer bones were also more frequent in the earlier phases, when wild animals made up about 50% of the overall assemblage, before being replaced mainly by domestic cattle during the Copper Age (Legge 1990, 236).

In his article about the fauna from the Late Neolithic in the central Balkans, Greenfield synthesizes published zoo-archaeological material acknowledging the limitations of the data (Greenfield 1991, 181). The distribution of 'age at death' of cattle and sheep bones, suggests a meat production model, with only goats being possibly kept for their secondary products like milk (Greenfield 1991, 181).

Secondary Products Revolution (SPR)

Although the term SPR appears primarily to concern the use of animals and animal products, it indirectly also relates to arable agriculture. Traction both for ploughing and transport would have impacted considerably on all existing spheres of Copper Age life.

When Sherratt first proposed the SPR, it was described as a significant and quite sudden shift, with milk, wool and traction appearing at the same time, around 3500 BC (Sherratt 1981). In 1983 he published a further article, revising some of his ideas, and instead of proposing a revolution at one particular point in time he charted the development of the different aspects independently (Sherratt 1983). The emerging picture is one of greater variability in the adoption of the different products or techniques, though some of the dates can be pushed even further back when taking into consideration recent research.

Milk was probably the first of the secondary products to be exploited by people in the Neolithic. While age at death profiles provide a relatively late date of about 4000 BC for the advent of milking in south-eastern Europe, artefactual evidence as well as lipid analysis on pottery vessels indicate that milking was already practiced in the 6th or even 7th millennium BC (Craig *et al.* 2005, 889; Craig *et al.* 2007; Russell 2004, 326-7). The use of wool as a textile is extremely difficult to trace, as are all organic materials. However, it seems to be agreed that during the Neolithic, flax was the major material used in textiles and wool was only widely used from the mid third millennium, meaning in the Bronze Age proper (Russell 2004, 327). Although the evidence for traction and ploughing is almost as difficult to obtain as for the use of wool, the current state of research seems to suggest that traction was used in south-eastern Europe by at least 4500 BC (Russell 2004, 329). How does this evidence fit with the topic of this thesis? The large hammer-axes and axe-adzes were the products of a society that had been already milking their cattle/sheep/goats for over a millennium, but had only recently began to use the muscle power of their cattle for traction, probably both for ploughing and transport. As we shall see below, there was a major shift in settlement patterns in some areas, with a move from large central settlements to smaller dispersed settlements in the mid to late 5th millennium BC. Could the use of easier transport and ploughing have allowed for smaller units to develop, and cultivate heavier soils? How do the large copper objects fit into this picture? These and other questions will be raised and discussed again in the later chapters, when the results will be reviewed and put into a wider context.

4.2.4 Natural resources

The resources needed for Neolithic and Copper Age daily life can all be found within the area under consideration. Wood, both evergreens such as pine, fir and spruce and

deciduous species such as oak, ash and beech, is widely available throughout south-eastern Europe. Clay sources are also abundant, which is evident in the great variety and number of ceramics. Sources for knapped and ground stone artefacts are also present throughout south-eastern Europe. (Constantinescu *et al.* 2002; Muraru 2000, 60; Rosania *et al.* 2008; Spears 1990; Voytek 1990, 440-441). Only obsidian is limited to northern Hungary, south-eastern Slovakia and south-western Ukraine (Biró 1984, 498).

Stating the obvious, copper is the most important natural resource in the present study. The two most famous copper mines exploited from the Copper Age onwards, lie in modern day Bulgaria and Serbia (Chapman and Tylecote 1983; Černych 1978b; Gale *et al.* 2003; Jovanović 1994; Krajnović and Janković 1995; Krajnović *et al.* 1995; Ottaway 1994; Pernicka 1999; Tasić and Tasić 2003). In a recent publication on copper sources in Slovakia, Schreiner was able to show that the Slovakian sources might also have been used from the Early Copper Age onwards (Schreiner 2007). In Bulgaria Aj-Bunar is so far the only copper mine whose exploitation can definitely be dated to the Copper Age (Gale *et al.* 2003, 155). In Serbia, Rudna Glava was probably exploited from at least the mid 6th millennium BC (Borić 2009, 237). The use of other proposed mines in Serbia like Majdanpek and Rudnik is only inferred from their lead isotope signatures that are similar to those from stratified ore pieces and copper objects (Pernicka *et al.* 1997, 42). The only area placed firmly within the distribution area of the axes with no evidence for Copper Age mining is the eastern Carpathian Basin. This does not mean that the numerous copper deposits present in the Apușeni Mountains, for example, were not exploited, but a detailed scientific study has not yet been carried out.

4.3 Copper Age groups of south-eastern Europe – where, when and how they lived and died

In the paragraphs below the settlement patterns and burial customs are compared for each geographical/cultural area through time. The areas have been chosen to simplify the comparisons between regional variations, taking into account topography, geography and ceramic styles. They are, of course, artificial creations and do not necessarily represent the boundaries between the cultural groups in the past. The boundaries of areas with a certain ceramic style also seem often to be very fluid and show a high degree of overlap. The research into the prehistory of south-eastern Europe has produced a high number of separate ‘cultures’ and sub-groups. Describing all of

these in detail would only confuse the picture so below is a synthesis of the main developments and the general settlement trends in this area.

4.3.1 Chronology – relative and absolute

To begin a discussion on the spatial and temporal distribution of cultural groups, a summary of the relative and absolute chronology in the study area has to be undertaken. The Copper Age was first recognised as a separate historical period in the late 19th century (Pulszky 1884) (see Chapter 5). Early attempts at establishing an absolute chronology by relating the relative chronology of south-eastern Europe via the Aegean with the first ‘literate’ societies in Egypt and the Near East have resulted in the so called ‘short’ chronology (Raczky 1995; Renfrew 1969). According to the short chronology, the Copper Age in the Carpathian Basin would have fallen in the period between 2300 and 1850 BC (Bognár-Kutzián 1972, 210; Raczky 1995, 51). With the advent of radiocarbon dating, this short chronology was called into question, as the increasing number of radiocarbon dates from south-eastern Europe seemed to suggest a much earlier date for the Copper Age. This led Renfrew to propose that metallurgy had developed independently in south-eastern Europe, and had not spread from the Near East (Renfrew 1969) (see Chapter 1). For a while the short and long chronologies seemed irreconcilable. However, in a publication on the relative chronology in south-eastern Europe and Anatolia in the early 1990s, Parzinger managed to bring the two chronologies together (Parzinger 1993). The chronology in the different countries is not only confused by the numerous groups and so-called cultures but also by the difference in terminology used. Because of these difficulties, the chronology and time scales will be discussed using calendar years cal BC. See Fig. 3 for a simplified overview of the relationship between the different groups and their absolute chronologies.

Cal BC	Transdanubia	Slovakian Carpatians	Alföld	Transylvania	Central and Western Balkans	Lower Danube, Black Sea coast and Thrace	Western Pontic Steppe
3000	Baden	Baden	Baden	—	Vučedol	—	
3500	Boleraz	Boleraz	Boleraz	Cotofeni	Cotofeni	Cernavoda	Cernavoda/ Usatovo
4000	Balaton-Lasinja	Bodrogkeresztúr	Hunyadi-Halom Bodrogkeresztúr	Bodrogkeresztúr/ Decea Mureşului	Bubanj Hum	Cernavoda/Pevec	—
4500	—	Tiszapolgár/ late Lengyel	Tiszapolgár Herpály/ Csöshalom	Tiszapolgár Petreşti	Tiszapolgár/ KSB*	KGK** VI/Varna	—
5000	Lengyel	Lengyel	Tisza/Vinča	Pre-Cucuteni/ Vinča-Turdaş	Vinča	Poljanica/Sava	Cucuteni-Tripolie Pre-Cucuteni-Tripolie
5500	LBK	Bükk LBK	LBK	LBK	—	Karanovo III/ Hotnica/Usoe	LBK
6000	Körös	Mesolithic	Körös	Criş	Starčevo	Karanovo I-II/ Ovčarovo	Bug Dnestr Group

*Krivodol-Sălcuța-Bubanj Hum
** Kodžadermen-Gumelnita-Karanovo VI

Fig.3: Simplified summary of the chronology of the cultural groups in south-eastern Europe between 6000 and 3000 cal BC (source: Author)

4.3.2 Around 6000 BC

At this point in time, the settlement patterns across most of south-eastern Europe are fairly similar. The settlements of the Körös group can be up to several hectares in extent, although the entire area was not occupied at the same time. The rectangular houses were made from an above ground wattle and daub construction (Kalicz 1998a, 258-259). Some of the earliest metal finds, small items like awls and pins made from hammered copper, are thought to come from Criş contexts in Transylvania, although the exact stratigraphy is contested (Luca 1999, 282-283). The Starčevo-Körös-Criş complex continued to play an important role in the 6th millennium BC. In southern Thrace, the first monochrome ceramics slowly disappeared, giving way to a new development. The so called Kremikovci-Karanovo I Complex emerged from about 6000 BC onwards. These early settlements appeared along the rivers on the floodplains, and formed the basis for the distinctive tell settlements in the territory of modern day Bulgaria (Budja 2004, 238). It is only in central Bulgaria that the tell settlements are known from around 6000 cal BC. Although the settlement structures do show some variation, the few known burials are almost all from within settlement contexts, burials of children and women under house floors or in pits are the most common.

Whereas Thrace and the lower Danube saw the continuation of the Kremikovci-Karanovo I complex during the 6th millennium BC, the Carpathian Basin, the Pontic Steppe area as well as the Central Balkans saw some rather significant cultural changes. It is in Transdanubia that the famous Linearbandkeramik (LBK) group was born, probably out of the Starčevo-Körös-Criş complex, although it runs parallel with its late phase. Settlements are situated along river terraces, but for the oldest phase only pits and no houses have been found so far (Kalicz 1998c, 263). Only in the later periods is there evidence for the classic LBK posthole structures. The LBK group, or variants thereof, dominated the entire Carpathian Basin, as well as the Pontic Steppe area, if only for a short period of time. During the mid 6th millennium BC, the disintegration of ceramic styles continued, with the development of the (Pre) Cucuteni-Tripolye groups in Transylvania and the Pontic Steppe, and the Vinča group in the Central Balkans. The Vinča ceramic tradition also penetrated into the Carpathian Basin. The domestic architecture consists of above ground post structures in flat settlements and the few known burials are situated in single inhumation graves within the settlements (Luca and Pinter 2001, 46).

4.3.3 Around 5000 BC

At 5000 cal BC the LBK groups in Transdanubia are replaced by the Lengyel group (Stadler *et al.* 2006). The painted pottery of the Proto-Lengyel and Lengyel group marks a clear break from the line ornaments of the LBK (Pavúk 1998, 317). The settlements of the Lengyel group are varied and change from sub-period to sub-period, although tell settlements are not known. Generally the settlements were now also on higher ground and not only on loess soil. They were made up of rectangular houses, sometimes within round earth and palisade structures (Pavúk 1998, 325-326). During the early Lengyel phases, the dead are still buried within the settlements.

A clear difference between the settlement patterns of Transdanubia and the Central Carpathian Basin can be seen with the development of the Tisza group at around 5000 cal BC and the emergence of the first tell settlements (Kalicz 1998d, 310). There is, however, a great variety in settlement style and size, although the tell settlements only occur south of the River Körös (Kalicz 1998d, 310). The flat settlements are often much larger than the tell settlements, as people build their new houses a few metres away from the old ones. Houses can be between 7 and 18 metres long and between 3 and 8 metres wide (Kalicz 1998d, 310). There is evidence for decorated house walls and floors being made from beams covered in clay. The dead are still buried within the settlements, although a special area seems to have been set aside in flat as well as in tell settlements (Kalicz 1998d). This is also the time when the first small copper objects begin to appear, mainly from grave contexts.

The Turdaş group is probably the most recognised manifestation of a ceramic tradition, which developed within Transylvania (Luca 2000a, 100). The pottery consists of both fine and coarse wares, the main decorating methods are incisions or symbol-like decorations (Luca and Pinter 2001, 72). Whether or not this might indicate an early form of writing is still hotly debated. What can be said is that these symbols are also typical for the Vinča group, indicating the close link between the two ceramic traditions.

The Pontic Steppe area as well as the eastern parts of Transylvania are home to the Cucuteni/Tripolye complex during the 5th millennium BC (Anthony 2004, 245). The dual terminology of the Cucuteni/Tripolye complex is typical for south-eastern Europe, as the same ceramic complex is called different names depending in which modern country the sites are found. Cucuteni is the Romanian name for this ceramic manifestation, and Tripolye is the name given to the same group in the Republic of

Moldova and Ukraine. The settlement patterns became more coherent compared to the early phases of the Pre-Cucuteni group. Situated mainly along the main rivers, on terraces and naturally defended sites, the settlements often had additional defences in the form of a bank and ditch (Ellis 1984, 48-49).

At 5000 cal BC the lower Danube and Bulgaria are broadly speaking still settled by the Karanovo complex as well as the Poljanica and Sava groups. The phenomenon of the tell settlements begins to spread northwards from southern and central Bulgaria.

In the central Balkans, the Starčevo group gave way to the Vinča group at around 5300 BC, which owes its name to the type site at Vinča – Bela Brdo near Belgrade. The early phases show a decrease in settlements compared to the Starčevo group, but from around 5000 BC, the settlement numbers increase again and they become much larger in size (Chapman 1990, 32-33). New C14 dates suggest that the copper mine of Rudna Glava was already in use during the first half of the 5th millennium BC (Borić 2009, 237). At the site of Belovode, copper slags have been found in the early Vinča levels of the site dating to the late 6th millennium BC (Borić 2009, 238). This is so far the earliest direct evidence for the practice of copper metallurgy in south-eastern Europe. Whereas in adjoining areas only small copper objects have so far been dated to the first half of the 5th millennium BC, some hammer-axes from the site of Pločnik are now thought to date to the first quarter of the 5th millennium BC (Borić 2009, 214). If these early dates for metallurgical activities are accepted, the development of metallurgy goes hand in hand with the increase in settlement numbers and size, as noted by Chapman (Chapman 1990, 32-33). This would mean that there is some discrepancy between the emergence of large copper objects in the central Balkans and Bulgaria and in the Carpathian Basin.

4.3.4 Around 4500 BC

Although the first copper objects appear already during the early 5th millennium BC, the bulk of heavy tools under consideration in this thesis are in circulation during the second half of the 5th millennium BC. It is curious, however, that new dates from the mine of Rudna Glava and Vinča settlement sites in the Morava valley suggest the abandonment of the mine and a discontinuation of settlements around 4500 cal BC (Borić 2009, 237).

In Transdanubia, the Lengyel culture was still going strong at this time and the first separate cemeteries appear which are always near larger settlements (Pavúk 1998, 327).

Most graves were single inhumations in a crouched position. Cemeteries were arranged in rows or groups of graves. Sometimes cremations are known also. There are rich grave goods for both sexes (Pavúk 1998, 327). The settlements of the Lengyel group never developed into tells. It is in the Lengyel group and its subgroups that the beginnings of metallurgy can be found in this area. The new emphasis on burying the dead as individuals in formal cemeteries outside the settlements is a recurring pattern at this time in south-eastern Europe, and it does indeed coincide with an intensification of metallurgy and the appearance of the heavy objects under consideration.

The Tisza group had a relatively short-lived stylistic unity over the whole of the Great Hungarian Plain, before the Herpály and Csöszháló groups split off in the northern Plain area (Kalicz 1998d, 313). Whereas the Csöszháló group settled mainly in flat settlements, the Herpály group could be characterised by numerous tell settlements. These tell settlements are compared to the settlement diversity of the Tisza group, very uniform in size, structure and shape (Kalicz 1998d, 314). The houses are similar to those of the Tisza group, but smaller, and a second storey could be established on the type site of Herpály (Kalicz 1998d, 314). The dead were again buried at the outskirts of the settlements. Some of the most significant evidence, at least in the present context, is the large number of copper objects which appear in both the Herpály and Csöszháló group, and which are almost absent in the Tisza group (Kalicz 1998d, 315). This seems to indicate that the metal 'boom' of the Tiszapolgár and Bodrogkeresztúr group probably had its origin in the geographical area occupied by the Herpály and Csöszháló groups.

The internal dynamics and tensions in eastern Hungary and western Romania shortly after the mid 5th millennium BC caused the 'homogenisation' of the ceramic styles and the birth of the Tiszapolgár group (Kalicz 1998b, 331). Other changes in this transition include the abandonment of tell settlements (Schier and Draşovean 2004), and the appearance of the first heavy copper implements. The Tiszapolgár group has its distribution in eastern Hungary, western Romania and Transylvania. In the South its boundary is the Danube (Kalicz 1998b, 331). The settlements of the Tiszapolgár group are small in size, usually less than 1 ha, and generally single-phased. Some tell-like settlements are known only from the southern distribution area (Kalicz 1998b, 331). The settlements are made up of the usual wattle and daub houses, although there seems to be some evidence for rammed earth structures without posts (Kalicz 1998b, 331). The

settlements are always near rivers, and often have a small ditch running around the settlements, whose function is not clearly understood (Kalicz 1998b, 331).

The type-site of the Tiszapolgár group is an organised cemetery, which characterizes the higher visibility of burial rites in the Copper Ages compared to the higher visibility of settlements in the Neolithic. Numerous cemeteries are known with grave goods including copper implements (Kalicz 1998b, 331). Although the grave goods show a great variety of materials, they are not as rich as at the famous cemetery of Varna. An interesting observation is that the use of *Spondylus* shells stops completely in the Tiszapolgár group, when jewellery imitating these shells is made from limestone (Kalicz 1998b, 332).

It is in Petrești and Cucuteni contexts that the first heavy copper implements appear within Transylvania. Although the appearance of the large objects goes hand in hand with other changes in the Hungarian Plain, the settlement patterns and burial customs in Transylvania seemingly retain their Neolithic character. Whether this is a real pattern, or simply the lack of evidence is difficult to say. Current research suggests that the Petrești group developed more or less out of the Turdaș group (Luca 2000b, 104), as many of the ceramic styles, especially the painting of the pottery before it is fired have their origin in the Turdaș group (Ellis 1984, 61). The settlements of the Petrești group were always situated along streams and rivers, during the early phases on the lower terraces, but moving into previously unoccupied territories in the later phases, with an increase in settlement number and size (Paul 1992, 17) The houses are similar to all houses of this period in south-eastern Europe, namely post constructions using wattle and daub for the walls (Paul 1992, 22-23). There are as yet no known cemeteries belonging to the Petrești group, and the few burials known are all from within settlement contexts (Paul 1992, 115).

The Pontic Steppe area is occupied by the Cucuteni/Tripolye complex throughout the 5th millennium BC. From the mid 5th millennium onwards, their settlements could reach town-like dimensions with more than 2000 houses, something never seen before in the prehistory of Europe (Lillie 2004, 358). The houses were elaborate rectangular structures sometimes even two storeys high (Ellis 1984, 49). The dead are invisible, with no known cemeteries before the latest phase of the Cucuteni/Tripolye group. There are some burials from settlements which have been found beneath the house floors from earlier phases (Lillie 2004, 358). Large copper objects are now in circulation. Hammer-

axes of the Pločnik type might be present even earlier as the Carbunga hoard is dated to Tripolye A. Dated only stylistically through the pottery, the 'window' spans an entire millennium (5500-4400 cal BC), which makes the dating of the first large copper objects in the area rather difficult. Looking back at the evidence from Pločnik, however, one can reasonably assume that the first heavy tools in this region might have also appeared in the first half of the 5th millennium BC.

At 4500 cal BC, tell settlements begin to appear in northern Bulgaria and along the Black Sea coast, and were in use until the end of the Varna/KGK VI (Kodžadermen-Gumelnița- Karanovo VI) complex at around 4000 BC (Todorova 1982, 16-17). This complex comes into being around 4500 BC and was the result of some homogenisation of ceramic styles. The Gumelnița group occupies the plains lying north of the Danube, whereas the similar Kodžadermen and Karanovo traditions are the Bulgarian equivalents. The tells of this cultural complex have highly planned settlement layouts, with extremely little space between the houses. The layouts of the settlements are all very similar, and these organised tells mark a strict departure from the flat settlements during the Neolithic in the same area (Todorova 1982, 78-79). The burial rites are varied, with formal cemeteries, as well as burials amongst and under the houses being known.

There is still some debate as to whether the Varna group is part of the KGK VI complex, or whether it is a group in its own right. It is quite possible that the cemetery at Varna has skewed this judgement, as it is truly unique and cannot be compared to any other site. It is argued that the cemeteries of the KGK VI complex are not as rich as the Varna cemeteries along the coast (Todorova 1995, 88). The time of the KGK VI and Varna groups is also the time when the heavy copper hammer-axes and axe-adzes were in use in this region.

In the central Balkans, the Vinča group begins to disappear in the mid 5th millennium and with it the large 'aggregated' villages. Instead the settlement structure becomes increasingly dispersed (Tringham and Krstić 1990, 576). At this time the amount of copper in circulation begins to increase (Tringham and Krstić 1990, 576), despite the very early start of metallurgy in the region and the surprisingly early termination of mining activities at Rudna Glava (Borić 2009). At the same time when the settlements begin to disperse again, the importance of burials increases with formal cemeteries and graves containing prestige grave goods becoming established (Tringham and Krstić

1990, 574). The end of the Vinča group does not coincide with a decrease in metallurgy. The circulation of the hammer-axes and axe-adzes seems to be independent of these changes in ceramic styles.

4.3.5 Around 4000 cal BC

Transdanubia is at this time still in the hands of the Lengyel group, although in its final phases. The Jászladány copper axe-adzes are thought to have their maximum circulation around 4000 cal BC in the Carpathian Basin. The central and eastern Carpathian Basin is occupied by the Bodrogkeresztúr group. The Bodrogkeresztúr group is often seen as an extension of the Tiszapolgár group due to the continuity in material culture (Kalicz 1998b, 333). The heavy copper implements continue to be one of the dominant types of material culture. Although settlement types are similar to the ones from the Tiszapolgár group, there are much fewer in number and as yet no direct evidence for houses has been found. One could say they are even more ephemeral than during the Tiszapolgár group, although the cemeteries prove that the population did not decrease (Kalicz 1998b, 334). Many Tiszapolgár cemeteries remain in use throughout the Bodrogkeresztúr period, and the grave goods are similar in style and diversity. Kalicz sees in the rich graves and numerous large copper and gold hoards a sign of increased stratification in the society, which can, however, be easily contested (Kienlin and Pernicka 2009) (see Chapter 11). The centre of copper metallurgy also shifted during this period firmly into the Carpathian Basin, with areas like Bulgaria seeing a sharp decline in copper objects, which in the Carpathian Basin comes only with the end of the Bodrogkeresztúr group (Kalicz 1998b, 336).

It is not clear whether the Decea Mureşului group is simply the Transylvanian variant of the Bodrogkeresztúr group or if it is an independent development. The group is thought to predate the appearance of the Bodrogkeresztúr ceramic tradition in Transylvania and is very short-lived. It ends when the Bodrogkeresztúr group becomes established (Luca 2000a, 107). Although not much is known about the settlement structure, it is the first group within Transylvania with large inhumation cemeteries, which are situated outside the settlements, a characteristic which points to a strong link with the Bodrogkeresztúr group. When the first heavy copper objects appear, there are no obvious changes in settlement patterns and burial customs, and it is only around 4000 cal BC in the Decea Mureşului group that formal large cemeteries appear outside the settlements.

In comparison with the neighbouring regions within the distribution area of the hammer-axes and axe-adzes, the Pontic Steppe area remained much more consistent, both in terms of settlement, and ceramic traditions. In fact there are no major shifts, until the beginning of the Bronze Age, and the decline in Copper Age metallurgy in the first half of the 4th millennium BC seems to pass almost unnoticed, without any major changes in settlement patterns taking place.

Around the Lower Danube and Bulgaria the end of the KGK VI and Varna groups at around 4000 involves the end of complex settlement structures, which are at their most abrupt in eastern Bulgaria, along the Black Sea coast. This is thought to be caused by environmental and social changes (Todorova 1991, 92). The tell settlements in central Bulgaria were used for somewhat longer, but even there a deterioration can be seen (Todorova 1991, 94). Western Bulgaria, on the other hand, remained largely stable, with the final stages of the Krivodol-Sălcuța-Bubanj Hum (KSBH) complex of the central Balkan area flourishing under the continued metal boom, similar to the Bodrogkeresztúr group in the Carpathian Basin (Todorova 1995, 90).

The KSBH complex is the main cultural group in the central Balkans shortly before and after 4000 BC. Krivodol being the Bulgarian variant, Sălcuța the Romanian, and Bubanj-Hum the Serbian one. It is the time when the most numerous axe-adze type (the Jászladány axe), is in circulation. The settlement patterns during the early phases are of a more dispersed nature, but at the same time substantial. They occupy hilltops and caves and in western Bulgaria some have mud-brick architecture (Todorova 2003, 90).

4.3.6 The decline of copper metallurgy in south-eastern Europe

The Baden group was the first ceramic tradition to unify western with eastern Hungary, meaning that Transdanubia and the Great Plain were inhabited by a homogenous group (Němejcová-Pavúková 1998, 384). The Baden group is also the last Copper Age group before the start of the Bronze Age. Not only the modern territory of Hungary was occupied by this final Copper Age group, but ceramic finds have shown that parts of Serbia and Bosnia also belonged to its sphere of influence (Němejcová-Pavúková 1998, 384). The settlements show great variety, be it lowland flat settlements, settlements on higher ground or tell settlements. Some settlements are defended but not all (Němejcová-Pavúková 1998, 393). There are hardly any traces of real architecture and the old problem of pit houses comes up yet again (Němejcová-Pavúková 1998, 393). Evidence for the burial practices is even rarer than for settlements and architecture.

Hardly any large cemeteries are known; there are a few small ones, as well as some cremations. It is interesting, however, that the burial within the settlements in 'rubbish' pits is again a common practice as it was in the Neolithic (Němejcová-Pavúková 1998, 395). The use of metal decreases drastically during the 4th millennium BC.

The late Copper Age period was dominated by the Baden group in Transdanubia, and the central Carpathian Basin, but in Transylvania, and parts of the Banat, the Coțofeni group established itself. The settlements appear in all altitudes and terrains, with late settlements appearing as high as 1000 m (Ciugudean 2000, 114-115). Some of these are only thought to have been occupied seasonally, perhaps for transhumant pastoralism. The settlement architecture has not yet been fully investigated, but small rectangular wattle and daub structures seem to be the norm (Ciugudean 2000, 115). The burial rites are varied as well, with both inhumation and cremation being practiced. The dead were laid to rest within the settlements, in caves and possibly in tumuli, although this is still under debate (Ciugudean 2000, 117). The large hammer-axes and axe-adzes are no longer in use, with metallurgy in decline, although there is evidence of local manufacture, and copper objects include daggers, flat axes and numerous small items (Ciugudean 2000, 116). The Coțofeni group marks the end of the period under investigation in Transylvania, and its end marks the beginning of the Bronze Age.

The vacuum created by the Late Copper Age hiatus along the Lower Danube and in western Bulgaria was filled by the Cernavodă group. The settlements were small and ephemeral. The graves were situated in cemeteries or isolated in the landscape and are often found under mounds or in simple pits (Todorova 2003). The Cernavodă group marks the end of the Copper Age with few copper objects being in circulation. It is only with the beginning of the Bronze Age that the population as well as the metal use picks up again.

In the Central Balkans the picture becomes increasingly confused during the 4th millennium BC. Suffice it to say that the late Copper Age groups of the surrounding regions, like the Cernavodă, Baden and Coțofeni can all be found in the Central Balkans. With the presence of these groups also come their settlement patterns and burial customs, which also reflect this disintegration. Although the decrease in metallurgy happened later than in western Bulgaria, it did also happen in the central Balkans. Only the Early Bronze Age Vučedol group marks the beginning of a new and

independent central and western Balkan cultural tradition, as well as increased metallurgical activity.

That the changes in settlement patterns and material culture are connected to changes in society, sometimes even down to the level of individual agency goes without saying. It is difficult, however, to propose a direct cause and effect interpretation of the changes taking place from the Late Neolithic until the end of the Copper Age in south-eastern Europe. One of the central questions concerning the present study is whether the advancements in metallurgy lead to the changes described in the paragraphs above, or if the changes in society enabled the increased use of metallurgy. The higher visibility of the house during the Neolithic, which was interpreted as the development of an ‘ideology of the house’ by Bailey (2000) does indeed stand in contrast to the more ephemeral settlement traces during the Copper Age and the much higher visibility of cemeteries. This is, of course, a generalisation as the dynamics between settlements, burial customs and copper metallurgy vary greatly from region to region as was made clear in the paragraphs above. The evidence for the changes taking place in the natural environment are unfortunately not detailed enough to allow for any firm interpretation regarding the possible causes for change to be made, although the time when the large copper hammer-axes and axe-adzes were in circulation seems to fall into a warmer period. The beginning of this warm period cannot be directly linked to the beginnings of the metal boom period, as the active phase of Rudna Glava and some early hammer-axes still fall within the preceding colder period. The end of the warm period, however, could well be linked to the so called ‘Late Copper Age’ hiatus in both metallurgy and settlement dynamics, at least tentatively. As can be seen, the changes happening around the copper hammer-axes and axe-adzes are complex and are probably due to a complicated interplay between many factors. More work needs to be carried out relating especially to the absolute dating of ceramic traditions as well as the beginnings of metallurgy in all areas of south-eastern Europe. Only a much finer resolution would allow firmer conclusions to be made.

4.4 Summary and conclusion

The environment of the distribution area of the copper hammer-axes and axe-adzes is topographically and culturally extremely varied. It is dominated by the Carpathian and Balkan Mountains as well as the great flood and river plains around the Danube and Tisza/Tisa. The time of the first hammer-axes (first half of the 5th millennium BC), as

well as the decline of Copper Age metallurgy in the 4th millennium BC, fall within colder periods. As can be seen from the archaeobotanical and faunal remains, the people in the Copper Age practiced a mixed subsistence, using both wild and domesticated resources (Schier and Draşovean 2004, 211-212; Greenfield 1991, 181). Hunting as well as gathering still played a large role; although its significance varied seasonally and spatially as well as temporally (Legge 1990, 235). All the major resources necessary in Copper Age life were available within the area under consideration. Especially the comparatively easy access to copper, both native and ores, must have played an important factor in the development of this region as the first metallurgical centre in Europe (Chapman and Tylecote 1983). The archaeology in the countries formerly behind the Iron Curtain has historically emphasised the pottery, settlement patterns and burial rites with a complete lack of any botanical or zooarchaeological analysis. This is now changing, but the results from archaeobotanical and zooarchaeological studies are as yet not detailed enough to allow any finer spatial and temporal differences to be reliably reconstructed.

The data on the settlement and burial patterns in Neolithic and Copper Age south-eastern Europe are complex and complicated by the numerous cultural groups. Their existence is unfortunately not always wholly justified, as they are not necessarily based on objective research or on the similarities or differences between the ceramics, but often on modern political borders, and the personal ambition of single scholars.

Although it is therefore difficult to generalise the patterns seen in the entire distribution area of the heavy copper axes, some trends can be identified. The small ephemeral and dispersed settlements of the Early Neolithic slowly give way to nucleated or aggregated settlements. These larger settlements of the mature Neolithic can be tell settlements or, indeed, large flat settlements (Lillie 2004; Parzinger 1993). Towards the Copper Age (mid 5th millennium BC), the settlement structure disperses yet again, but the overall framework behind this change is not the same as it was in the Early Neolithic (Tringham and Krstić 1990). This can be seen most clearly in the new way the dead are buried from the mid 5th millennium onwards. Instead of being buried within the settlements, often under the house floors or in ‘rubbish’ pits, extramural formal cemeteries are used with crouched or extended inhumation burials (Kalicz 1998b). The grave goods indicate increased differentiation in status amongst the deceased, which can be seen particularly well in Varna, where besides the copper hammer-axes, large amounts of gold are also interred with some of the deceased (Todorova 1995). One

could also describe the changes as the increasing visibility of the individual in the archaeological record. The interpretation of these changes will be continued in the final chapters. What is certain is that the copper hammer-axes and axe-adzes under consideration can be generally associated with this increasing visibility of the individual in the mortuary record.

5 History of research

5.1 The 'discovery' of the Copper Age

The large copper implements, namely the axe-adzes and hammer-axes of south-eastern Europe have inspired and puzzled scholars from at least the 19th century onwards. It is due to these objects that Kubínyi was the first to suggest that the three age system devised by the Scandinavian scholar Thomsen might not apply to Hungary (Kubínyi 1861, 83). The first scholar to mention a separate European Copper Age according to Pulszky was Dr. Wilde, director of the Royal Academy of Ireland in 1861 (Pulszky 1884, 1). Only three years later, Keller joined Dr. Wilde in his opinion. While discussing a possible lake village which was discovered during building works on Lake Garda, he states that some copper objects similar to Hungarian ones had been found within the old wooden posts (Keller 1863, 140). He discussed the fact that the numerous copper tools and weapons from Hungary and the surrounding countries could be used to argue for a separate Copper Age (Keller 1863, 141). He claimed this to be the case in south-eastern Europe, and argued that this would imply a plentiful supply of copper and the absence of bronze in the repertoire of the early metal smiths (Keller 1863, 141). F. Römer concluded in 1866 that the Hungarian copper objects dated to an earlier period than the Bronze Age (1866, 26). The following years saw the debate intensify as many influential scholars still argued against the notion of a separate Copper Age (Pulszky 1884, 6-7).

In 1876 a 'Symposium of Prehistory' was held in Budapest, for which an exhibition of copper finds from the National Museum and private collections was organised (Pulszky 1884, 7). It was the first time that such a large number of copper objects had been seen in the same place (Pulszky 1884, 7). Pulszky gave a talk on the Copper Age in Hungary, but despite the evidence, many still had reservations. The main reasons which were used against a separate Copper Age were the scarcity of copper finds in Europe, that the copper finds could be explained due to a temporary lack of tin reaching Hungary, and that copper might be better suited for certain objects than bronze (Pulszky 1884, 7). In 1883, Pulszky published his influential book on the Copper Age in Hungary, and 1884 saw the publication of the German translation (Pulszky 1884, 1). On the first few pages Pulszky covered the debate on the existence of the Copper Age, responding to some of the arguments against its existence (Pulszky 1884, 1-11). The scarcity of copper finds from Europe could not be taken as a reason against a separate Copper Age, as the

numbers had increased dramatically (Pulszky 1884, 8). If as some have argued the copper objects were made due to a temporary lack of tin, the shapes and styles would be similar to the bronze ones which is, however, not the case (Pulszky 1884, 8). The argument that copper might be a more suitable material for certain objects is taken apart by Pulszky when he asks which objects these might be, as copper is a much softer material and certainly not more suitable for axes than bronze (Pulszky 1884, 9).

5.2 The origin and meaning of the copper axes

In 1893, Much concerned himself with the relationship between the European Copper Age and the culture of the *'Indogermanen'* (Much 1893). Despite the dubious topic and the many inaccuracies in the content of the book, Much had some interesting ideas regarding the origin of the large copper objects of south-eastern Europe. He claimed that copper axes developed directly from stone axes as they are found together in cremation cemeteries (Much 1893, 48). He further claims that the diversity seen in the copper axe morphology is not due to chronological developments, but rather due to the presence of large quantities of raw materials during this period, and that each copper axe had a pattern made from stone (Much 1893, 209). The difference between some copper and stone axes was due to the discovery of the inherent different mechanical properties of copper (Much 1893, 198). He therefore argued for the local origin of the large copper objects, partaking in a debate that was still continuing some decades later. Much was also one of the first scholars to analyse the chemical composition of some of the copper objects (Much 1893, 48). He also stated that the re-melting of copper artefacts probably meant that the axes we know today are only a small proportion of objects present in the past (Much 1893, 191).

Around 1900, the term 'Copper Age' was firmly integrated into archaeological practice. Hampel, who also took an interest in the large copper objects, argues for a separate Copper Age as "...this period, in which copper plays a leading role in certain regions, lasted over many generations" (Hampel 1896, 57). Despite this 'leading role', copper as a material was not efficient enough to completely replace stone as bronze did during the Bronze Age (Hampel 1896, 57). This is a common opinion throughout the discourse on copper objects, which is due to the relative softness of copper compared to stone and bronze. Even though this is often used to interpret the copper objects as non-utilitarian items, Hampel interprets the hammer-axes and axe-adzes as tools and notes the resemblance to the stone shaft-hole axes (Hampel 1896, 62). A further interesting

observation he makes is the fact that these distinct forms, (hammer-axes and axe-adzes) are almost missing completely during the Bronze Age, and only appear again during the Iron Age (Hampel 1896, 63). He explains this fact by saying that the copper and stone hammer-axes and axe-adzes were used throughout the Bronze Age, which contradicts his statement that bronze completely replaced stone and copper as it was more efficient.

These sometimes contradictory observations and conclusions by the early scholars are due to the importance they ascribed to metals above all other materials. It is one of the longest lasting and therefore most visible materials and the role it played in early research can be seen in this quote from Myres: “The moment of the introduction of metallurgy is, in the history of any civilisation, a crisis second only in importance to the introduction of fire” (Myres 1898, 171).

The debate on the origin of these objects was carried on by Schmidt who firmly believed that similar examples in bronze from Troy and Crete were later in date than the copper axes from south-eastern Europe. He even went as far as saying that the eastern Mediterranean examples were influenced by the axes from the Carpathian Basin (Schmidt 1911, 601; 1912, 20-25). That the copper axes from the Carpathian Basin are much earlier than the examples from Troy is of course true as even though the stratigraphy of these finds is not certain (Schmidt 1912, 22-23), the earliest settlement layer from Troy dates to the beginning of the 3rd millennium BC (Korfmann 2001, 347), more than a millennium later than the hammer-axes and axe-adzes from south-eastern Europe.

Some of these early works on the copper hammer-axes and axe-adzes propose interesting ideas and theories, which are in part still valid today, particularly concerning the local origin of these axes. It therefore seems somewhat odd to find that most scholars writing in the early 20th century try to find their predecessors in the Aegean or the Near East. In 1913, Nagy (1913, 295) published an article in which he tried to ascribe the different copper axe types to different ethnic groups, his ideas and conclusions, however, are somewhat flawed to say the least.

Although Childe created one of the earliest typologies for the copper axes, his main aim was to try and find the ‘Aegean predecessors’ and to clarify the chronological relationship between these axes (Childe 1923, 172-173). J. Schráníl, writing on the prehistory of Bohemia and Moravia, interprets the few copper hammer-axes and axe-adzes as imports from Hungary although their origin is described as oriental (Schráníl

1928, 88-89). A further typology is devised by Dunăreanu-Vulpe in 1929 (Vulpe 1975, 9).

The notion of a local development of the copper axes in question returns with Schmidt's (1932) publication on the Cucuteni group. He firmly rejects Childes (1923) theory of a Caucasian or eastern Mediterranean origin and argues instead that the south-eastern European metal industry developed out of the local stone industry. His argument is not based on chronology but on the difference in production techniques and typology between the axes from the two different regions (Schmidt 1932, 89). He describes the European axe-adzes as the "unification of two thoughts which are embodied through the process of casting". The axe from Maikop, on the other hand, is forged together very inorganically from two separate pieces (Schmidt 1932, 90). Whereas Schmidt argues for a local development of the axes from a typological point of view, Dullo argues the same using typological observations as well as chronological discrepancies as evidence (Dullo 1936, 142). Gaul is another author who believes in the autonomy of the south-eastern European Copper Age (Gaul 1942, 408).

By the 1940s it was generally accepted that the copper hammer-axes and axe-adzes originated in south-eastern Europe. Roska and Popescu favour a Transylvanian origin, whereas Berciu talks about the Danube/Carpathian area in general (Berciu 1942; Popescu 1944; Roska 1942). Popescu might agree with a local development, but does not agree with most scholars who think the copper axes developed out of the stone industry. Instead he argues that the stone axes imitated the copper axes (Popescu 1944, 32).

5.3 Typology, production and provenance

In the 1950s, Driehaus published a detailed paper on the dating and origin of Danubian axe types' (Driehaus 1952). He dates the earliest simple hammer-axes to the Gumelnița-Pločnik phase and the second horizon of hammer-axes and axe-adzes at least in Hungary and Transylvania to the Bodrogkeresztúr group (Driehaus 1952, 1). He goes into considerable detail over the typology and distribution of the axes, and claims that the different workshops were near the copper ore deposits (Driehaus 1952, 2). Other detailed studies on a local scale were undertaken by scholars from the Czech Republic, Slovakia, Hungary, the former Yugoslavia, Bulgaria, and Romania (Garašanin 1954; Marović 1953; Patay 1958; Patay *et al.* 1963) It was also in the 1950s that two 'outliers'

were published, one of them from northern Germany near the coast of the Baltic Sea (Berlekamp 1956; Driehaus 1957).

In the late 1950s and 1960s some of the most groundbreaking scientific research into these early copper artefacts was carried out and published. Pittioni and Coghlan carried out a series of metallographic analyses on hammer-axes and axe-adzes, looking into the production technique (Coghlan 1961; Pittioni 1957). Although the interpretation of the findings is questionable (see Chapter 6), they established beyond doubt that these objects were cast.

While Pittioni and Coghlan were looking at the microstructure of the axes, the so-called SAM (Studien zu den Anfängen der Metallurgie) carried out by Junghans, Sangmeister and Schröder, (1960, 1968a, b, c, 1974) analysed the chemical composition of thousands of copper and bronze objects from the old world. The tradition of analysing the composition of archaeological artefacts goes back at least to the early 19th century, when a pharmacist and chemist from Berlin analysed archaeological artefacts from the Mediterranean (Caley 1967, 120). The results from the SAM analyses were used to divide the metal objects into different groups, depending on their impurity patterns. Both the sampling technique and the method used to create the groups have been criticized (Pernicka 1984, 520-524; Slater and Charles 1970). However, it is the direct application of the resulting clusters to specific archaeological assemblages and ore bodies which has seen the most lasting and rightful critique (Budd et al. 1995). Although later use of cluster analysis and an ever-increasing dataset have largely confirmed the groups originally created as part of the SAM project (Krause 2003, 16; Krause and Pernicka 1996, 531; Pernicka 1984), their direct application to the archaeological record can never be persuasive (Budd et al. 1995, 168). It is only with keeping these limitations in mind that the original database of the SAM project can and has been employed repeatedly, to analyse compositional ‘clusters’, in order to understand different geographical territories, workshops and routes of trade (Beşliu and Lazarovici 1995; Krause 2003; Ottaway 1981, 142).

The main conclusions from the SAM project, according to Junghans, Sangmeister and Schröder, can be summarised as follows. The early metal objects in south-eastern Europe were mainly made using two metal groups, namely E00 and N (1960, 90; 1968a, 54). A further compositional group which begins to appear in the Copper Age is FC. Other groups at that time include C1A, C1B as well as C2AB and C2C. All these

groups are present within the assemblage of the copper hammer-axes axe-adzes (Junghans *et al.* 1968a, 54). Group N has no detectable trace elements, and it was therefore argued that it might be native copper (Junghans *et al.* 1968a, 14). The composition of the other groups mentioned are presented in Fig. 4.

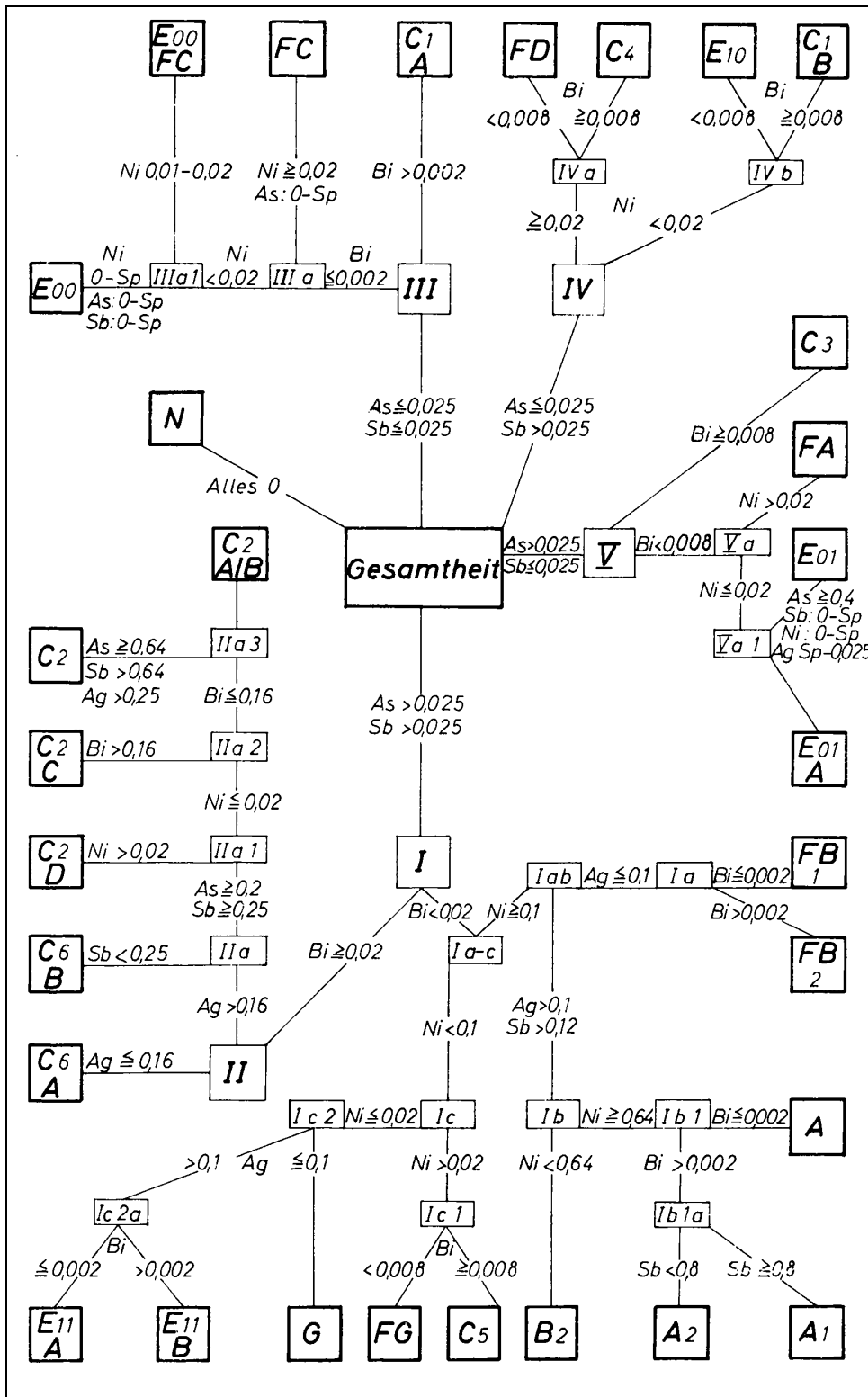


Fig. 4: The different metal groups according to the SAM project (source: Junghans *et al.* 1968a, p. 2, Fig. 1)

The last significant piece of research, which was published in the 1960s, was an article by Schubert on his thesis about the copper hammer-axes and axe-adzes from south-eastern Europe (Schubert 1965). Schubert claimed that all previous attempts to create typologies and chronologies for the copper axes were somewhat flawed due to an

incomplete dataset and insufficient stratigraphic information (Schubert 1965, 275). He attempted for the first time to create a typology and chronology for the entire distribution area of the axes (Schubert 1965, 274-295). Schubert's typology is still in use today (see Chapter 9). He was also the first to consider the circular marks in greater detail, a common feature on some of both the hammer-axes and axe-adzes.

5.4 The creation of catalogues and scientific analysis

In 1970 the first volume of the PBF (Prähistorische Bronzefunde) series relevant to this research was published cataloguing copper and bronze axes from Slovakia (Novotná 1970). The PBF series on copper and bronze axes are 'national' catalogues of metal artefacts from Europe and are an invaluable basis for further research. Soon after the Slovakian PBF volume, Vulpe published the Romanian copper axes (Vulpe 1975), and Mayer included the copper axes from Austria in his volume (Mayer 1977). Most authors of the PBF series used Schubert's typology although more types and subtypes were added. The 1970s not only saw the beginning of the publication of extensive catalogues, but regionally more cultural studies were also published in which the copper axes were mentioned and, to a certain extent, interpreted. One such study is Bognár-Kutzián's (1972) research on the Tiszapolgár group in the Carpathian Basin. She used a different typology, but dealt mainly with the hammer-axes, as axe-adzes are still uncommon during the Tiszapolgár group (Bognár-Kutzián 1972, 144). During the Cold War era it became increasingly difficult for western scholars to work on sites and material in the countries behind the Iron Curtain. However, Russian archaeologists were quite active, especially during the 70s, publishing work on the chemical composition of copper axes, the possible origin of the ore as well as metallographic analysis (Černych 1978a; Černych 1978b, c; Todorova 1981, 1). It was Černych who coined the term 'Balkan-Carpathian metallurgical province' (Černych 1978c).

Two further PBF volumes were published in the 1980s completing the catalogues of the copper hammer-axes and axe-adzes from the modern countries in which they are most densely distributed (Patay 1984; Todorova 1981). Only Romania, Hungary and Bulgaria have separate PBF volumes for the copper axes as there are enough axes from these regions to justify it. Patay and Todorova are still using Schubert's typology, although they added some new regional subtypes.

In the early 1990s the PBF volumes by Říhovský and Žeravica were published on the axes (both copper and bronze) from Moravia and Croatia respectively (Říhovský 1992;

Žeravica 1993). Říhovský tried for the first time to develop an entirely new typology using letters and numbers only instead of the usual place names, in order to obtain a more objective picture (Říhovský 1992, 21). The idea is noteworthy although in practice difficult to use (see Chapter 9).

Although many of the criticisms of the SAM groups have been refuted (see above), it is still better to use more up to date information, as it is available. The SAM project was published in the 1960s and many of the cultural and chronological aspects are outdated as they still used the pre-C14 short chronology. Pernicka's work a (1995a, 97) on re-evaluating the SAM groups was continued with the SMAP (Stuttgarter Metallanalysenprojekt) and FMZM (Frühe Metallurgie im zentralen Mitteleuropa) projects. The old SAM data as well as a vast number of new analyses was (re) interpreted and analysed using average-link cluster analysis in the 1990's (Krause 2003, 15-21; Pernicka 1995a, 97). It was possible to match the five main branches of the original SAMII 'tree' with five main metal classes. Class III contains the clusters of pure copper (2, 5, 13 and 14) see Table 4.

Table 4: The relevant matching clusters and SAM groups for Copper Age south-eastern Europe (source: after Pernicka 1995a, Fig. 43)

SAM group	Cluster (after Pernicka)
N	2
E00	2
E00FC	7
FC	7, 21
C1A	2, 18

Three further articles on provenancing early copper artefacts from Bulgaria and the Balkans are extremely relevant to this research. They showed that when combining compositional data with lead isotope analysis, it is possible to make more conclusive statements regarding the possible provenance of objects and ores (Gale *et al.* 1991; Pernicka *et al.* 1997; Pernicka *et al.* 1993). It was shown that the raw material for copper objects from settlements near the mines of Rudna Glava and Aj-Bunar did not necessarily come from those mines (Gale *et al.* 1991; Pernicka *et al.* 1997; Pernicka *et*

al. 1993). The results pose many interesting questions about longer distance trade and exchange routes. It also indicates that most copper deposits used during the Copper Age are still, or will always remain, unknown. The axe-adze from northern Germany is joined by another outlying axe-adze, which probably comes from Denmark. The artefact is published by Klassen and Pernicka, who state that it is probably from the Balkans, judging by the chemical composition as well as the morphology of the axe (Klassen and Pernicka 1998, 43).

Černych's notion of the 'Balkan-Carpathian metallurgical province' was used again in two publications by Ryndina and Ravich (Ryndina and Ravich 2000, 2001). Metallographic results were published and theories regarding the production techniques were put forward. The missing moulds for example are explained by proposing that the axes were cast into graphite moulds, which would not have survived the last five or six thousand years (Ryndina and Ravich 2000, 2001). More recently, Ryndina published a methodological article on metallography in the journal *Historical Metallurgy* (2009). Part of the article is her results on some axe-adzes, making her research more widely available. In 2002 a further PBF volume was published by Dergačev on the Copper and Bronze Age metal finds from the Republic of Moldova (Dergačev 2002). Gale and Stos-Gale continue the debate on metal sourcing, using both chemical composition and isotope analysis in order to shed more light on the movements of metals in Copper Age Bulgaria (Gale *et al.* 2003).

The three last publications to date, which are directly concerned with the copper axes in question, are all published in the Ottaway Festschrift. All three papers deal with the production technique of the hammer-axes and/or axe-adzes, showing that there is a real need to fully understand the *chaîne opératoire* (Boroffka 2009b; Heeb 2009; Kienlin and Pernicka 2009). Lastly, the PBF volume on the Serbian axes is still in press, but will close the circle of the PBF publication covering now the entire distribution area of the copper hammer-axes and axe-adzes (Antonović 2010).

5.5 Summary

The copper hammer-axes and axe-adzes were the very reason the Copper Age was established as a separate period and added to the classic three age system, at least in south-eastern Europe. It was Pulszky who published the seminal work on these developments (1884). After the Copper Age had been accepted as a separate period by most scholars, the debates began to focus on the origin of the large copper axes from

south-eastern Europe. Even before the age of C14 dating, some scholars argued for a local development of the copper axes, although some insisted on a Near Eastern origin. This was mainly due to the fact that the south-eastern European Copper Age was still thought to be contemporary with the early levels of Troy. The advent of radiocarbon analysis changed the situation dramatically, pushing the date for the Copper Age back about one millennium. This shift led Renfrew (1969) to suggest the independent invention of metallurgy in south-eastern Europe. After the establishment of the dating and possible origin of the axes, scholars concentrated on creating extensive catalogues, devising typologies for categorisation and using scientific analysis in order to investigate the material properties, possible provenance and production. Although the axes have received a comparatively large amount of attention, many questions, particularly concerning the production still remain unanswered.

6 Copper Age metallurgy and shaft-hole axes from South-Eastern Europe – evidence, problems and potential

This chapter will summarise the Copper Age metallurgical background (mining and smelting) within south-eastern Europe, before looking at the copper shaft-hole axes in more detail. Some of the uncertainties and problems especially concerning their production will be discussed in the light of a recent (re)discovery of a possible axe blank of an axe-adze. The questions arising from this chapter will provide the basis for the analytical approaches and results in the following chapters.

6.1 Ore deposits and Copper Age mines

One of the starting points for the study of early metallurgy has always been the distribution of ore deposits, particularly copper. Maczek, Preuschen and Pittioni compiled a comprehensive list of the major deposits in south-eastern Europe. There are copper deposits in Slovakia, Romania, Croatia, Serbia and Bulgaria (Maczek *et al.* 1953, 65-75). Although the only mines with clear evidence for Copper Age exploitation are Rudna Glava in Serbia, Aj-Bunar in Bulgaria and to a certain extent Špania Dolina in Slovakia (Černych 1978b; Chapman and Tylecote 1983, 373; Glumac 1991, 9; Jovanović 1979, 103; Ottaway 1994, 53-55, 67; Žebrák 1995), it is doubtful whether these mines were the only ones exploited during that period (Jovanović 1990, 55), especially as many of the copper objects analysed do not fit the lead isotope and chemical composition fingerprint of either Aj-Bunar or Rudna Glava (Pernicka *et al.* 1997, 143).

Superimposing an early 20th century distribution map of the copper axes shows an accumulation of these artefacts around the Transylvanian ‘Ore Mountains’. This is used as an argument for the exploitation of these deposits during the Copper Age (Maczek *et al.* 1953, 76; Sherratt 1976, 571). The presence of exploitable copper resources does not necessarily mean that they were exploited in the Copper Age, as can be seen when looking at the evidence from Cyprus (Gale 1991, 43; Muhly 1989, 1). A more recent article has collected direct and indirect evidence for prehistoric copper and gold mining in Romania (Boroffka 2009a). Although most examples date to the Bronze Age one hammer-axe is supposed to have been found in a mine near Baia Mare (Boroffka 2009a, 126). There is also some evidence for Early Bronze Age exploitation from the mountainous areas in the Banat region of south-western Romania (Ottaway 1994, 70). Only future survey work, which has so far been almost missing completely within

Romania (Boroffka 2009a, 121), will hopefully help to obtain a clearer picture of prehistoric mineral exploitation in Romania.

There are several ways of identifying prehistoric copper mines. The presence of grooved stone hammers, found around and in the possible mining sites, is a good indicator of prehistoric extractive metallurgy (Bogosavljević 1995, 37; Ottaway 1994, 43; Žebrák 1995, 13). Other tools used in prehistoric mining activities are antler and bone picks (Ottaway 1994, 44-45). The presence of these early mining tools is, however, not enough to date the sites in question. Relative dating can be achieved when typologically distinct pottery fragments, or even complete vessels, are present in a secure context. An interesting example are the pottery 'hoards' and 'altars' from mining shafts in the Rudna Glava mine, which are typologically part of the Gradac phase of the Vinča group (Jovanović 1979, 106-107; 1990, 57; Jovanović 1994; Ottaway 1994, 54). Dating of Rudna Glava has now been confirmed by radiocarbon dates, which place the mining activities firmly within the 6th and 5th Millennia BC (Borić 2009, 237). Aj-Bunar has been dated by Karanovo VI Gumelnița pottery to the first half of the fifth millennium cal BC (Gale 1991, 41; Ottaway 1994, 55).

Compositional and lead isotope analysis in ore sourcing

A further method of establishing prehistoric copper mines is through compositional and lead isotope analysis. Samples of ores and objects can be analysed and matched, exposing new potential copper mines, or matching objects to already known mines. This is a very simplified account, as both compositional and lead isotope analyses bring with them numerous problems (Budd et al. 1995; Ixer and Budd 1998; Needham 2002; Ottaway 1994, 157-163; Pernicka 1986; Schulz 1983). The SAM project (see Chapters 2, 5 and 10) was the so far largest project, analysing the chemical composition of some 22,000 samples (Junghans *et al.* 1960, 1968a, b, c, 1974). The samples included objects from all over Europe, but the second part of the project, which was designed to carry out a comprehensive analysis of the European copper ores, was unfortunately never completed (Pernicka 1995a, 66). All early projects used optical emission spectrography, which has now been replaced by other methods with higher resolution like atomic absorption spectroscopy, neutron activation analysis, X-ray fluorescence and inductively coupled mass spectrometry (Gilmore and Ottaway 1980, 241; Ottaway 1994, 155). Despite the advances in technology, the chemical composition of objects and ores is not enough to securely match an object to a specific ore source. Ottaway

identified five key problems when using compositional analysis to identify the metal source of objects (Ottaway 1994, 157).

1. Ores from the same deposit can have differing trace element compositions
2. Ores with similar trace element proportions can originate from different deposits
3. Not enough research has been carried out into the behaviours of different trace elements during the smelting and casting processes.
4. The composition within copper objects is often not homogeneous
5. Metal is a recyclable material, and any mixing and re-melting of objects originally from different deposits, can bias the results

It is now widely accepted that in order to match objects to their metal source, a combination of chemical composition and lead isotope analysis should be used (Begemann *et al.* 2001, 44; Needham 2002; Budd *et al.* 1995; Ottaway 1994, 163; Pernicka 1995a, 99; Schmitt-Strecker and Begemann 2005, 50). The advantage of lead isotope analysis is that the values do not change throughout the process of mining, smelting and casting (Ottaway 1994, 162; Schmitt-Strecker and Begemann 2005, 50). Even though the isotope ratios are not affected by smelting and casting, the methodology is not as straightforward as it might seem (Budd *et al.* 1993b; Gale and Stos-Gale 1992; Gale and Stos-Gale 1993a; Gale and Stos-Gale 1993b; Leese 1992; Pernicka 1992, 1993; Reedy and Reedy 1992; Sayre *et al.* 1992, 1993). Lead isotope ratios can vary within a deposit and overlap between different deposits (Budd *et al.* 1993a, 243; Gale and Stos-Gale 1992, 311; Pernicka *et al.* 1997, 106). This has obvious implications for the accuracy of matching objects to their ore sources. The accuracy can be maximised when all three possible isotope ratios are taken into account (Gale and Stos-Gale 1992, 311). A further problem is the possibility of lead from a different source finding its way into the finished product through fluxes or indeed the recycling of metals (Pernicka 1992, 325). Slags are therefore sometimes more useful in matching up working areas to finished objects as they include all the lead that would be in the finished object (Pernicka 1992, 325).

Despite these problems, some very insightful case studies have been published from the 1990s onwards. Two important research projects were published in the 1990s, by a group led by Gale and a group led by Pernicka representing the 'British' and 'German'

schools of lead isotope analysis respectively (Gale *et al.* 1991; Gale *et al.* 1997; Pernicka *et al.* 1997; Pernicka *et al.* 1993). Both projects looked into the assignment of artefacts to specific ore sources in Bulgaria and Serbia using a combination of chemical composition and lead isotope analysis. The publications come to similar conclusions regarding the use of the two known copper mines Aj-Bunar and Rudna Glava. Whereas no objects or ore pieces from archaeological contexts which share both a chemical and lead isotope ‘finger print’ with the ore samples from Rudna Glava were analysed, quite a few stratified ore pieces from settlements as well as objects can be traced back to Aj-Bunar (Gale *et al.* 1991, 72-73; Pernicka *et al.* 1997, 143)

In a more recent article, Gale *et al.* (2003) looked again at the possible provenance of copper objects and ores from Bulgaria. The main patterns were confirmed as none of the objects analysed (except possibly one) can be traced to Rudna Glava whereas quite a few objects might have been made from Aj-Bunar copper (Gale *et al.* 2003, 169). Although some objects sampled from Pločnik and Varna have a similar lead isotope ratio to the deposits of Aj-Bunar, the results for all the objects are slightly displaced from the normal distribution of the lead isotope ratio. As the objects alone have a consistent signature, the authors argue that they might come from a so far unknown copper deposit, which has a slightly different signature to Aj-Bunar (Gale *et al.* 2003, 169).

In an interesting study carried out by Schmitt-Strecker and Begemann, the results from both lead isotope analysis and chemical composition of Copper Age heavy tools point to the copper deposits at Majdanpek, in Serbia (Schmitt-Strecker and Begemann 2005, 58), adding a further possible mine to the already mentioned sites for the Copper Age. This was confirmed by objects from Belovode and possibly Selevac and Medvednjak (Radivojević 2007, 109). The determination of lead isotope ratios and chemical composition of artefacts from Belovode and recent investigations in Bulgaria have also finally produced evidence for objects and ore pieces coming from the copper mine of Rudna Glava (Dimitrov 2002, 136; Iliev *et al.* 2007, 12; Radivojević 2007, 109). The results of the lead isotope studies for Serbian and Bulgarian artefacts has shown how complicated the routes of supply and trade must have been during the Copper Age. It is unfortunate that Hungary and Romania have not seen similar research activity. As it is, the Carpathian Basin is still a blank when it comes to the provenance of the metal for the copper hammer-axes and axe-adzes. This is probably due to the lack of confirmed Copper Age mining sites from this area. The studies mentioned above have shown,

however, that lead isotope analysis can identify possible copper deposits even if there is no archaeological evidence for prehistoric exploitation.

6.2 Smelting

The next stage in the metallurgical process is the smelting of ores. Despite the clear evidence for Copper Age mining there was, until recently, hardly any evidence for smelting (Ottaway 1994, 56). Although more evidence has come to light, the discrepancy between the amount of copper being exploited and the known slag finds is too large to be explained by the simple absence of evidence. One theory which might explain this discrepancy is thought to lie in the low iron content of copper objects from Europe. Metallic iron is only obtained and taken up by copper in a reducing and, therefore, slagging smelting process (Craddock 1990, 70). The low iron content of European artefacts points therefore to a smelting process carried out in open, oxidising furnaces (Craddock 1990, 70). Thinking of the many copper ore deposits where only primary copper ore was available, it must have been possible to smelt these ores in an oxidising environment. Craddock mentions one example where the formation of metallic copper was noted during the experimental roasting of sulphide ores (Craddock 1990, 70). Other experiments have also shown that it is possible to smelt oxide as well as sulphide copper ores in oxidising conditions, without a formal furnace structure being necessary (Craddock 1990, 70; Lorschneider *et al.* 2003, 306; Timberlake 2007, 34). The lack of any smelting related refractory ceramics also points to a 'simple' smelting process.

Examples of possible smelting sites seem to confirm non-slagging smelting in oxidising environments. One such site, which has evidence of smelting and manufacture is Selevac, yielding ore, slag and copper prills (Glumac and Tringham 1990, 551). A re-evaluation of the hand-written notes of the original excavation at Vinča comes to the conclusion that a number of pits might have been used for copper smelting (Antonović 2002, 36). Although there are some slag finds, their conspicuous absence seems to confirm that copper was smelted in simple open furnaces or even hearths.

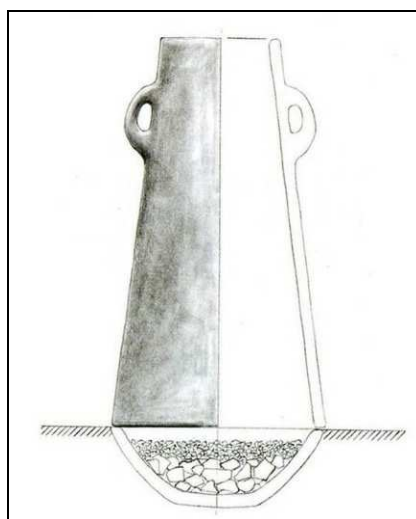


Fig. 5: Conical vessel from Belovode, which was interpreted as a ‘furnace chimney’ (source: Radivojević 2007, p. 40, Fig. 29)

Recent excavations at Belovode in eastern Serbia, have uncovered exciting new evidence for the processing and smelting of copper ore dating to the late 6th millennium BC (Borić 2009, 208; Radivojević 2007). Large conical vessels without a bottom have been found (see Fig. 5) and interpreted as ‘chimneys’, which would have been placed on top of a bowl furnace or hearth to create an upward draught and increase the temperature for the smelting of copper (Radivojević 2007, 28). However, a second inspection of the vessels has not found any adhering slag or vitrification, which should have been visible had they been used for the smelting of copper (Radivojević *et al.* 2010, 2779). This also means that at Belovode there is no evidence for formal installations of furnaces. Despite this fact, the authors argue against the mainly ‘slagless’ smelting proposed for early metallurgy, as they say such a scenario is unrealistic (Radivojević *et al.* 2010, 2777). Their claim is confirmed by the investigation of slag pieces from the site of Belovode, which contain previously molten copper particles (Radivojević *et al.* 2010, 2777). Although an intentional entirely slagless smelting process is called into question, the evidence does suggest a smelting process in simple ‘holes in the ground’ at temperatures of about 1100 degrees Celsius at variable redox ratios and temperature conditions (Radivojević *et al.* 2010, 2783-4). This would, of course, explain why there is hardly any evidence for Copper Age furnaces.

It is generally assumed that only oxide ores were smelted during the Copper Age of south-eastern Europe. However, an analysis carried out on Copper Age objects and crucibles from Bulgaria suggests that at least sometimes both oxide and sulphide ores

were smelted, probably in the same charge (Ryndina 1999). Through careful re-evaluation of early excavations and increased use of experimental archaeology it might be possible to better understand the missing smelting activities. A picture which seems to emerge is that the ore must have been transported or traded away from the mines, and smelted locally (Shennan 1999, 359).

6.3 The production and use of metal artefacts

After smelting the ore, the metallic copper has to be transformed into objects through casting and/or hammering. As mentioned in the introduction, the earliest copper artefacts including awls and fishhooks in south-eastern Europe date to the 6th millennium BC (Ottaway 1994, 229-231; Pernicka *et al.* 1997, 46; Todorova 1981, 4), and were probably made from native hammered copper. Evidence for the use of malachite in the form of beads or powder for pigments is found even earlier (Borić 2009, 237). The ‘sudden’ explosion of hot metallurgy (smelting and casting) opened up opportunities for new artefact forms. The copper axes with central shaft-hole are the most substantial example of the new skills which developed after the initial invention or even discovery of the unique properties of copper. Not only are these axes unique to south-eastern Europe at this time, the early hammer-axes can also be argued to copy local ground stone axes. The local innovation of these enigmatic objects can therefore be seen almost as a certainty (see also Chapter 1). This local impulse for the invention of large cast copper axes, as well as their large numbers, is the reason the Carpathian region developed or is seen to have developed into a metallurgical centre (Ryndina and Ravich 2000, 7). South-eastern Europe was indeed a real centre and objects made in the area travelled hundreds and even thousands of kilometres (Klassen 1997).

6.3.1 The copper axes with central shaft-hole – their shapes and distribution

Before looking closer at the possible production, the different axe shapes within the assemblage under study will be considered. All scholars working on this material have probably divided the objects into hammer-axes and axes with two cutting edges. At the end of the 19th and the beginning of the 20th century, the shaft-hole axes with one cutting edge were also seen to be part of this group of objects, but they are now dated to the very end of the Copper Age and the early Bronze Age. A striking difference is also that there are numerous mould finds for the later shaft-hole axes, which sets them apart

from the hammer-axes and axes with two cutting edges. By far the most common form is the axe-adze (see Fig. 7 B).



Fig. 6: A hammer-axe and an axe-adze (source: Author)

An axe-adze has two cutting edges either side of the central shaft-hole, one of which is set vertical, and the other horizontal. This is why they are sometimes called axes with crosswise opposed cutting edges or ‘Kreuzschneidige Axthacken’. The term axe-adze describes the two cutting edges, as one can only be used as an axe and the other as an adze when the object is hafted. The second most common object form is the hammer-axe (see Fig. 6 A). As the name suggests, one end of the object is an axe cutting edge, whereas the other is a blunt end, like a hammer.

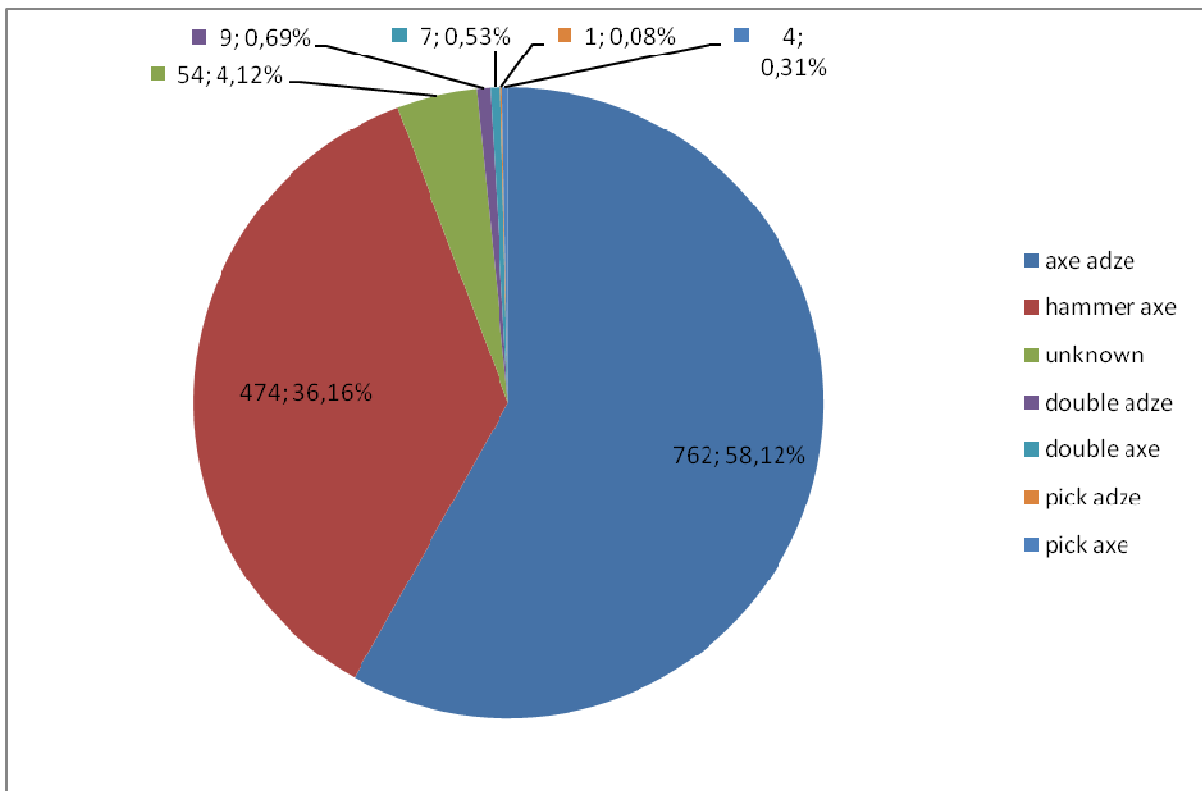


Fig. 7: Number and proportion of different axe forms (source: Author)

4% of axes are fragmented or broken in such a way that it is not possible to tell what form they are (see Fig. 7). The last four shapes, or shape combinations make up just under 2% of the known early copper axes with a central shaft-hole (see Fig. 7). The double-adze has an adze-like cutting edge either side of the shaft-hole; the double-axe has an axe-like cutting edge either side of the shaft-hole. The pick-axe has one pointed end and an axe cutting edge, and the pick-adze has again one pointed end, the other arm ending as an adze. In theory the different forms can be combined in any number of ways, which makes the domination of axe-adzes and hammer-axes a point of interest when thinking about the function or utility of these objects. Why, for example, was a hammer-end always combined with an axe-end and not for example with an adze-end? One has to remember, of course, that the objects available to us today are only a fraction of the objects which would have been in circulation during the Copper Age, but still, a total of over 1300 objects is a decent sample size and such obvious patterns, as seen in Fig. 7 are clearly significant.

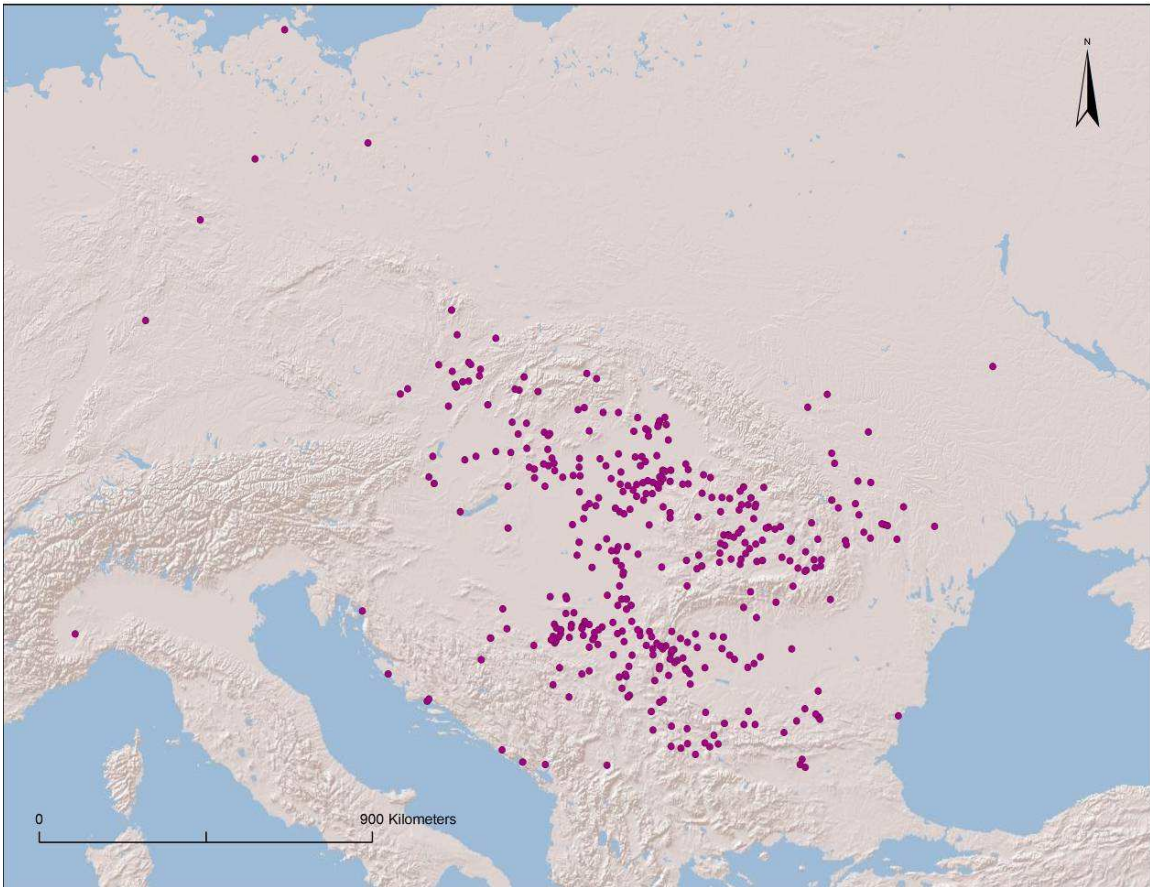


Fig. 8: The spatial distribution of axe-adzes (source: Author)

Looking at the spatial distribution of the axe-adzes and hammer-axes (see Fig. 8 and 9) it becomes apparent that there is not a marked difference between the two object forms, although some slight variations should be highlighted. The axe-adzes cluster in at least three distinct areas, namely the northern Hungarian plain, Transylvania and around the Danube gorges, making for a relatively even spread throughout the distribution area. The hammer-axes, on the other hand, are visibly more common in the northern parts of the study region, the only cluster occurring in the North of the Hungarian Plain. Both axe types are also found hundreds and even thousands of kilometres away from the main distribution area.

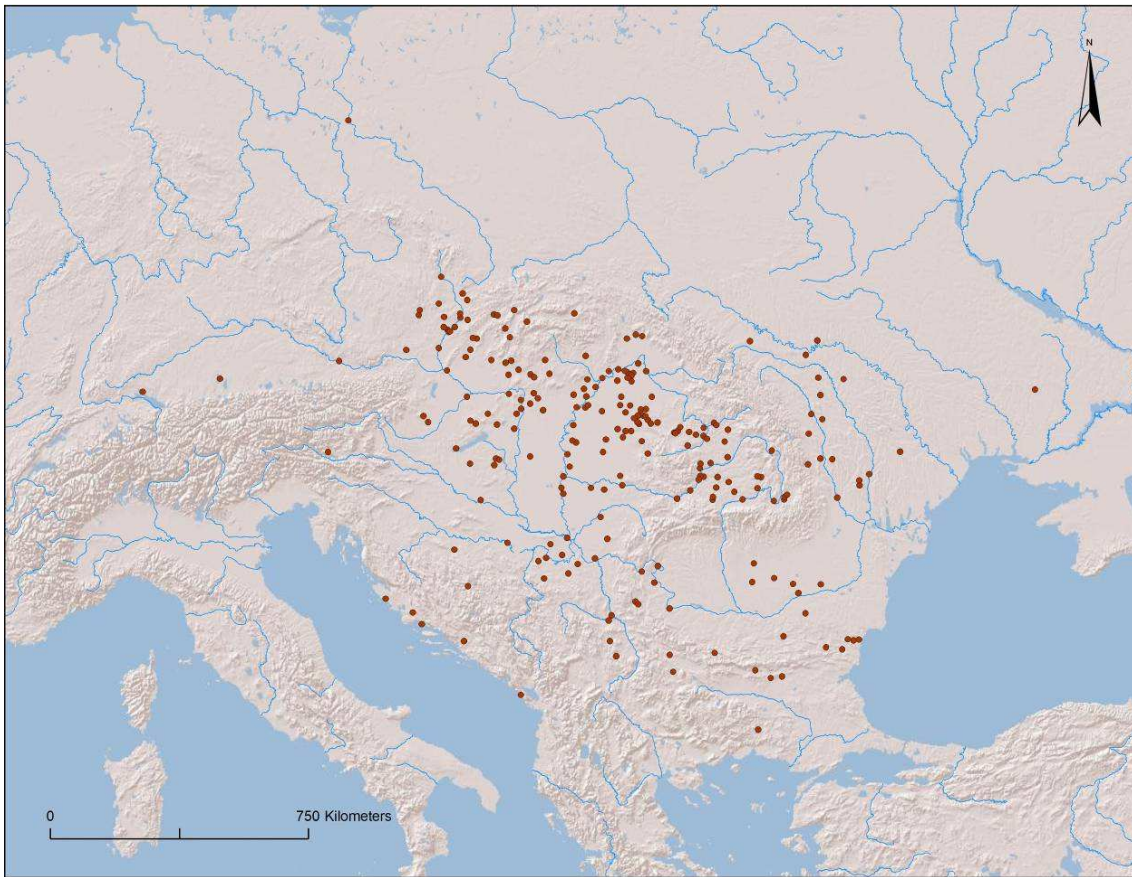


Fig. 9: The spatial distribution of the hammer-axes (source: Author)

6.3.2 Problems and possibilities of production – a re-discovered copper axe blank

Although it is only possible to discuss the mining and smelting of the metal for the large axes indirectly (see above), one might have thought that the production and use can be considered in direct relation to the artefacts under study in this thesis. However, this is only true to a certain extent, as the majority of axes are single finds, and there is not a single known Copper Age ‘casting’ site which can be said to have been used for the production of these axes. This scarcity of any tools or artefacts related to the production process does not only concern the large copper axes, but, to varying degrees all metal artefacts.

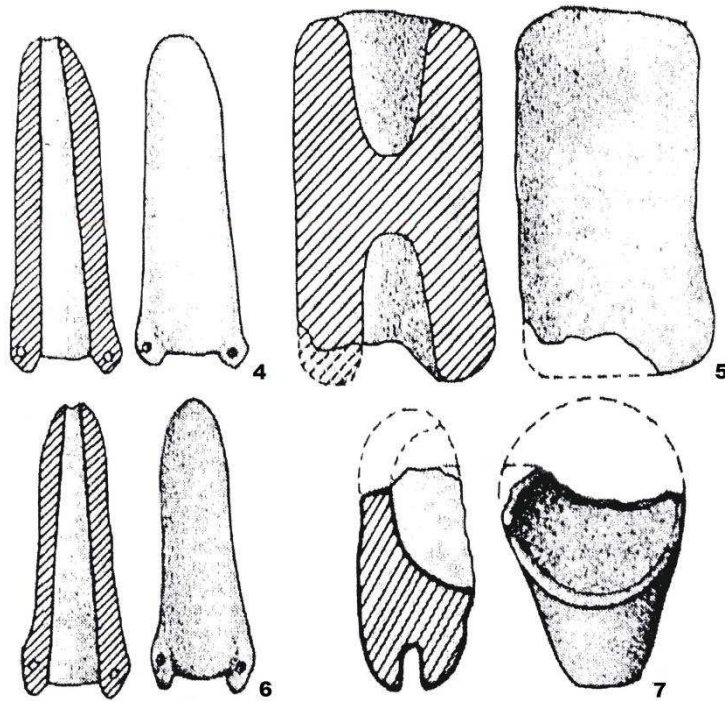


Fig. 10: Two tuyères, described as phalli in the original publication (4, 6), a crucible (7) and an unidentified clay object (5) (source: Cucos 1995, Fig. 67)

Although there are isolated finds of tuyères and crucibles (see Fig. 10), which do attest the (s)melting process, moulds or fragments of moulds are entirely unknown from south-eastern Europe. A recent article has drawn attention to a number of moulds for copper axe-adzes from Iran, Afghanistan and Uzbekistan (Boroffka 2009b, 252-253). They do indeed look like the moulds one might have imagined for the copper axe-adzes of south-eastern Europe. They are open one-piece or two-piece moulds, with inserted cores for the shaft-hole (see Fig. 11), and would have to be broken in order to free the cast axe. It is argued that such moulds could have been used in south-eastern Europe, as the earliest mould, which was found at Tepe Ghabristan, Iran is contemporary with the later axes from south-eastern Europe (Boroffka 2009b, 254). However, as the oldest mould dates to around 4000 cal BC (Mathews and Fazeli 2004, 64), it is unlikely that these Near Eastern moulds had a connection to the copper axes from south-eastern Europe.

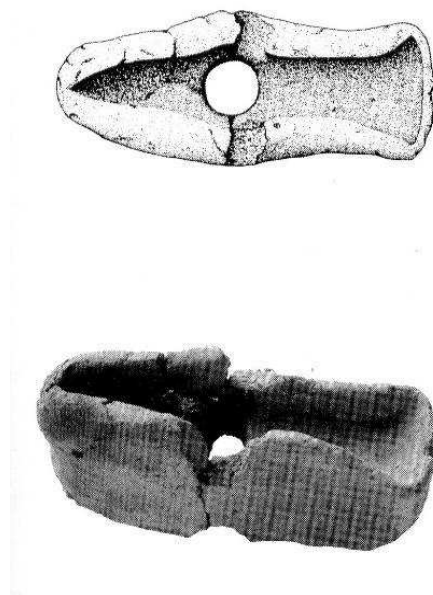


Fig. 11: A mould for an axe-adze from Tepe Ghabristan, Iran (source: Boroffka 2009, p. 253, Fig. 6)

The higher ratio of moulds to axes from Central Asia makes the missing moulds from south-eastern Europe even more puzzling. The few tuyères and crucibles from south-eastern Europe show that if fired clay moulds existed they would have been found by now, even if they were broken to extract the finished object. What sort of material might have been used, which does not survive in the archaeological record? One possibility could be unfired clay. Although the temperature of copper during casting lies well above 1000° C, it is not maintained long enough to fire the clay mould. Unfired clay disintegrates after being left in the rain, meaning it would not likely survive 6000 years. A second alternative, which would hardly leave any traces for the excavator to find, is casting into sand. This technique has also been proposed for some objects during the Bronze Age (Goldmann 1981; Ottaway and Seibel 1998). Due to these difficulties it is not surprising that there is no consensus regarding the production techniques of the copper hammer-axes and axe-adzes from south-eastern Europe. Metallographic analyses do indicate that the copper axes were cast (Kienlin and Pernicka 2009; Pittioni 1957; Renfrew 1969; Ryndina and Ravich 2000, 2001), but exactly how they were cast is still uncertain. This becomes particularly apparent when comparing the suggestions made in the literature (see Table 5). The lack of consensus is sometimes also due to researchers being unaware of the full extent of published material.

Table 5: Different production techniques for the copper axes from south-eastern Europe from the literature

Source	Production technique
Childe 1944, 9-10	Axes were not cast, but forged from native copper.
Berciu 1942	Lost wax casting, although some might have been only forged
Garašanin 1954, 71	Notes hammer marks on many axes and a casting seam on one axe from Serbia. (The 'casting seam' is probably created by corrosion)
Coghlan 1961; Pittioni 1957	Cast in open moulds, possibly without shaft-hole core. Finished by forging, shaft-hole drilled or forged?
Charles in Renfrew 1969, 40-42	Cast in open moulds, shaft-hole created through clay core. Finished by forging.
Vulpe 1975, 18	Cast in open moulds, shaft-hole created through clay core. Finished by forging
Patay 1984, 13	Cast in open moulds. In some cases the shaft-hole was punched through the still liquid metal.
Ryndina and Ravich 2000, 9	Cast in two part open, partially open and closed moulds, including core for the shaft-hole. Finished by forging.
Mareş 2002	Lost wax or two part moulds.
Kienlin and Pernicka 2009, 270	Cast in two part closed moulds, including core for the shaft-hole. Only minor finishing through forging.

This means that the analysis of the microstructure of these axes is one of the more reliable methods to shed light on the potential production. Metallographic analyses were mainly published in the 1950s and 60s as well as during the last 10 years (Coghlan 1961; Kienlin and Pernicka 2009; Mareş 2002; Pittioni 1957; Renfrew 1969; Ryndina 2009; Ryndina and Ravich 2000, 2001). Pittioni, Coghlan and Charles are in agreement that the axes were cast in open, fairly basic moulds (even rectangular), and were later finished through forging. They justify their claim through the presence of oxygen inclusions on one (upper) side of the axes (Renfrew 1969, 31). Ryndina and Ravich (2000, 9; 2001, 7) come to a slightly more differentiated result, as they propose a variety of different mould shapes (open, partially open and closed moulds) for the different axe types. They also used the presence of oxygen inclusions on only one side of the axes as the reason for the use of open and partially open moulds (Ryndina and Ravich 2000, 9). Kienlin and Pernicka (2009, 270) on the other hand, come to the conclusion that at least the axe-adzes were cast in closed moulds as oxygen inclusions do not occur on just one side of the objects. This difference might be due to the fact that they only sampled axes at the cutting edge, whereas the other scholars took samples from all over the axe body (Coghlan 1961; Pittioni 1957; Renfrew 1969; Ryndina and Ravich 2000). A further disagreement lies in the production of the shaft-hole. Pittioni

and Coghlan suggest that the shaft-hole might have been added after the object was cast through drilling or drifting (Coghlan 1961, 70-72; Pittioni 1957, 27). Charles, Ryndina, Ravich and Kienlin on the other hand believe that the shaft-hole was created by using a core during the casting of the axes (2009; 1969; 2000). The theory of creating the shaft-hole after the object was cast is outdated according to the current state of research (Kienlin and Pernicka 2009, 270). However, the re-discovered axe blank in question has re-opened the debate on the production of the shaft-hole.

History and description of the axe blank

On first sight the artefact might be described as a blank of a copper axe-adze that was waiting to be finished by forging. This circumstance in itself is unique and remarkable. However, this blank becomes even more interesting for the debate on production as it does not have a shaft-hole (see Fig. 12). It is therefore astonishing that it has so far never been mentioned in any of the discussions on production. The axe blank has been lying in the storerooms of the Museum für Vor-und Frühgeschichte Berlin and was never recognized for what it really was until I was looking at some finished copper axes on the store shelves in the summer of 2009. I can only assume that researchers looking into the south-eastern European copper axes never actually got access to the storerooms as they would have immediately spotted the importance of this object. It is also the case that a number of finished axes from the Museum in Berlin are still unpublished, and do not appear in the PBF volumes. The axe blank was given to the Museum in 1909 by an unknown benefactor. The findspot is given as Holics-Göding in the former Austro-Hungarian Empire. The names refer to the two modern towns of Holič (Slovakia) and Hodonín (Czech Republic), which lie facing each other either side of the Morava River. The object was given to the museum together with two finished axe-adzes from the same findspot, which might indicate that they were all part of a hoard. As there is no more detailed information on the find circumstances this will remain only an assumption. The axe blank was even sampled and analysed for its chemical composition as part of the SAM project. Despite this, the object never came to the attention of archaeologists researching the copper axes from south-eastern Europe. This might be due to the fact that it was described simply as 'axe blank' (Analysen Nr. 9825) amongst 22,000 objects and could therefore refer to any axe of any period. This unique find therefore, remained undiscovered and can only now contribute to the debate on the production of the copper hammer-axes and axe-adzes.

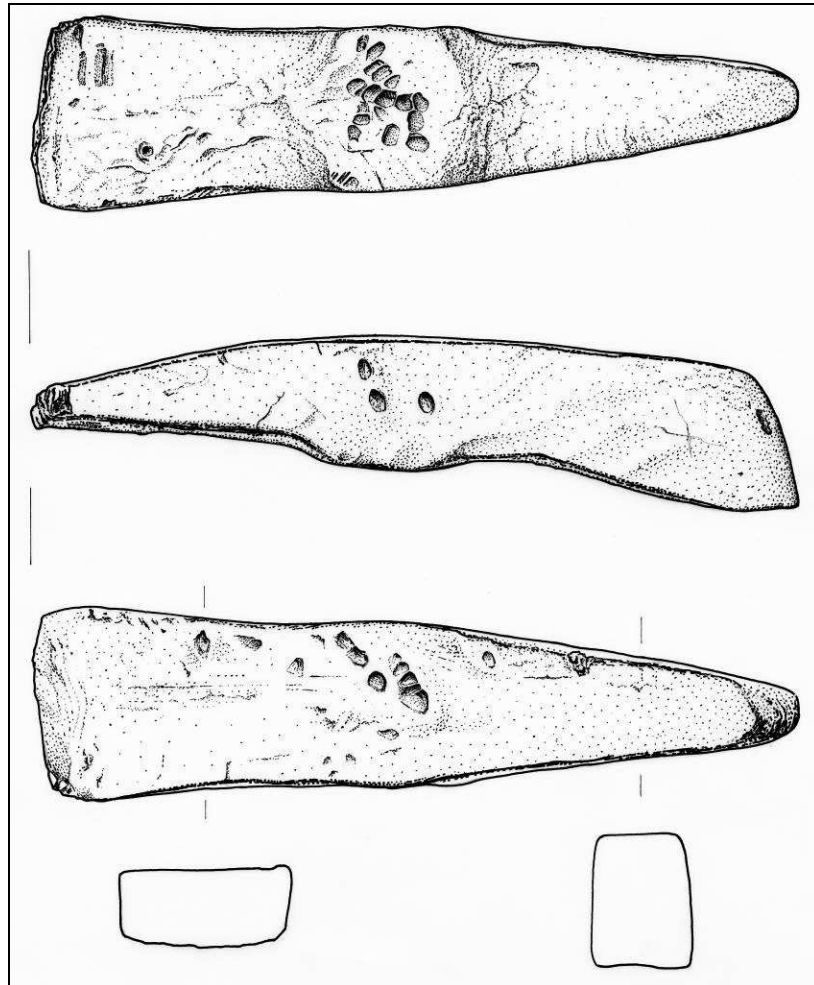


Fig. 12: Drawing of the re-discovered axe 'blank' from the Museum für Vor-und Frühgeschichte Berlin (drawing: D. Greinert)

The axe blank is 18.7 cm long and weighs 1332 g. The surface is relatively smooth and only slightly corroded. The colour is a dark reddish brown with some dark green patches. The object has one axe and one adze arm (see Fig. 12). The upper surface is almost straight, which might point to the object having been cast in an open mould. However, the adze arm is bent downwards when looking at the axe in profile. There is a central thickening visible both on the lower and upper side, which looks as if it was made for the shaft-hole. The axe cutting edge is still blunt and has a thickness of about 1 cm. The adze cutting edge shows clear signs of deformation. Important details are the round marks, which are situated on the lower (17 marks) and upper (6 marks) side where the shaft-hole would be located, as well as on one side (3 marks). There are no casting seams or traces visible and the surface of the lower and upper side are identical. This means that the conditions during casting were the same on both sides (closed mould). Alternatively there might have been a stage in the production sequence after casting, which resulted in the homogeneity of the surface.

Possible meaning of the 'axe blank'

Before looking at the implication this object has for the general understanding of the production sequence of copper axe-adzes and hammer-axes, we need to consider the different potential explanations of how this 'axe blank' was made, and how it was meant to be finished. There are two aspects which need to be discussed in more detail. Firstly, the artefact is very 'chunky' and it would take a lot of time, skill and effort to transform it into a slender and elegant axe-adze. The second aspect is the missing shaft-hole. Let us first look at the effort involved at finishing the object. Metallographic analysis has shown that a number of steps were involved in making the axe-adzes, including casting, cold working and/or hot working (Kienlin and Pernicka 2009, 265). It is only the extent of the hot and cold working which is still being debated. Some even argue for a rectangular solid block as the cast blank for the hammer-axes and axe-adzes (Renfrew 1969, 40), whereas two recent studies argue that the shape of the cast blank would be much closer to the final form and that hot and cold working was only used to finish the surface (Kienlin and Pernicka 2009, 270; Ryndina and Ravich 2000, 9). The shape of the 'axe blank' under discussion might be placed somewhere between these two approaches. It is odd, however, that the 'blank' was not cast closer to the final shape, as this does not seem to be a big step technologically. The same question can, of course, be posed regarding the missing shaft-hole. Why was it not cast as well? Although the overall shape of the possible axe blank has to be taken as intentional; the missing shaft-hole can be interpreted in a number of different ways.

1. Shaft-hole was intended to be added later
2. Shaft-hole was forgotten
3. It is not a blank but an ingot
4. It is not a blank but a pattern

What are the arguments for each of the different explanations?

Alternative 1 Axe blank, shaft-hole was intended to be added later

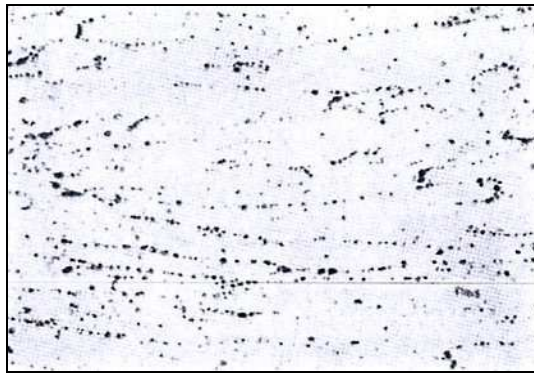


Fig. 13: Elongated grain boundaries along the shaft-hole (source: Pittioni 1957, Fig. 15)

It seems technically extremely difficult to insert a shaft-hole into a solid piece of copper with the materials available in the Copper Age due to the ductility of the material. However, there are two possibilities worth considering. The shaft-hole might have been punched/cut through the heated metal with a mallet and hardened copper chisel. The other possibility would be to drill the shaft-hole as was done for the Neolithic stone axes. Both options have been already proposed by Coghlan (1961). His experiments were based on findings published by Pittioni (1957) and some new metallographic results from copper axe-adzes and hammer-axes from the Ashmolean Museum (Coghlan 1961, 59). One of the most interesting features was that the microstructure around the shaft-hole had a very different character to the rest of the object (Coghlan 1961; Pittioni 1957). The grains were elongated or stretched, which made Pittioni suggest that the shaft-hole was put in after the object was cast (Pittioni 1957, 27). It was suggested that the elongated grain structure (see Fig. 13) along the shaft-hole was caused by punching through the heated copper. The lip present around the shaft-hole in some axe types would be caused by this action and the forging used to finish the object (Pittioni 1957, 27). See also Chapter 7.



Fig. 14: A fragmented axe-adze with potential traces of a chisel on the shaft-hole walls (source: Author)

These ideas were taken up by Coghlan who had detected a similar pattern of grain elongation of the boundaries along the shaft-hole in the axes from the Ashmolean Museum (Coghlan 1961, 70). However, rather than opt for the forced punching of the re-heated object to obtain the shaft-hole, Coghlan explored other options like drilling or drifting after it had been cast, in order to replicate the elongated grain boundaries (Coghlan 1961, 70-72). Although he proposed the drilling of the shaft-hole, he only tried the drifting and cutting of hot copper experimentally (Coghlan 1961, 70-75). The drifting did not alter the microstructure along the shaft-hole, and the chiselling was carried out using a bronze chisel, which would not have been available during the Copper Age. The chiselling of the shaft-hole would leave the interior irregular, which is not observable in the majority of axes. It is therefore unlikely that this technique was used in prehistory. However, there are some examples which do have some odd cutting marks visible on the inside of the shaft-hole (Fig. 14). It is difficult to ascertain, whether these marks have a connection with the production process or not. They might have also been added later, either intentionally or by accident, although they occur too frequently for the latter.

Coghlan's idea of drilling the shaft-hole is illustrated in Fig. 15. Having looked at numerous hammer-axes and axe-adzes, it is difficult to imagine that the shaft-holes were inserted in the way proposed by Coghlan. They are too regular and do not show any traces of such small holes having been cored, as little indentations would surely be visible in the wall of the shaft-hole.

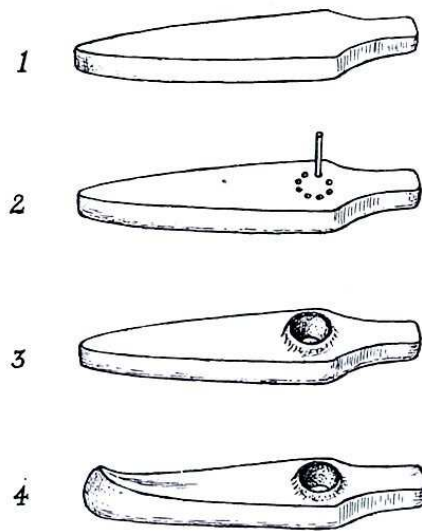


Fig. 15: Coghlan's proposed method of copper axe production (source: Coghlan 1961, Fig. 14)

The irregular marks seen on the axe blank might, at first sight, be connected with drilling the shaft-hole after casting, as they occur where the shaft-hole would be situated (Fig. 12). They also look very similar to those proposed by Coghlan (Fig. 15). The marks could have been either made by drilling, or through driving in some sort of punch into the still soft or already hardened metal. When looking at these marks in detail, we can see that they are oval in shape, which means that they were not drilled. It can therefore be assumed that they were punched, although it is not possible to say if the metal was soft or hard. The section of the marks is semicircular, which makes them different to the marks seen on the finished objects (see Chapter 10). The more decorative marks on the finished objects have rectangular sections, and sometimes small central protuberances. If the object under discussion was indeed an axe blank into which the shaft-hole was meant to be driven in later, the marks would be considered the first step in the process. As the marks were punched, however, it is unlikely that an entire shaft-hole could be produced through repeated punching with a blunt object. A second production step would be necessary, for which we do not have any evidence so far.

Alternative 2 Axe blank, shaft-hole was forgotten

A further explanation could be that the shaft-hole was forgotten, meaning the object is in fact an erroneous cast. The round marks could in this case be explained as an attempt to 'save' the axe. If this were the case why did the object survive and why was it not re-

melted immediately? The fact that the 'blank' was found together with two finished objects might point to the hoard of a metal smith, who planned to re-melt the flawed cast later on.

Alternative 3: Ingot

The 'blank' could also be explained as an ingot. The solidity, compactness and relative weight might also be used as an argument for this alternative explanation. However, as it is so far the only find of this nature, it is rather unlikely that it is an ingot.

Alternative 4: Pattern

The object in question might have been used as a pattern to press a negative of the object to be cast in either wet sand or clay. A shaft-hole would in this case not be necessary, as a core could be inserted into the mould (see Chapter 7). This technique would be compatible with the theory that the axes were cast into sand or unfired clay moulds. Although this explanation might seem plausible, there are two factors that speak against it. A pattern can be made much more quickly and easily from clay or wood. The other aspect is that the punched marks, which occur on three sides of the objects, cannot be explained if the artefact was meant to be a pattern.

Thinking about the possible axe blank discussed above, the only alternative explanation which seems to hold up to closer scrutiny, is the subsequent drilling of the shaft-hole. The axe blank is, as already mentioned, extremely solid and intense forging would be necessary to transform it into the final shape. If some axes did indeed start as such rough blanks, the subsequent creation of the shaft-hole might have the simple reason that it would not be deformed during the forging process, as the shaft-hole in finished axes are almost always circular. A circular cast shaft-hole might be preserved using the horn of an anvil, but as yet there are no known anvils from the Copper Age. Whether a wooden instrument could have been used for the same purpose is difficult to establish. The oval marks might have been created through fixing the object to something during the forging, although this would not explain why they occur on three sides. It is unlikely that the shaft-hole was forgotten during the casting process as this would make it even during the Copper Age a very rare object. Considering that the surviving axes today are thought to represent only a fraction of the axes in circulation in the past, it is improbable that specifically this artefact should have survived. I think it also unlikely that the artefact was used as a pattern as this would not explain the punched marks. The same

goes for the explanation as an ingot, as surely more examples of the same shape would have survived. Comparisons cannot be made as so far it is a unique find. A ritual explanation has to be mentioned at this point as well, although this will always remain speculation. The fact that the axe blank might have been part of a hoard is not enough to discuss this possibility at greater length. The most likely explanation therefore remains that the shaft-hole was meant to be added later.

6.3.3 The implications for the copper axes in general

At first sight, this object seemed like an answer to the riddle of production, but on closer inspection it creates more questions than it answers. The current knowledge about the manufacture of the copper hammer-axes and axe-adzes stands partly in contrast to the axe 'blank'. If we did not take the finished axes into account, an explanation as a blank would be the most convincing alternative, which would imply that the shaft-hole was added later. However, the shaft-hole lips, which are present on the vast majority of axe-adzes, are a clear argument against the subsequent creation of the shaft-hole. We cannot rule out though that in some examples the shaft-hole might have been drilled or driven through the solid metal, especially as there are some axe types which do not have any shaft-hole lips. Some of the earliest copper axes are the hammer-axes of the Pločnik type (Patay 1984, 39). These axes are very like the stone shaft-hole axes of the same period. This similarity to the ground stone axes could be used as another argument for the shaft-hole being drilled. Maybe not in the way proposed by Coghlan (see Fig. 15) but a thicker drill piece might actually work and would explain both the missing shaft-hole lips in some axe types as well as the axe blank discussed above (see Chapter 7). Pittioni has already pointed out that the casting of a rough shape in an open mould, with the shaft-hole being added in a separate step, shows great similarities to the production of stone shaft-hole axes (Pittioni 1957, 27). Clearly if this was the case it would have interesting implications for thinking about innovation and cognitive processes of the Copper Age metal smiths. To use the same technique to obtain a shaft-hole in the early copper axes as was used for the stone axes would mean that rather than fully understanding the qualities of the new material, early copper smiths clung to their traditional techniques.

As even the axes without shaft-hole lips were poured, the creation of the shaft-hole when the metal had cooled down seems somewhat odd. Pouring liquid metal into a pre-

shaped mould is a fairly large conceptual step to make from grinding a stone into an axe shape. One could argue that the melting of the metal and the pouring into a mould would make it almost inevitable that the shaft-hole itself was part of the mould. However, it is dangerous to assume the most logical explanation from our modern point of view, as techniques evolve due to a multiplicity of factors and entanglements, related to the specific environment of an invention at the time (see Chapter 3).

There is a further possibility, mentioned by Pulszky as far back as 1884. “Copper axe-axes and hammers are usually an exact copy of the stone axes and hammers, with the main difference being that the shaft-hole in the copper axes and hammers was not drilled or cast, but was achieved by piercing the glowing copper with a copper rod, which led to the development of a sort of ring around the shaft-hole, which is often far too irregular to be seen as decoration” (Pulszky 1884, 59). Patay states that certain types of hammer-axes do seem to show morphological indications of a process where the shaft-hole was forced through when the copper was still hot (Patay 1984, 13). Although this production technique would not explain the axe types without shaft-hole lips or indeed the ones with shaft-hole lips at either side. What it could explain, however, are the axes that only have one shaft-hole lip at the bottom (see Chapter 7). The picture which is emerging is that the axes might have actually been produced by a multiplicity of production techniques, but more research is necessary to understand the picture fully.

The question of an open or closed mould being used for the casting of these objects could potentially be answered by a systematic analysis of the microstructures. The study carried out by Ryndina and Ravich (2000, 9) is a very good starting point, as they too argue for a variety of different mould shapes having been used. Such an investigation could also answer if the artefacts were cold-worked or forged after casting (Kienlin 2004, 2006; Kienlin and Pernicka 2009). Recent experimental research has also shown that it might be possible to determine the mould material by looking at the microstructure of the archaeological objects (Jochum Zimmermann *et al.* 2002; Wang and Ottaway 2003; Wang and Ottaway 2004). At the moment, though, the experimental reference collection available through published material is only in its early stages (see Chapter 8).

6.4 Conclusion

Having looked at the evidence for Copper Age mining and smelting within south-eastern Europe, it becomes clear that the metallurgical background of the copper

hammer-axes and axe-adzes is not very well understood. Compositional and lead isotope analysis have shown that the known Copper Age mines cannot have been the only ones, as many objects have entirely different ‘fingerprints’ (Schmitt-Strecker and Begemann 2005, 58). The smelting of the ore was probably carried out in a more or less domestic context, some distance away from the actual mining sites. However, as there is very little evidence for smelting, like slag or formal furnace structures in general, future work might yet uncover large smelting sites closer to some as yet unknown mines. Hundreds or even thousands of kilos of copper must have been smelted somewhere, as the many objects, both large and small, testify. To research these questions further is beyond the scope of this thesis. However, questions regarding the production of the axes themselves, concerning the melting and casting of copper, were explored through experimental archaeology as well as metallographic analysis (see Chapter 7 and 8). There are two main areas worthy of further exploration. The first one concerns the actual melting of the copper (what crucibles did they use?), and the second the casting of the axes (what moulds did they use? How was the shaft-hole produced?). The melting can only be explored experimentally, as this is the only way to try and re-create possible taskscapes as there is not much archaeological evidence. The discussion concerning the possible axe blank has illustrated the problems around the actual shape and material of the moulds, as well as the production of the shaft-hole. In the next two chapters, these problems will be explored, as new insights are gained through an embodied approach to experimental archaeology as well as the analysis of the microstructures of experimentally cast axes and an original Jászladány axe.

7 The Experiments

As I have argued in Chapter 3, experimental archaeology is an invaluable methodology when trying to understand past techniques from an ‘a priori’ perspective. Through the direct engagement with the material world we can not only find answers to our pre-formulated hypotheses, but also expose new questions as well as problems in our theoretical models. Taskscapes and even related *meshworks* can be better understood through such a practical, hands-on approach. In this chapter, experimental archaeology will be employed as an essential part of a holistic approach to archaeometallurgy and archaeology in general. A short discussion of experimental archaeology will be followed by my own experiments.

7.1 Experimental Archaeology – history, definition and scope

Although an experimental or practical approach to the study of the past is as old as archaeology itself, the term experimental archaeology was probably first used or published in Ascher’s 1961 paper on the same topic (Ascher 1961). The term is perhaps in need of some clarification. John Coles describes experimental archaeology as “a convenient way of describing the collection of facts, theories and fictions that have been assembled through a century of interest in the reconstruction and function of ancient remains” (Coles 1967, 1). This fairly ‘open’ definition of the term is actually rather realistic. Although some scholars would prefer to see the term only being used for experiments carried out in the scientific sense of the word (Hypothesis-Experiment-Validate/Refute), the current understanding of the word in general encompasses a variety of practical activities and approaches to the archaeological record.

For some the term experimental archaeology is synonymous with controlled scientific experiments whereas for others it encompasses the vast array of ancient crafts and living history groups, usually situated within open air museums. Reynolds describes an experiment as the testing of a hypothesis under controlled conditions in order to either validate or reject the hypothesis (Reynolds 1999, 157). He states quite clearly that he does not consider activities like re-enactment or demonstrating and learning ancient skills as being part of experimental archaeology (Reynolds 1999, 156). He writes that “it is extremely unfortunate that these activities have become generally subsumed under the overall title of experimental archaeology” (Reynolds 1999, 156). However, the fact that these activities have become part of the general understanding of experimental archaeology cannot be reversed. Mathieu has a slightly different approach to

experimental archaeology. Although he agrees with Reynolds about the basic form (controlled and repeatable) and function (testing of hypothesis to generate analogies about the past) of an archaeological experiment (Mathieu 2002, 1; Reynolds 1999, 157), they disagree about the issues it can deal with. Mathieu (2002, 3-4) includes issues such as phenomenological studies as well as system replication into the scope of experimental archaeology, which are entirely concerned with archaeologically invisible processes. Reynolds (1999, 158) on the other hand thinks, “no experiment can be designed to enhance our understanding of human motive or emotion in the recent or remote past” (Reynolds 1999, 158). Past emotion is impossible to retrieve, but motive might not be beyond the scope of experimental archaeology.

As mentioned above, the scientific experiment with a clear hypothesis stands in contrast to the experiential replication of objects, to name but two possibilities. Although the different approaches are all part of experimental archaeology, one should clearly state when publishing experimental work what approach was taken and how it relates to the archaeological record (Cunningham *et al.* 2008a; Lammers-Keijsers 2005; Outram 2008). The boundaries between the different types of experimental archaeology are often fluid and there is “always an element of experience in an experiment”, but there is “not always an experiment in an experience” (Cunningham *et al.* 2008b, vi). As already discussed in Chapter 3, we can only retrieve as much of the potential past taskscape as possible, if we engage with the material world with all our senses, as it is through this engagement that our theoretical models can be tested. More importantly, the engagement with the material world makes it possible to add many more dimensions to our taskscape. These dimensions were reduced in our minds, and are only made visible when things do not work out as expected. This is why it is so important to pursue both an embodied or experiential approach as well as a scientific experimental approach.

7.2 Actualistic outdoor casting

In order to obtain a deeper, practical understanding of the tasks and problems involved in melting and casting copper using only materials which would have been available in the Copper Age, the first part of the experimental approach were a series of trial experiments. The main problem of these trial experiments concerned the actual technique employed for melting the metal in large enough quantities. The term trial experiment is used as the technique itself was being tried and modified after each run. Not a single undisputed Copper Age casting site is known from the archaeological

record, although judging by the experiments carried out, they could easily have been misinterpreted as hearths. A trial run, carried out as part of my MA dissertation, using a bowl furnace supplied with air from below the crucible, was not successful in melting pure copper in large enough quantities. In September 2006, it was possible to work with and learn from a Swiss bronze casting group called 'Experiment A'. Bronze was melted and cast for five days using different furnace designs and air supplies. The most efficient and reliable model was based on a tuyère found at Sanskimost, in Bosnia and Herzegovina (Fiala 1899). Although the tuyère dates to the Bronze Age and the copper axes are much earlier, it was decided to use this technique for the casting experiments carried out as part of this thesis, as they must have melted the metal somehow, and it would not influence the end result of producing actualistic copper axes. These pre-experiments were carried out with the financial support of the Historical Metallurgy Society through the Coghlan Bequest.

7.2.1 Aim and materials

Aim:

The aim of these trial experiments was to melt enough copper using only prehistoric materials to fill a two part clay mould and to gain experience and skill in order to make the process reliable and efficient enough to be used for producing large sample sizes of objects for a variety of experiments. The better understanding of the possible Copper Age taskscape for the casting of copper axes was a further important aim of the experiments.

Materials:

Bellows

As can be expected, there are no surviving Copper Age bellows from the archaeological record. Leather bag bellows similar to the ones used by 'Experiment A' were made as they were easy to use and made from entirely organic materials. In order to connect the two bellows to the one tuyère a pair of leather 'trousers' were made (Fig. 16).



Fig. 16: The finished furnace, tuyère, pipes and bellow (source: Author)

Pipes, tuyères, crucibles and moulds

For the actualistic outdoor casts the mould, a two part fired clay mould, remained a constant, as the process of melting the copper in the first place had not yet been successfully accomplished. The pipes connecting the bellows to the tuyère via the leather ‘trousers’ as well as the tuyères, crucibles and moulds were made using Devon earthenware clay mixed with sand at a proportion of about 2:1. The objects were then fired at 750° C in an electric kiln. The size of the crucibles was, at first, based on archaeological examples (see Fig. 10).

Furnace construction

A hole was dug into the ground and lined with the same clay mixture that was used for the pipes, tuyères, crucibles and moulds (Fig. 16). The platform or flat area by the side of the hole was made to scrape the charcoal onto when placing the crucible inside the furnace. This helps keep the charcoal soil free inside the furnace. If too much soil gets into the furnace the silica content vitrifies, which lowers the temperature as it is mixed with the charcoal creating pockets where no combustion takes place. A small fire was lit inside the furnace to dry the clay slightly before adding the charcoal.



Fig. 17: The partly filled mould after casting session 1 (source: Author)

7.2.2 Casting session 1

Cognizant of the problems during a previous casting session, only a small amount of copper was added to the crucible. This would not fill the mould, but the first session should simply test if the setup was working properly. Once the furnace was full with glowing charcoal, the charcoal was scraped onto the side platform, and the crucible was placed directly underneath the tuyère opening, in the hot spot, with about 5–7cm between the rim of the crucible and the tuyère. The charcoal was then piled over the crucible and up to the ‘eyes’ of the tuyère. In order to test if the copper was molten it was possible to insert a green willow shoot into the crucible. Running the shoot along the bottom of the crucible one could feel if there were any lumps left. Once the copper was molten it was also possible to feel a slight ‘bubbling’ or ‘simmering’ when inserting the shoot into the crucible. It took 2.5 hours to melt the metal which was mainly due to the bellows, as they were not as efficient as anticipated. The leather of the finger loops stretched, which made it difficult to grip when operating the bellows. The two students helping had never bellowed before, so that the first hour was spent practicing and the air flow was not always constant. This was a recurring problem, as there were different students helping each time. The wooden tongs were simply made by splitting a branch some way up and tying a little wedge between the two sides. The mould was tied together using a leather strap, and situated in a small trench. For the first cast, the mould had not been pre-heated. The charcoal was scraped aside, the tongs were used to grab the crucible with one arm, and with the other arm a stick was held onto the rim of the crucible in order to stop the charcoal from blocking the pouring cup. The process of pouring the copper worked surprisingly well for the first trial. As anticipated, it was only enough copper to fill the bottom half of the mould (Fig. 17). The surface of

the copper was fairly smooth but very porous or spongy (Fig. 18), quite unlike the archaeological axes. It was interesting to observe the complete vitrification of the ‘mouth’ of the tuyère (Fig. 19).



Fig. 18: The cast from session 1 (source: Author)



Fig. 19: The partly vitrified tuyère (source: Author)

7.2.3 Casting session 2

This time the process was repeated as above, but the crucible was filled to its full capacity, and some amendments to the bellows meant that they were working more efficiently. The same two-part clay mould was used, although this time it was preheated next to the furnace. Despite these alterations, it took two hours to melt the metal. After pouring the metal, the mould was again not filled, even though the amount of copper which could fit into the crucible had been weighed, and it was equal to the weight of the axe that the mould was copying. Again the surface was porous, although it felt slightly more solid (Fig. 20).



Fig. 20: The cast from session 2 (source: Author)

7.2.4 Casting session 3

In order to finally fill the mould, a larger crucible was made for the third casting session. This time it took three and a half hours to melt the copper. The mould was again pre-heated by the side of the furnace. When I attempted to take out the crucible with one arm it was realised that it was too heavy and both arms had to be used to pour. This meant that it was not possible to hold the charcoal off, which blocked the pouring cup. The rest of the copper was poured onto the clay surface next to the furnace. There was a ring around the crucible wall of un-molten copper. As the crucible had been in the furnace for three hours it could only mean that the diameter of the crucible was too large for the tuyère opening. The axe piece from the last cast was the most solid casting without any obvious porosity (Fig. 21).



Fig. 21: The cast from session 3 (source: Author)

7.2.5 Conclusion

Although it was not possible to make the casting process efficient and reliable enough to create a large sample size of copper axes for further experiments within the financial and temporal framework of this research, it was nevertheless the most insightful part in terms of trying to create a possible Copper Age-like taskscape. The engagement with the material was able to expose one of the major problems, as the crucible size known

from Copper Age contexts was insufficient to melt enough copper to cast even an axes-adze of average weight. When a larger crucible was used (not based on archaeological parallels) it was found to be too heavy to be lifted by one person with one arm, making it impossible to pour the metal in a controlled manner while at the same time holding off the charcoal form blocking the pouring cup. This embodied approach shows that the process must have been carried out differently, involving more persons in one way or another (see Chapter 11). The experiments also illustrated how ephemeral these activities can be, which might explain why not a single casting site is known from archaeological contexts. These early furnaces can easily be misinterpreted as hearths. A further observation was the importance of seeing metallurgy as a composite technique, with many other materials and processes involved. One should study metallurgy in a more organic way, taking into account the invisible processes as well as the visible metallic remains, in short by thinking about the entire taskscape.

7.3 Shaft-hole experiments

After the outdoor trials (7.4), an experiment with a larger sample size was necessary to examine the production process in more detail. Due to time and financial constraints, it was decided to concentrate on the production of the shaft-hole, as this is one of the key areas of the operational sequence, which might also give information on other aspects of the manufacture. The evidence, literature and arguments for and against the different ways for creating the shaft-hole have been discussed in detail in Chapter 6. When the experiments were planned and carried out I was unfortunately not yet aware of the axe blank from the Museum für Vor-und Frühgeschichte. The creation of the shaft-hole after the object had been cast was therefore not taken as seriously as it should have been and only the drilling of the shaft-hole was tried. In retrospect the punching or cutting of the shaft-hole using a mallet and hardened copper chisel should have been tried as well but is, at least within this PhD research, no longer possible.

The working hypothesis for designing the experiments was that the earliest hammer-axes of the types Pločnik and Vidra, that do not have any shaft-hole lips, might have been obtained by drilling through the body of the axe. Hammer-axes and axe-adzes with only one shaft-hole lip might have been cast, and the shaft-hole was punched in while the metal was still liquid or soft. The more elaborate axe-adzes and hammer-axes, which often have a lip at either side of the shaft-hole, could be produced in open or closed moulds. The shaft-hole lips seem to indicate that they were cast in closed moulds, but

the microstructure seems to show that one side of these axes had a higher degree of oxygen enrichment, pointing to an open mould. In order to investigate some of these issues, an experiment was set up using a portable gas furnace in the open air.

7.3.1 Brief description, aims and materials of the experiment

18 Simplified axe shapes were cast into open sand moulds. Six were cast with a clay core in place during the process of casting, six were cast and the shaft-hole punched in while the metal was still liquid and six were cast with the shaft-hole not in place as it was planned to drill them when the metal had cooled down using Copper Age materials. Three axes of each method were air cooled and three were water quenched.

Aims of the experiment

- To see if it is possible to cast copper into open sand moulds
- To produce metallographic samples for a reference collection of copper cast into open sand moulds both air-cooled and water quenched
- To see if it is possible to punch the shaft-hole through the still liquid copper shortly after it has been cast
- To see if it is possible to drill the shaft-hole through an axe 'blank' after it has cooled down using materials and skills available in the Copper Age
- To see if the different techniques used to obtain the shaft-hole produce a diagnostic pattern in the microstructure along the shaft-hole in order to compare them to the archaeological axes
- To produce metallographic samples for a reference collection of shaft-holes being obtained through a clay core, punching and drilling

Materials

Furnace

The furnace which was used for these experiments was a CM 350 PB SAFETY TILT CRUCIBLE FURNACE made by Flamefast. The graphite crucible can melt up to 10kg of copper in about 40 minutes to 1 hour. The metal can then be poured by tilting the drum, which contains the crucible (see Fig. 22). As mentioned above, it was not possible to melt enough copper for one of the axes under investigation using the

‘Copper Age furnace’, let alone produce a large enough sample size for metallographic analysis. As the metal had to be molten somehow, a gas-fired furnace used outside was deemed an acceptable compromise, which would not impact on the end result of the experiment.



Fig. 22: The gas fired furnace (source: Author)

Sand bucket moulds

Sand was used for the mould material for two reasons. There is no evidence for surviving Copper Age moulds in the archaeological record, which means, as stated above, that an archaeologically invisible material would have had to be used. Sand is the obvious choice. A further consideration was the action of punching the shaft-hole through the liquid metal. This was only possible by using an open sand mould, as the punch would be able to sink into the sand at the bottom of the shaft-hole. As the only variables tested should be the method of shaft-hole production, all axes were cast in the same sand moulds (see Fig. 23). A metal bucket was filled with slightly moist sand. A pattern made from unfired clay was impressed into the sand and taken out again. This had to be done just before the metal was poured, as the mould would lose its shape if the edges began to dry. The actual shape and size of the axes cast for the shaft-hole experiment were designed to use as little copper as possible, while at the same time providing enough body for the shaft-hole. This was done to minimise the costs, as copper is an expensive material. There was enough copper molten each time to cast

three axes. The mould bucket was only turned for the next axe to be filled when the last one was solid, so as not to disturb the microstructure while the metal was still cooling down.

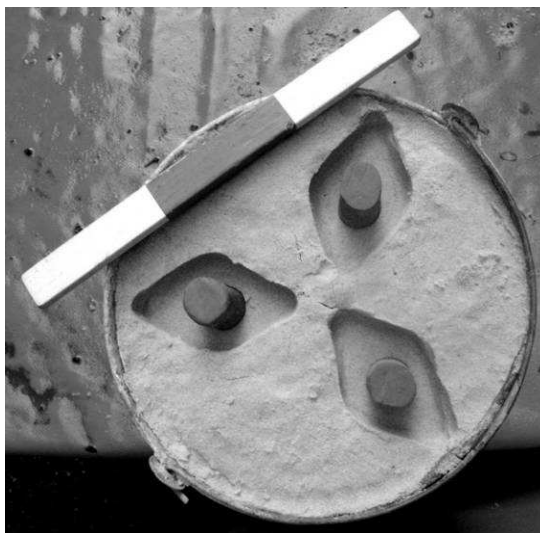


Fig. 23: Sand moulds for the clay core series (source: Author)

7.3.2 The clay core series

For this method, unfired but completely dry clay cores were used. They were made using Devon earthenware clay, which was tempered with sand at a ratio of 2:1. The cores were inserted after the mould had been created using the clay pattern. They were placed about 2 cm into the sand in order to achieve some stability during the casting (see Fig. 23).

The liquid copper flowed around the cores and began to solidify. During the cooling down of the copper, the clay cores began to disintegrate. Although they had been drying for 12 days in a heated environment, they seemed to explode in the intense heat of the copper. Small particles of clay were flying through the air, providing a safety hazard which had not been anticipated. However, the face shield worn for the fire and heat exposure, served well to protect against these small missiles. An interesting observation from this experience would be that there was nothing left of the clay cores, which might have been identified archaeologically as a clay core used for producing the shaft-hole in a copper axe. There was also no need to break the core out of the shaft-hole once the axe had cooled down as it had all disintegrated.

7.3.3 The punching series

For this part of the experiment, the same method was used to produce the moulds as in the clay core series, except that no core was inserted. Instead the shaft-hole was produced by punching through the molten metal after pouring using a wooden stick. The wooden sticks used were pointed to ease the process. In some archaeological axes the bottom end of the shaft-hole is slightly smaller than the top, which could be explained by a pointed punching tool. The wood was dry so as to avoid spitting of the hot metal during the punching.

Even though, in theory, the six samples should all be the same except for the cooling regime, it was realised that this is almost impossible using the punching method. The shaft-hole was punched approximately 5 seconds after the mould had been filled. Although this was the same for all the six samples, slight variations in the start time, and duration of the punch were inevitable. If the punching started too soon, the results might be the same as using a clay core. If, however, the metal was too solid, it would have been impossible to punch through the body of the axe. The timing of the punch in this experiment was probably on the safe side, as there is more room to explore punching slightly later in the cooling process. The stick did catch fire when it touched the hot metal, but only along the top of the shaft-hole where the burning wood was in contact with oxygen. Inside the shaft-hole the stick only charred. It was easy to take it out once the metal was solid, as the charring had made the circumference of the stick smaller than at the start.



Fig. 24: The bow drill being used on one of the copper axe blanks (source: Author)

7.3.4 The drilling series

The axe bodies for the drilling series were cast in the same way as the previous two series (see above). The only difference was that the metal was left to solidify entirely before any attempt was made to produce the shaft-holes. As this part of the experiment was designed to test the feasibility of drilling the shaft-hole through solid metal, a drill had to be made using materials available in the Copper Age. As drilling through copper had not been tried before, at least not in published form, it was an exercise in trial and error. A bow drill was built using a flint point for the drill. The drill point was inserted into a split branch and fixed using wet sinew. When the sinew had dried and contracted, the drill point was securely fixed and the bow drill was tried (see Fig. 24). It worked in principle, but the flint splintered and wore down much quicker than anticipated. The cord used for the bow also disintegrated, and many modifications had to be made to the design before it was working efficiently. In the end a leather string worked best for the bow and a thicker flint point was used, which was polished in order to decrease the splintering. Coarse, angular sand was used as an abrasive. The setup worked well when drilling through fired clay and even stone. It also worked on copper but was so incredibly slow that after one entire day of drilling, the shaft-hole was a mere indentation in the surface of the axe.

It became clear that it was impossible to finish even one axe in the time frame available using this technique. In order to sample at least one of the axe blanks from the drilling series, a further compromise was made. The stone drill bit was modified using a grinder, so that it matched the fitting of an electric drill. The drill had adjustable speeds, and the lowest setting was equivalent to the speed of a bow drill. The use of the electric drill did therefore not impact on the end result of the experiment (see Fig. 25). A faster speed than that obtained using a bow drill might have created more heat, resulting in a different microstructure of the metal. However, the flint drill point was not suited to being mounted in a metal drill fitting. To solve the problem of crumbling, different materials were tried. Drill points made from wood, bone, antler, copper and different types of igneous and sedimentary rock were tried (see Fig. 26).

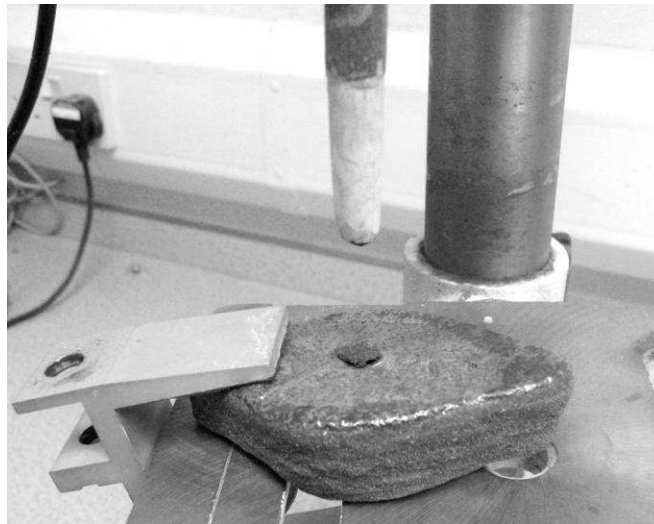


Fig. 25: Attempt at drilling the shaft-hole using a wooden drill point in an electric drill (source: Author)

Surprisingly the wooden drill points with sand as an abrasive worked best, although they needed re-shaping more or less every five minutes (see Fig. 25). Even when using the setup which worked best it was impossible to finish the shaft-hole as it simply took too long. The depth achieved was less than 1cm and the diameter was much smaller than the one seen in the archaeological axes which average about 3cm. It was still possible to take a sample for metallographic analysis of the 'shaft-hole' profile.



Fig. 26: The different materials used as drill points. A: sedimentary rock, B: igneous rock, C: antler, D: wood, E: copper (source: Author)

7.4 Macromorphological results and observations

The macromorphological characteristics of the experimentally cast axes can be directly compared to the characteristics of the archaeological axes, which allows for some interesting observations to be made. Regarding the axes cast with a clay core in place, it can be said that the majority produced in this way, (5 of 6 axes) did not produce a shaft-hole lip. It was thought that perhaps some of the lips seen in the archaeological axes might be caused by some of the metal flowing into the gap between the clay core and bottom of the mould. Only one axe showed this phenomenon but only along one quarter of the shaft-hole (see Fig. 27). This would not explain the lips seen in the archaeological axes, which are present all around the shaft-hole in an even thickness (see Fig. 28).



Fig. 27: Experimentally cast axe from the clay core series (source: Author)



Fig. 28: Archaeological axe of the Jászladány type (source: Author)

As mentioned before, there was surely more than one way of making these axes, especially as there is such great diversity in shape and size. The majority of the axe-adzes and also some hammer-axes like the Mezökeresztes type might well have been cast in closed moulds and a different sort of mould might produce more even lips than were produced in these experiments. Especially the axe-adzes which show a lip on

either side of the shaft-hole are more likely to have been produced in closed moulds. Some of the early hammer-axes on the other hand, like the Pločnik and Holič types do not have a shaft-hole lip on either side. One could therefore surmise that the early hammer-axes might have been produced using the clay core method in an open mould (see Fig. 29).



Fig. 29: An experimental axe from the clay core series (A and D) and an archaeological axe of the Pločnik type (B and C) (source: Author)

On the other hand the early hammer-axes might have been produced using the drilling technique. A further observation backing up this theory is that the wall of the shaft-holes from the early hammer-axes is extremely smooth, which has been impossible to obtain using the clay core or punching methods. Thinking back to the difficulties experienced during the experimental drilling, however, makes this production technique seem somewhat more unlikely. Although the difficulties might be due to a lack of time and experience, further work needs to be done in order to ascertain the feasibility of the drilling method, especially in the light of the new (re)discovery of the axe blank with missing shaft-hole from the Museum für Vor-und Frühgeschichte Berlin (see Chapter 6).

The resulting macro-morphology of the punched axes shows a striking similarity to some of the archaeological examples. It is mainly the so-called Szendrő type, which shows the distinctive shaft-hole lip. As can be seen on Fig. 30, the lip created at the lower side of the axe through punching during the experiment can be compared almost directly with axes of the Szendrő type. In terms of the macro-morphology, it is possible

to say that it is highly likely that the Szendrő type was made using a punching method when the metal was still soft or liquid.



Fig. 30: An experimental axe from the punching series (B and C) and an archaeological axe of the Szendrő type (A and D) (source: Author)

7.5 Summary and conclusion

The value of using experimental archaeology as part of a holistic research methodology has been illustrated and discussed. The many different approaches to experimental archaeology should not be seen as a stumbling block. Instead this shows what a dynamic field it really is. The important issue is that the practical engagement with material culture can answer questions which would otherwise remain unanswerable, and at the same time open up completely new avenues of research. The engagement with the material also allows the researcher to ‘get to know’ the material and many experimental activities call for a high level of specialised skills, which can only be learned through experience and time.

Despite the lack of time and skill in this present research much was learned from the practical engagement with the production processes of the copper hammer-axes and axe-adzes, both on an experiential level, and on a scientific level. It was possible to explore the many dimensions of a copper-working-taskscape. The felt weight of the objects and therefore of the amount of copper necessary for casting them suggests that the process must have been thoroughly choreographed, and carried out by a number of different individuals. Macro-morphological observations were able to shed light on the probable diversity in production, with the punching of the shaft-hole through the still liquid metal being one amongst a number of other techniques. The metallographic

analysis and results presented and discussed in the next chapter, will carry on this debate while illustrating a further methodology or step in a holistic approach of the study of metallurgy.

8 Metallography

During metallographic analysis, the microstructure of objects can be investigated using reflected light microscopy. This makes it possible to obtain evidence regarding the composition and phases of the metal as well as on aspects of production including casting, cold/hot working and annealing. Information on these issues is visible in the microstructure, as they affect the formation and recrystallisation. It is therefore an invaluable method that sheds light on aspects of production, which would otherwise remain hidden. The main problem with this technique is that it relies on destructive sampling. It is therefore no surprise that not many artefacts have been analysed, as museums are very protective of their collections. However, if the micrographs taken are collected and accessible to everyone, metallography is a great technique to be used in conjunction with experimental archaeology. Experimentally produced axes can be sampled without the need to consider aspects of conservation and protection and they can be produced under known conditions, according to pre-formulated hypotheses. Although a number of studies have used this approach and it is being used as part of this research, there is great potential for future work.

8.1 Preparation and recording of metallographic specimen

As mentioned in Chapter 7 samples were taken from all experimentally cast axes as well as from one privately owned original axe-adze. The axes from the actualistic outdoor castings were sampled along the body and/or the cutting edge using a v-shaped cut. It is important that one side of the v-shaped sample is at a 90° angle to the edge of the object, to enable the examination of possible directional characteristics of the microstructure (Scott 1991, 58). The axes from the shaft-hole experiment (see Chapter 7) as well as the original axe-adze were sampled at the shaft-hole, where a whole straight section was taken out of the side of the axe. While cutting the samples, I made sure that the blade did not get too hot by touching it frequently.

All samples were mounted using a cold mounting powder and liquid catalyst. Cold mounting resins have two advantages: no specialist equipment is needed, and the temperatures definitely do not get high enough to affect the microstructure of the metal. In this case the Struers Durofix 2 kit was used. Before setting up the samples in the moulds, they were powdered with an anti-stick powder, which helped getting the mounts out of the moulds, once dry. The samples were placed into the moulds with the side to be polished face down. The resin was mixed using two parts powder to one part

liquid. The Durofix 2 resin is usually dry enough to be taken out of the moulds after about 15 min, but should not be ground or polished for at least 8 hours.

The grinding of the mounted samples is necessary to obtain an even and level surface, however, irregular the sample is. This is done using sand paper, which is fixed onto a rotating disk. In this particular case, four different grain sizes were used (80, 120, 270 and 600). When changing from one grain size to the next, the sample was turned 90°. It is then possible to see when the scratches from the previous grain size have disappeared. Between grinding on the different sizes, the samples were washed with warm water in order to clear any grains from the surface, which might contaminate the sample.

The polishing is done on special polishing cloth, which is fixed to a rotating disc. Diamond paste was added to the polishing cloth, as well as an ethanol based lubricant. The diamond paste determines the grain size (diamond microns) but the polishing cloth also increases in smoothness. Diamond pastes of 6, 3 and 1 micron were used. It acts as an abrasive and the lubricator helps the sample slide more easily on the polishing cloth. As a complete novice it was almost impossible to create completely 'scratch free' samples, and many areas of my samples do still show some scratches of differing sizes even after careful polishing.

The mounted samples were all photographed, drawn and inserted into the recording sheets I prepared for the microscopic analysis. On these drawings and photos, the original top/bottom/shaft-hole surfaces of the samples were marked in relation to their original position in the object. All samples were viewed and recorded using brightfield reflected light microscopy, before and after etching, at x50 and x200. A 'Zeiss Axiovert 40 Mat' microscope with an AxioCam digital camera and Axiovision software was used for the purpose. The samples were etched using alcoholic ferric chloride for about 10 seconds. After being held into the etchant the samples were rinsed under running water immediately in order to stop the etching process. Particularly porous samples proved to be the most difficult as the etchant penetrated deeper into the samples and was more difficult to rinse out. Some samples had, even after numerous tries, areas where the etching process had carried on for too long. These are visible as almost rusty smears, especially around porous regions on some samples. For each sample 'random' pictures were taken near all the different surfaces (bottom/top/side/shaft-hole of original object) as well as in the centre.

8.2 Results

The results of the metallographic analysis will be presented using some representative micrographs. The total number of micrographs taken will be included on the cd submitted together with this thesis. Before describing the results in more detail, some general points about the formation of the microstructure of copper will be made. Depending on the way an object is cast, the microstructure will show a fairly regular grain structure, with roundish or hexagonal grains (Scott 1991, 6). The amount of cuprous oxide and porosity heavily depends on the amount of air reaching the metal during the casting and solidification process (Scott 1991, 6). If there is a high amount of cuprous oxide present between the grain boundaries, the un-worked cast or primary structure can be seen in an unetched state. However, the grain boundaries themselves are only made visible through etching the sample (Scott 1991, 69). All experimental casts fall into this category as they were not worked upon any further, nor were they annealed. Further steps in the production sequence would leave their traces in the microstructure but are also only visible when the sample is etched, although deformation on objects with oxides between the grain boundaries can be visible in an unetched state.

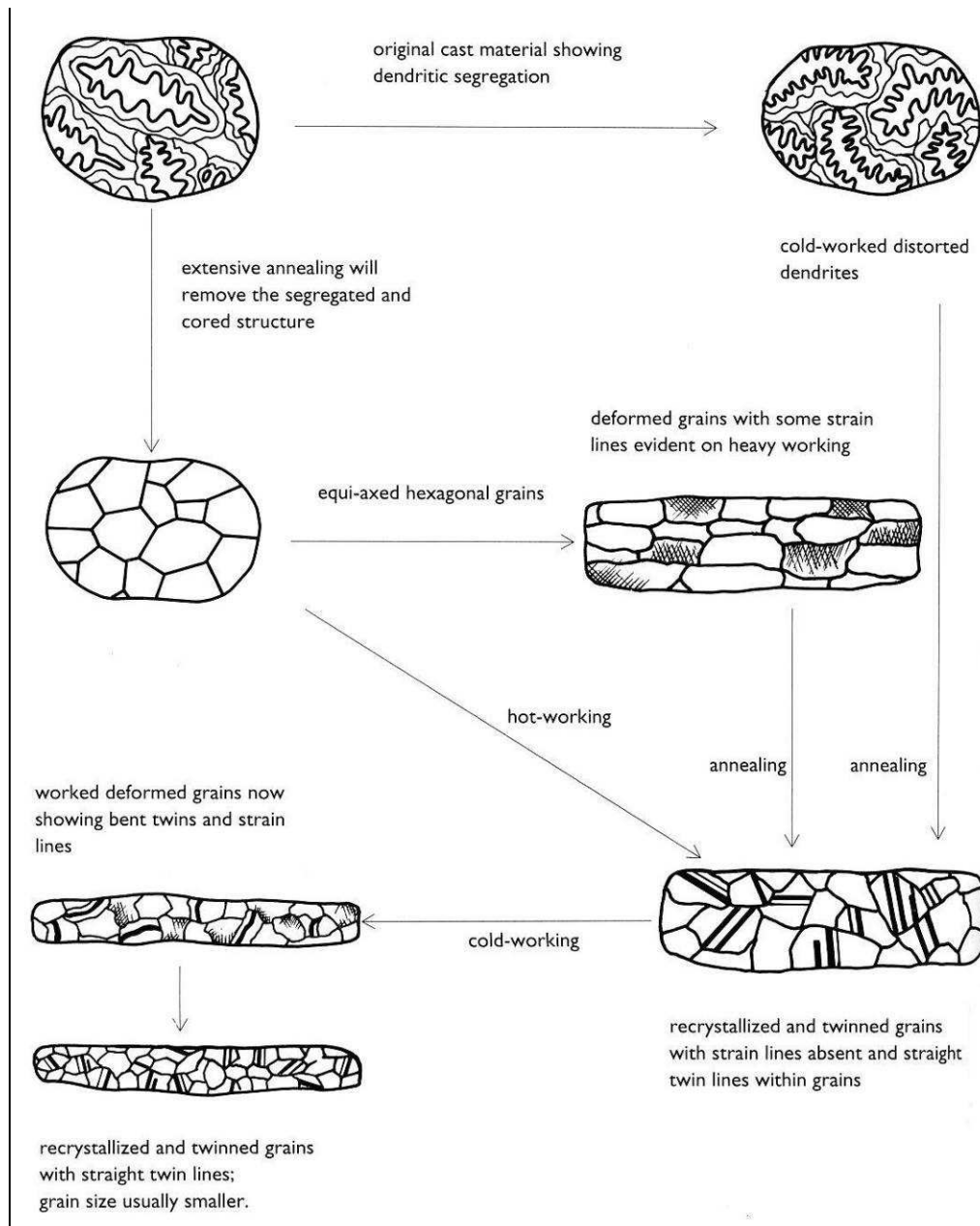


Fig. 31: The processes influencing the microstructure of metals (source: Scott 1991, p. 8, Fig. 12)

Hot working will deform the original grains but also, depending on the temperature, recrystallise the microstructure. This means that the original grains and their deformation will only be visible through the oxides, which formed during solidification between the grain boundaries. Cold working, on the other hand, does not cause the overall structure to change but will lead to strain lines in the localised area where the metal was being worked. If the object is annealed, all strain lines will disappear causing a completely recrystallised microstructure (see Fig. 31). This makes it difficult to distinguish between hot working and cold working if the cold working was followed by an annealing

process. There are, however, indirect ways of establishing if the deformation before the last re-crystallisation process was caused by cold or hot work. Both the grain size and the almost complete removal of residual coring have been used to argue for the objects having been exposed to very high temperatures (Kienlin and Pernicka 2009, 265; Ryndina and Ravich 2000, 10). If cold working was the last step in the production sequence it is clearly visible in the microstructure.

8.2.1 Actualistic outdoor casts

Three objects were cast during the actualistic experiments, namely I, II and III (see Chapter 7). Objects I and II were sampled at the cutting edge and along the side (see Fig. 32). Object III was only sampled on the side as just the very tip of the axe mould had filled with metal.



Fig. 32: The object cast in session I with the two samples taken for metallographic analysis from the cutting edge (sample 1) and the side (sample 2) (source: Author)

Let us briefly look back at the exact casting conditions before comparing the micrographs of the three different casts (see Chapter 7 for more detail). The bivalve closed mould for the object cast in session I (metallographic samples 1 and 2 taken from the cutting edge and side respectively) had not been preheated and the cast metal was air cooled. The resulting axe half looked spongy and the samples taken show, even to the naked eye, that there is a lot of porosity and the centre of the object contains a void, which probably occurred due to shrinkage during the cooling phases, as there was not enough metal to fill the empty areas once the outside had solidified. The same mould was used for casting sessions II and III, but on both occasions it was preheated next to the furnace. The finished objects were again air cooled. The two axe halves from

sessions II and III were much less porous on the surface and especially object III had a very solid feel (see Chapter 7).

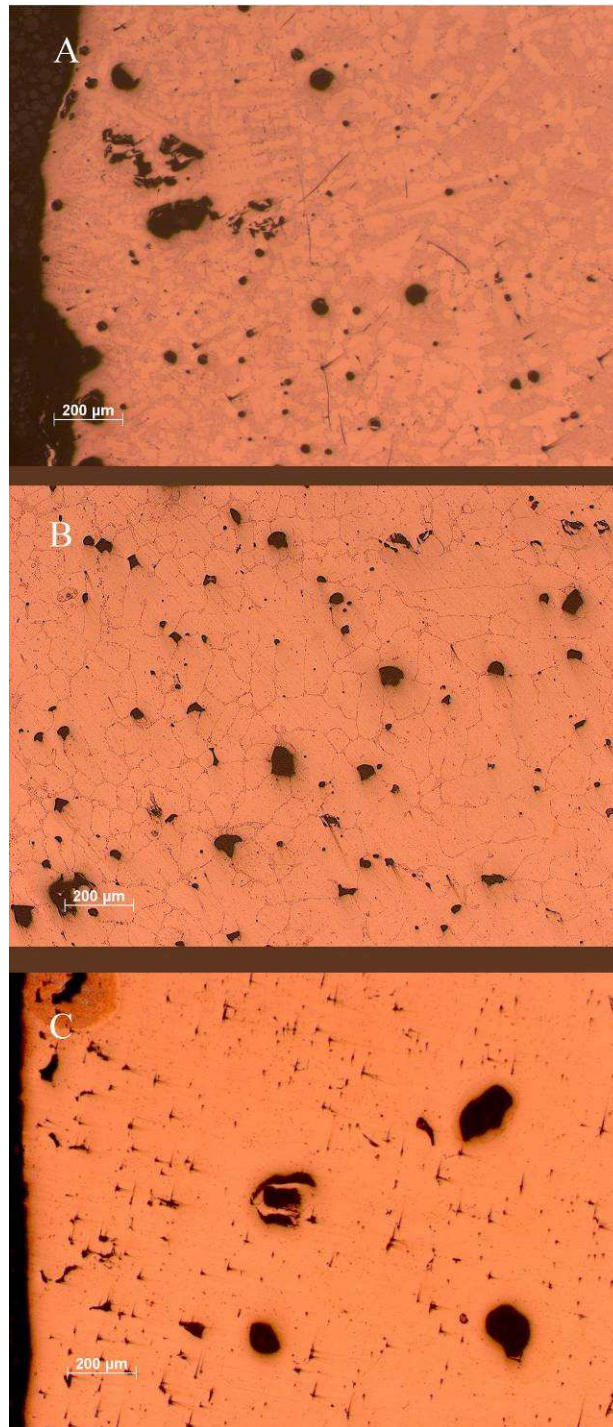


Fig. 33: Micrographs of the three outdoor casts before etching A-casting session I, B-casting session II and C-casting session III (source: Author)

The metallographic analysis of the samples from the actualistic casting sessions confirm the increasing density of the three casts. When looking at the porosity of the three different casts, there does not seem to be such a large difference between the samples (see Fig. 33 and 34), although it was very evident that the cast from session I was a lot

more porous on the surface than the other two. Although there is no marked difference in the porosity in the interior of the samples, the increasing density is evident in the microstructure. Looking at Fig. 29, which shows the samples before etching, we can see that the sample from cast I has a fernlike grain structure (dendritic). Comparatively large areas between the dendrites are taken up by oxides. Unfortunately it was not possible to determine the exact composition of these oxides but they are probably made up of (Cu+Cu₂O)-eutectic. The sample from session II (see Fig. 33) has considerably fewer oxides between the grains, and the grains are in general smaller and the majority have no dendritic structure. The object, which felt the most solid from the outside was from session III. The micrograph of the unetched sample shows indeed an almost oxide free cast. There is some porosity but the grain boundaries are not visible in the unetched version, which is due to the missing oxides.

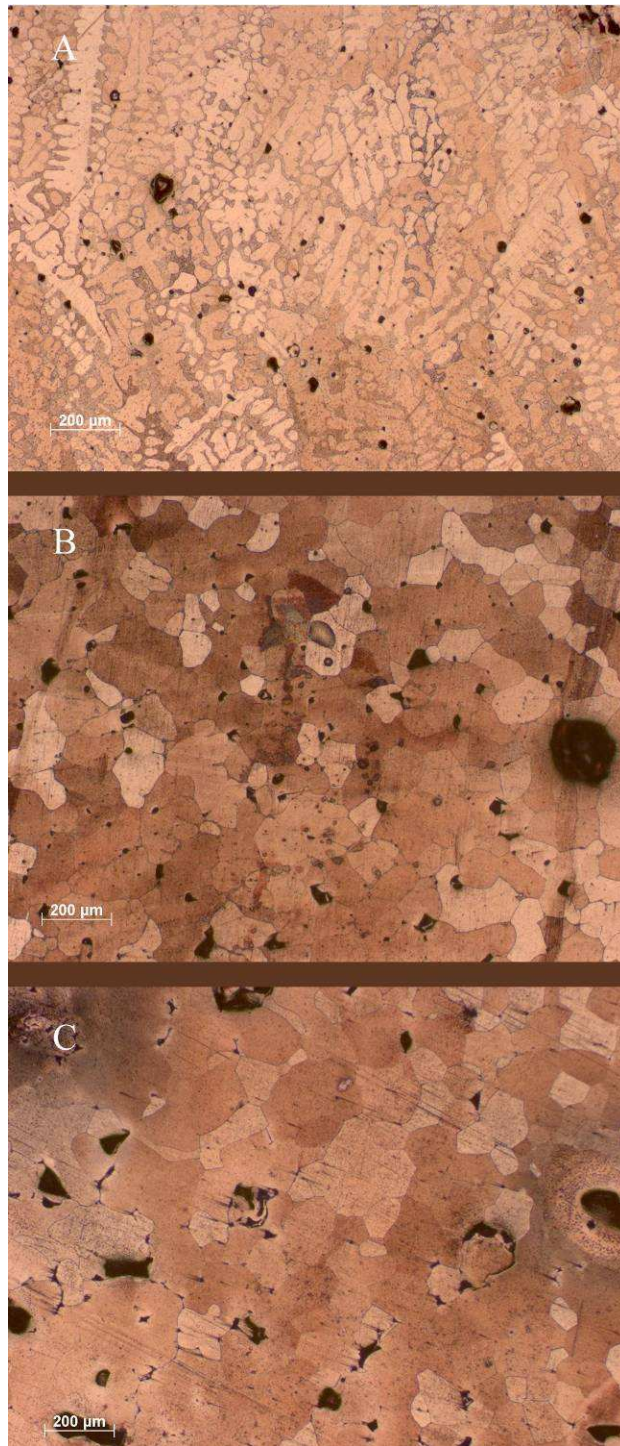


Fig. 34: Micrographs of the three outdoor casts after etching A-casting session I, B-casting session II and C-casting session III (source: Author)

The etched micrographs show again the different oxide distributions between the samples but also make the grain boundaries visible, even in the sample from session III (see Fig. 34). The dendritic structure of the cast from session I is even clearer and the samples from sessions II and III can almost be described as having an equiaxed hexagonal grain structure, which is the perfect state of cooled down copper (Scott 1991,

6). Particularly the cast from session III has a textbook grain structure of hexagonal grains, and as good as no oxides (see Fig. 34 C).

These results show that it probably did make a difference whether the mould was preheated or not. The object from session I, which had not been cast into a preheated mould, shows by far the highest formation of oxides. It is interesting that there was such a difference in oxide uptake between the objects cast in sessions II and III, as both times the mould had been preheated and all other steps were also the same. Of course, in an actualistic outdoor environment, there are many variables which cannot be controlled and, unfortunately, the temperature of the melt could not be recorded. The difference in the microstructure could therefore be due to a variety of reasons and would be a good topic for further experiments.

8.2.2 Shaft-hole experiment

To begin with I will compare the main features of the samples, which are not related to the production method of the shaft-hole. The overall microstructure of the samples should be very similar as the main variable remained constant (open sand mould). Slight differences are to be expected between the air cooled and the water quenched examples. There are indeed many similarities but also some variation even between samples cast in the same way (see Table 6).

Table 6: The descriptions and qualities of the metallographic samples (source: Author)

	Oxide enriched zone (top/bottom/side)	Oxides between grain boundaries (none/some/a lot)	Grain shape (round/amorphous/dendritic/hexagonal/mixed)	Grain size (small/medium/large/mixed)
PWQ 1 (sample 7)	None	Some	Mixed hexagonal, round and amorphous	Mixed
PWQ 2 (sample 8 and 9)	Top and some on bottom	A lot	Round	Small
PWQ 3 (sample 10 and 11)	Top	Some	Amorphous	Large
PAC 1 (sample 12 and 13)	Some at top and bottom	Some	Mixed amorphous and hexagonal	Mixed
PAC 2 (sample 14 and 15)	Top, a little on side	A lot	Mixed amorphous, hexagonal and dendritic	Mixed

PAC 3 (sample 16 and 17)	None	Some	Mixed amorphous and hexagonal	Mixed
CCWQ 1 (sample 18 and 19)	Top	Some	Mixed amorphous and hexagonal	Mixed
CCWQ 2 (sample 20 and 21)	Top	Some	Mixed amorphous and hexagonal	Mixed
CCWQ 3 (sample 22 and 23)	Top and bottom	Some	Mixed amorphous hexagonal and dendritic	Mixed
CCAC 1 (sample 24 and 25)	Top	Some	Mixed amorphous and hexagonal	Mixed
CCAC 2 (sample 26 and 27)	Top	Some	Mixed amorphous, dendritic and hexagonal	Mixed
CCAC 3 (sample 28 and 29)	Top	A lot	Mixed amorphous and dendritic	Mixed
DAC (sample 30)	Top	Some	Mixed amorphous and dendritic	Mixed

In particular the punched and water quenched samples PWQ 1 -3 (samples 7 - 11) illustrate clearly that there can be great variation in the microstructure even when all known variables are kept the same (see Fig. 34).

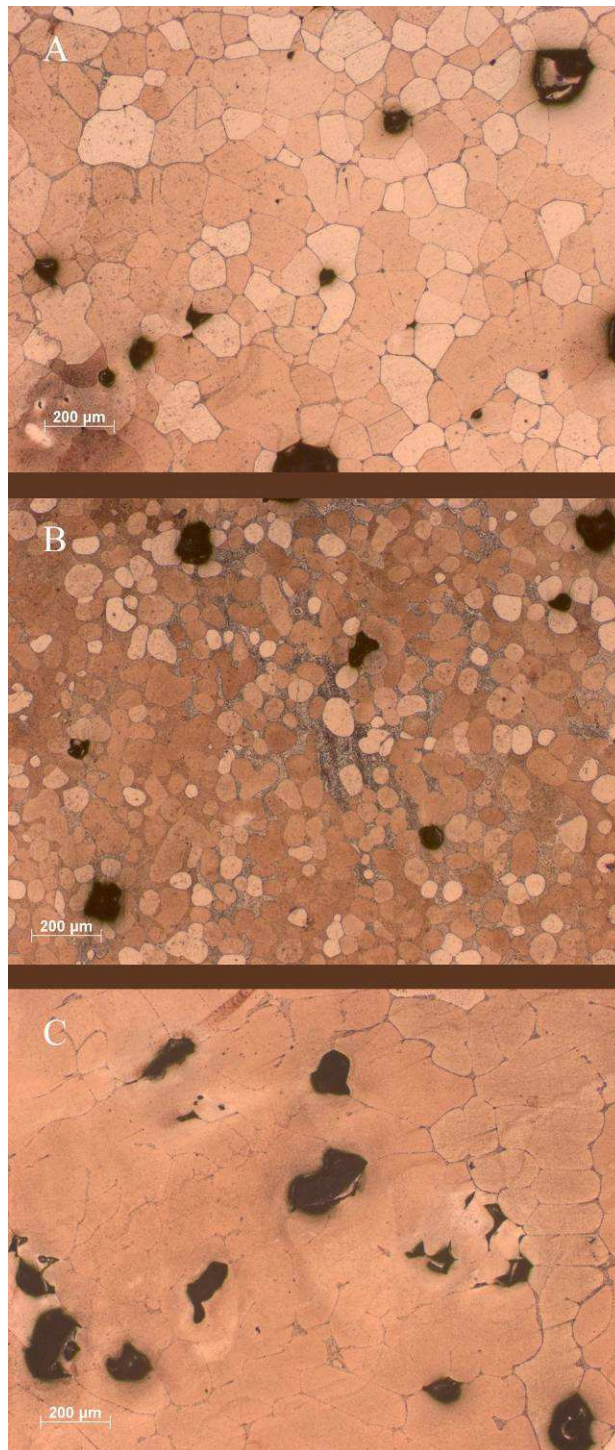


Fig. 35: The three samples from the shaft-hole experiment, which were punched and water quenched. (A-PWQ1, B-PWQ2, C-PWQ3) (source: Author)

PWQ 1 has a more or less hexagonal grain structure with some oxides between the grain boundaries, whereas PWQ2 has smaller round grains with relatively large areas of oxides between the grains. PWQ3 has larger amorphous grains with only few oxides (see Fig. 35), yet they were all cast and water quenched under the same conditions. Although the temperature of the molten metal inside the furnace was unfortunately not

measured due to the lack of suitable equipment, samples 7-11 were cast from the same charge of molten metal, making it impossible that a difference in temperature caused these variations. As three axes were cast from one charge of molten metal, it could be argued that the metal would cool down while the axes are being cast, leading to a cooler casting temperature for the last axe. However, there is no evidence of such a variation between the microstructures of the rest of the ten sampled axes, which means that this cannot have been the reason either. More experiments will be necessary to answer this question. Of course the samples themselves are not homogenous in their microstructure, but the features described above relate to the main characteristics in the centre of the sample. Especially towards the outside the variability of grain size and shape increases in all samples. This variation in microstructure between objects cast in exactly the same environment illustrates how important it is to work with larger sample sizes.

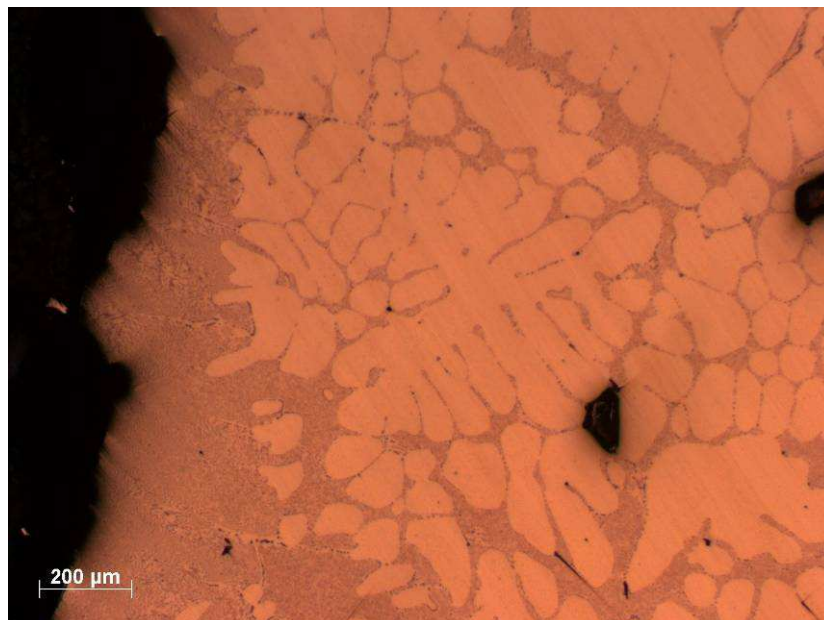


Fig. 36: The top surface of unetched sample 22 (CCWQ3) (source: Author)

Besides this variability in microstructure there are some distinctive common elements in the majority of samples. The increased oxide presence does tend to happen on the top surface, which was in direct contact with the air during pouring and solidification (see Table 6 and Fig. 36). The sides and the bottom surfaces, in contact with sand, have significant less oxide enriched areas. Besides PWQ 2 and PWQ3 the cast objects do share a broadly similar microstructure with a mix of hexagonal and amorphous grains. Some experimental casts even show a dendritic structure. These dendrites tend to occur

towards the outer surface, particularly the top, in areas of high oxide enrichment (see Fig. 36).

The production of the shaft-hole

The main aim of the experiment was the investigation of the potential shaft-hole production techniques. As mentioned in Chapter 6, Pittioni and Coghlan (1961, 70-72; 1957, 27) have suggested that the shaft-hole might have been created after the axes were cast. Other scholars argue instead that some shaft-holes might have been punched into the still liquid metal straight after casting (Patay 1984, 13). Evidence for the former are supposed to be some linear deformations running parallel to the shaft-hole walls which are visible in the microstructure seen in some sampled axes (Coghlan 1961, 70-72; Pittioni 1957, 27). The theory of punching the shaft-hole is based on macromorphological observations only (Patay 1984, 13). As part of this experiment three alternative shaft-hole production techniques were tried, namely the casting around a clay core, the punching of the liquid metal and the drilling of the solid metal after casting (for a more detailed discussion see Chapter 7). The metallographic analysis of the experimentally cast objects was used to compare distinctive patterns of the three different production techniques as well as looking for evidence which might confirm the longitudinal deformations observed by Pittioni and Coghlan (1961, 70-72; 1957, 27). As the differences or the lack of differences between the water quenched and the air cooled cast objects was discussed above, it will not be considered as part of the discussion of the shaft-hole production techniques.

Clay core

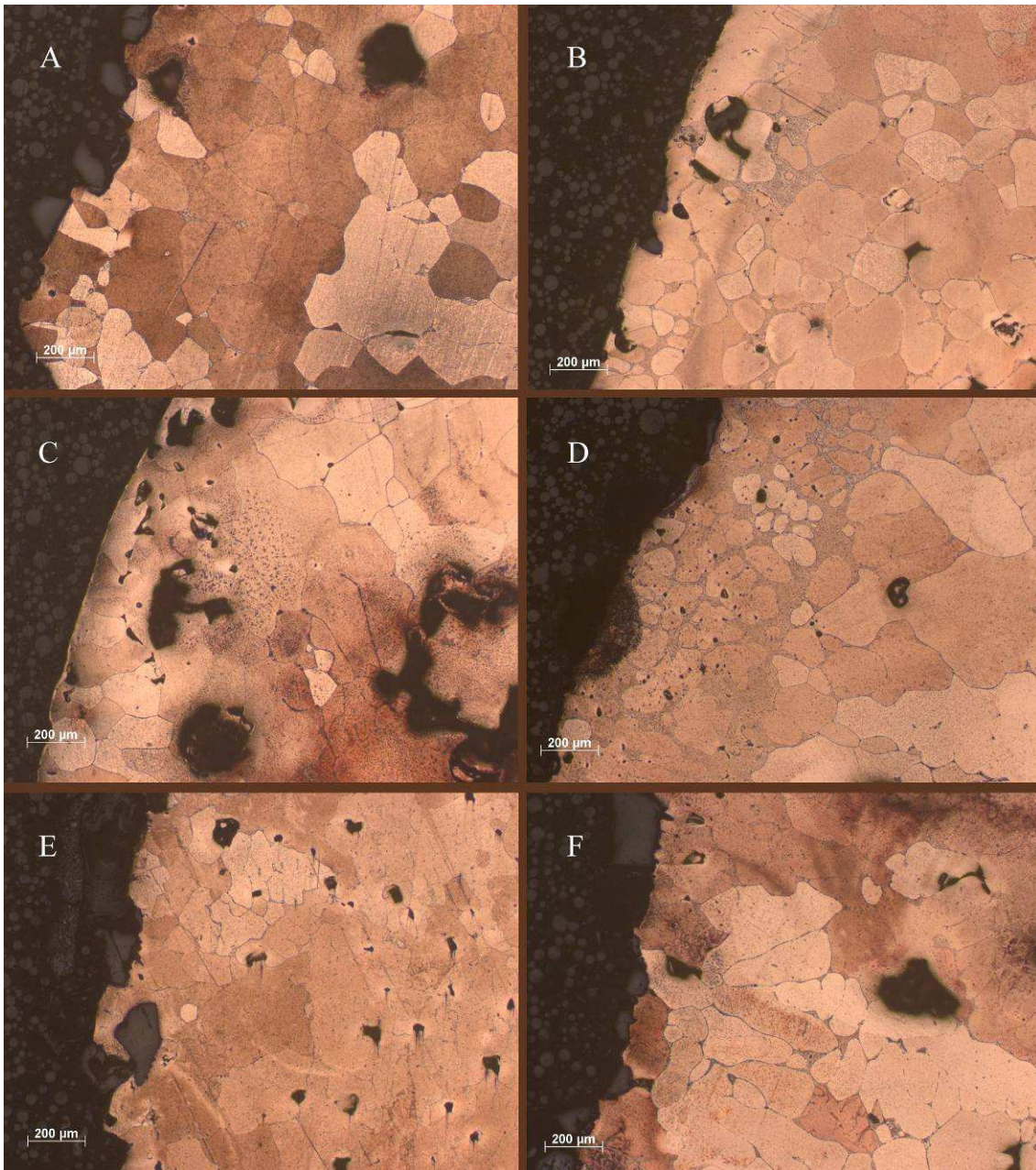


Fig. 37: Sections along the shaft-hole of the three air cooled samples cast around a clay core (source: Author)

The micrographs presented in Fig. 37 show representative sections taken along the shaft-hole of the three air cooled objects cast around a clay core. The shape and size of the grains as well as the presence of oxides varies as described above, and cannot be used to argue for a distinctive pattern for the use of clay cores. However, the grains along the shaft-hole do not look markedly different to the grain structure in the centre of the object as well as near other surfaces. What can be noted is that some areas of the samples have an increased porosity towards the shaft-hole surface (see for example Fig. 37 C), although this trend is not very prominent. The actual shaft-hole surface is not

completely smooth, but overall fairly straight. As expected, there is no longitudinal deformation of the grain structure visible along the shaft-hole. The samples, which were cast around a clay core and subsequently air cooled, show exactly the same characteristics as the water quenched samples (see Fig. 37 and 38).

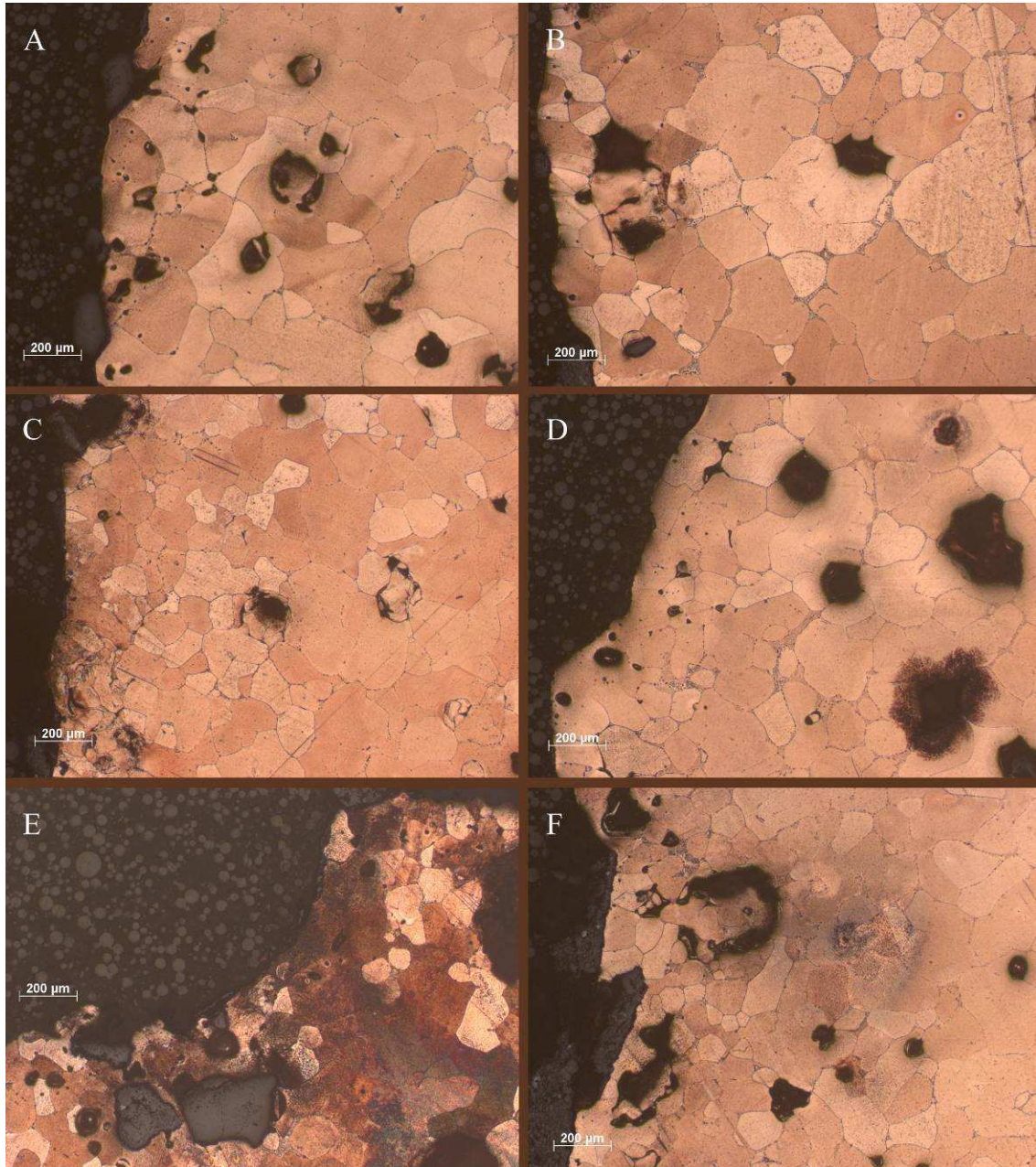


Fig. 38: Sections along the shaft-hole of the three water quenched samples cast around a clay core (source: Author)

There is some increased porosity towards the shaft-hole and the surface is fairly straight. Again there is no evidence for any deformation along the shaft-hole. Creating the shaft-hole by casting around a clay core into an open sand mould does not leave any specific features. In fact the area around the shaft-hole does not look any different than the

regions near the other surfaces, where the metal came into direct contact with the moulding sand (see enclosed CD).

Punched

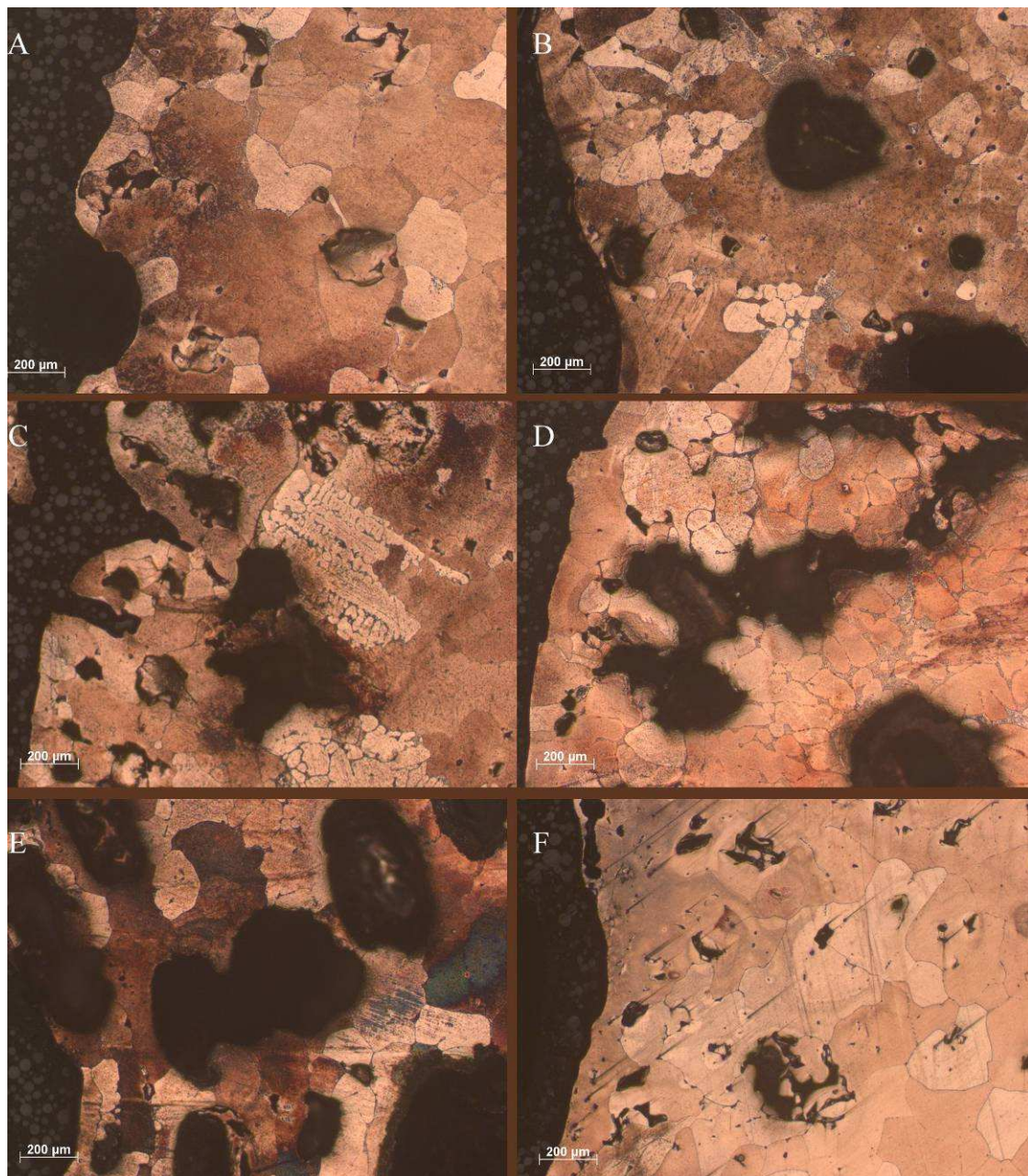


Fig. 39: Sections along the shaft-hole of the three air cooled samples with punched shaft-holes (source: Author)

Looking at the micrographs from the punched shaft-hole series, the difference to the experimental axes cast around a clay core becomes apparent immediately. Both the air cooled samples as well as the water quenched ones are a lot more porous towards the surface of the shaft-hole (see Fig. 39). Some pores are roundish and comparatively large (see Fig. 39 B) whereas others are more longitudinal and fill out the spaces between the

grain boundaries (see Fig. 39 A). The porosity is not necessarily homogenous along the entire length of the shaft-hole, as some samples have areas with hardly any pores near the surface (see Fig. 39 F). The surface of the shaft-hole walls is not as smooth or straight as the walls of the clay core series. It could be described as jagged and irregular, although there are some exceptions (see Fig. 39 B and 40 F) Again, there was not one sample that had entirely straight or smooth shaft-hole walls, but there are sections of some samples, which cannot be described as jagged or irregular. However, the overall impression clearly confirms that the punching of the shaft-hole has a stronger impact on the shaft-hole walls than the casting around a clay core.

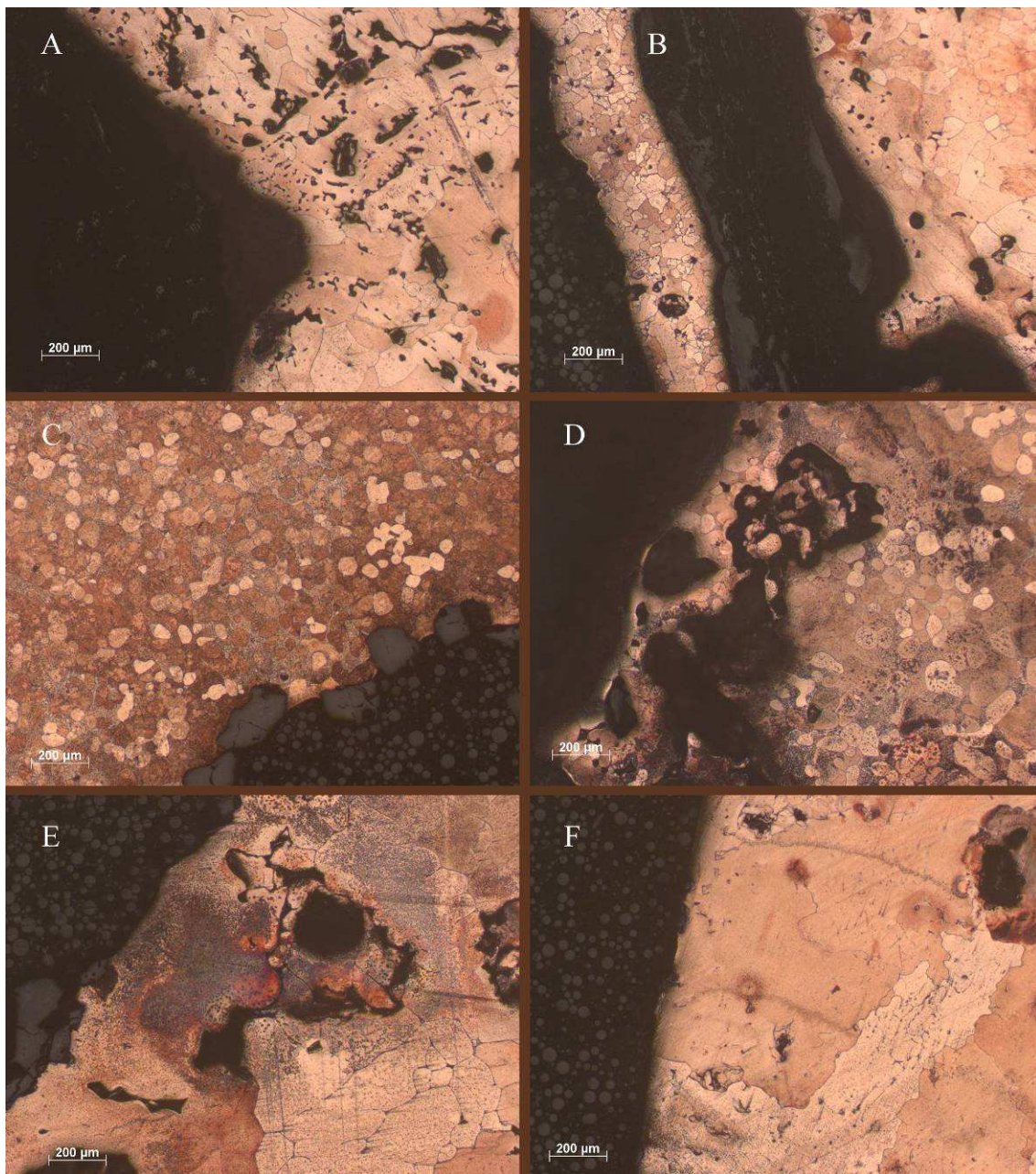


Fig. 40: Sections along the shaft-hole of the three water quenched samples with punched shaft-holes (source: Author)

One of the aims for this experiment was to find out if the punching of the shaft-hole might cause the longitudinal deformation seen in some archaeological axe samples by Coghlan and Pittioni (see Fig. 13) (1961, 70-72; 1957, 27). As the results show, this is clearly not the case. Although the punching does create specific characteristics along the walls of the shaft-hole, which can be clearly defined, they cannot explain the deformation seen in some archaeological axes. The action of driving the pointed wooden pole through the metal was done when the metal was still liquid. The grains only start forming when the metal solidifies, which obviously happened after the shaft-hole had been punched. The original theory that some of the downward force of the punch might happen late enough to deform some of the grains did not prove correct. This means that the search for the cause of the longitudinal deformation continues.

Drilled

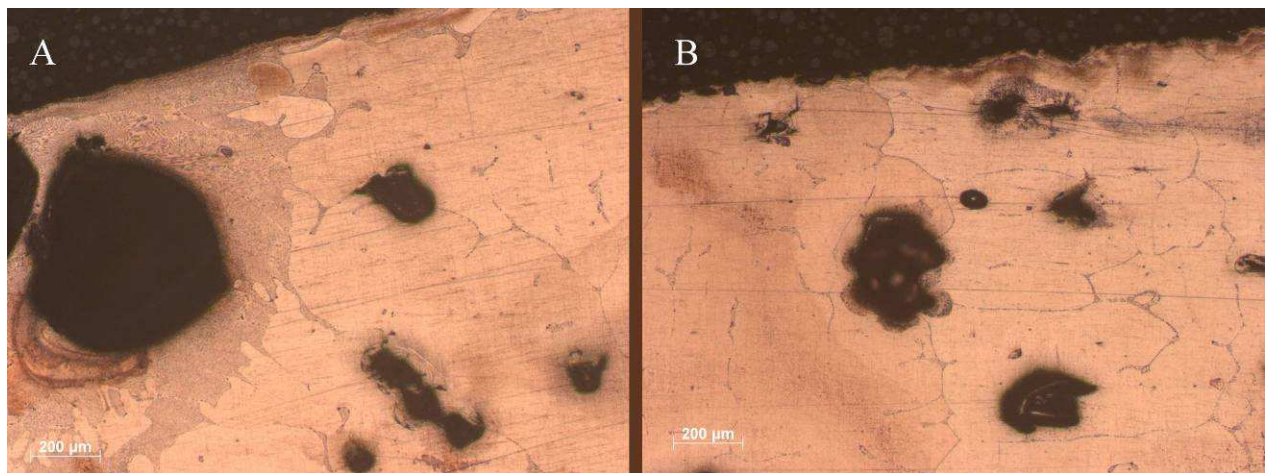


Fig. 41: Sections along the 'shaft-hole' of the drilled sample (source: Author)

Coghlan and Pittioni argue that the longitudinal deformation along the shaft-hole might have been caused by drilling the shaft-hole after the axe was cast. The drilling of the shaft-hole proved to be extremely difficult. It was only possible to partly drill one experimental axe blank (for a detailed discussion see Chapter 7), which unfortunately means that the sample size for this part of the experiment could not be maintained. As Fig. 41 shows, the drilling of the shaft-hole leaves by far the most straight and regular surface. There is no increased porosity towards the shaft-hole, and no longitudinal deformation of grains. This means that the premise of Coghlan and Pittioni cannot be upheld. The deformation observed in some of their sampled axes must have been caused by a different process or a secondary production step like forging. It could be argued that if the drilling had been carried on to drill the entire shaft-hole, more friction would

have been created and some deformation of the grain structure might have taken place. However, I think that this is extremely unlikely. Even if there was enough heat created to change the microstructure, an elongation of the grains cannot be explained in this way.

Summary

None of the three shaft-hole production techniques can explain the longitudinal deformation seen in some archaeological axes. The axes cast around a clay core do not show any significant changes to the shaft-hole surface or indeed the microstructure around the shaft-hole. Both the surface and the microstructure look metallographically indistinguishable from the side and bottom surfaces, which were in contact with the sand mould during cooling. The punched objects did show production-specific changes to the microstructure around the shaft-hole, like the increased porosity and a very uneven surface. However, the grains around the shaft-hole do not look any different to the grains of the rest of the object. Drilling the shaft-hole leaves the smoothest surface although other than the even shaft-hole, there are no specific changes to the microstructure. That none of the experimental production techniques cause the longitudinal elongation does of course not mean that they were not practiced during the Copper Age. As seen in Chapters 6 and 7 the macromorphology of some archaeological axes indicates that all three methods (clay core, punching, drilling) might have been used. The evidence so far suggests that there was not just one way of making the copper hammer-axes and axe-adzes, but many different ones. Unfortunately not many axes have been analysed metallographically, but, at the end of this chapter, the types and shapes, which have been sampled will be presented and compared to the experimental ones.

8.2.3 Archaeological axe

As previously discussed it was unfortunately impossible to sample a larger number of archaeological axes for metallographic analysis from museums as I did not get permission to do so. It is, after all, a destructive technique. However, instead I was given access to a Jászladány axe-adze from a private collection. In order to compare the results to the experimentally produced axes, the axe was sampled on one side of the shaft-hole. The sample was taken and prepared in the same way as the other experimental samples (see above). The sample was again analysed using reflected light microscopy. Photos were taken at a magnification of x50 and x200.

When looking at the micrographs of the original axe-adze it is possible to say that the microstructure definitively shows the presence of oxides between the original grain boundaries. It is probable that the oxides are made up of the (Cu+Cu₂O)-eutectic, as it has been shown that this is the case with most axe-adzes sampled (Kienlin and Pernicka 2009, 265). The original microstructure was re-crystallised through annealing or hot working (see Fig. 42). The deformation of the oxide chains indicates where the object was deformed and worked prior to being annealed. In this case the area along the top half of the shaft-hole has seen some intense deformation, whereas the lower shaft-hole half only shows some slight changes to the original cast structure (see Fig. 43).

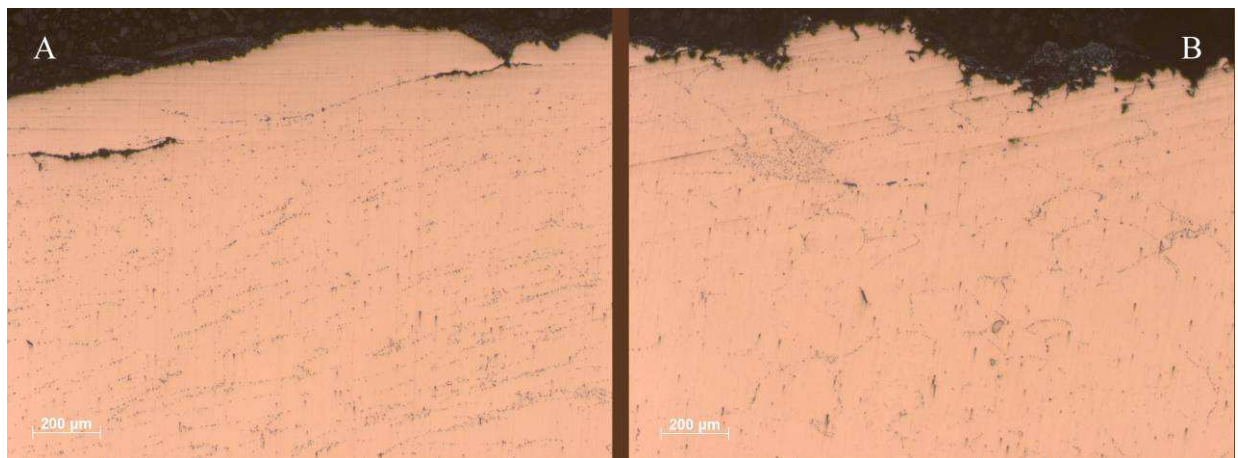


Fig. 42: The deformation of the as cast structure near the top end of the shaft-hole (A) and the lack of deformation near the bottom end (B) (source: Author)

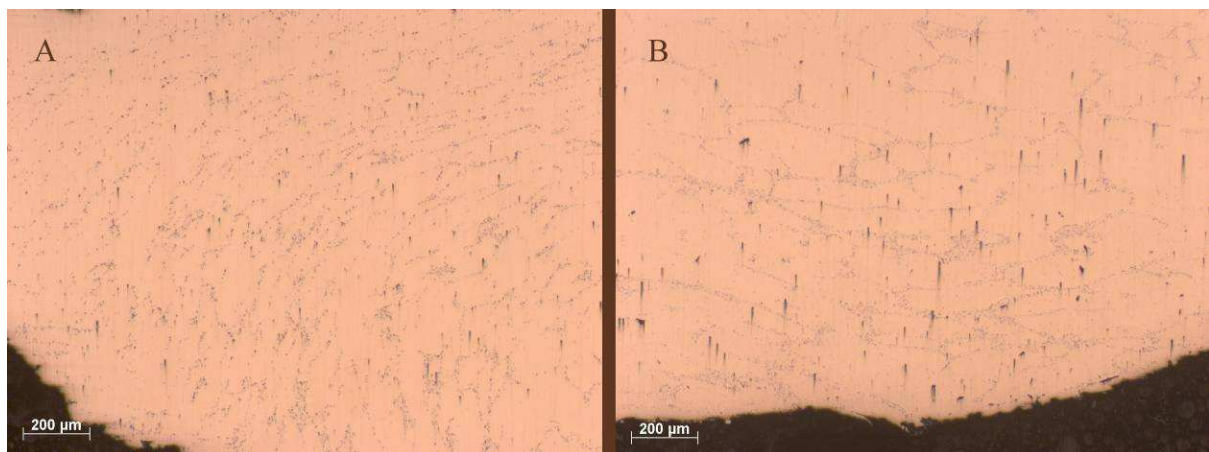


Fig. 43: The deformation of the as cast structure near the top of the outer surface (A) and the lack of deformation near the bottom of the outer surface (B) (source: Author)

The deformation is not localised to the shaft-hole, as it is also visible in the interior of the section as well as on the outer surface, where it is also more intense towards the top half (see Fig. 43) The heavy deformation at the top of the sample is also illustrated by a fragment along the top of the shaft-hole (see Fig. 44). It is difficult to say, however, if

an attempt was made to forge the fragment back onto the shaft-hole wall, or if it split during the heavy forging activity.

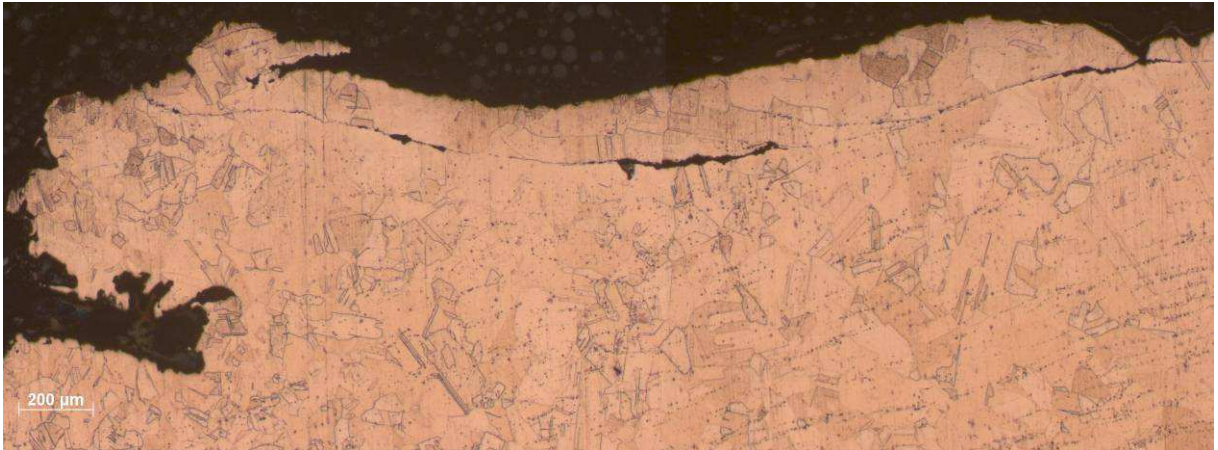


Fig. 44: A fragment along the top of the shaft-hole (source: Author)

Along the outer surface, towards the mid-section, there is also an area rich in copper oxide (see Fig. 45), which can be a sign that the area in question was at the surface of an open mould during solidification. Porosity is fairly evenly spread throughout the whole sample as can be seen on Fig. 42, 43 and 45.

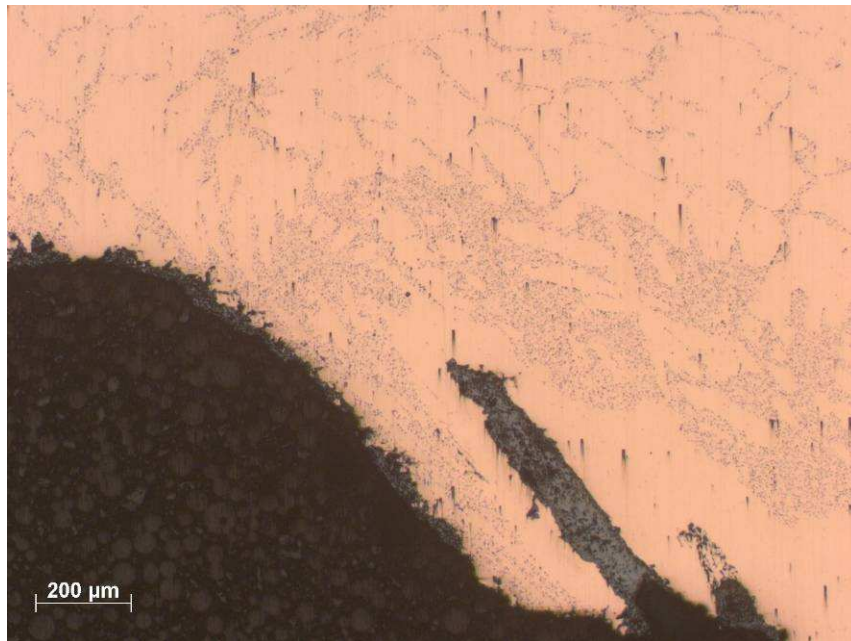


Fig. 45: The outer surface of the sample where there is a high copper oxide concentration (source: Author)

The overall microstructure of the etched sample is characterised by a re-crystallised structure. Throughout the sample the annealing twins are visible and the oxide distribution still hints at the primary cast and deformed structure (see Fig. 46 and appendix V). The outer surface seems to have been worked more thoroughly, as the

annealing twins and the re-crystallised grain structure are denser in this area (see Fig. 42).

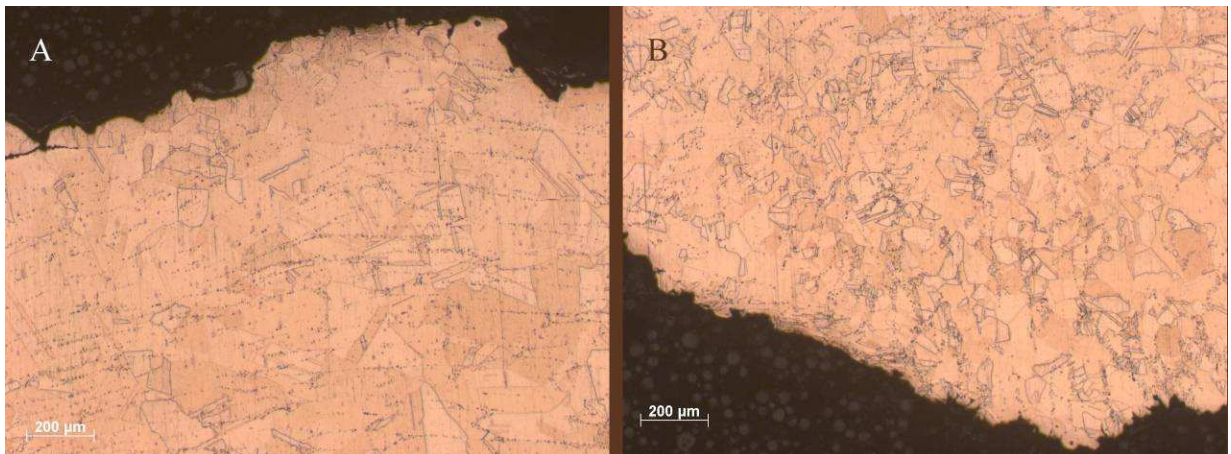


Fig. 46: The shaft-hole (A) as well as the outer surface of the sample (B) (source: Author)

Most of the sample does not seem to have been worked after it was annealed. It is only in the area near the lower half of the outer surface that we can see some strain lines (see Fig. 47) These indicate that the axe was, at this point, cold worked after the last anneal or hot work.

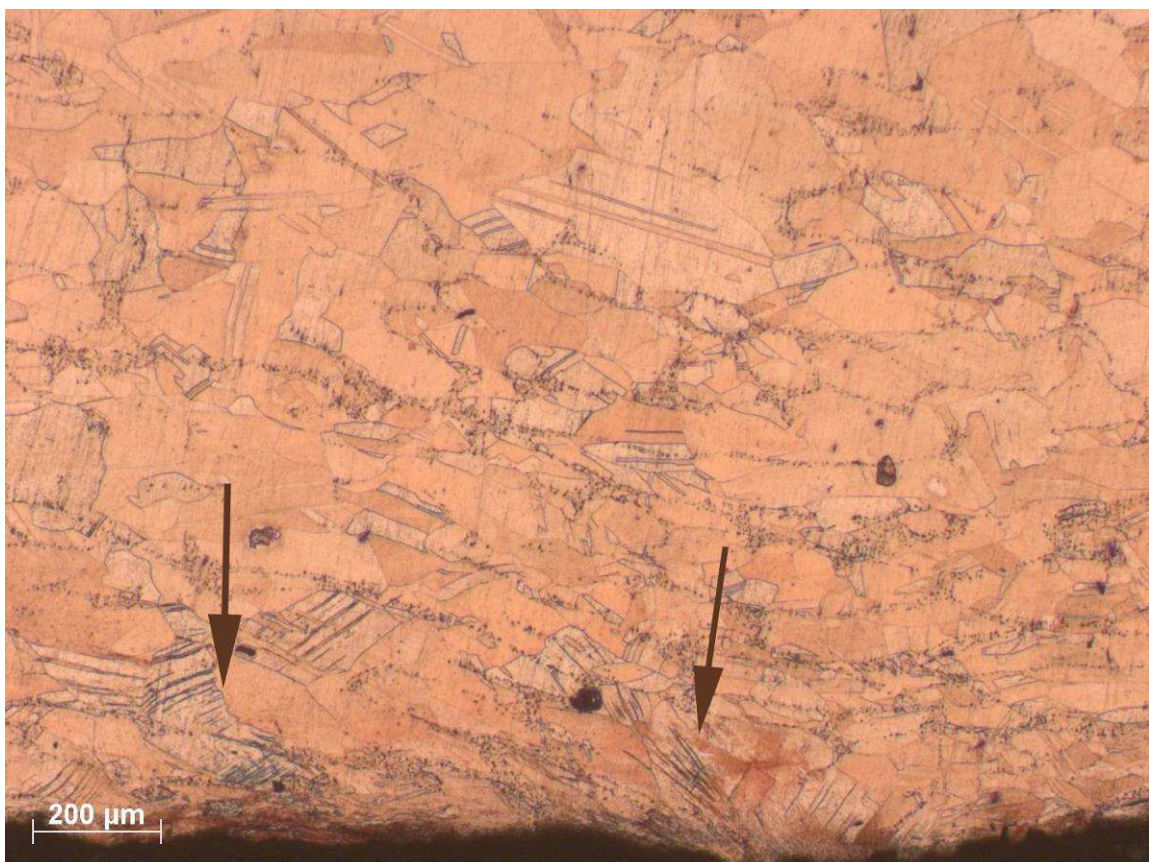


Fig. 47: Strain lines near the lower half of the outer surface (source: Author)

What can these observations tell us about the production sequence of this particular axe-adze? It was definitely cast, probably in a fairly rough shape. The final shape was finished through hot forging, which has been demonstrated for other Jászladány axe-adzes (Kienlin and Pernicka 2009). The shaft-hole was probably cast using a core of some sort, which was integrated into the mould. Although taking into account the axe blank discussed in Chapter 6, it is difficult to discount completely the possibility that the shaft-hole was added later. The metallographic evidence is also not conclusive. The fact that only the area around the top half of the shaft-hole seems to be heavily deformed suggests that the deformation did not necessarily have anything to do with the production of the shaft-hole. The deformation also raises the question how the round shape of the shaft-hole was maintained if indeed it was cast. Any forging activity carried out after the shaft-hole was created would also deform the shaft-hole unless some sort of rod was inserted in order to stop the shaft-hole from changing shape. It is therefore not possible to say how and when the shaft-hole was created. What is certain, however, is that most of the forging was carried out before the final anneal. Only along the outer surface of the sample are a few strain lines visible, which indicate some cold work at this point, being the last visible step in the production chain. This example illustrates that not every question can be answered through the analysis of the microstructure of archaeological specimens. In order to finally find the answer to the production of the shaft-hole, many more experiments need to be carried out and their results compared to archaeological axes. There might, of course, be different methods of creating the shaft-hole, which were used for different types of axes. This does not change the fact that more experiments, especially forging ones, are necessary in the future in order to answer this question.

8.3 The results in their archaeological context

One of the main problems of comparing the microstructures of the experimentally cast axes to the archaeological ones is that most were not worked further after casting. As described above, the microstructure of metals changes considerably when cold or hot worked and annealed. The primary structure shows deformation and the original grain boundaries can change beyond recognition due to re-crystallisation and the formation of the secondary structure. There are two reasons why the experimental axes were not worked further after casting. Firstly, a whole new set of experiments would have had to be designed and carried out, as it is not possible to test more than one specific question at a time. To design a meaningful forging experiment and to know what sort of original

shape one would need a clear understanding of the skills involved would be necessary. This leads into the second reason why the axes were not worked further after casting. In order to carry out experiments on hot/cold working and annealing, the experimenter would not only need to understand the detailed processes involved, but also need the necessary skill and experience of this craft. These prerequisites were not achievable in my case and any attempts to learn such skills can quickly be dismissed, as the time necessary for such an undertaking would greatly exceed the possibilities of a doctoral thesis. This illustrates nicely one of the dilemmas of experimental archaeology, as academics often do not have the necessary skill to use this methodology to its full potential. Despite these limitations, the results can still be used to throw light on two aspects of production when compared to the archaeological axes.

These two aspects are the formation of oxides, as well as the structure of the surface of the shaft-hole. For these problems only the primary structure is of any concern, which is present in both the archaeological axes and the experimental ones. The formation of oxides has a twofold importance. The increased presence of oxides on only one surface can be used to argue for the use of open moulds for the casting of these axes and the presence of oxides between the grain boundaries might help to better understand the casting process as well as the choices made by the prehistoric metal workers.

Table 7: A summary of the micrographs from the literature (source: Author)

Source	Axe type	Sample place	Observations	Sample or analysis nr.
Pittioni 1957	Hammer-axe Székely-Nádudvar	Across shaft-hole, across hammer arm, across axe arm and cutting edge	Oxides between grain boundaries present, deformed along shaft-hole and cutting edge. (Pittioni: Solid casting made, shaft-hole inserted later). Re-crystallised microstructure no evidence for final cold work	Axe nr. 9096, analysis 135
Pittioni 1957	Hammer-axe Unclassifiable but developed with shaft-hole lip	Across shaft-hole	Oxides between grain boundaries present, deformed along shaft-hole. (Pittioni: possibly solid casting, shaft-hole inserted later). Re-crystallised microstructure no evidence for final cold work	Axe nr. 4795 analysis 149

Coghlan 1961	Axe-adze Jászladány	Across shaft-hole	Oxides between grain boundaries present, deformed along shaft-hole. Surface of shaft-hole very uneven and porous. (Re- crystallised structure not clearly visible)	Axe nr. 1927-1542
Coghlan 1961	Axe-adze Kladari (?)	Across shaft-hole	Oxides between grain boundaries present. No clear indication of deformation near SH, only along top SH lip some marked striation of oxide. (Re-crystallised structure not clearly visible)	Axe nr. 1927-1538
Coghlan 1961	Axe-adze Jászladány	Across shaft-hole and cutting edge	Oxides between grain boundaries present. Elongated grains running at right angles to the SH. (copper compressed from top and bottom?) Top surface near SH lip patch of almost pure oxide with some dendrites. (Re-crystallised structure not clearly visible)	Axe nr. 1927-1541
Coghlan 1961	Hammer-axe	Top surface of axe arm, cutting edge and shaft- hole	Oxides between grain boundaries present. Highly worked multidirectional structure around top of shaft-hole. No increase in oxides near top surface, elongated grains and strain- markings near cutting edge. (Re-crystallised structure not clearly visible)	Axe A
Coghlan 1961	Hammer-axe	Top surface of axe arm, cutting edge and shaft- hole	Oxides between grain boundaries present and increase of oxides near top and bottom surface. Deformed along cutting edge and shaft-hole. Cracks in Cutting edge, two sides forged together.	Axe B
Patay <i>et</i> <i>al.</i> 1963	Axe-adze fragment Jászladány?	Axe arm, near shaft- hole and adze cutting	Oxides between grain boundaries present only some deformation. Not clear from where sample was taken. Re-crystallised	Find nr. 10

		edge	microstructure no evidence for final cold work	
Patay <i>et al.</i> 1963	Axe-adze fragment Jászladány?	At shaft-hole and adze arm near shaft-hole	Oxides between grain boundaries present only some deformation. Not clear from where sample was taken. No etched sample published	Find nr. 62
Renfrew 1969	Hammer-axe	At SH	Oxides between grain boundaries present. Increase of oxides near top, no deformation near shaft-hole. Re-crystallised microstructure no evidence for final cold work	1927-1512
Renfrew 1969	Axe-adze Jászladány	At SH	Oxides between grain boundaries present, deformation along shaft-hole and outer surfaces. Increase of oxides near top. Re-crystallised microstructure no evidence for final cold work	1927-1541
Ryndina and Ravich 2000	Hammer-axe Vidra	Cutting edge and SH	Oxides between grain boundaries present, deformation along shaft-hole and outer surfaces. Re-crystallised structure, cold working seen along SH	1379
Ryndina and Ravich 2000	Hammer-axe Varna	Cutting edge	Oxides between grain boundaries present, deformation at cutting edge. Re-crystallised grain structure indicates high temperature forging. No evidence of cold work	1368
Ryndina and Ravich 2000	Hammer-axe Pločnik	Cutting edge and SH	Oxides between grain boundaries present, deformation at cutting edge and shaft-hole. (Re-crystallised structure not clearly visible)	181
Ryndina and Ravich 2000	Fragmented hammer-axe or axe-adze	Axe body	High density of oxides. Difficult to say anything else as image is bad quality	1313

Ryndina and Ravich 2000	Axe-adze Mugeni	Bottom of axe arm, Adze cutting edge, SH	Oxides between grain boundaries present, deformation at cutting edge and shaft-hole. Large polyhedrons indicate forging took place at about 1000° C. Re-crystallised structure with strain lines near adze cutting edge and SH indicating cold working	372
Ryndina and Ravich 2001	Axe-adze Mugeni	Bottom of axe arm, SH	Oxides between grain boundaries present, deformation at cutting edge and shaft-hole. Large polyhedrons indicate forging took place at about 1000° C. Re-crystallised structure with strain lines near shaft-hole indicating cold working	369
Ryndina and Ravich 2001	Axe-adze Jászladány	Axe body, near cutting edge and near shaft- hole	Oxides between grain boundaries present, deformation at cutting edge and shaft-hole. Large polyhedrons indicate forging took place at about 1000° C. Re-crystallised structure not clear enough	370
Ryndina and Ravich 2001	Axe-adze Jászladány	Axe arm, Axe cutting edge, at SH and near SH?	Oxides between grain boundaries present, deformation at cutting edge and shaft-hole. Large polyhedrons indicate forging took place at about 1000° C. Re-crystallised structure with strain lines near shaft-hole indicating cold working	1290
Ryndina and Ravich 2001	Axe-adze Jászladány	Along SH	Oxides between grain boundaries present, deformation at shaft-hole. Large polyhedrons indicate forging took place at about 1000° C. Re-crystallised structure with strain lines near shaft-hole indicating cold working	1291
Ryndina and Ravich	Axe-adze Jászladány	Axe arm, Axe cutting edge and	Oxides between grain boundaries present, deformation at shaft-hole.	1292

2001		Adze arm	Large polyhedrons indicate forging took place at about 1000° C. Re-crystallised structure with strain lines indicating cold working	
Kienlin and Pernicka 2009	Axe-adze Jászladány	Axe cutting edge and adze cutting edge	Oxides between grain boundaries present, deformation along both cutting edges. Re-crystallised structure with no evidence for cold working.	48
Kienlin and Pernicka 2009	Axe-adze Jászladány	Axe cutting edge and adze cutting edge	Oxides between grain boundaries present, deformation along both cutting edges. Re-crystallised structure with no evidence for cold working.	175
Kienlin and Pernicka 2009	Axe-adze Jászladány	Axe cutting edge and adze cutting edge	Oxides between grain boundaries present, deformation along both cutting edges. Re-crystallised structure with no evidence for cold working.	178
Kienlin and Pernicka 2009	Axe-adze Jászladány	Axe cutting edge and adze cutting edge	Oxides between grain boundaries present, deformation along both cutting edges. Re-crystallised structure with no evidence for cold working.	179
Kienlin and Pernicka 2009	Axe-adze Jászladány	Axe cutting edge and adze cutting edge	Oxides between grain boundaries present, deformation along both cutting edges. Re-crystallised structure with no evidence for cold working.	205
Kienlin and Pernicka 2009	Axe-adze Jászladány	Axe cutting edge and adze cutting edge	Oxides between grain boundaries present, deformation along both cutting edges. Re-crystallised structure with no evidence for cold working.	206

The objects cast actualistically, were cast in closed, two-part moulds and do not show enhanced oxide formation on one side. The axes cast in open sand moulds for the shaft-

hole experiment, on the other hand, do show that more oxides are formed on the top surface, which is in direct contact with the air during casting and solidification. However, on some axes, an increase in oxide enrichment could also be seen on the lower surface. It is therefore difficult to use the presence of increased copper oxides on one side to come to a conclusion about the mould shape used. Only when axes are sampled at several different points can the presence of oxides be indicative of whether the axes might have been cast in open or closed moulds. Table 7 summarises the results of all sampled axe-adzes and hammer-axes from the literature. A total of 27 axes have been sampled and the results were published between 1957 and 2009. Only four of the axes show an increase in oxides on just one surface. One axe has copper oxides on both sides, and for the rest it is impossible to say as they were either sampled at only one place, or are not published in full. In fact the quality and method of recording is very variable, so that it is often difficult to compare the samples. Only the pictures relevant to the individual interests of the authors are published and addressed in the text. Of the four axes which do show an increase in oxides on just one surface, one is a hammer-axe and three are axe-adzes. One hammer-axe has an increase in copper oxides both near the top and the bottom surface. Although it is difficult to make any statements whether closed or open moulds were used for casting these axes, there are some examples with a clear increase in oxides near the top surface, which might suggest the use of open moulds. The archaeological axe sampled as part of this research also shows this pattern. Fig. 48 shows images of two archaeological axe-adzes, as well as one of the experimental cast axes. The microstructure with dendrites surrounded by the oxides is very similar and is caused in all likelihood by the use of an open mould.

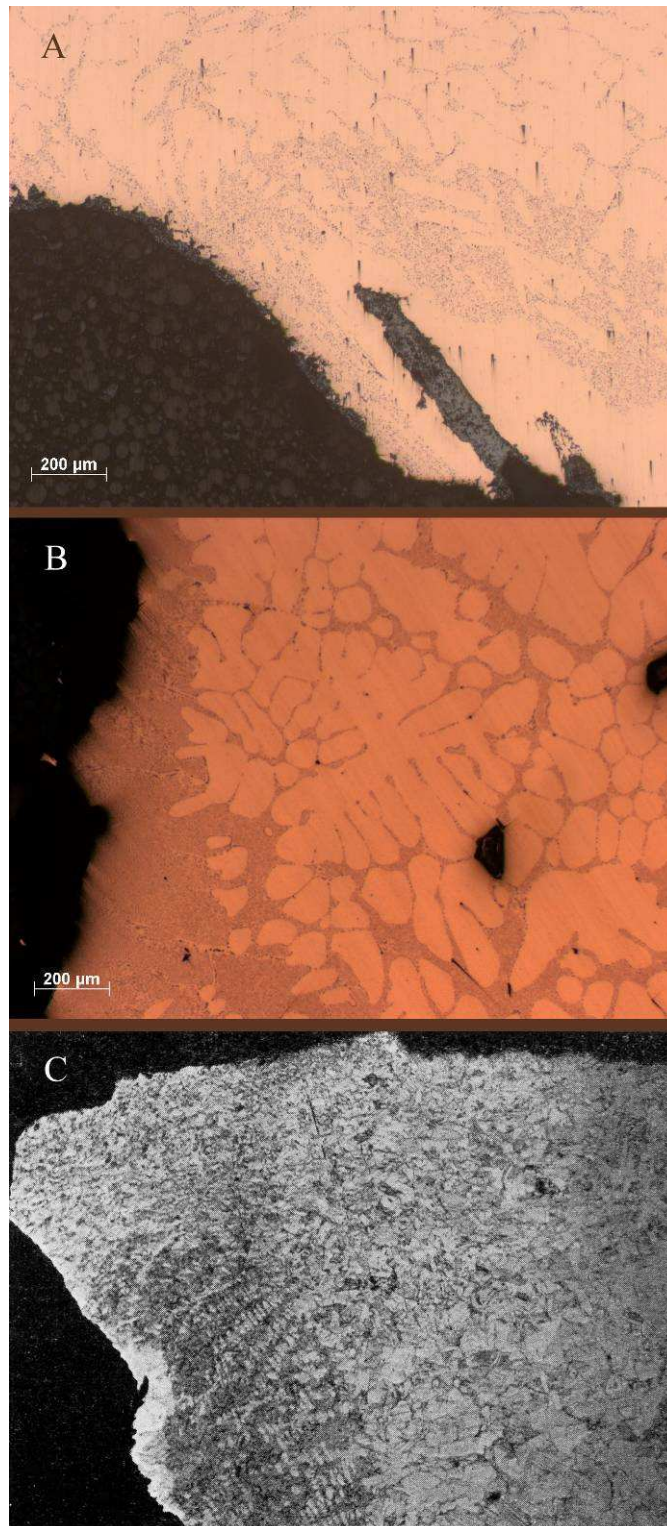


Fig. 48: Oxide enrichment of two archaeological axes (A and C) and one experimental one (B) (source: A-B Authors and C Coghlan 1961, p. 65, Fig. 9)

The presence of oxides between the grain boundaries has been discussed in a recent article (Kienlin and Pernicka 2009). Kienlin and Pernicka make two central statements regarding this issue. They argue that the presence of oxides between the grain boundaries does not in fact make the metal impossible to cold or hot work as is generally assumed in modern metallurgy. It is true that it does make the metal more

brittle and hard, but not to such an extent as to make further forging impossible. The second statement they make regarding the formation of oxides between the grain boundaries is that it was caused by the particular method of casting. It was noted that only the early (horizon 1) axe-adzes and flat axes (hammer-axes were not analysed for this article) showed this distinctive pattern of oxides between the grain boundaries. The Late Copper Age (horizon 2) flat axes on the other hand had almost oxide eutectic-free microstructures, which is usually seen as an improvement of the mechanical properties of the object (Kienlin and Pernicka 2009, 265-266). Kienlin and Pernicka argue that this difference is due to a change in casting technique from horizon 1 to horizon 2 axes (2009, 265-266), meaning that less oxygen is reaching the metal during melting and casting. If we look at the objects cast outside with Copper Age materials in closed moulds, it becomes clear, however, that it is possible to obtain almost oxide free casts, very similar to the horizon 2 objects even with 'primitive' techniques (see Fig. 29). The microstructures of the shaft-hole experiments on the other hand show that all of the 13 axes sampled had oxides between the grain boundaries. The crucibles were, in both cases, covered during the melting either by charcoal or a graphite lid. The process of pouring was longer for the actualistic casts, which would mean that more oxygen could be absorbed than in the shaft-hole experiments carried out with the electric furnace. However, the only oxide-free cast was obtained in this trial. The only difference, which could have substantially influenced the formation of oxides, is the shape of the mould. Whereas a closed mould was used for the actualistic trials, open sand moulds were used for the shaft-hole experiments. I therefore think that the mould type might actually be the reason for this oxide pattern. This would, of course, mean that the axe-adzes were probably cast in open moulds.

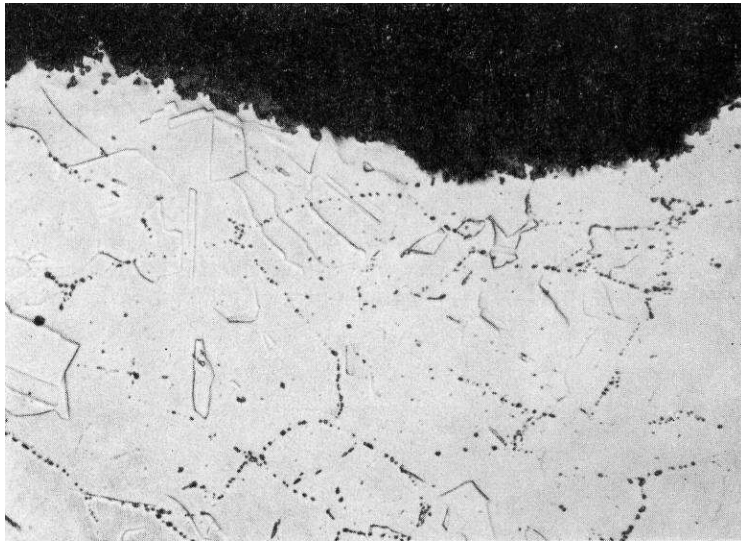


Fig. 49: An old micrograph of a shaft-hole surface of an axe-adze (source: Coghlan 1961, p.62, Fig. 6)

The most useful micrographs in the literature for comparing the surface of the shaft-hole of the experimental to the archaeological axes were published by Coghlan (1961, 62). All sections published by Coghlan as well as the micrographs of the archaeological axe sampled for this thesis research are fairly irregular. They do not, however, have an increase in porosity near the surface of the shaft-hole (see Fig. 49). When comparing this to the experimentally cast axes they are most similar to the axes cast around a core. The punched axes are too craggy and porous along the shaft-hole and the drilled axe is too smooth (see Fig. 39 and 41). The archaeological axes which can be compared are all Jászladány axe-adzes. It is therefore likely that these axes were cast with a shaft-hole core in place. This assumption is not, however, confirmed by the axe blank discussed in Chapter 6, as it was cast without a shaft-hole, but has the rough shape of an axe-adze. What has to be considered as well is that the surface of the shaft-hole might have changed through the forging work carried out after casting. A further aspect, which would have to be investigated through experiments, is, if using the hafted axes for a long time would leave identifiable trace in the microstructure. As the experimental axes are in an 'as cast' condition it could be argued that it is not possible to make any assumptions based on the results obtained in these experiments. Especially the more porous structure of the punched axes below the surface might well disappear if the metal was compacted parallel to the shaft-hole, as the longitudinal deformation of some axes suggests. This illustrates again how important further forging experiments would be for the untangling of the production technique.

Although no experiments have been carried out to look at hot/cold working and annealing, the evidence from the literature on archaeological axes will be briefly examined. Once more the varying quality of the published micrographs as well as the discussion of their properties is a problem. As Table 7 illustrates, some authors concentrate on presenting and discussing the primary structure whereas others seem to be more interested in the secondary traces of forging, annealing and cold work. There are three publications which are the most useful for looking at the actual production technique of the axes after casting. Two articles published by Ryndina and Ravich (2000, 2001) and one by Kienlin and Pernicka (2009) use the presence and absence of oxides and strain lines as well as the size of the re-crystallised grains to come to conclusions about cold working after casting, annealing and the temperatures, which were used to anneal or forge an object. What can be said is that every single copper axe micrograph which has been published also in the older literature has been annealed or worked at temperatures at which the microstructure re-crystallised. Ryndina and Ravich argue that they can establish which temperature range was used for annealing or hot working by looking at the grain size of the re-crystallised grains (2000, 10). They conclude that some axes were heated up to temperatures of up to 1000°C, whereas other axes like one Pločnik hammer-axe, were only annealed, forged or welded at temperatures between 300 and 500° C and 600-800°C (Ryndina and Ravich 2000, 10). If this could be confirmed by future work, it would be a great opportunity to distinguish between different traditions of manufacture in space and time. However, grain size can also be affected by other variables like previous deformation, which means that this will not be as straight forward as portrayed. The evidence for cold working is also not homogenous between all sampled axes. Whereas some were cold worked along the shaft-hole and cutting edges, others were not cold worked at all. As cold working increases the hardness and can therefore be seen as a desirable working step in the *chaîne opératoire*, its presence and absence, especially along the cutting edge, can again be used to identify different practices and choices made by the Copper Age metal workers. Some research carried out to date has successfully applied this idea (Kienlin and Pernicka 2009), however, a more detailed discussion will be presented in the final chapters including the cultural implications.

8.4 Summary and conclusion

In this chapter the results of the metallographic analysis carried out on the experimental axes was presented and discussed. Axes cast in an actualistic outdoor environment into

bivalve closed moulds as well as axes cast into open sand moulds using an electric furnace were sampled. The samples of the actual outdoor casts mainly illustrated the effect the shape and the pre-heating of the mould has on the formation of the microstructure. Whereas the axe cast in the cold mould had a much higher oxide concentration throughout the whole of the sample, casting in pre-heated moulds reduced the formation of oxides. The objects cast for the shaft-hole experiment did not differ much in their overall microstructure even though some were air cooled and others were water quenched. The main difference was noted on and near the surface of the shaft-hole walls. The clay core series had slightly irregular surfaces inside the shaft-hole, the punched series a very irregular surface with a lot of porosity and the drilled axe had the smoothest surface. None of the samples, not even the punched ones, showed any longitudinal deformation of the original cast structure along the shaft-hole. The samples also showed that an increase in copper oxides on the upper surface is related to casting in open moulds. The examination of the micrographs from archaeological axes both from published material and sampled by me, showed that some also had an increase of copper oxides on the upper surface, making open mould casting for at least some axes more likely. Other aspects of production visible in the microstructure of archaeological axes are the temperature of annealing and the presence and absence of cold working after annealing. Both show that there is great variety in the production techniques of these axes. In general the results from the archaeological axes would have been more useful if the casting experiments had been combined with forging ones. This was not possible within the framework of this research as stated above. Still, the new micrographs add to the small reference collection and are invaluable for future research.

9 A new typology for the copper hammer-axes and axe-adzes

Studying material culture from an archaeological or indeed anthropological perspective usually means engaging with or devising a typology for a specific object category. Things are grouped into types, respecting their similarities and differences. Assemblages are structured in order to enable interpretation. We all order the things around us, both consciously and unconsciously and the categorization of objects is at least as old as the first modern humans. When the theoretical debate on typology, mainly carried out in the 1970s (Hill and Evans 1972; Whittaker *et al.* 1998) asks whether present day categorizations of archaeological artefacts are real or constructed, the answer lies somewhere in the middle. The artefacts are the only surviving link between the people who made them in the past, and the archaeologist who is trying to understand and interpret them. As studies have shown (Whittaker *et al.* 1998), a group of people asked to sort the same assemblage into types can all come to very different conclusions. It is therefore obvious that any patterns people in the past might have perceived when looking at material culture are irretrievable for us today. However, some differences in a particular past assemblage can be significant both in the past and today, depending on the question one wants to ask. Looking at technological aspects of production, the outward form of the objects will be the deciding factor when devising a typology. These differences in form would have been significant in the past too.

9.1 Previous typologies

Copper hammer-axes and axe-adzes have a very long a history of research and the bulk of the axes known today were found in the late 19th and early 20th century. The first attempts to create a typology were carried out by Pulszky and Childe. Pulszky (1884, 57-69) divided the axes into hammer-axes, fat axe-adzes, slim axe-adzes (Jászladány) and large objects (Mezőkeresztes). Childe (1923, 172-173) split them also into four groups (A, B, C and D), although only groups A and C actually belong to the early copper hammer-axes and axe-adzes from south-eastern Europe. Group A includes all axes without shaft-hole lips, and group C encompasses the axes which became known as Jászladány as well as Székely-Nádudvar type axes (Childe 1923, 172-173). Other early typologies were created by Dunăreanu-Vulpe, Berciu, Roska, Driehaus and Garašanin (Berciu 1942; Driehaus 1952; Garašanin 1954; Vulpe 1975, 13)

The typology still in use today was set up by Schubert (1965) in his thesis on the copper axes from south-eastern Europe, which was unfortunately never published in full. He worked with the largest assemblage of hammer-axes and axe-adzes so far, avoiding the modern national boundaries during the creation of his typology. He divided the axes into hammer-axes (one hammer end and one axe end) and axes with two cutting edges. The latter group included not only the axes-adzes, but also all other combinations of cutting edges, like double adzes, and pick axes. He went on to divide each of these two groups into three subgroups, labelled I-III (see Fig. 49), with each subgroup being divided into different types. The names for these types were based on the names of findspots. From the 1970s onwards, the series 'Prähistorische Bronzefunde' began to be published (see Chapter 5). The PBF series are catalogues of specific materials which have created a firm base for many research projects.

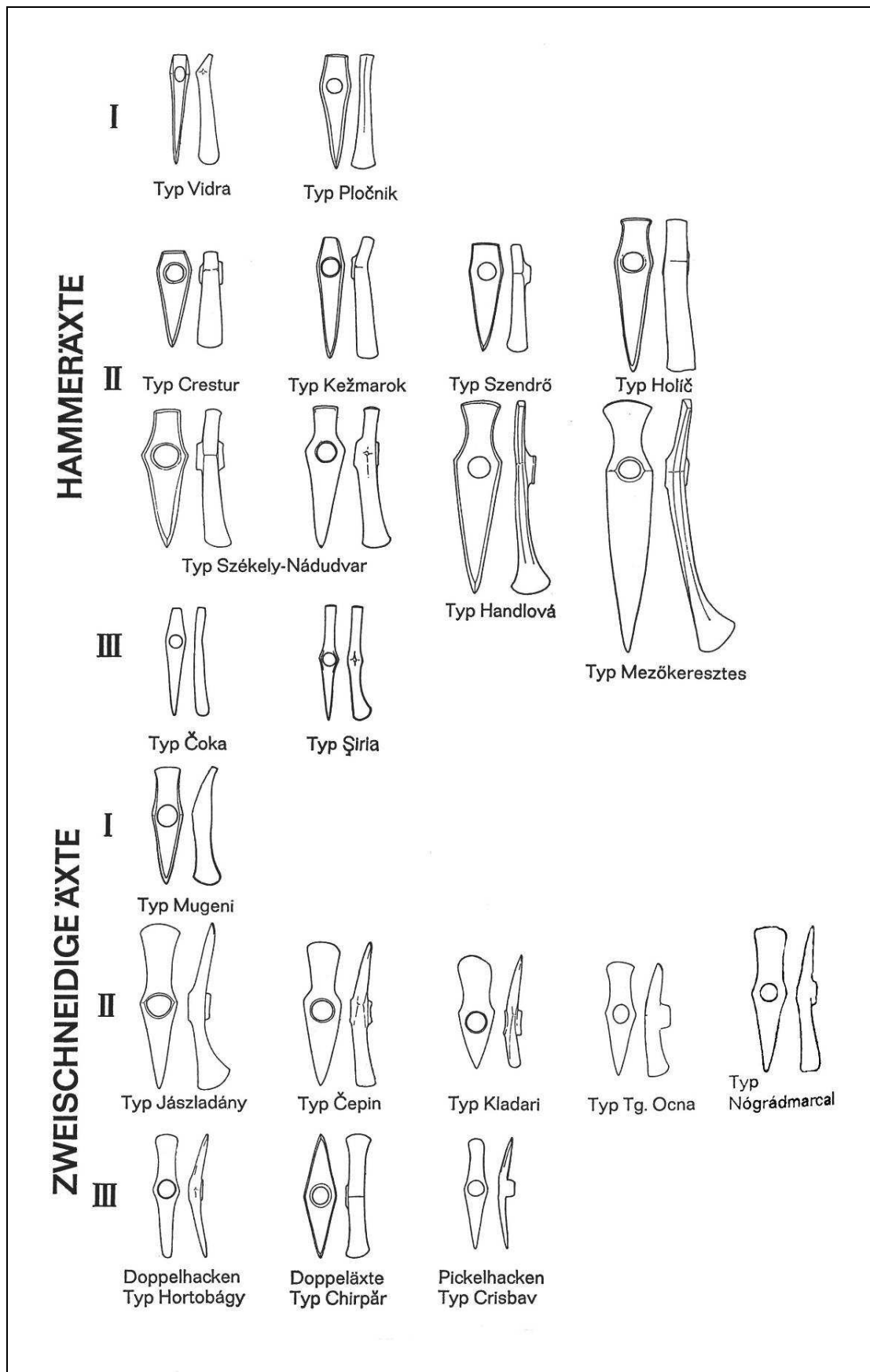


Fig. 50: The typology as devised by Schubert (source: Schubert 1965, p. 276, Fig. 1)

The first PBF volume covering the copper axes in question was published in 1970 by Novotná and dealt with the axes from Slovakia (Novotná 1970). She took over Schubert's basic typology, but added extra types and variants with names from Slovakian findspots. Vulpe and Mayer also published their PBF volumes in the 1970s on the Romanian and Austrian axes respectively (Mayer 1977; Vulpe 1975). In the 1980s, Todorova and Patay dealt with the copper hammer-axes and axe-adzes from Bulgaria and Hungary, and like previous PBF authors, they used Schubert's typology, adding new types and variants giving them names from local findspots. Říhovský (1992) was the only author of a PBF volume to devise an entirely new typology as mentioned already in Chapter 2. The three latest PBF publications did not take over Říhovský's system of categorising the copper hammer-axes and axe-adzes; instead they again used Schubert's typology, whilst creating local types and variants named after local findspots (Antonović 2010; Dergačev 2002; Žeravica 1993)

9.2 The new typology

To begin with, a system similar to Říhovský's, but somewhat simpler, was tried. It was also thought important to use a neutral terminology in order to make the new typology applicable to the entire distribution area of the axes in question. After a great many attempts at categorising and ascribing different levels of importance to different features and characteristics, it was realised that it is not possible. There is a problem with weighting different characteristics. The present assemblage of hammer-axes and axe-adzes includes clear types which stand out, but when defining them, one characteristic can have varying levels of importance in different types. This means that it is impossible to ascribe fixed levels of importance to different features as quite similar looking objects would end up in completely different types. For example the presence or absence of shaft-hole lips might be used as a characteristic to divide the hammer-axes into two groups. For the majority of the hammer-axes this actually works really well, but for the hammer-axes with a round hammer arm section this seems artificial, as a natural group would be split into two and lumped together with objects that are obviously different (see appendix I). It is, on the other hand, also impossible to use the shape of the hammer arm section as a dividing characteristic for all hammer-axes, as axes with square or rectangular section often share most other features and should be in the same group. This example illustrates that it is artificial to impose a weighting for different features when devising groups and types of hammer-axes and axes-adzes, as such boundaries are not actually visible in the material.

It is for these reasons that I decided to take over most of Schubert's groups and types as well. The material is exceptionally diverse and any 'objective' approach of classifying and weighting different features did not work. Looking closely at Schubert's typology showed that it was based on 'real' groups and types and not on the definition and weighting of artificiality constructed characteristics. 'Real' groups and types are understood in this context as clusters of similar objects which are visible in the assemblage. Although the type names Schubert used were all based on findspots, they have become so widely accepted and known that they very much belong to the history of research. Scholars working with this material, or on the Copper Age of south-eastern Europe in general, simply know what axe type is meant when one speaks about 'Jászladány' for example. However, instead of using the new local types and variants created by the authors of the PBF volumes, variations within Schubert's types were grouped into variants using neutral designations. The diversity within the types is difficult to categorise in contrast to the types themselves. It was not possible to find 'real' variants within the types, as the transitions between the differences are fluid. Vulpe mentions this difficulty too in the PBF volume on the copper axes from Romania (1975, 13). The variants were therefore defined by constructing different characteristics. The weighting of the features was different for each type, as the type-specific variations were taken into account.

9.2.1 The groups and types

It was decided to divide the assemblage into three categories:

Category 1 - hammer-axes

Category 2 - axe-adzes

Category 3 – double-axes and double-adzes

Category 4 – Pick-axes and pick-adzes

The axes belonging to categories 3 and 4 are extremely rare (see Fig. 7) and can therefore not be subdivided any further. Their distribution is also inconclusive. It is only the axes from the first two categories which will be dealt with below.

The hammer-axes were divided into four main groups. **Group I** includes the types Vidra and Pločnik and can be described as simple types without shaft-hole lips. **Group II** includes the developed types with shaft-hole lips Crestur, Szendrő and Székely-

Nádudvar. **Group III** is made up of the types Handlová and Mezökeresztes, which are particularly large objects, forming quite distinct types. **Group IV** is the last group and includes the type's Čoka and Şiria, both sharing a round hammer arm section. They are also much slimmer and look somewhat more elegant compared to the other hammer-axes. Patay used this as a reason to separate them from the rest of the hammer-axes, and called them battle-axes (Patay 1984, 9). As these two types do have one blunt hammer end and one axe end, they will in this present typology still be part of the hammer-axes, as they were in Schubert's typology. The term 'battle-axe' will not be used as this implies a known function for the objects, which is not at all possible to ascertain. Comparing my groups and types to the typology of Schubert one can see that not all of Schubert's types were used (see Fig. 49 and appendix I). The type Holič was not used because only two axes fitted the exact definition, whereas most probable Holič contenders could just as well be part of the type Székely-Nádudvar. The boundaries between many features are rather unclear and flowing, a problem which became even more apparent when separating the different variants. The type Kežmarok was merged with the type Szendrő as they are too similar to be classed as two types. This was also done by Patay also (Patay 1984, 9).

The axe-adzes were divided into three groups. **Group I** only includes the Mugeni type, as they do not have any shaft-hole lips. **Group II** includes the developed types with two shaft-hole lips, Jászladány, and Kladari. **Group III** is made up of the type Tg. Ocna-Nógrádmárcal, which only has a shaft-hole lip on the bottom side. Again not all of Schubert's types were used. The type Čepin was dispensed with as the few possible examples of this type could be either categorised as Jászladány or indeed Kladari. The types Tg. Ocna and Nógrádmárcal were merged as they are too similar to make up two separate types (see Fig. 49 and appendix I).

Table 8: The different groups and types of hammer-axes with description (source: Author)

Hammer-axes		
Group	Type	Description
I	Pločnik	No shaft-hole lips, boat shaped or pentagonal outline, straight almost parallel side view, rectangular hammer arm and end, hammer end shorter than axe end
	Vidra	No shaft-hole lips, pentagonal outline, mostly oval shaft-hole, short hammer arm sharply bend at shaft-hole (visible in side view only), hammer end shorter than axe end
II	Crestur	Shaft-hole lips present on both sides, stocky or ‘fat’ pentagonal outline, mostly straight but sometimes bend side view, hammer end shorter than axe end
	Szendrő	Shaft-hole lips only present at bottom, pentagonal or boat shaped outline, side view straight or hammer arm bend at shaft-hole, hammer end shorter than axe end
	Székely-Nádudvar	Shaft-hole lips present on both sides, top one can be integrated into axe body, outline shows marked corners at shaft-hole height, sides of hammer arm bend inwards in outline, sides of axe arm are sometimes straight in outline or bend inwards, side view straight or bend, hammer end mostly shorter than axe end
III	Handlová	Shaft-hole lips only present at bottom, outline shows marked corners slightly above shaft-hole height, sides of hammer arm bend inwards in outline, hammer end curved like a fan in outline, sides of axe arm are straight in outline, axe arm slightly bend in side view, hammer arm almost straight in side view, hammer end shorter than axe end
	Mezőkeresztes	Shaft-hole lips present on both sides, top one integrated into axe body, very large and heavy compared to rest of assemblage, sides of hammer arm bend inwards in outline, hammer end curved like a fan in outline, sides of axe arm are straight in outline, whole axe curved in side view, particularly the axe arm, hammer end shorter than axe end
IV	Čoka	No shaft-hole lips, round hammer arm and end section, slim boat shaped or pentagonal outline, hammer end shorter than axe end, straight or slightly curved side view
	Širia	Shaft-hole lips possible, round hammer arm and end section, slim outline shows marked corners at shaft-hole height, sides of hammer arm bend inwards in outline, sides of axe arm bend inwards in outline, axe and hammer arm at proportion of 1:1, axe arm curved in side view

Table 9: The different groups and types of axe-adzes with description (source: Author)

Axe-adzes		
Group	Type	Description
I	Mugeni	No shaft-hole lips, outline shows marked corners at shaft-hole height, sides of hammer arm bend inwards in outline, sides of axe arm can be straight or bend inwards in outline, axe and adze arm at proportion of 1:1, whole object curved in side view,
II	Tg. Ocna-Nógrádmargal	Shaft-hole lips only present at bottom, lips can be very marked, outline shows marked corners at shaft-hole height, sides of hammer arm bend inwards in outline, sides of axe arm can be straight or bend inwards in outline, axe and adze arm at proportion of 1:1, whole object curved in side view,
III	Jászládány	Shaft-hole lips present on both sides, top one integrated into axe body, outline shows marked corners at shaft-hole height, sides of hammer arm bend inwards in outline, sides of axe arm can be straight or bend inwards in outline, axe and adze arm at proportion of 1:1, whole object curved in side view,
	Kladari	Shaft-hole lips present on both sides, top one integrated into axe body, stocky or ‘fat’ outline, outline shows marked corners slightly above shaft-hole height, sides of hammer arm bend inwards in outline, hammer end can be curved like a fan in outline, sides of axe arm are straight in outline, axe arm shorter than adze arm

Table 10: Axes with other combinations of cutting/hammer arms and their descriptions (source: Author)

Axes with other combinations of cutting/hammer arms		
	Type	Description
Category 3	Double adzes	Shaft-hole implement with two adze arms
	Double axes	Shaft-hole implement with two axe arms
Category 4	Pick adzes	Shaft-hole implement with one adze arm and one pick
	Pick axes	Shaft-hole implement with one axe arm and one pick

The types listed in Tables 8-9, some of which were slightly adapted from Schubert’s original typology, are fairly easy to define and most of them are groups which jump out at one immediately. This approach is not necessarily the most objective or scientific, but

it proved much more effective than defining and weighting different features and characteristics without taking into account the internal dynamics of the material. It is probably correct to say that prehistoric craftspeople did not make objects according to the presence or absence of certain characteristics. It is therefore justified to look for inherent groups within an assemblage as Schubert had done.

9.2.2 The variants

By far the most common hammer-axes are the axes of the Székely-Nádudvar type and the most common axe-adzes the Jászladány type. It is particularly these two types which have been subdivided into subgroups by the authors of the PBF volumes and called after local findspots, creating confusing national assemblages which cannot be directly compared. This is the most important reason for reviewing and renewing the typology.

The process of subdividing the types into variants turned out to be much more difficult than anticipated. Whilst there are axes within most types which clearly differ from one another when looking at specific features, there are just as many objects which cover the entire scale between the different features identified. It is therefore extremely difficult to mark out inherent groups. This is due to two reasons, the techniques used to manufacture the object and the changeability of certain features due to re-sharpening or use.

Production

It is safe to say that the copper hammer-axes and axe-adzes were produced by casting. However, it is unclear in what state they were cast, as pretty much all axes were forged into their final state. Forging is a technique which cannot be used for all metals; the other important metal besides copper which can and was forged is, of course, iron. It lies in the nature of forging that the final shape cannot be as closely controlled as if an object were cast into its final shape, which is the case with bronze objects. There are therefore no two copper axes which could be called 'gussgleich', which means that they came out of the same mould. It is quite possible that the same pattern and/or mould was used for a number of axe-adzes for example, but the final stages of the manufacturing process would obliterate the traces of such an event. It is the forging which caused this great variability within the assemblage and makes it extremely difficult to categorise these objects beyond the main types. That it is possible to see the main types as homogeneous groups, which might indicate that their differences were predetermined

by the shape of the mould, while differences within the types which are difficult to define are due to individual forging variations.

Use-wear, re-sharpening and corrosion

In addition to the variability in shape caused by finishing the objects through forging, there are the unintentional changes certain features go through when they are used, re-sharpened or left to the elements. This is probably the biggest problem when trying to set up a typology, as differences in features defined as significant can, in fact, be simply the outcome of use or re-sharpening. The cutting edge of the adze-arm of an axe-adze for example, sometimes has straight sides, whereas at other times it has a fan-like broadening towards the cutting edge. This broadening could well happen through repeated re-sharpening and thinning out of blunt edges. It is therefore quite possible that two different looking objects which an archaeologist has classed as two different variants or even types, actually used to look the same when they were first made, except that one object had been used more than the other. Unfortunately it is impossible to tell if this was the case or not, but this difficulty has to be kept in mind when defining types and variants for a typology. There are, of course, features and characteristics which are less prone to changes through unintentional actions. In the current typology, features which are less likely to have been caused by unintentional actions and processes were viewed as being of more importance when defining variants of the major types. Such technological considerations are new in the history of research of the copper hammer-axes and axe-adzes, as all previous typologies have been made without any critical reflections of how the features used to differentiate between types and variants have come into being.

The variants

Pločnik

As stated above, the type Pločnik is the most 'simple' type, and shows a great similarity to the polished stone axes of the Neolithic. Indeed the two oldest-dated contexts where these large copper objects appear, namely the Carbuna Hoard (Tripolye A, 5500-4400 cal BC) in the modern Republic of Moldova and the settlement of Pločnik in Serbia (Vinča/Gradac phase late 6th to early 5th millennium BC), contain only hammer-axes of the Pločnik type amongst copper flat axes and chisels, polished stone axes and other smaller objects (Dergačev 2002, 11; Šljivar 2006, 103). Some Pločnik axes have also

been found in later contexts, dating to the end of the 5th millennium BC. The variability within the Pločnik axes was fairly easily defined as being caused by two main differences. The outline of the axes was either boat shaped or pentagonal, and the overall proportions were either rather stocky or slender. Not giving either one of these features more importance, the Pločnik axes were divided into four variants. (see appendix III). Both characteristics, the shape of the axe outline and the overall shape, are least likely to have been changed through repeated use, re-sharpening or indeed corrosion.

Pločnik A - stocky boat shape

Pločnik B - stocky pentagonal

Pločnik C - slender boat shape

Pločnik D - slender pentagonal

The spatial distribution shows that variants A and B occur mainly within the Carpathian Basin and in north-west Serbia. Variants C and D on the other hand occur in the entire study area (see appendix III). This means that it is the overall axe shape which is the decisive factor for the geographic pattern and not the outline. Only slender Pločnik axes were found in the south-eastern corner of the study area, the stocky ones only occurring in the north-western zone.

Vidra

The Vidra axes from known contexts which can be securely dated cluster around the mid to late 5th millennium BC. They do look more ‘developed’ than the Pločnik axes, which the dates seem to confirm. The Vidra axes were divided into two variants (see appendix III).

Vidra A – stocky

Vidra B – slender

The division between the stocky and slender Vidra axes is similar to the distribution of Pločnik axes, with slender axes occurring mainly to the south of the Lower Danube, and stocky ones to the North of the Danube (see appendix III).

Crestur

The Crestur axes cannot be securely dated, although one example comes from a Tiszapolgár burial context, which suggests that they were in circulation during the late 5th millennium. Although they do show some variability, it is not clear cut, and the overall number is too small to allow for the definition of any variants beyond the main type (see appendix. I). Their spatial distribution confirms this homogeneity, as almost all Crestur axes come from the northern Carpathian Basin, particularly the area around the upper Tisza and lower Körös rivers (see appendix III).

Szendrő

The dating of the Szendrő axes is as difficult as the Crestur axes, with only one axe coming from a Tiszapolgár burial context. This means they were probably in use at about the same time during the late 5th millennium BC. Two variants were classified for the Szendrő axes, which can be clearly defined. The majority of these axes have a straight side view, but some are bent at the shaft-hole (see appendix I). Some scholars have suggested that the bending might have happened when the shaft-hole was punched while the metal was still soft (see Chapters 6 and 7).

Szendrő A – straight side view

Szendrő B – bent side view

There is no difference in the spatial distribution of the two variants. Although there are fewer axes of variant B, both styles concentrate in the hilly region of the southern West Carpathians in Hungary and Slovakia (see appendix III).

Székely-Nádudvar

The axes of the type Székely-Nádudvar are the most numerous amongst the hammer-axes. Unfortunately it is not possible to date them securely. It is only possible to say that they were present during the Tiszapolgár period, which means during the late 5th millennium BC. They are, in and of themselves, not at all homogenous but the transitions between the different shapes are often fluid making it difficult to define new variants. The nine variants which were defined are based on the outline, the overall

shape (stocky or not) and the type of the shaft-hole lips (see appendix I) The different outlines can be defined as consisting of a combination of straight or inward curving axe and hammer sides. These are again two criteria which should not be influenced too much by unintentional actions such as use and re-sharpening. Depending on the sides of the hammer end, it can be either mushroom-like or straight. As it is a hammer end, this feature too cannot have been caused by re-sharpening as the hammer end is blunt already by definition. The nature of the shaft-hole lips differs only at the top. The bottom shaft-hole lip usually looks like it is added on or created while the shaft-hole is made. It has a 'stuck on' look. The top lip on the other hand can either look like the bottom ones just described, or they are integrated within the axe body, as if they were part of the mould. The illustrations are not always good enough, however, to distinguish between the two.

The variants are:

Székely-Nádudvar A – Stocky

Székely-Nádudvar B – The edges of all four sides curves inwards in outline, the hammer end is shaped like a mushroom

Székely-Nádudvar C1 - The edges of all four sides curves inwards in outline, the hammer end is rectangular with parallel sides, neither shaft-hole lip is integrated into axe body

Székely-Nádudvar C2 - The edges of all four sides curves inwards in outline, the hammer end is rectangular with parallel sides, the top shaft-hole lip is integrated into axe body

Székely-Nádudvar D1 – The sides of the axe arm are straight in outline, the sides of the hammer arm curve inwards, the hammer end is shaped like a mushroom, neither shaft-hole lip is integrated into axe body

Székely-Nádudvar D2 - The sides of the axe arm are straight in outline, the sides of the hammer arm curve inwards, the hammer end is shaped like a mushroom, the top shaft-hole lip is integrated into axe body

Székely-Nádudvar E1 - The sides of the axe arm are straight in outline, the sides of the hammer arm curve inwards, the hammer end is rectangular with parallel sides, neither shaft-hole lip is integrated into axe body

Székely-Nádudvar E2 - The sides of the axe arm are straight in outline, the sides of the hammer arm curve inwards, the hammer end is rectangular with parallel sides, the top shaft-hole lip is integrated into axe body

Székely-Nádudvar E3 – Clearly definable boat shape, belonging to the E variant

Székely-Nádudvar X – isolated not definable variants

The Székely-Nádudvar axes are found almost exclusively north of the Danube within the Carpathian Basin. Concentrations can be noted in the northern Alföld, Transylvania, and along the Morava (March) river as well as the middle Danube (see appendix III). Only variants A and B show a specific distribution, with all other variants occurring throughout the Carpathian Basin. Axes of variant A are mainly found in the western Carpathian Basin, whereas variant B occurs in Transylvania. Outliers are found along the Balkan, Adriatic coastline.

Handlová

The Handlová axes are very few in number and are very homogeneous, meaning that there are no variants to be defined. None come from datable contexts, but judging by their developed shape and style, they are definitely not part of the early axe assemblages. As they show some similarities with the Mezökeresztes axes, a tentative date of around 4000 cal BC can be postulated (see appendix I). Handlová axes are one of the few axe types which have a very distinct distribution, in this case in the western most tip of the Carpathian Arc (see appendix III).

Mezökeresztes

These are the largest early copper objects by far, measuring up to 40cm in length and more than 3.5 kg in weight. Again this type is very homogeneous, and there is no need to define any variants. There are a couple of axes from possible secure contexts where they are found together with material belonging to the Tiszapolgár and Bodrogkeresztúr groups. This would mean that the Mezökeresztes axes were in use at around 4000 cal. BC, but it is not clear if they were also in use earlier and/or later. Their spatial

distribution concentrates in the north-eastern Pannonian Plain, although some axes also occur along the middle and lower Danube (see appendix. III).

Čoka

The Čoka axes clearly date to the second half of the 5th millennium BC, with axes coming from Varna II and III burial contexts as well as from Tiszapolgár burials. This is a clearly definable homogeneous type and no variants were classified (see appendix I). Despite this their spatial distribution does not show a clear concentration (see appendix III). A number of objects classified as Čoka axes in the PBF volume on Serbia, clustering around the area where the Tisza and Sava join the Danube, cannot be actually defined as Čoka axes according to the new typology.

Şiria

The axes of the type Şiria are a developed version of the Čoka type. They are, however, not as clearly datable as only one axe comes from a possible Bodrogkeresztúr context. This would mean they were in circulation around 4000 cal. BC. Again it is a homogeneous type and no variants were defined (see appendix I). The Şiria axes do show a spatial concentration along the Middle Danube and Tisza (see appendix III).

Mugeni

Not a single axe of the Mugeni type has been found in a datable context. Although they do show some variability, it is not clear cut, and the overall number is too small to allow for the definition of any variants, beyond the main type (see appendix. I). Although Mugeni axes are found on the Black Sea coast and on the Adriatic, there are three distinct clusters occurring in the south-eastern tip of Transylvania, around the lower Sava and to the south-eastern of the Iron Gates along the Danube (see appendix III).

Tg. Ocna-Nógrádmartal

As the name suggests, the type Tg. Ocna-Nógrádmartal is a combination of two types. Schubert defined the two types according to morphological differences, with the Tg. Ocna axes with long shaft-hole lips occurring mainly in the eastern Carpathian Basin, Moldavia and around the Lower Danube, hence the Romanian name. The Nógrádmartal axes have the same overall outline but have a shorter shaft-hole lip. They seem to occur more frequently around the Western Carpathians in northern Hungary and Slovakia. In general though the two types are fairly similar and not always so easily to define or distinguish. This has probably led to the geographical origin of the axes being deemed more important than the overall shape in the PBF volumes from Romania and Hungary (see appendix I). Vulpe (1975, 13) states that if similar variants are present in two different locations it warrants a different name in itself. However, both the distribution and the shapes are not clear cut, which is why the two types were combined and the origin was not taken into account while defining the variants. Defining similar axes as different types according to their geographical location would create misleading distribution patterns.

The axes of the type Tg. Ocna-Nógrádmartal are not datable. Although not as numerous as the Jászladány axes, they do show some considerable internal variations, and can be loosely divided into five variants. The features used to differentiate between the variants are the overall axe shape, the lower shaft-hole lip, and the outline of the adze arm. All of these criteria except the outline of the adze arm can be said to have been created intentionally. The difference in shape in the outline of the adze arm, however, could be due to re-sharpening and use as was discussed earlier. It was nevertheless used to divide the larger C variant into C1 and C2 as the difference is clearly visible. One just has to bear in mind that these differences might not be intentional (see appendix I).

Tg. Ocna-Nógrádmartal A1 – short and stocky with an extremely long lower shaft-hole lip

Tg. Ocna-Nógrádmartal A2 – short and stocky with a less pronounced lower shaft-hole lip

Tg. Ocna-Nógrádmartal B – extremely long and thin axe body with lower shaft-hole lip

Tg. Ocna-Nógrádmарcal C1 – long axe body with slight lower shaft-hole lip and fan like adze arm

Tg. Ocna-Nógrádmарcal C2 - long axe body with slight lower shaft-hole lip and straight adze arm sides

Tg. Ocna-Nógrádmарcal X - isolated not definable variants

The stocky axes with long shaft-hole lips (A1) do indeed cluster around the eastern most corner of the Carpathian Basin but so do the stocky axes with less pronounced shaft-holes. The long and more slender axes are found in the western Carpathian Basin and around the lower Danube (see appendix III). The Tg. Ocna-Nógrádmарcal axes in general are distributed fairly evenly over the whole study area.

Jászladány

The axes make up almost half of the overall assemblage of hammer-axes and axe-adzes. For their comparatively large number, only a few axes come from datable contexts. The few axes found in situ indicate that they were in circulation during the late 5th and the early 4th millennium BC. The Jászladány axes are, despite their large number, fairly homogeneous when it comes to criteria which were probably intentional. Only the stocky axes stand out as one variant which was definitely intentional. The other differences within this specific type are the outline of the adze arm, and the outline around the shaft-hole. Both were used to create the variants, although in some axes these differences might have been caused by use, re-sharpening or even corrosion. The boundaries between the variants are often fluid, making it difficult to apply them to each and every axe (see appendix. I).

Jászladány A1 – round outline around shaft-hole, straight to almost straight adze sides in outline

Jászladány A2 - round outline around shaft-hole, slight fanning of adze arm in outline

Jászladány A3 - round outline around shaft-hole, strong fanning of adze end in outline

Jászladány B1 – two corners either side of shaft-hole in outline, straight to almost straight adze sides in outline

Jászladány B2 - two corners either side of shaft-hole in outline, slight fanning of adze arm in outline

Jászladány B3 - two corners either side of shaft-hole in outline, strong fanning of adze end in outline

Jászladány C – stocky axe body

Jászladány X - isolated not definable variants

The Jászladány axes are found over the entire distribution area of the copper axe-adzes and hammer-axes. There are, however, three distinct areas with a high density of finds, namely the northern Pannonian Plain, Transylvania, and along the Danube around the Iron Gates. It is difficult to identify spatial patterns which are specific to certain variants, although looking at the three ‘cluster zones’ some slight differences can be noted. Variant A does not cluster within Transylvania, whereas variants B and C occur in all regions. Only variant A2 seems to have a specific concentration around the Iron Gates (see appendix III).

Kladari

Not a single axe of the Kladari type has been found in a datable context. However, they were probably not in circulation before the last third of the 5th millennium BC, as they are technologically similar to the Jászladány axes. They do not show enough variation to justify the creation of any variants. The Kladari axes show a number of clear spatial concentrations, along the Sava, the Velika Morava and around the Iron Gates. Some isolated examples occur in the Pannonian Plain, Transylvania and along the Adriatic (see appendix I and III).

9.3 Conclusion

Though I started out to devise an entirely new classification system for the copper hammer-axes and axe-adzes from south-eastern Europe, I ended up producing more of a deconstruction and reformation of the generally accepted typology. A number of major changes were made nevertheless, and it is hoped that the ‘new typology’ will be more user-friendly and better suited to the material, which comes from such a large area. The

aim was to overcome the modern national borders and find a system which can be applied to the entire assemblage, without imposing artificial boundaries. The result is the continued use of the major type names as known from Schubert and used in all the major publications in the last 30 or so years with only some structural changes. These major types were then divided into new variants, which try to portray the variability or homogeneity within the types, using neutral designations. This neutrality is important for enabling the application of the typology to the entire assemblage.

The spatial distribution does show some type- and sometimes, variant-specific patterns. A number of types, particularly the Jászladány axes occur throughout the study area, whereas other types have a more localised origin. This has some interesting implications, as some axe forms seem to 'ignore' or transcend the cultural boundaries, whereas others seem to be typical for a certain cultural group, like the Kladari axes for the Vinča and/or Krivodol-Sălcuța-Bubanj Hum complex. Although certain concentrations fall within an area of a specific cultural group or ceramic tradition, the clusters are often even more localised than that. The three main clusters, in Transylvania, the northern Pannonian Plain and around the Iron Gates cannot be clearly identified as core areas for local cultural groups.

10 Patterns and trends in the copper axe assemblage

A number of important issues will be approached in this chapter through analysing the data using graphs, tables and GIS distribution maps. The distribution, (missing) context as well as the marks⁵ and fragmentation of the copper axes will be discussed from different angles. Patterns in the composition and dimensions of the objects will be investigated, before the results of the different themes are integrated in the summary. It is only the hammer-axes and axe-adzes which are present in large enough numbers to be used for these purposes. The double-adzes and axes, as well as the pick-axes and adzes, will therefore be disregarded in the following queries and analyses. The hammer-axes and axe-adzes will be contrasted throughout this chapter if appropriate in order to get closer to the possible functional differences between the two major object classes under consideration.

10.1 Distribution and Context

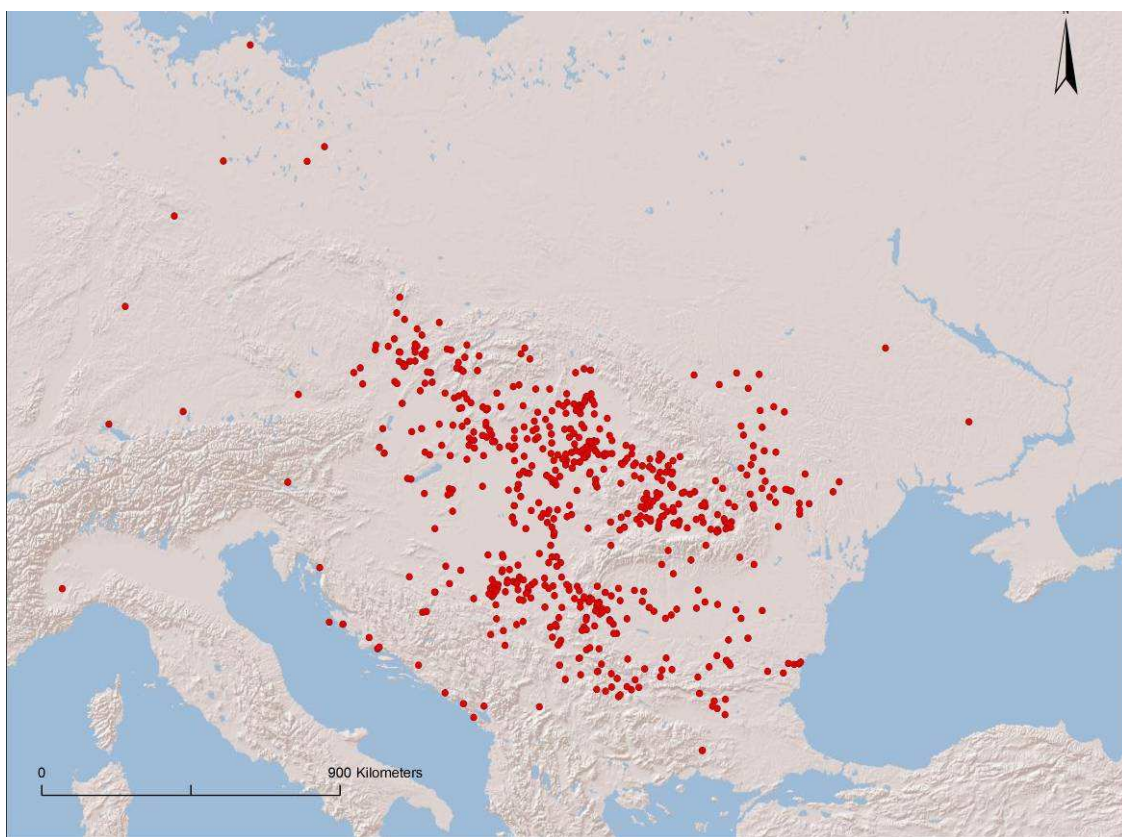


Fig. 51: The distribution of all Copper Age hammer-axes and axe-adzes with known findspots (source: Author)

⁵ Although it is the axe 'marks' are usually talked about as 'decoration', I specifically do not use the term 'decoration' when writing about them in general, as this implies a function, which can, at the moment not be verified.

10.1.1 Distribution

When mapping all hammer-axes and axe-adzes with known findspots (see Fig. 51) three main concentrations become apparent: one in the north-eastern Pannonian Plain, one in Transylvania and the last along the Middle Danube around the Iron Gates. The two clusters lying within the Carpathian Basin might belong to the same zone, as they are only divided by the Romanian western Carpathians. As mountainous areas have generally only a few axe finds, they might not represent a true division between two different clusters. To the north of this mountain range, the two areas are clearly connected with numerous axe finds along the Someş/Szamos river valley. We could therefore talk about a Carpathian and a Danubian concentration of copper axes. Although the main distribution of the axes is surprisingly compact there are a number of interesting outliers. Two of the furthest are an axe-adze found near Stralsund in northern Germany (ID1198), and one in Pollenzo, northern Italy (ID1313).



Fig. 52: The main distribution area of the copper axes from south-eastern Europe (source: Author)

Looking closer at the main distribution area, the two/three clusters are still evident (see Fig. 52). It is interesting to observe that none of the three areas where the distribution of the axes is at its densest matches the exact territory of the cultural groups in question. Although the northern Alföld is firmly part of the Tiszapolgár region, it is just a small part of the overall area settled by this Copper Age group. The two other areas with a dense cluster of axes (Transylvania and Iron Gates) can be characterized by not belonging to a core region of any of the groups, but rather being situated in border regions of different cultural groups. If the concentration of axes in certain areas was not directly linked to any of the cultural groups, what were the factors influencing these clusters instead? It could simply indicate that these regions were more densely settled than others. Alternatively it could have something to do with the local supply networks of copper and copper artefacts. The cluster around the Iron Gates could be linked to the copper mines around Majdanpek, as Rudna Glava was not in use anymore at the time when most axes were in circulation. The same could be said for the Transylvanian cluster as it lies in close proximity to the Romanian Ore Mountains. Unfortunately not a single mine has been identified in this area, not even through lead isotope analysis as is the case with Majdanpek. It is only the cluster in the northern Hungarian Plain which is some way removed from the nearest copper deposits in Slovakia. It is therefore not possible to answer this question for certain as many cultural, technological and environmental reasons could account for this pattern.

The map also seems to indicate that a substantial proportion of hammer-axes and axe-adzes concentrate along the rivers. In order to test this supposition, axes lying within a buffer zone of 1km either side of the major rivers were selected using ArcView. Surprisingly, only 44 out of 895 axes were actually contained in this 2km wide zone along the main rivers. Looking closer at the shapefile of the major rivers it became evident that the rivers were represented by one line only, disregarding the width of the rivers completely. For smaller rivers this is not a problem, but the Danube cannot be represented by a single line. As the Danube can be up to 1,5km wide, a thin line drawn on one side or even in the centre of the course of the river would not accurately contain the axes within 1km either side of the river. A second shapefile was created digitising both sides of the Danube as well as all smaller rivers in the distribution area of the axes, which are visible on the base map used.

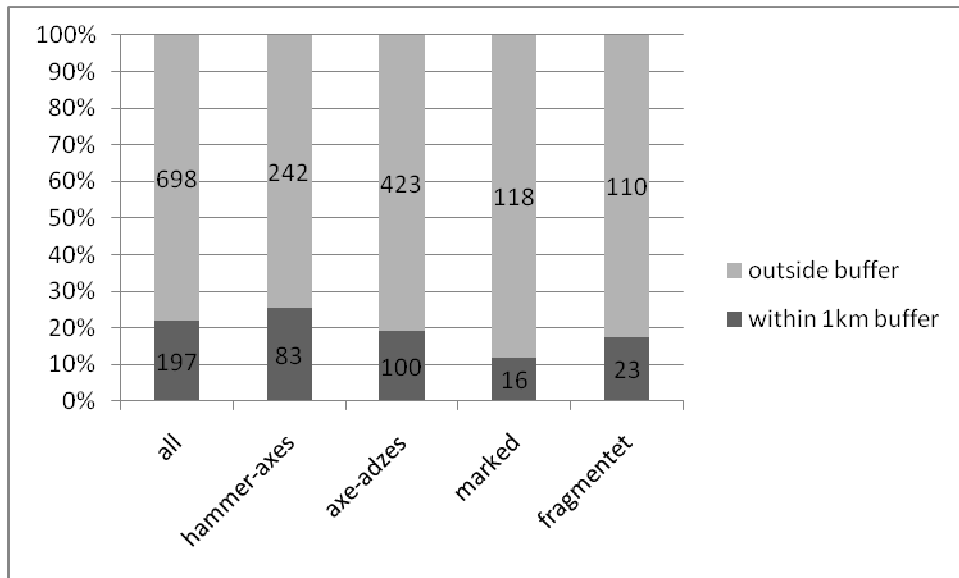


Fig. 53: The proportion of different axe groups, which occur inside and outside a 1km buffer zone around the rivers (source: Author)

When creating a buffer around the rivers from the second shapefile, 197 out of 895 axes lie within 1km of the rivers. Fig. 53 shows that this is just over 20%. Investigating the proportions of hammer-axes and axe-adzes as well as marked and fragmented axes lying within the buffer zone separately, slight differences can be noted (see Fig. 53). However, they are not clear enough to suggest a direct relationship between waterways and the deposition of particular axe shapes.

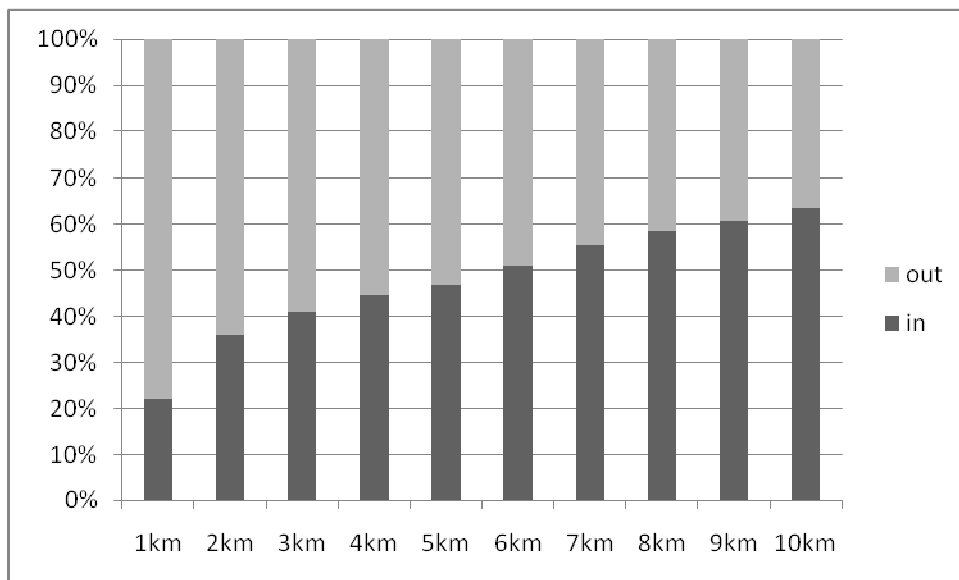


Fig. 54: The proportion of axes occurring within different distances of the rivers (source: Author)

The appearance that a substantial proportion of axes are found close to rivers as seen on the distribution map (see Fig. 52) is not confirmed by these results. It is of course a question of scale. When enlarging the buffer zone to 10 km, more than half of all axes

fall within this area (see Fig. 53). Although axes lying more than 1km away from rivers do not necessarily have a direct relationship with a river, they confirm the settlement patterns of the time. Most sites do occur in river valleys or on river terraces. The fact that more than half of all axes are found within an area of 10km either side of a river simply reinforces the fact that most of people's daily life in the past was linked in certain ways to the major river systems. Whether it was the actual rivers or the specific ecology and geography around rivers which attracted people most, remains unanswered.

10.1.2 Context

It is important to stress that the vast majority of objects under study are isolated finds (see Fig. 55). Only 17% come from a secure context and an extra 9% come from a possible known context. The situation is not helped by the sometimes haphazard excavation and publication techniques practiced in south-eastern Europe.

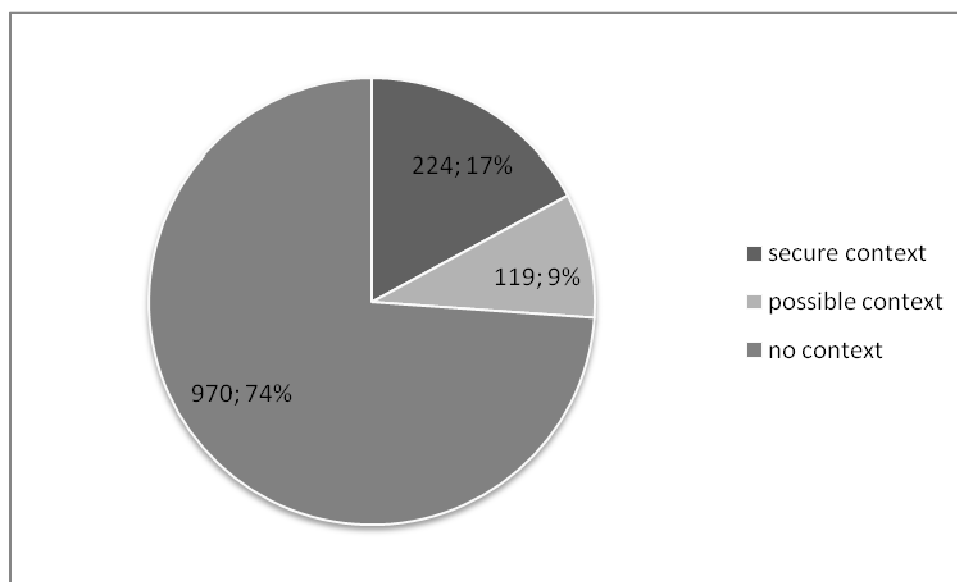


Fig. 55: The proportion of axes coming from secure, possible and no contexts (source: Author)

The objects which do come from a known context, come either from hoards, burials or settlements (see Fig. 56). One problem of this dataset appears when we compare the proportion of axes coming from settlement and burial contexts to the proportion of axes coming from hoard contexts.

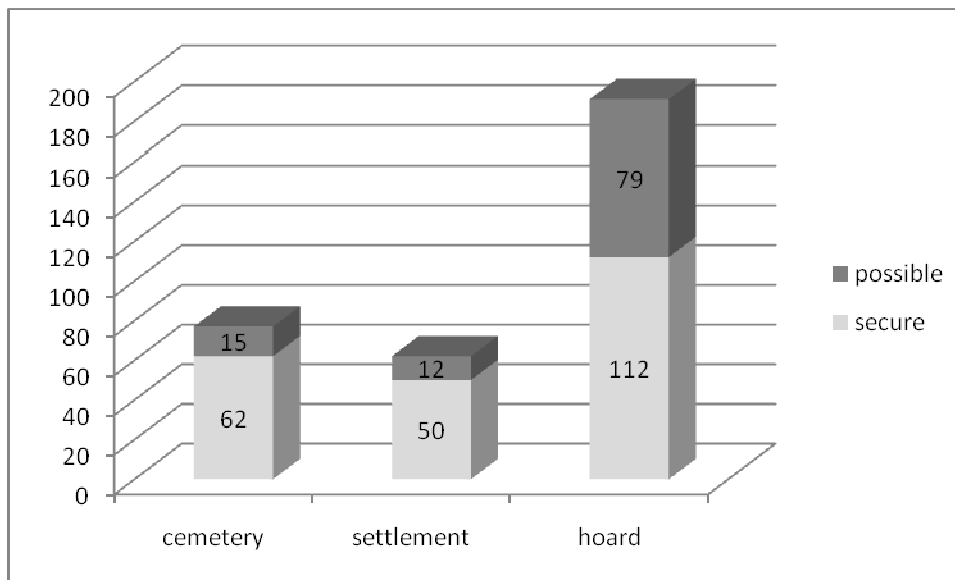


Fig. 56: The number of axes coming from different contexts (source: Author)

The large number of isolated finds are more likely to come from unidentified hoards than from a settlement or burial context, as hoards generally occur without any other connected finds or features, and are therefore easily missed. Of course settlements and cemeteries can also be missed, especially if the axes were ploughed up and subsequently found on the field, but not as likely as a hoard. This means that the true proportion of the different contexts will never be known, although the prevalence of objects coming from hoards might be even more pronounced in reality (see Fig. 56).

Although the number of axes coming from known contexts is fairly small and the comparison of the different find situations is not always easy, there seems to be a pattern emerging when comparing the two main axe categories. As there are considerably more axe-adzes than hammer-axes, the values in Fig. 57 are expressed in percentages of the total number of objects. Only objects coming from secure find circumstances have been used for the graph in Fig. 57.

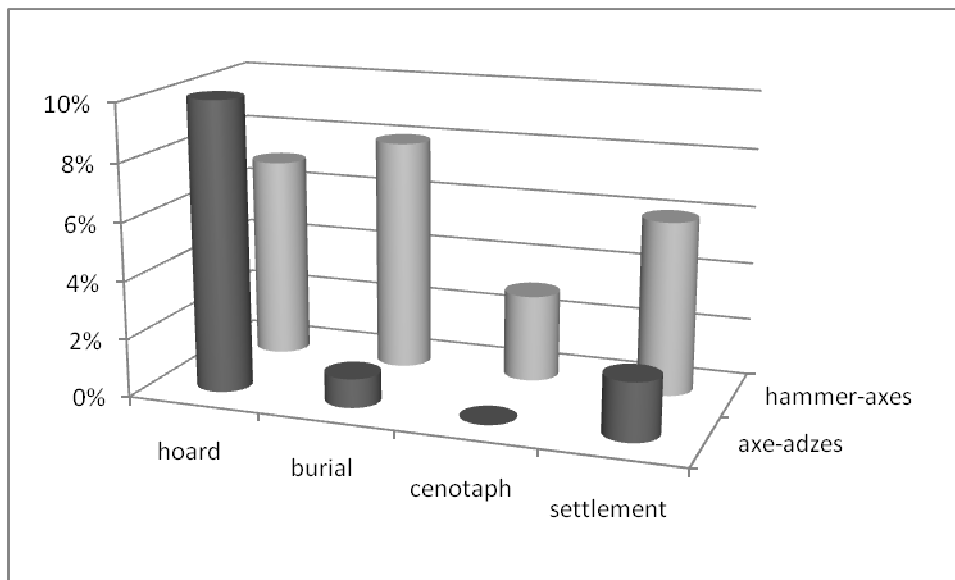


Fig. 57: The proportion of hammer-axes and axe-adzes coming from different contexts (source: Author)

Whereas hammer-axes are relatively evenly distributed across all four contexts, axe-adzes come mainly from hoards. Might this indicate a difference in function between these two object categories? The low proportion of axe-adzes coming from burials compared to hammer-axes might suggest that they did not play as large a role in actions of display. However, other lines of evidence like possible spatial and temporal differences between the practices have to be looked at before coming to any conclusions.

Looking at the spatial distribution of axes coming from different contexts, some clear regional differences become evident. It can be seen in Fig. 58 that axes from settlement contexts are clearly concentrated along the eastern edge of the distribution area. Axes from burials/cenotaphs come mainly from the Hungarian Plain and eastern Bulgaria. Axes from hoard contexts do not show such clear trends, although it could be argued that they are more common in the western regions of the distribution area.

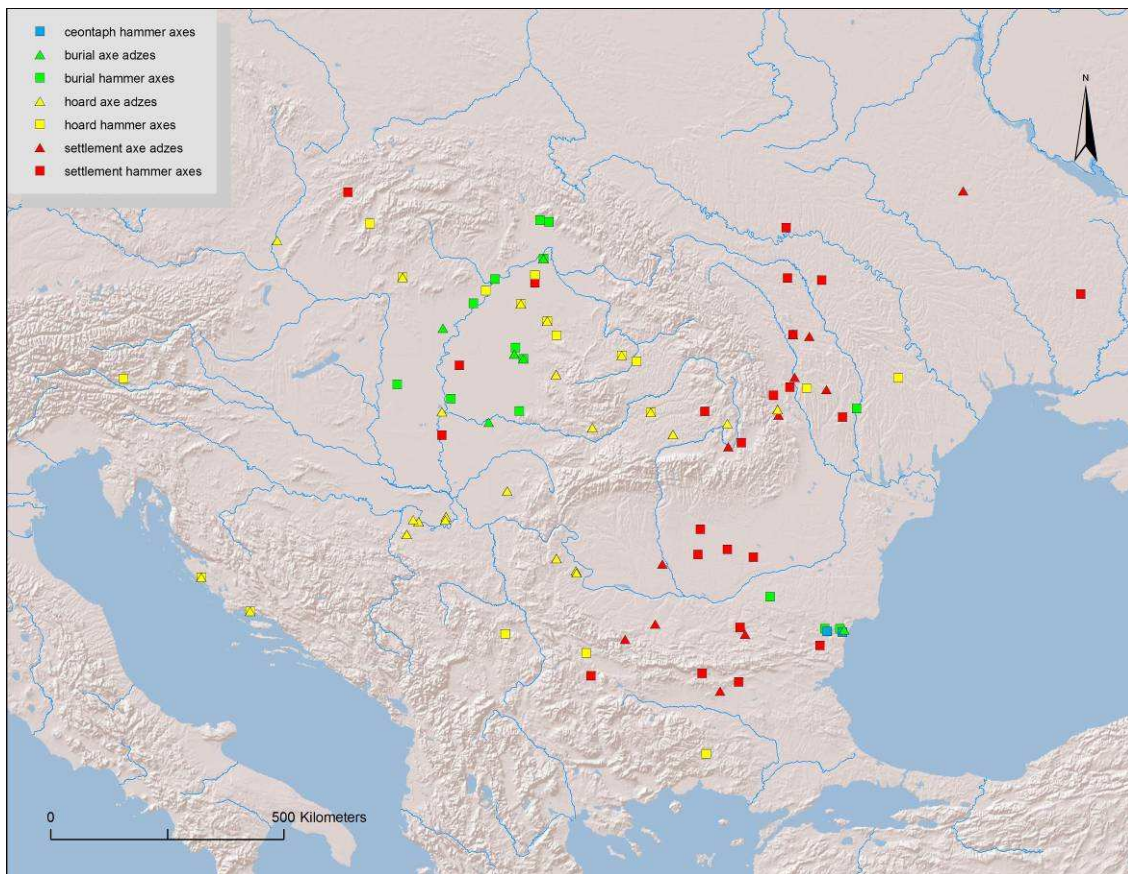


Fig. 58: Axe-adzes and hammer-axes from three different contexts (source: Author)

Settlements

The lack of axes coming from settlement contexts in the western area is curious. However, looking back at the settlement history of the Hungarian Plain one has to remember that there was a major shift from numerous tell settlements to fewer, more ephemeral settlements with the appearance of the first large copper axes. The lack of ‘obvious’ settlements might well bias the data. Many axes from settlement contexts, which were found in situ came from burned down houses. There are numerous cases where a deliberate, possibly ritual burning down of houses has been proposed (Bailey 2000, 191). The problem is that in the majority of cases there is not enough information on the exact circumstances of excavation to identify if a house was burned down deliberately or accidentally. The importance of such a differentiation lies in the meaning it would have for the deposition of the axes. If a house burned down accidentally, the axe would have been left in the house because this is where it was used or stored last. The axe would have been deposited accidentally too. If, on the other hand, a house was burned down on purpose, the objects within the house might be placed there

purposefully and knowingly taking on a more 'hoard-like' character. Looking at Fig. 56 it is evident that a higher proportion of hammer-axes come from settlement contexts than axe-adzes. This relationship has been confirmed as being statistically significant to a high degree of confidence using a chi square test (P value < 0.0001). However, as there is not a major difference in the overall distribution of hammer-axes and axe-adzes, it is unlikely that this would have an impact on the spread of axe finds from settlements. It is therefore likely that the prevalence of hammer-axes coming from settlement contexts is a real trend. Although the spatial distribution of axes coming from settlements might be biased by the nature of settlements and/or the burning down of houses it could also point to variations in customs or traditions between the different cultural regions.

Hoards

Although the real number of axes coming from hoards is difficult to ascertain, a slight trend in their spatial distribution can be noted. As the proportion of hammer-axes coming from hoard contexts is not significantly different to the axe-adzes as has been confirmed by a chi squared test (P value = 0.5289), the axe shape can be discounted as a factor when interpreting the spatial variation of the finds. The axes coming from hoard contexts (see Fig. 57) seem to be more common in the western Balkans and the Carpathian Basin. The lower Danube, as well as the areas around the Black Sea, is largely devoid of hoard finds. If this is a true tendency the tradition of hoarding or depositing valuable items might have been more important in the societies of the Tiszapolgár, Bodrogkeresztúr Vinča and KSBH groups than in the KGK VI complex of the lower Danube.

Burials

Looking at Fig. 57, the axes coming from a burial context seem to be confined to the Carpathian Basin. Although there are more cemetery sites containing graves with copper axes in the Carpathian Basin than anywhere else in the distribution area, by far the largest proportion of axes from graves and cenotaphs (25, 59%) comes from the cemetery of Varna. The remaining 41% come from 18 other cemetery sites, which have between one and seven axes each. Varna is in many regards a special case, as it is by far the richest known cemetery of the European Copper Age. Three of the four cemeteries containing copper axes from Bulgaria lie in and around Varna on the coast of the Black Sea, and only one of the 33 axes is an axe-adze, the rest being hammer-axes. The axes

coming from burial contexts show a clear and significant difference between the two axe forms. This was also confirmed through a chi square test (P value <0.0001). Despite the overall prevalence of hammer-axes in burials, the cemeteries in the Carpathian Basin do not share this trend with the cemeteries on the Black Sea and the lower Danube. Axe-adzes are almost as common as hammer-axes in graves on the Hungarian Plain. The cemetery at Tibava in modern day Slovakia is an exception, as all seven large copper axes are hammer-axes. Interpreting these results is difficult as it is debatable whether the sample size is large enough. However, the elites of the KGK VI and Varna groups seem to have favoured hammer-axes as grave goods, whereas the Tiszapolgár and Bodrogkeresztúr groups used both axe forms in their funerary rites.

The difference in spatial distribution between the axes from hoards, settlements and burials probably illustrates both the varying practices and distinct meanings the objects had in certain areas, as well as the nature of archaeological preservation. The presence of settlement finds from Bulgaria and the lack of settlement finds in the Carpathian Basin are more likely to confirm the type of regional archaeological evidence than any specific custom or practice linked to the copper axes. The vast majority of known sites from the Tiszapolgár and Bodrogkeresztúr group are cemeteries. It is therefore understandable that the axes from known context ought to come from cemeteries and not from settlements in the Carpathian Basin. The Copper Age KGK VI complex on the lower Danube and the Black Sea on the other hand is famous for its tell settlements as well as some extremely rich graveyards. It is therefore especially the distribution of hoard finds, which might tell us about differing practices between eastern and western parts of the study area.

10.2 Composition

The data for the investigation on chemical composition were obtained from a study on Copper and Early Bronze Age metallurgy between the Carpathian Basin and Baltic Sea, which was one of the outcomes of two projects (SMAP and FMZM) funded by the VW-Stiftung in the 1990's (2003) (see also Chapters 2 and 5). The two projects combined the old SAM data (Studien zu den Anfängen der Metallurgie) with new analyses. Multivariate cluster analysis was then used to test the old SAM groups, and to achieve new interpretations on a more regional level (Krause 2003, 87). The 34 clusters obtained by Pernicka using the complete dataset can be compared with some variations

to the 29 SAM groups (Krause 2003, 87; Pernicka 1995a, 97). For a correlation between some original SAM groups and the new clusters see Table 4 in Chapter 5.

Table 11: The clusters from the complete dataset and their chemical characterization, as well as the number of axes, which fall into each cluster. (source: adapted from Krause 2003, p, 89, Fig. 39)*The axes refer only to those objects, which are relevant to this research, namely the early copper axes from south-eastern Europe.

Cluster no.	Copper variety	Trace elements (main elements printed bold)	Class	No. of axes* per cluster
1	Classic 'Ösenringkupper'	As, Sb, Ag , (Bi), no Ni	Fahlore copper without Nickel (IIa)	8 (1,8%)
2	Purest copper	No measurable trace elements	Pure copper (IIIa)	381 (85,6%)
3	With occasional traces of Ag	As , no Sb, Ni, Bi	Arsenic copper (Va)	19 (4,3%)
4	Eastern alpine copper	As, Ni , Sb, no Bi	Fahlore copper with Nickel (Ib)	1 (0,2%)
5		As, Ni , no Sb, Ag, Bi	Pure copper with slight traces of As and Ni (IIIb)	3 (0,7%)
6		Sb, As, Ag, kein Ni, Bi	Arsenic copper (Vb)	12 (2,7%)
7	Copper with higher traces of Sb and Ag	Sb, Ag , no As, Ni, Bi	Antimony copper (IVa)	16 (3,6%)
8	Singen copper	As, Sb, Ni, Ag	Fahlore copper with Nickel (Ia)	1 (0,2%)
10	Similar to 'Ösenringkupper'	As, Sb, Ni, Ag, no Bi	Fahlore copper without Nickel (IIb)	2 (0,4%)
11		Sb, Ag, Ni , no As, Bi	Antimony copper (IVb)	1 (0,2%)
12	Fahlore copper without Ag	As, Sb , no Ag	Arsenic copper (IIIc)	1 (0,2%)

Table 11 shows the categorization of the relevant clusters for this study, as well as the number of axes which fall into each cluster. These clusters belong to the 34 clusters obtained from the complete dataset analysed by Pernicka in the 1990's (1995a, 97). As can be seen on Table 11, the vast majority of copper hammer-axes and axe-adzes falls into cluster 2. It is the purest copper, with only slight traces of impurities. The relationship of the impurities is given as: $Ag > (As/Sb/Ni)$ (Krause 2003, 90). The view that parts of cluster 2 might represent native copper has been invalidated, as cluster 14 (containing no As and Bi, but traces of Sb, Ag and Ni) is now thought to be an indicator for native copper (Krause 2003, 89-90). The purity of the copper might point to the fact that a lot of Copper was already recycled during the Copper Age. The constant re-melting might therefore lead to a refining of the copper, as trace elements are lost in the process (Jochum Zimmermann et al. 2004). Indeed, experiments have shown that most elements except tin are affected by repeated remelting although the extent of loss varies greatly from element to element (Jochum Zimmermann et al. 2004, 134). This means that recycling might indeed result in a 'purer' copper. However, there two reasons why this cannot be used for a straight forward explanation of the pure copper in cluster 2. Pieces of ore have also been sampled, which show a similar degree of purity (SMAP database in Krause 2003). The process of recycling also means that 'fresh' metal was added to the cycle from time to time, making it unlikely that a gradual purification over time would occur. It can be noted that none of the axes in question fall into cluster 14, making it likely that they were not made from native copper. Although most axes fall into cluster 2, there are a number of axes falling into clusters 1, 3 and 6, which are normally thought of as Early Bronze Age metal groups. This shows that especially the 'fahlore' metals, must have been in use earlier than generally assumed (Krause 2003, 144).

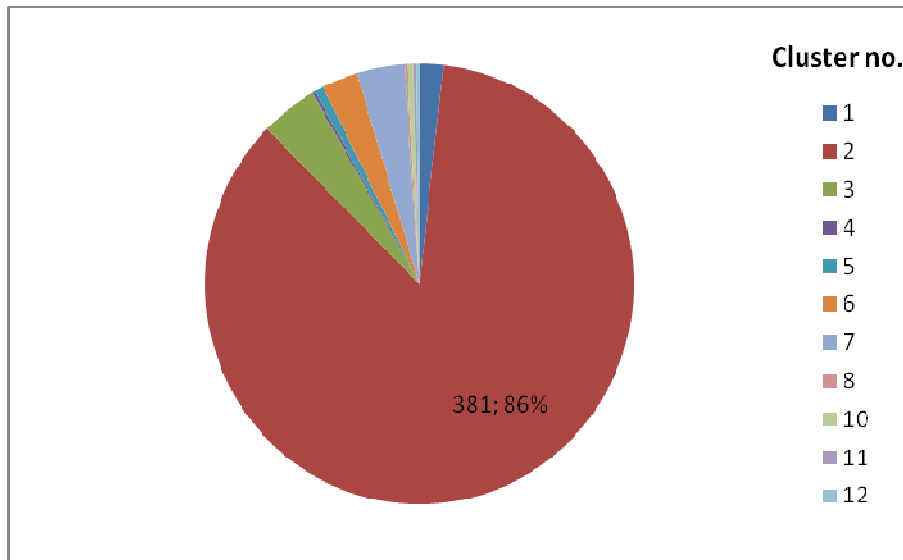


Fig. 59: The vast majority of axes fall into cluster 2 (Data: Krause 2003, Graph: Author)

That one cluster has such a prominence (see Fig. 59) makes it difficult to depict any patterns or relationships in graphs and diagrams. It was therefore decided to take out cluster 2 (for Fig. 60), in order to make the remaining data and patterns more visible. However, as Fig. 60 compares the number of hammer-axes and axe-adzes per cluster, the proportion of the two axe shapes in cluster 2 was also analysed. With 30% of axe-adzes and 27% of hammer-axes falling into cluster 2, there is no clear difference between the frequencies of the two shapes.

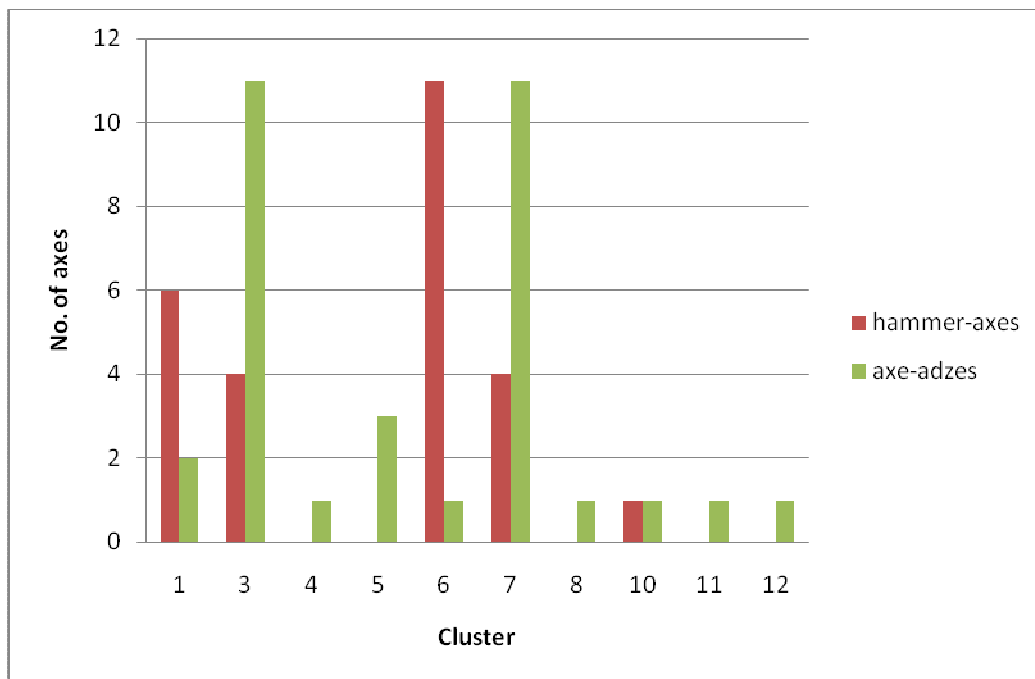


Fig. 60: The number of hammer-axe and axe-adzes in each relevant cluster. The clusters are based on the level of 34 clusters obtained from the complete dataset by Pernicka (Data: Krause 2003, Graph: Author)

As Fig. 60 shows, axe-adzes occur in all relevant clusters, whereas hammer-axes only occur in five of them. Due to the small sample size, this does not necessarily have any meaning. The fact that there are more axe-adzes than hammer-axes in general also makes it unlikely that this pattern has any significance. The same goes for the axe-adzes dominating clusters 3 and 7. The only potentially meaningful distribution is the higher number of hammer-axes than axe-adzes being present in clusters 1 and 6. It could therefore be argued that there might be a link between the two clusters and the shape of the hammer-axes, although the sample size is just too small to discuss this in more detail.

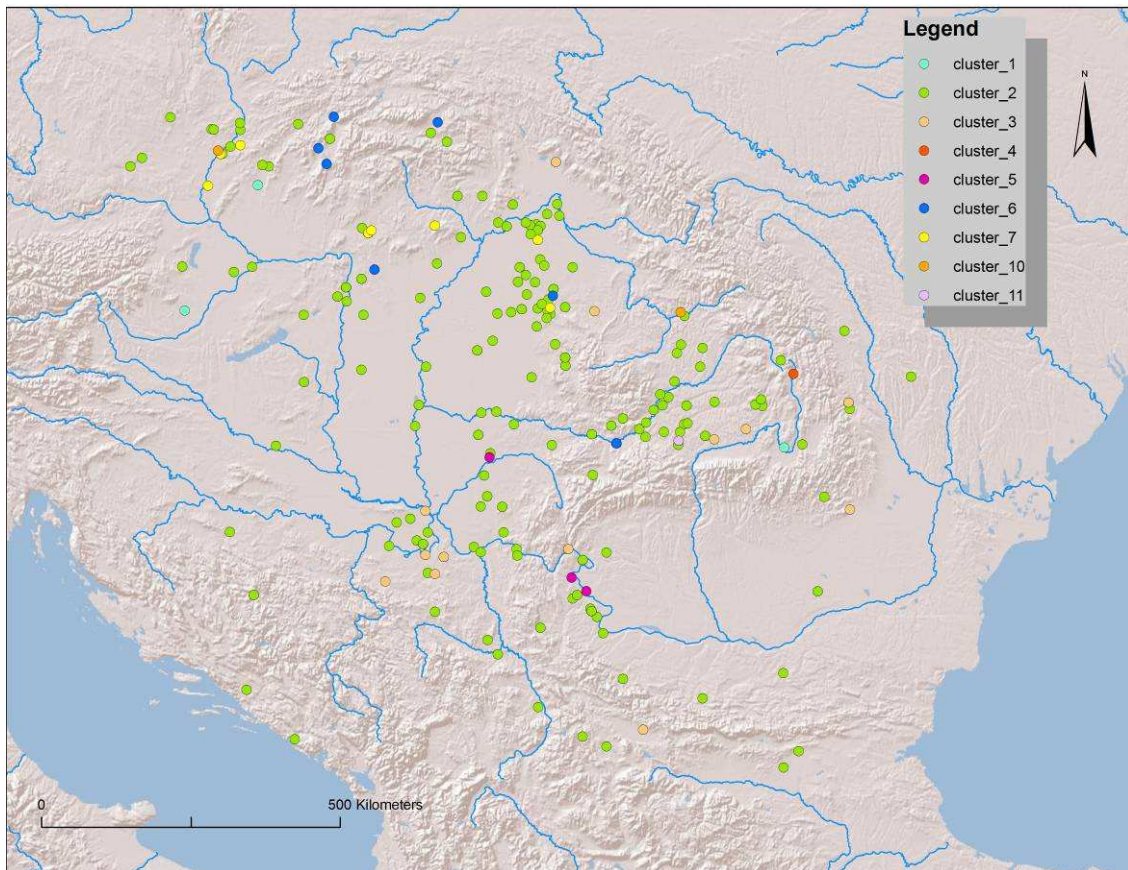


Fig. 61: The distribution of the relevant clusters out of the 34 clusters based on the complete dataset (Data: Krause 2003, Map: Author)

When mapping the relevant clusters (see Fig. 61), the prominence of cluster 2 becomes apparent again. It has, however, no spatial concentration, being instead dispersed over the whole of the distribution area of the hammer-axes and axe-adzes in question. Some of the smaller clusters paint a different picture. Clusters 6 and 7 seem to concentrate around the northern Hungarian Plain as well as the Slovakian Carpathians. Clusters 3 and 5 can be found mainly in the southern Hungarian Plain, around the Iron Gates and in Transylvania. However, when looking at the distribution of the relevant clusters in the whole of Europe (see Fig. 61 and Appendix IV), it becomes apparent that the patterns as seen on Fig. 61 do not necessarily indicate a real trend. Cluster 5 has its European centre between the Slovakian Carpathians and the western Alps (see appendix IV), so it is probably just coincidence that it seems to cluster around the Iron Gates in Fig. 61. Although cluster 3 occurs throughout Europe, it does concentrate on the Iberian Peninsula, making the concentration along the Danube seem rather random. Cluster 6 does not have a marked single concentration, instead small clusters are found throughout Europe (see appendix IV). Although cluster 7 has a concentration in

southern France, it also clusters around the Slovakian Carpathians, making it the only cluster whose real distribution might actually be visible in the copper hammer-axes and axe-adzes as can be seen on Fig. 61 and appendix IV.

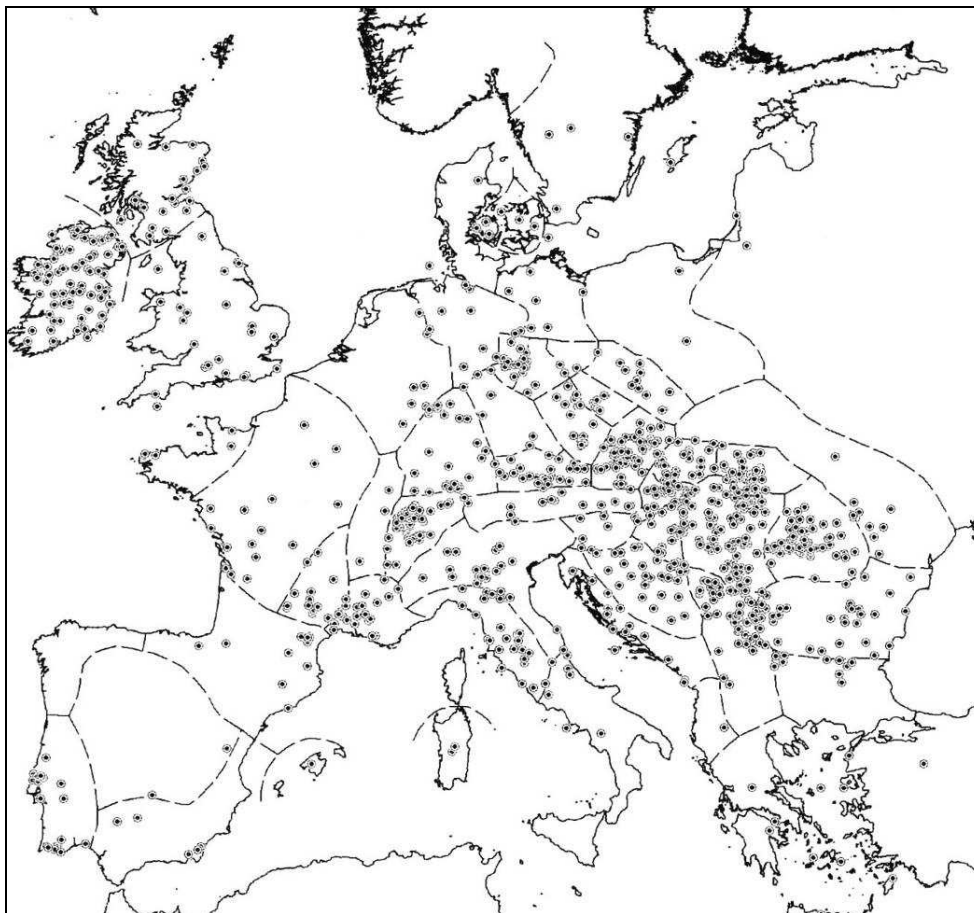


Fig. 62: The Europe-wide distribution of all copper objects falling into cluster 2 (source: Krause 2003, p. 125, Fig. 83)

Cluster 2 (see Fig. 62) is the only cluster with a clear concentration in south-eastern Europe, especially the Carpathian Basin. However, as it is also distributed in Central Europe and Ireland, the application of cluster 2 to the present study is questionable. In fact the usefulness of the 34 clusters for archaeological interpretation has also been called into question by Krause (2003, 129). It is argued that the 34 clusters based on the complete dataset do not have any chronological or spatial relevance (Krause 2003, 121-122). This seems to be confirmed by the analysis above, in which these clusters were applied to the copper hammer-axes and axe-adzes only. Especially cluster 2 has such a general distribution that further differentiation would be desirable.

It is due to these problems, that new clusters were created based only on some regional assemblages and/or some specific object types (Krause 2003, 122). Unfortunately for this present study, none of the regions chosen are directly relevant to the distribution area of the copper axes in south-eastern Europe. The regions/objects are: North Alpine EBA, Aunjetitz groups in eastern Germany, Aunjetitz groups in Bohemia, Middle Danube and western Carpathians (Lower Austria, Moravia and Slovakia), as well as the EBA ingots of Central Europe. Only the clusters obtained from material from the Middle Danube and western Carpathians have some relevance to the present study, which is why they will be presented and discussed below.

Analyses from the following regions were used for the regional study mentioned above: western Slovakia, Moravia, Lower Austria and north-western Hungary (Krause 2003, 109). In total 4167 samples were used, only 9% of which are from Late Neolithic and Copper Age artefacts, as the majority date to the Bronze Age (Krause 2003, 9-10).

Table 12: The clusters of the regional study and their chemical characterization, as well as the number of axes, which fall into each cluster (Source: based on Krause 2003 p, 323-328)*The axes refer only to those objects, which are relevant to this research, namely the early copper axes from south-eastern Europe.

Cluster no.	Copper variety	Trace elements	Class	No. of axes* per cluster
1	Copper with only few trace elements	As/Sb/Ni/Ag	Pure copper (IIIa)	26
4	Classic 'Ösenringkupfer II'	As/Sb>Ag>(Ni)	Fahlore metal without Nickel(IIa)	1
7	Copper with low levels of Sb and Ag	Sb>Ag>(As/Ni)	Pure copper (III)	1
10	Classic 'Ösenringkupfer I'	As/Sb>Ag>(Ni)	Fahlore metal without Nickel (IIa)	3
11	Classic 'Ösenringkupfer III'	As/Sb>Ag>(Ni)	Fahlore metal without Nickel (IIa)	1
13	Copper with Sb and Ag content	Sb>Ag>(As/Ni)	Antimony copper (IVa)	9
27	Copper with As and Sb content	Sb/As>(Ag/Ni)	Arsenic copper (Vc)	3

Table 12 summarises the relevant clusters of the regional analysis to the present research. It also lists the number of copper hammer-axes and axe-adzes falling into each cluster. As the data are only available for a fairly small area of the total distribution area of the axes, it is not surprising that there are only 44 axes which fall into the regional study published by Krause. Fig. 63 clearly shows that the weighting of the different clusters is different to the 34 clusters from the complete dataset, as 59% come from only one cluster. Cluster 1 can be compared to cluster 2 of the first dataset discussed above both being pure copper, but the remaining clusters take a greater share of the total number of axes.

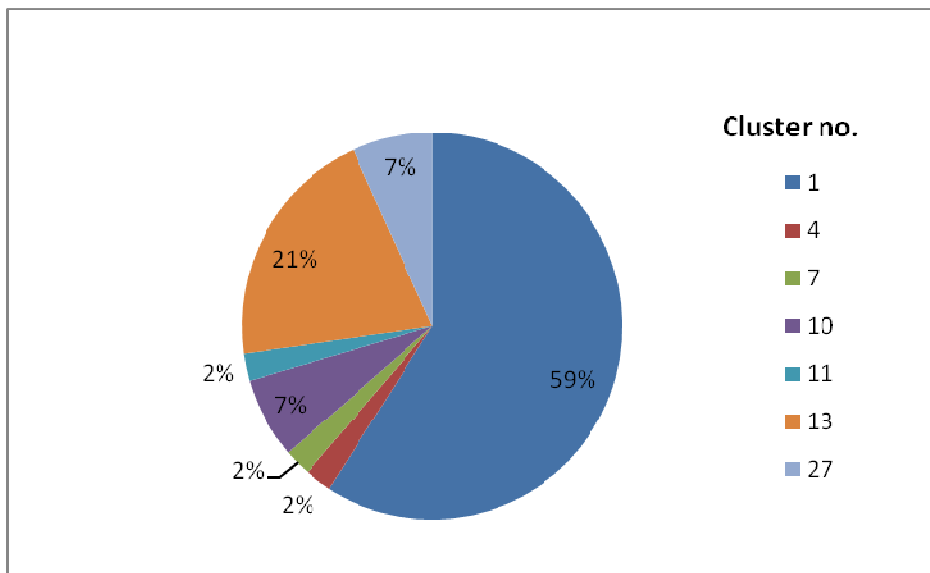


Fig. 63: The percentages of axes coming from the relevant level 40 clusters (Data: Krause 2003, Graph: Author)

According to Krause clusters 1, 5 and 13 are the three most useful and important Late Neolithic clusters, although cluster 5 is not relevant to the axes under consideration. Cluster 1 is, as mentioned above, a pure copper, with a centre of distribution in the Carpathian Basin, although some objects made from this copper are found in Central Europe, southern Scandinavia and the Alpine foothills (Krause 2003, 152). It is difficult to say anything more about this cluster, as neither its distribution nor any other parameters give rise to any noteworthy patterns. Although this is also related to the small number of objects, cluster 13 does seem to be specific enough to be tied down to a specific region and even a specific type of axe. With a concentration in the Slovakian Carpathians it is assumed that the raw material came from the copper ore deposits in the same area (Krause 2003, 152). This antimony copper is similar to the SAM group CIB, which Patay also located in western Hungary and Slovakia. He states that it was the Nográdmárcal axes that are mainly made from this copper (Patay 1984, 10-11). This was already suggested by Schubert, who even called this copper type ‘Nográdmárcal’ (Krause 2003, 152). When looking at which types of axes fall into cluster 13, seven of the eight axes are of the new type Tg. Ocna- Nográdmárcal C1, which does indeed cluster around the Slovakian Carpathians (see appendix III). The number of objects in the other clusters is far too small to be used for any meaningful interpretations.

This result is the only information so far, which could be extracted from the new data on chemical composition. This is mainly due to the fact that a localised clustering has only

been carried out for a fairly small area of the distribution of the copper axes under study. Most of the artefacts from the Carpathian Basin as well as the Balkans have not been analysed in enough detail to be used for further studies. This is unfortunate as there might be a wealth of information locked away in the raw data of the SMAP project, which can only be unlocked through more regional cluster analyses carried out by specialists.

10.3 Dimensions

Morphometrical data was also collected for the copper axes under consideration. The length, weight and shaft-hole diameter were recorded where possible. The width or depth was not recorded as this information was often missing, and there was not one standardized point at which these dimensions were recorded. As the majority of axes have been added to the database from the PBF volumes, the dimensions were taken from there, if available. However, although the length was published fairly frequently, weight and shaft-hole diameter were regularly absent. This was not a problem for the axes I viewed personally in museums as I could record the missing metric data. For the axes which I did not record personally, I used the scaled drawings on the plates from the PBF volumes, to record the length and diameter of the shaft-hole. The weight could not be measured in such a way, and it could therefore only be recorded for 705 out of 1313 axes. The length could be recorded in the ways described above for 1218 out of 1313 axes. The data are not as accurate as one would like, as I often encountered differences of up to 5mm between the length given in the PBF catalogues and the length which I measured personally in the museums or from the scaled drawings. However, this margin of error will be accepted for carrying out some data analysis on the length and weight of the axes. The shaft-hole diameter will not be used, as it was even more difficult to measure than the length, and there is also no agreed way and place of measuring. The shaft-hole diameter is often different depending on which side of the axe it is measured, and some are oval in shape. It was therefore decided not to use that data for any further analysis.

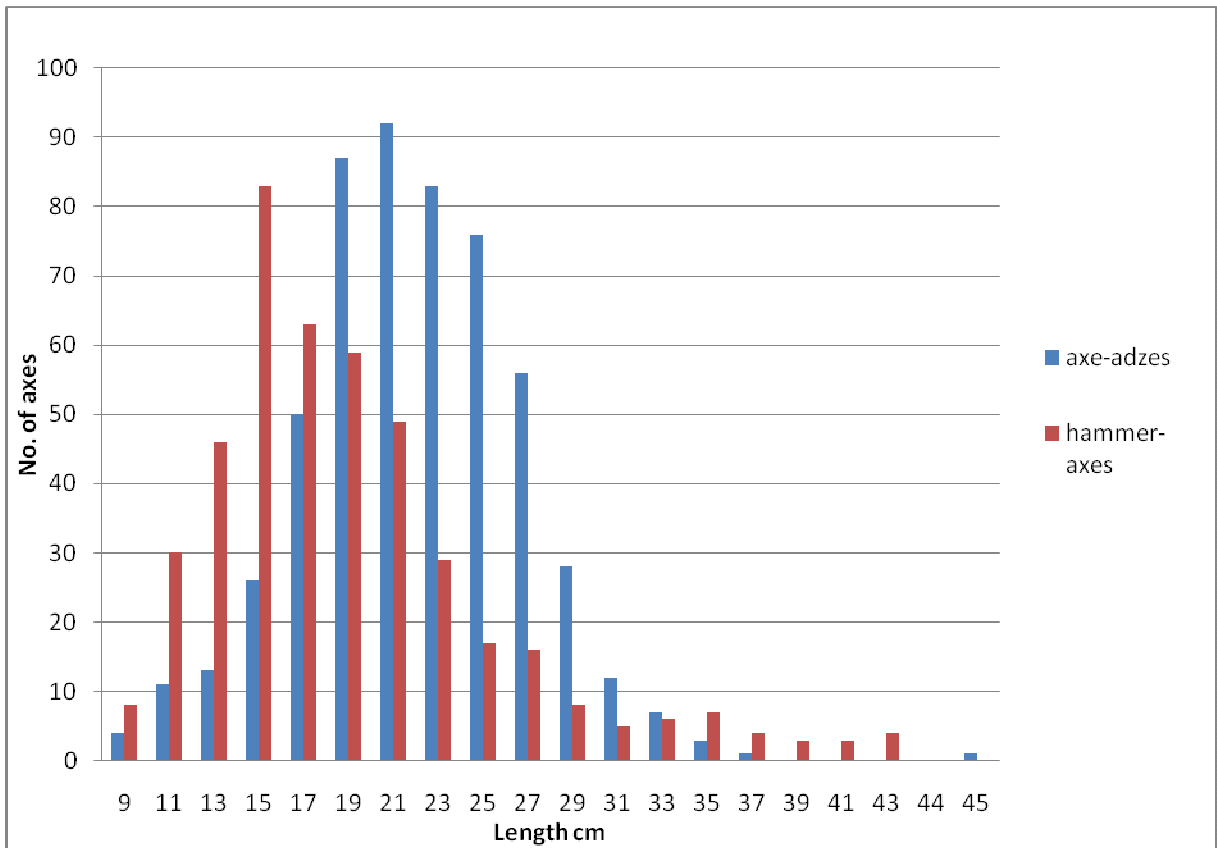


Fig. 64: Distribution of length values for the hammer-axes and axe-adzes (source: Author)

For the analysis of the length and weight of copper axes, the hammer-axes and axe-adzes were separated. The length and weight are, to a certain extent, two related variables although the depth and width also influence the length to weight ratio. When looking at only the length of all hammer-axes and axe-adzes (see Fig. 64), we can see that the majority of axe-adzes are slightly longer than the hammer-axes. The length values of the hammer-axes are not evenly distributed, as they have a longer tail, due to a few very long examples. The distribution of the length values of the axe-adzes, on the other hand, is symmetrical.

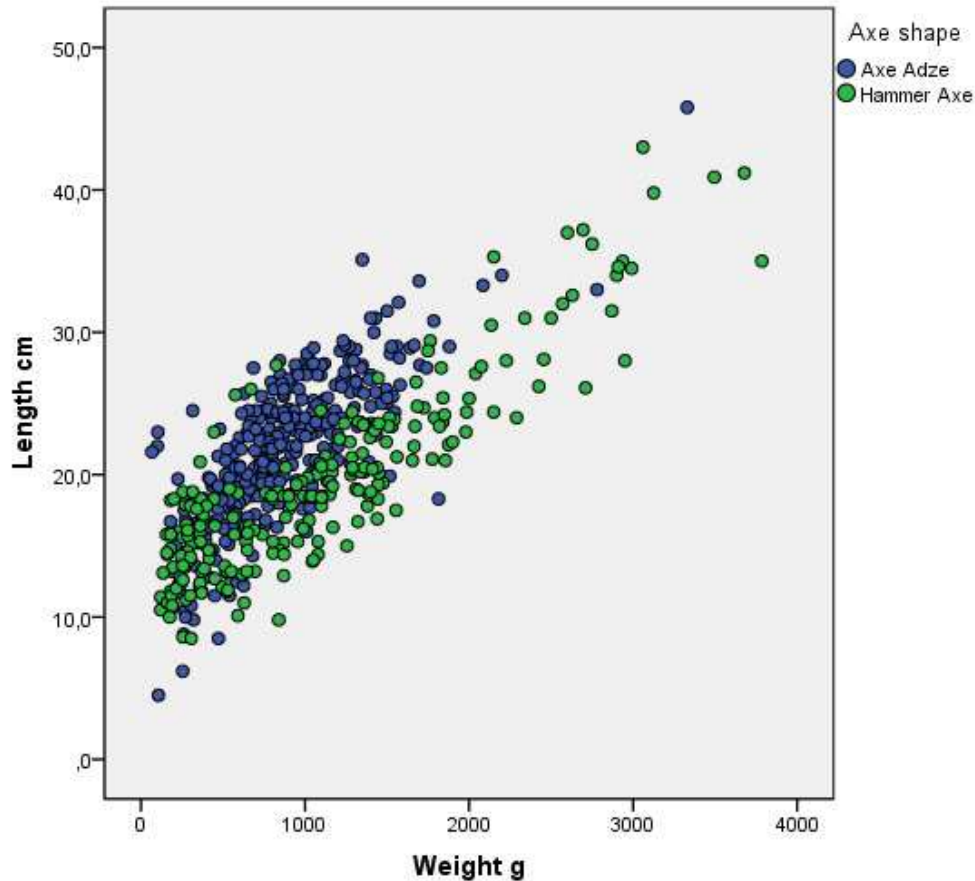


Fig. 65: The weight and length values for the hammer-axes and axe-adzes (thanks go to S. Suhrbier)

If we combine the length and weight data, we can again see that there is a clear difference between hammer-axe and axe-adzes (see Fig. 65). The axe-adzes cluster in a fairly distinct area, although some different groups might be discernible. The hammer-axes have a much wider distribution, with more distinct clusters. It is obvious that the weight is related to the length of the artefacts, although there is some variation as the spread is quite wide with some heavier but shorter axes compared to lighter but longer ones. There is a tendency for the axe-adzes to be slightly longer with the same weight. This confirms the observation, that most hammer-axes are stockier than the axe-adzes. The copper smiths of the past used less material for making the axe-adzes, giving them a more elegant shape. This fact has been used to confirm that the axe-adzes tend to occur slightly later in time as they are more developed and technically advanced. This is a simplistic argument, as many examples of past techniques have shown that our

modern ideas of practicability and advancement cannot be directly transferred onto past objects.

Table 13: The codes for the different axe types used for Fig. 65 (thanks go to S. Suhrbier)

Code	Axe form	Axe type
2	Hammer-axe	Čoka
3	Hammer-axe	Crestur
8	Axe-adze	Jászladány
16	Axe-adze	Kladari
17	Hammer-axe	Mezőkeresztes
19	Axe-adze	Mugeni
21	Hammer-axe	Pločnik
25	Hammer-axe	Şiria
27	Hammer-axe	Székely-Nádudvar
37	Hammer-axe	Szendrő
39	Axe-adze	Tg. Ocna-Nógrádmarec
45	Hammer-axe	Vidra

The variability of the weight to length ratio cannot only be used to distinguish between hammer-axes and axe-adzes, but it might be possible to confirm the typology to a certain extent. In order to test this, all types with 10 or more objects were coded as can be seen on Table 13.

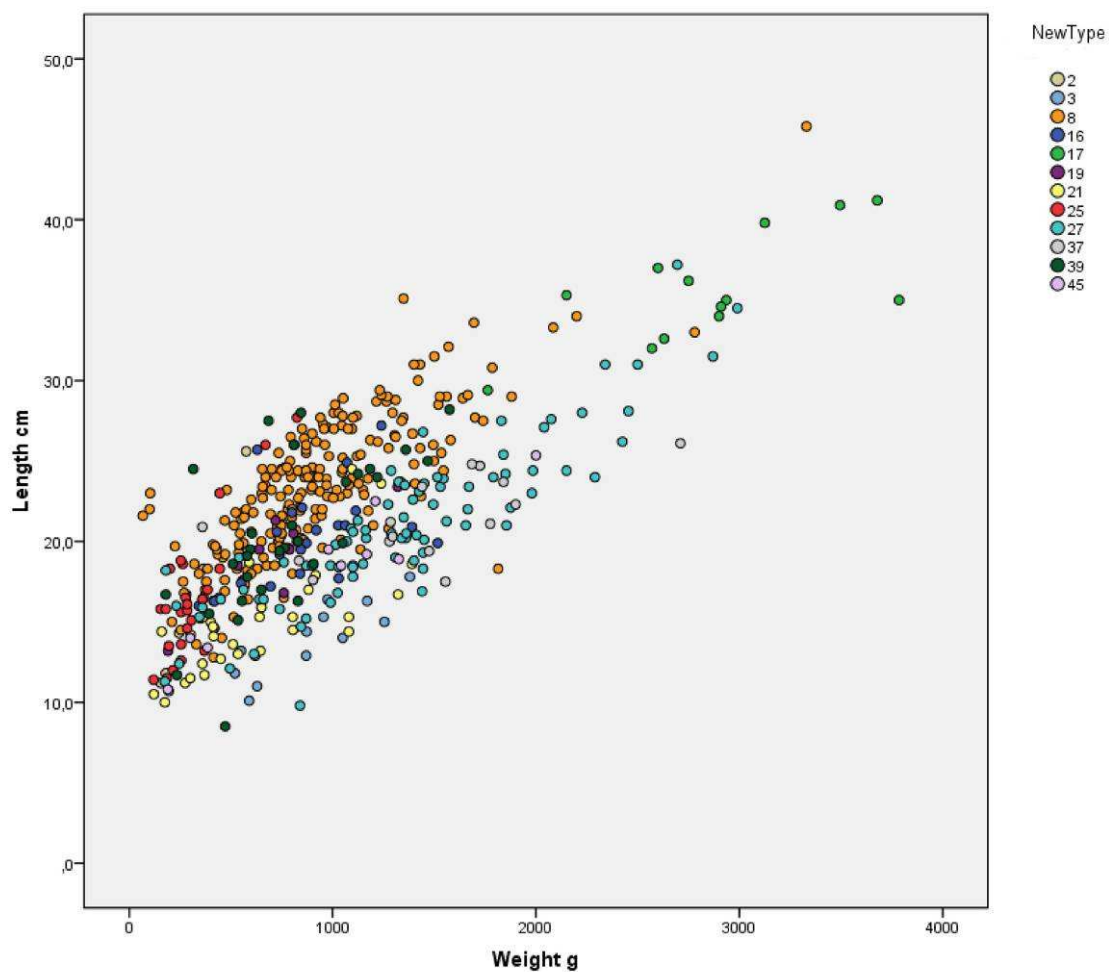


Fig. 66: The weight and length values for the different axe types (thanks go to S. Suhrbier)

The division between the two axe forms is still clearly visible, with the Jászladány (orange), Kladari (dark blue), Mugeni (dark purple) and Tg. Ocna-Nógrádmargal (dark green) axe-adzes clustering in the upper segment of the distribution (see Fig. 66). There is no great difference between the specific axe-adze types discernible in the data, except that the Jászladány axes also have some larger examples, both in terms of weight and length compared to the other three axe-adze types. In the case of the hammer-axes, some of the types can be seen quite clearly in this graph (see Fig. 66). The small and slender Şiria axes (red), for example, have quite a distinct distribution in the lower regions of the axe-adzes. The large Mezökeresztes axes (green) occupy the top right hand corner of the graph, as was to be expected. The Pločnik axes (yellow) also belong to the smaller types; the most numerous hammer-axe type Székely-Nádudvar (light blue) is represented over almost the entire length and weight spectrum. They almost

mirror the Jászladány axes but are slightly heavier and shorter. It is difficult to discern any of the other types, mainly due to their smaller numbers.

The weight and length data of the copper hammer-axes and axe-adzes confirm that there is a difference between the two forms, as well as between the different types. The impression that the axe-adzes use less copper for objects of a similar length is confirmed by the metric data, as hammer-axes tend to be heavier and shorter. The types with the largest numbers of axes, can also be distinguished by their length/weight ratio, confirming the typology. It is unfortunate that the data is not complete for all axes, and that the shaft-hole diameter could not be used for comparative analysis. However, the data has shown that the differences in weight and length are related to the axe shape and type, and have nothing to do with possible fixed values like an early form of currency. The distribution of the length and weight values is too variable for that.

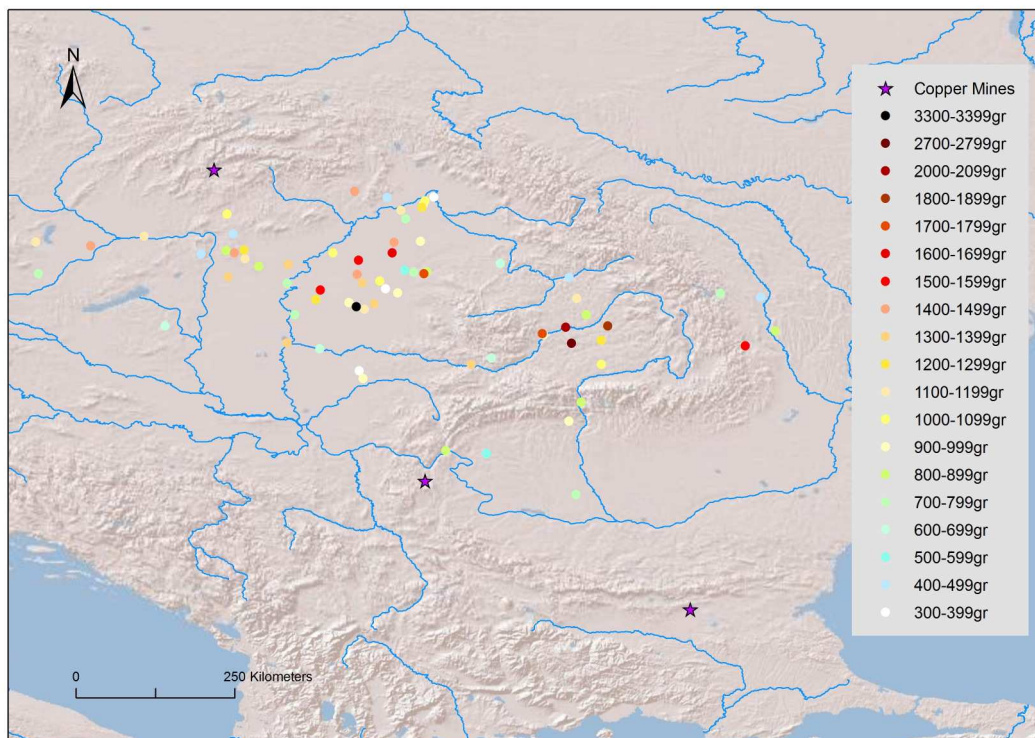


Fig. 67: The distribution of Jászladány axes by weight (source: Author)

When thinking about the weight of these axes, it is particularly their density or ‘heaviness’ that can be identified as one of the most significant characteristics. The handling and transport not only of the objects themselves, but also the materials necessary to make them must have required considerable man and/or animal power. A further question would therefore be if the heavier axes tend to cluster nearer to the

known Copper Age copper mines or even copper deposits. As there is great variability in weight between the different axe types as stated above, such an analysis would only be viable within a single type. As the sample size of the axes with known weight is fairly small, the only type, which can be considered are the Jászladány axes. They are also particularly suitable as it is one of the few types that are found throughout the entire distribution area. Unfortunately there are only 83 Jászladány axes with known coordinates and known weight. However, as this is the only axe type which is at all suitable for such an analysis, the results are shown in Fig. 67. The distribution of the 83 axes clearly shows that within the sample used, the heavier axes do not concentrate near the known Copper Age mines. The heaviest axes are found in the Alföld area as well as in Transylvania. Although the sample size is, in my opinion, too small to come to any general interpretations based on this pattern, if it were a real pattern, it would have interesting implications. The Alföld area has the densest distribution of copper axes, which means the people living there were some of the prime users of these objects. If the heaviest objects also concentrate within this area, it shows that the distribution was mainly due to non-practical reasons, probably connected with power or even ritual relations between the groups of south-eastern Europe.

10.4 Axe marks

A number of hammer-axes and axe-adzes from south-eastern Europe have distinct marks and/or decorations. They have been interpreted as decoration as well as the marks of a specific metal workshop (Patay 1984, 14; Vulpe 1975, 17-18). For some examples it might even be plausible to explain them as being part of the production process. Schubert was the first and so far only scholar who looked at the marks of the large copper hammer-axes and axe-adzes in more detail (Schubert 1965, 286-295). He identified in the 1960s that the presence of these marks is determined by the axe form and type as well as the spatial distribution (Schubert 1965, 295). Most of his findings can be confirmed in this present study.

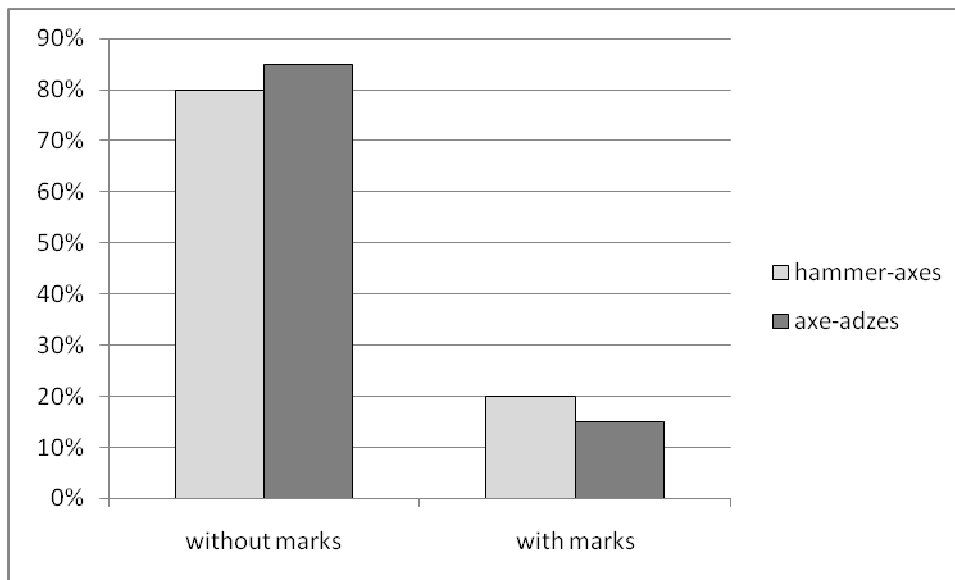


Fig. 68: Percentage of hammer-axes and axe-adzes with and without marks (source: Author)

As can be seen in Fig. 68, the proportion of hammer-axes and axe-adzes with and without marks is fairly similar. When looking at the different axe types, the Jászladány axe-adzes and the Székely-Nádudvar hammer-axes are by far the most common types (see Table 14). It is noticeable that certain axe types of the hammer-axes do not have any marks at all. These are the ‘simple’ types Vidra and Pločnik as well as the Čoka type. When Schubert was writing his article, axes of the Şiria, Mugeni as well as the Tg Ocna-Nógrádmargal type were not known to have been marked either (Schubert 1965, 287), although this has now changed (see Table 14). The presence of marks on certain axe types confirms the temporal affiliation of these axes. Unmarked axes all belong to types largely known as ‘early’, whereas marked axes are the more developed, later types. The Jászladány axes can be dated fairly securely to the later 5th and early 4th millennia BC, through a number of objects found in cemeteries of the Tiszapolgár and Bodrogkeresztúr groups. Only very few axes of the types Székely-Nádudvar, Szendrő, Crestur and Mezőkeresztes come from known contexts that can be related to the Tiszapolgár and/or Bodrogkeresztúr groups. As marks can be present on these types as well as on the Jászladány axes, it confirms that they are largely contemporary. The presence of marks also helps to date the axes of Kladari, Tg Ocna-Nógrádmargal and Handlova type, as they cannot be dated by any other means at the moment.

Table 14 : The number of marked axes per type (source: Author)

Jászladány	103
Székely-Nádudvar	53
Mezőkeresztes	9
Kladari	6
Szendrő	6
Crestur	6
Handlová	6
Şiria	2
Tg Ocna-Nógrádmargal	3
Mugeni	1

There are a number of recurring marks which appear either alone or in different combinations with each other. They were sorted and a code was given to each style (see appendix III). The most common element is the circle, which usually occurs in different quantities around the shaft-hole. In some cases the entire axe is covered in these circular marks. One circle either side of the shaft hole is the most frequent combination (see appendix III). Another group are the axes marked with half moons or semicircles, which can either occur alone or together with one or more circular elements (see appendix III). Other marks include oval marks, zigzag lines as well as grooves. These only occur once or twice and have to be regarded as unusual.

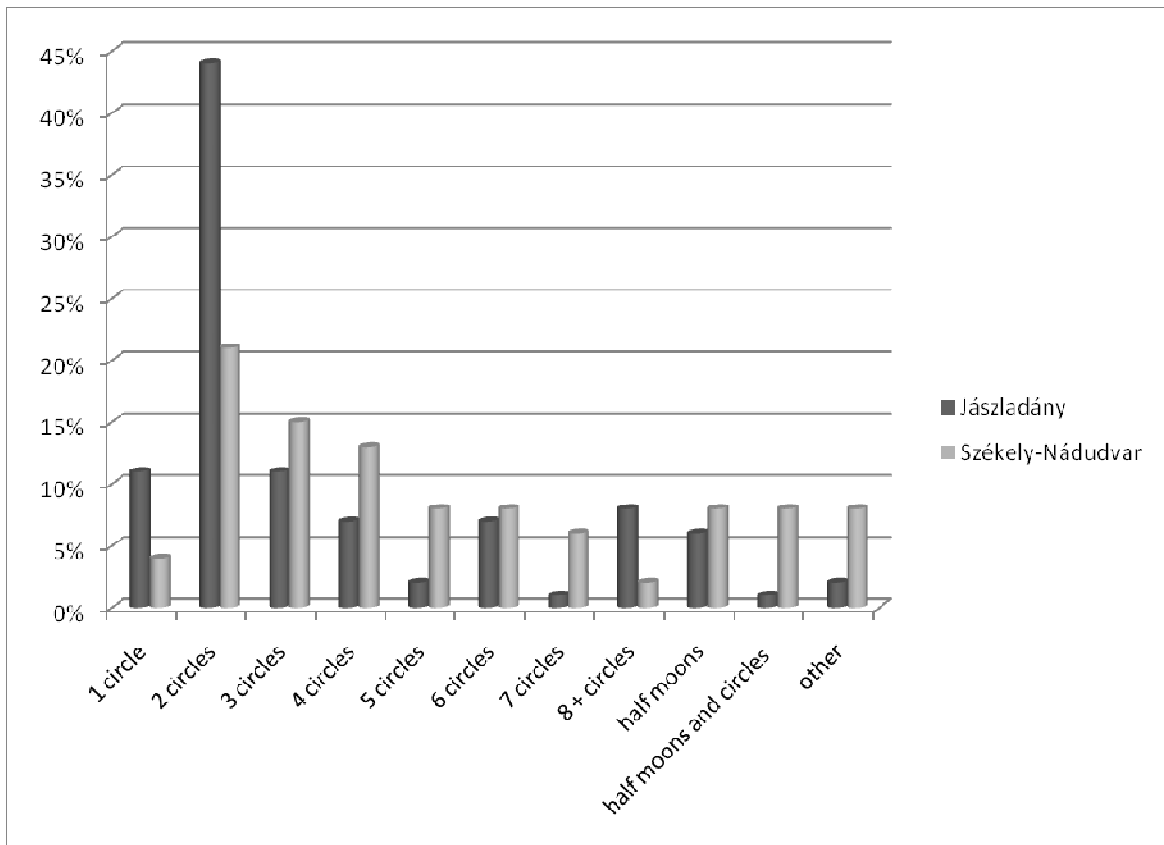


Fig. 69: Comparing the different styles of markings for Jászládány axe-adzes and Székely-Nádudvar hammer-axes in percentages of the total number of marked axes of both types (source: Author)

Fig. 69 compares the different styles on the two axe types most commonly marked. Only the style with one or two circular marks is more common amongst the Jászládány axe-adzes than amongst the hammer-axes of the Székely-Nádudvar type. Three and four circles can be found in about equal amounts on both axe types. The sample size of axes with combinations of five and more circles is too small to allow any generalisations to be made, although the hammer-axes seem to be the more likely candidates to be marked with more than one or two circles. A higher number of elements and style combinations are definitely more frequent on hammer-axes. It could generally be said that the axe-adzes dominate the ‘simple’ styles, whereas the hammer-axes are more frequently marked with complex combinations and elements.

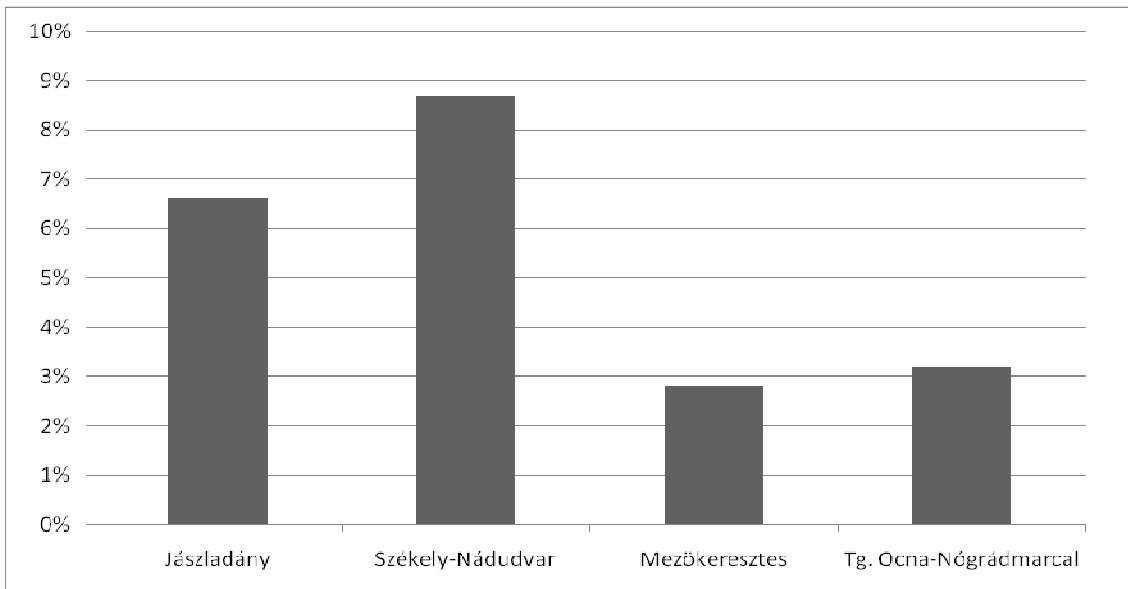


Fig. 70: The percentages of axe types marked with two circles, one on each side of the shaft-hole (code 2a) (source: Author)

In order to establish whether the style of marks stand in relationship with the axe types, all axes with code 2a were compared, as this combination (2 circles, one on each side of the shaft-hole) is by far the most frequent (52) and therefore provides a decent sample size. The graph above (Fig. 70) shows that there is no clear difference between the axe types. The two types, which are overall most common (Jászladány and Székely-Nádudvar), are also marked more frequently with the style 2a. That only four types are found marked with this combination does not necessarily mean anything, as the number of marked axes of other types is extremely small. The distribution of a specific marking style can therefore not be linked to axe type, according to the existing data.



Fig. 71: A Neolithic stone axe belonging to the Salzmünder group from the Museum für Vorgeschichte in Halle, Germany (source: Author)

As mentioned above, different suggestions have been made in the literature as to the exact meaning of the marks. It is safe to say that the more complex and/or ornamental patterns and marks (see appendix III) have probably been added for decorative purposes only. The question remains if the simple recurring marks and combinations were either the 'signature' of a specific metal-smith or part of the production process. In order to try and understand the meaning of the marks, their possible method of production should be looked at in more detail.

The circular marks shall be considered first. They usually have a rectangular cross section, although some circular marks are filled bearing a striking resemblance to the decoration on a number of Neolithic stone shaft-hole axes from north-eastern Germany (see Fig. 71 and 72). These stone axes probably belong to the Salzmünder group, which dates to around the mid 4th century BC. The two artefact types have both a temporal as well as a spatial overlap, if only marginally so. We will probably never know whether one was influenced by the other, but the decoration on the stone axes shows one way the marks on the copper axe could have been made. The ornaments and the shaft-holes of the stone axes were made using a (bow) drill. If the circular filled marks on the copper axes were drilled as well, it could be used as an argument in the debate concerning the production of the shaft-hole (see Chapter 6). However, what would speak for the drilling of the marks on the copper axes besides the similarities in appearance to the stone axes? Drilling would cause the marks to be completely round, which some of them are. Other filled marks have a more oval shape speaking against the drilling technique having been used. The 'unfilled' circular marks are not likely to have been made by drilling, as the cross section is rectangular. Using a solid drill would leave a 'v' or 'u' shaped cross section. It is currently impossible to tell whether some of the circular decorations were produced by drilling. The circumstantial evidence warrants nevertheless a discussion on the possibility of this production technique, especially seen in the light of the debate about the manufacture of the shaft-hole (see Chapter 6).



Fig. 72: A marked hammer-axe (source: Vulpe 1975, plate 3, 33)

Another method of creating the circular decorations is the punching of the still soft or even hardened metal. This method could account both for the ‘filled’ circular marks as well as for the ‘unfilled’ ones. The ‘filled’ marks could have been punched with a hollow object like a bone, which might also explain their sometimes uneven shape (see Fig. 72). The unfilled circular marks, on the other hand, would have been made using a solid artefact, made from wood, stone, antler or copper. The choice of material obviously depends on the state of the metal when the marks were punched. So far no stone or metal objects are known which could have been used for such a purpose. The state of the metal when the marks were made is difficult to ascertain without experimental archaeology. Through my own experience some possibilities can be reflected upon. Metal cools and hardens in a matter of seconds rather than minutes, making it difficult to punch more than a few marks before the metal cools down completely. This means the metal was heated up again to add all the marks and the marks were punched very quickly. This would explain their sometimes haphazard spatial distribution. They could also have been added when the copper had already turned solid, although experiments would need to verify these different possibilities.

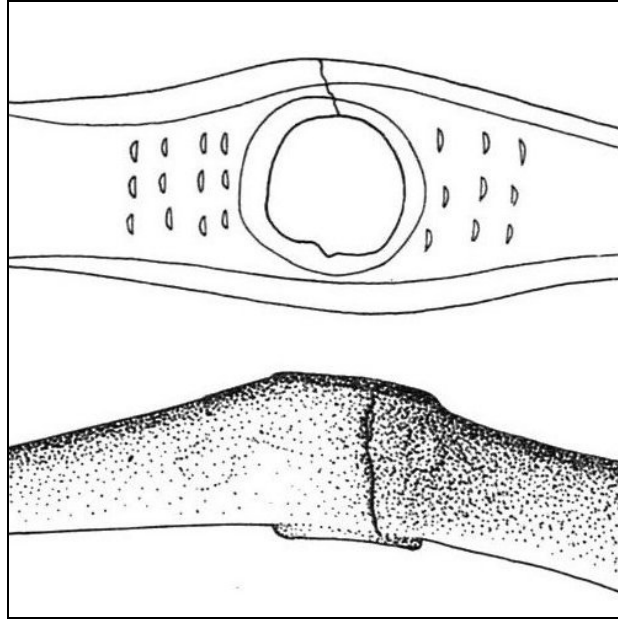


Fig. 73: An axe-adze with 'half moon' marks (Source Vulpe 1975, plate 25, 184)

The non circular marks on copper axes include half moon and sickle shapes as well as sporadic linear features (see Fig. 73 and appendix III). The sickle shapes only occur on one axe, which strengthens the argument that they were meant to be circular decorations. It looks as if the punch was uneven and not pushed in deep enough. (see appendix III). This explanation seems likely, as one circle is complete, meaning it was probably pushed in further than the rest. If this were true, it would clearly indicate that the marks on at least some of the axes were punched and not drilled. The half moon decorations can be smaller than most of the circular marks, and occur in greater numbers (see appendix III and Fig. 73). It is possible that they were punched using a split bone for instance, as their imagined diameter is comparable to some circular marks. Both the circular and half moon marks can have different sizes on the same axe. This could be due to the fact that the object used as a punch had a tapered end and the force to drive the punch into the metal was not the same for every element. The linear marks include forged grooves and one axe has concentric circular lines (see appendix III). It is not possible to comment on the possible production of the latter as the drawing is not good enough and the piece is probably heavily corroded. Considering the arguments and evidence laid out above, it does seem more likely that the marks were punched and not drilled, although it is not possible to say exactly how they were punched.

Let us now consider the possibilities of why these marks were punched. About two-thirds of marked axes can be described as ornamental. These are the axes with three or more circular marks as well as any different elements like half moons and combinations thereof. When there are only one or two marks, they might have a connection with the production process. Especially axe-adzes frequently have two marks either side of the shaft-hole on the lower side (see Fig. 74). It is difficult to imagine that they might have something to do with the casting process, although as there are as yet no known moulds, the possibility cannot be excluded. The marks could also be connected to the forging of the axe, when they might have been made to clamp or fix the axe to an anvil. Until the entire production sequence is not unravelled, this will never be known for certain.

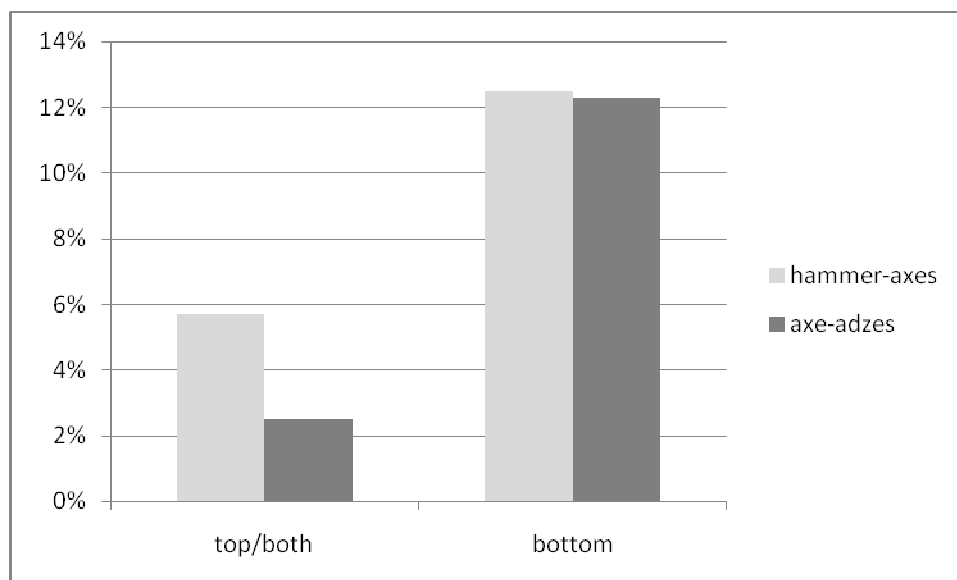


Fig. 74: The side of decoration for hammer-axes and axe-adzes (% of the total number of hammer-axes and axe-adzes) (source: Author)

Another approach to better understand the meaning of the marks would be to look at which side most of the decorations and/or marks occur. Fig. 74 shows that the upper sides of hammer-axes are decorated more often than those of axe-adzes, and a chi square test has shown that the association between the variables is statistically significant (P value = 0.0180). Amongst the axes decorated on the bottom only, there is no great difference between the two axe forms.

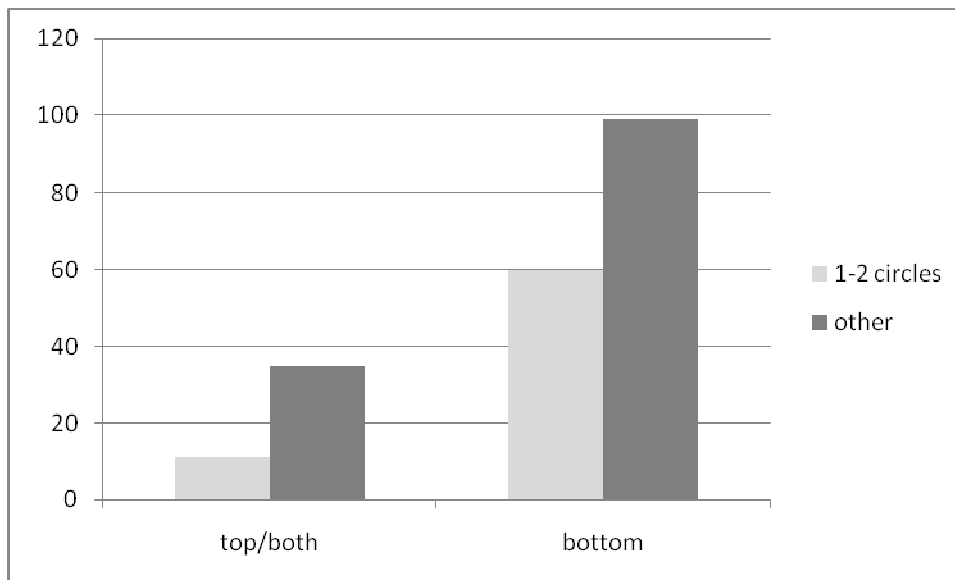


Fig. 75: The types of decoration, which are more common on the upper and lower side of axes (source: Author)

It would seem logical that the more ornate and complicated decorations would occur on the top and the simple marks, which might have something to do with the production process, on the bottom. Although there is a slight tendency towards such a trend (see Fig. 75) it is not clear enough. The overall association of the variables is also not statistically significant (P value = 0.1126). What is far more apparent is the overall majority of axes with marks on the bottom (see Fig. 75). This is rather odd as the marks on the bottom would not have been visible when the axes were hafted. For the simple marks this is not surprising, their function as decoration is questionable anyway. It also gives strength to the argument that they might have been part of the production process or, indeed, marks of a specific metal workshop. What is slightly startling, however, is that the more ornamental decorations also occur more frequently on the bottom. This must mean that they were not necessarily made for a decorative display to be seen by as many people as possible, but had an altogether different meaning. It is feasible that the more complex and decorative elements might also have been marks of specific metal workshops. It is not possible that they were the personal ‘signature’ of the owner, as the marks and their combinations are not diverse enough.

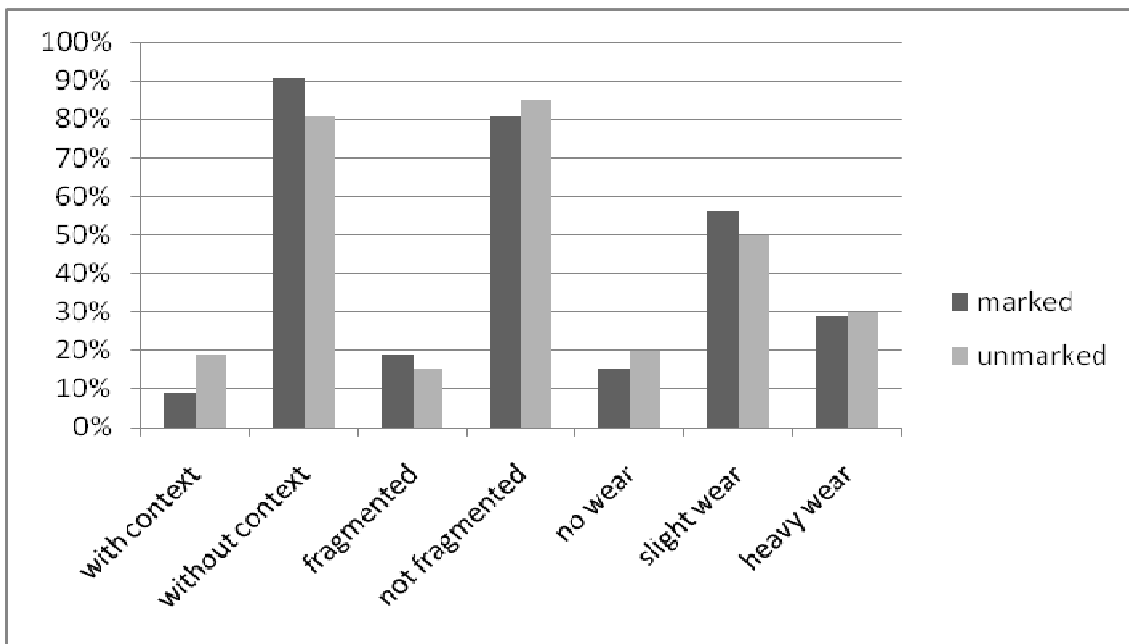


Fig. 76: The proportion of marked and unmarked axes with and without context, fragmented and not fragmented as well as for the different stages of wear (source: Author)

Two further lines of enquiry into the axe marks are their possible relationship with context, on the one hand, and fracture and deformation patterns on the other. Looking at the potential relationship between marks and context, it is important to point out that there are only 20 marked axes, which come from known contexts. Comparing the proportion of marked and unmarked axes coming from known and unknown contexts, it is possible to see that there is no obvious relationship between the two features (see Fig. 76). Although the number of marked axes for which there is information on fracture and/or wear patterns is larger than for the marked axes with known context, the result is the same. It is not possible to relate the ‘custom’ of marking the axes to either wear or fragmentation, as the proportion of both marked and unmarked axes, which are fragmented and worn are similar (see Fig. 76).

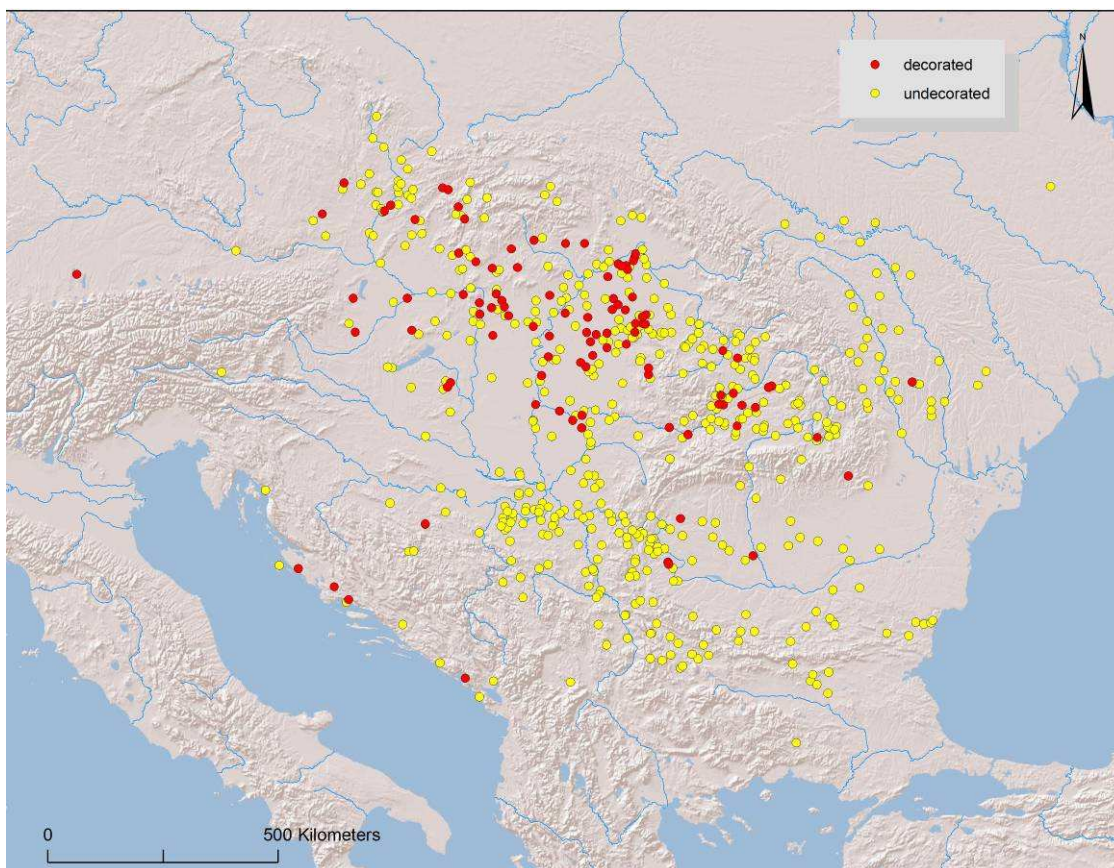


Fig. 77: The distribution of marked and unmarked copper axes from south-eastern Europe (source: Author)

The last variable relating to the marked axes, which will be looked at is the spatial distribution (Fig. 77). This time an obvious relationship can be discerned in the data. The marked axes clearly concentrate within the Carpathian Basin, and are at their densest to the North of the River Körös/Criș. As was already noted by Schubert, the distribution of the marked axes match the distribution of the hammer-axes Székely-Nádudvar (see appendix III), which are the most frequently decorated hammer-axes (Schubert 1965). The axe-adzes of the Jászladány type, however, are found in about equal numbers both north and south of the Danube, but only axe-adzes found to the North of the Danube are marked. It clearly shows that the marking of copper axes was a more localised phenomenon than the production of specific axe types. This can also be demonstrated when looking at the remaining axe types, occurring less frequently marked than the Jászladány and Székely-Nádudvar axes. The distribution of the Mezőkeresztes, Crestur, and Şiria types largely corresponds to that of the marked axes in general (see appendix III). The axe types Kladari, Szendrő, Handlová and Tg Ocna-Nógrádmarec have a slightly different spatial focus, although they also occur within the

Carpathian Basin (see appendix III). Thinking about the possible meaning and function of the different marks, the spatial distribution of the different decorative elements could be helpful. If indeed they were the marks of different workshops, the different styles and combinations should cluster in specific areas. This is, however, not the case (see appendix III). The spatial distribution of the different mark combinations indicates that the most common styles, (one and two circles) have fewer outliers than the more complex and less common decorative combinations. Axes with just one circle only occur within the Carpathian Basin, and axes with two circular marks have only two outliers just across the southern Carpathians (see appendix III).

The marks on the copper axes pose more questions than they answer. The proportion of marked hammer-axes and axe-adzes is fairly similar. Hammer-axes tend to have more complex combinations, whereas axe-adzes are preferably marked with one or two circles. The majority of marks occur on the lower side of the axes, making it unlikely that they were platforms for display. The production of the marks cannot be unravelled; it seems, however, more likely that they were punched than drilled, probably using an organic artefact, as no stone or metal artefacts are known. Possible relationships of the marks with context, fragmentation and wear could not be established. Overall the habit of marking axes is confined more or less to the Carpathian Basin. The distribution does not allow for an interpretation as workshop marks, although this cannot be ruled out. It is therefore difficult to understand the meaning and possible function of the marks. What can be said is that it must have been a custom or tradition within the Carpathian Basin largely confined to the cultural sphere of the Tiszapolgár and Bodrogkeresztúr group. Although the custom of marking the axes does not seem to be related to their find context, wear or types, it does have spatial and temporal restrictions.

10.5 Fragmentation and deformation

A further approach for shedding more light on the dynamics of the copper hammer-axes and axe-adzes is the analysis of fragmentation and deformation patterns. In this chapter the results of spatial patterns as well as queries of the database will be presented.

10.5.1 Fragmentation

In his book on fragmentation, Chapman (2000, 100-101) noted that fragmentation amongst the copper axes seemed to be a localised phenomenon, occurring mainly amongst the axe-adzes from Romania. Drawing attention to the parts that are missing,

he explains the fragmented axes as the visible remains of a possible practice of 'enchainment', which is understood as the link between (broken) objects, people and places and the personal memories this entails (Chapman and Gaydarska 2007, 203) (see Chapter 11).

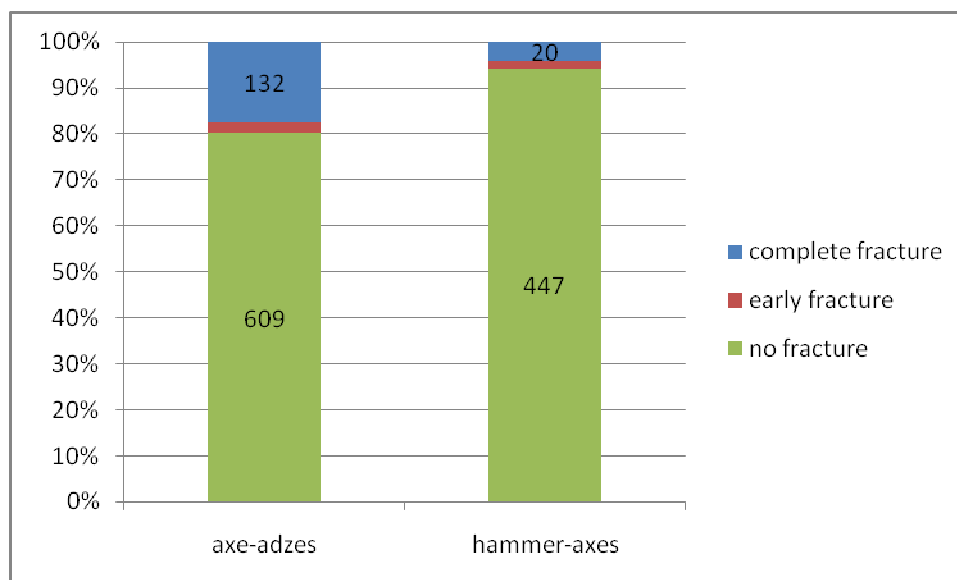


Fig. 78: The number of hammer-axes and axe-adzes with complete and early fractures from the whole study area (source: Author)

Firstly it can be confirmed that fragmentation does occur more frequently amongst axe-adzes than amongst hammer-axes (see Fig. 78), although the type of axe-adzes does not seem to affect the rate of fragmentation significantly (see Fig. 79). The difference in fragmentation between hammer-axes and axe-adzes has been confirmed through a chi squared test with the result that the relationship between the axe shape and the fracture patterns is statistically significant to a very high confidence level (P value <0.0001).

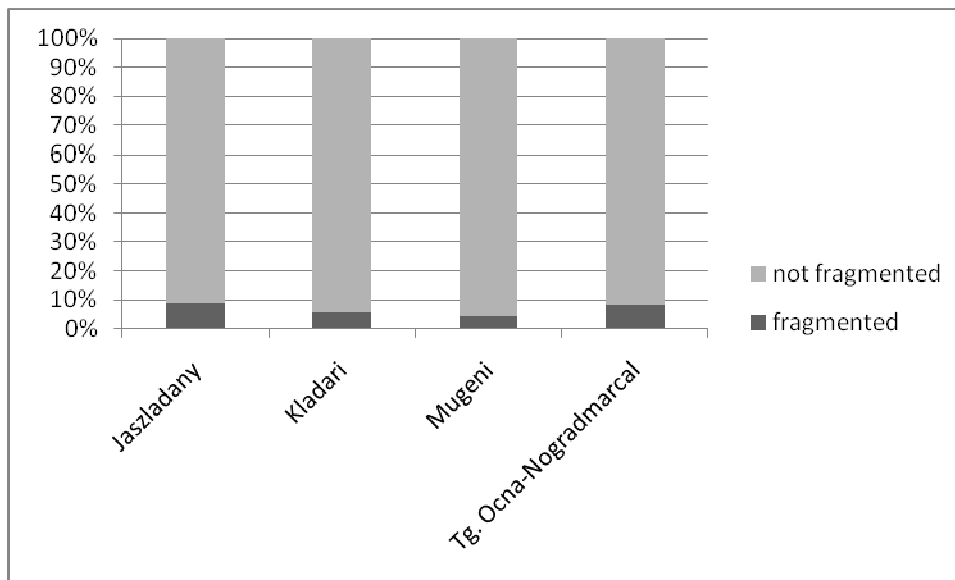


Fig. 79: The proportion of fragmented and not fragmented axes per axe type (source: Author)

Chapman’s claim that the proportion of fragmented axes coming from Romania is larger than the proportions coming from Hungary and Bulgaria can only be partly confirmed.

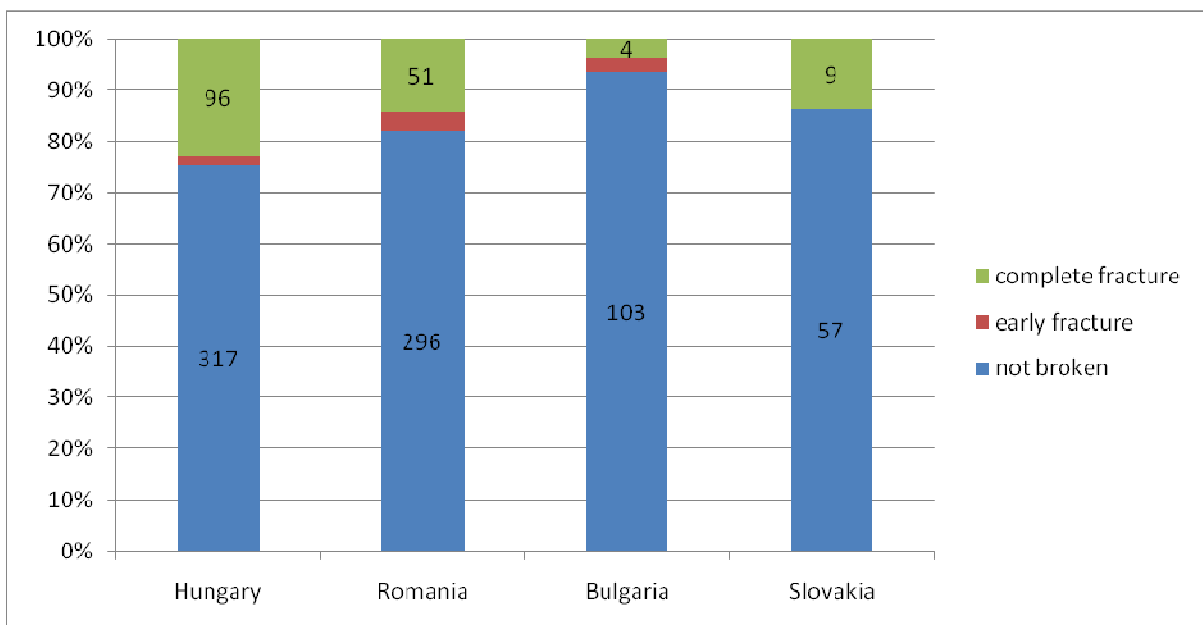


Fig. 80: The proportion of fragmented axes per country (source: Author)

As can be seen on Fig. 80, Hungary has a higher proportion of fragmented axes than Romania. However, this artificial division of axes according to the modern national borders does not help to establish the true extent and spread of the ‘practice’ of fragmentation

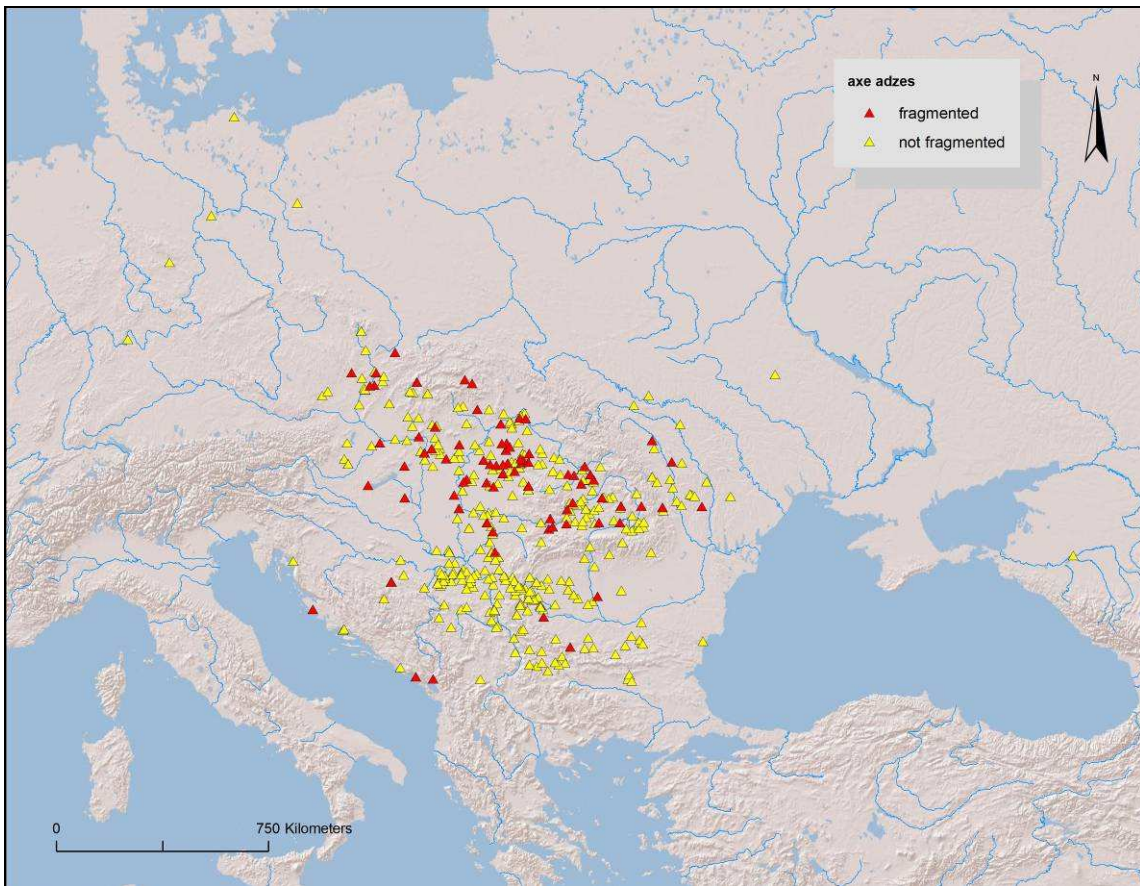


Fig. 81: The spatial distribution of fragmented and complete axe-adzes (source: Author)

Fig. 81 shows a map of fragmented and complete axe-adzes. The most obvious pattern is that the distribution of broken axe-adzes, is similar to the distribution of marked axes (see Fig. 77). They occur mainly within the Carpathian Basin, to the North of the Danube, with a clear cluster in the northern Pannonian Plain. This suggests that the ‘practice’ which led to the fragmentation of axe-adzes was restricted to the Carpathian Basin and not to Romania as was postulated by Chapman (2000, 103).

As there is a definitive pattern to the spatial distribution of fragmented axes, it seems probable that at least some were broken deliberately. An axe could either be bent back and forth in order to make it brittle until it broke, or alternatively, it could be heated until soft and then cut with a chisel and hammer.

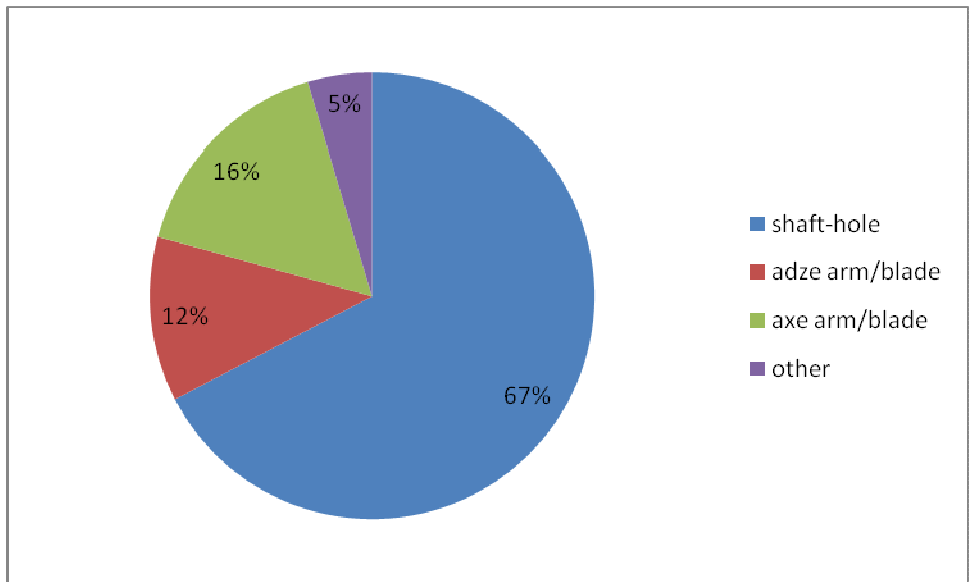


Fig. 82: The places of fracture amongst axe-adzes (source: Author)

Both methods should leave characteristic traces. The vast majority of axes are broken along the shaft-hole (see Fig. 82). None of the axes examined personally, which had been fractured along the shaft-hole, show clear signs of being cut with a chisel. It is much more likely that they broke due to an increasing brittleness of the material, as the fractures are porous and not greatly deformed (see Fig. 14). Some axes, which are fractured along the axe or adze arm, however, do show clear signs of being cut with a sharp instrument, probably in a heated state (see Fig. 83).



Fig. 83: The axe and adze arm were probably cut with a sharp instrument (source: Author)

Considering the fact that most fractures occurred through an increasing brittleness of the material at the shaft hole, where mechanically the object is exposed to the greatest stress during use, the fragmentation of many axes might not necessarily be a deliberate act after all. This is also confirmed by many early cracks, which appear at one or both sides of the shaft hole (see Fig. 84).



Fig. 84: Two early cracks on either side of a shaft-hole of an axe-adze (source: Author)

However, why would axes from the Carpathian Basin be more prone to breaking than their counterparts south of the Danube? The axe-adzes are typologically very similar on either side of the Danube, which means that the production technique can probably not be used as an argument. The differential qualities of the axes can be explained by a different use and/or function in both regions. Axe-adzes in the Carpathian Basin might have been used for heavier duty tasks, a premise already put forward but quickly rejected by Chapman (2000, 103). Alternatively the chemical composition might differ, which could have an effect on the mechanical properties of the metal. As was discussed above, the clusters obtained using analyses of the chemical composition of the artefacts (Krause 2003), are not directly relevant to the entire assemblage of the copper hammer-axes and axe-adzes in question. It was therefore decided to compare the presence and absence of certain elements directly in order to try and answer the question posed above.

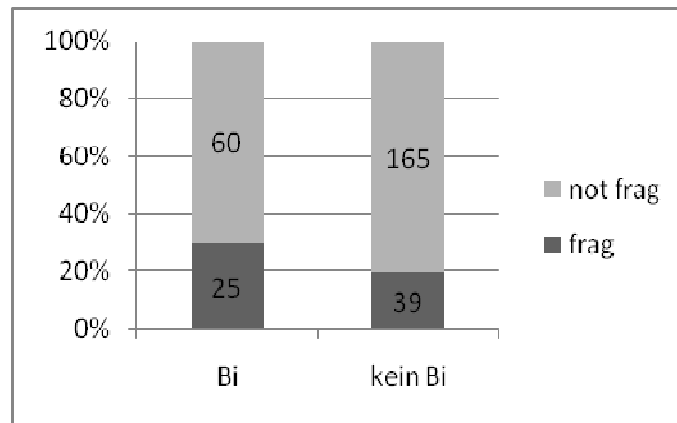


Fig. 85: The fragmented and complete axes with and without bismuth (source: Author)

When comparing the proportion of different trace elements amongst fragmented and complete axes, only bismuth and silver occur more frequently in broken axes (see Fig. 85). Iron, cobalt, zink and gold are more frequent in complete axes and nickel, antimony, arsenic and lead occur equally often in broken and complete axes. The mechanical properties of silver exclude this element from having an impact on the breakability of the axes, leaving only bismuth as a possible contender. Bismuth is a very brittle metal and leads to segregation during the cooling phases resulting in an inhomogeneous composition (Slater and Charles 1970, 208). When testing the relationship between the presence and absence of bismuth and the fragmentation statistically however, the association is classed as not quite statistically significant (P value = 0.0627). Only experiments will be able to demonstrate if these properties can indeed affect the axes to such an extent. There is, however, one last line of enquiry which might shed some light on this problem. When looking at the spatial distribution of copper axes containing bismuth (see Fig. 86) it becomes apparent that they seem to share a pattern with the fragmented axes, occurring mainly to the North of the lower Danube, in the Carpathian Basin.

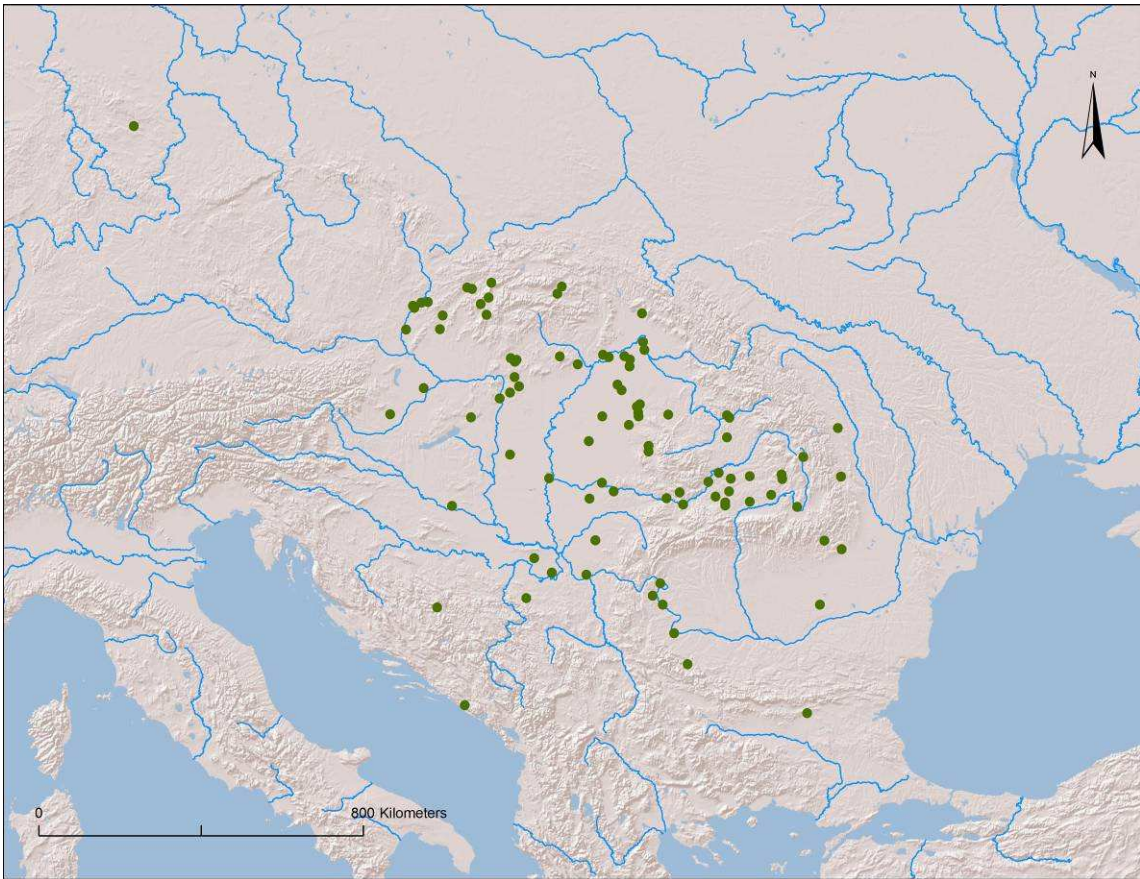


Fig. 86: The distribution of copper hammer-axes and axe-adzes containing bismuth
(source: Author)

Although this is still no conclusive evidence against a practice of intentional fragmentation within the Carpathian Basin, it allows an alternative explanation for the restricted spatial distribution of broken axes. It does not explain though why axe-adzes have a higher proportion of fragmentation than hammer-axes, as both axe shapes contain bismuth in about equal proportions. However, axe-adzes are usually much thinner around the shaft-hole, therefore making it more likely that they would break when used on a regular basis.

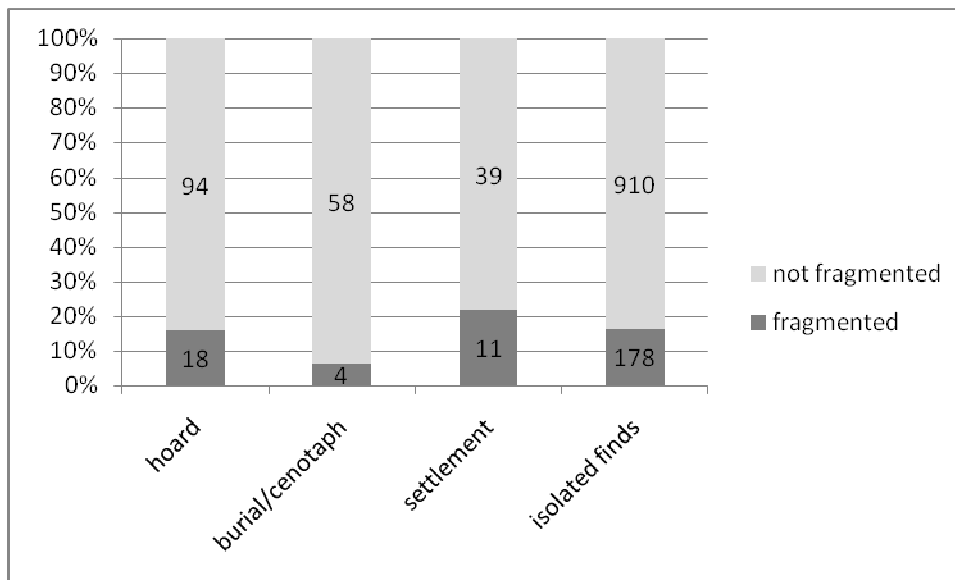


Fig. 87: The proportion of fragmented axes amongst the different find contexts (source: Author)

Another hint for deciding whether the axes were broken deliberately might be found when looking at the proportion of axes coming from different contexts (see Fig. 87). Although there is a tendency for fragmented axes to come more frequently from settlements and less so from burials, the sample of axes coming from known contexts is too small to make any definitive statements. When testing the relationship between these variables statistically, only the burial/cenotaph data was statistically significant (P value = 0.0467). The hoard and settlement data was not significant, meaning the association could be random (P value = 1.0000 and 0.3290 respectively). However, as there are only four fragmented axes from burial contexts, we cannot assume with much confidence that fragmented axes are less common in graves simply because the relationship was classed as statistically significant.

10.5.2 Deformation

As mentioned in Chapter 2, the wear or use and/or deformation traces were recorded using the terms ‘none’, ‘slight’ and ‘heavy’. All broken objects, were classed as showing ‘heavy’ deformation. However, when looking at the data on the use/deformation/wear of the axes, a similar pattern to that of the fragmented axes was discernible, as the broken objects ‘bias’ the general picture. I say ‘bias’ as the wear and deformation is usually recorded along the cutting edge, and although an axe might be broken, the cutting edges do not necessarily show any wear at all. One possibility might be to categorize the wear patterns only on the cutting edges. This creates another problem, as fragmented axes have a missing part, usually one cutting edge or hammer

arm, which cannot be categorized. It was therefore decided to use only complete axes for the analysis of the data on wear and deformation.

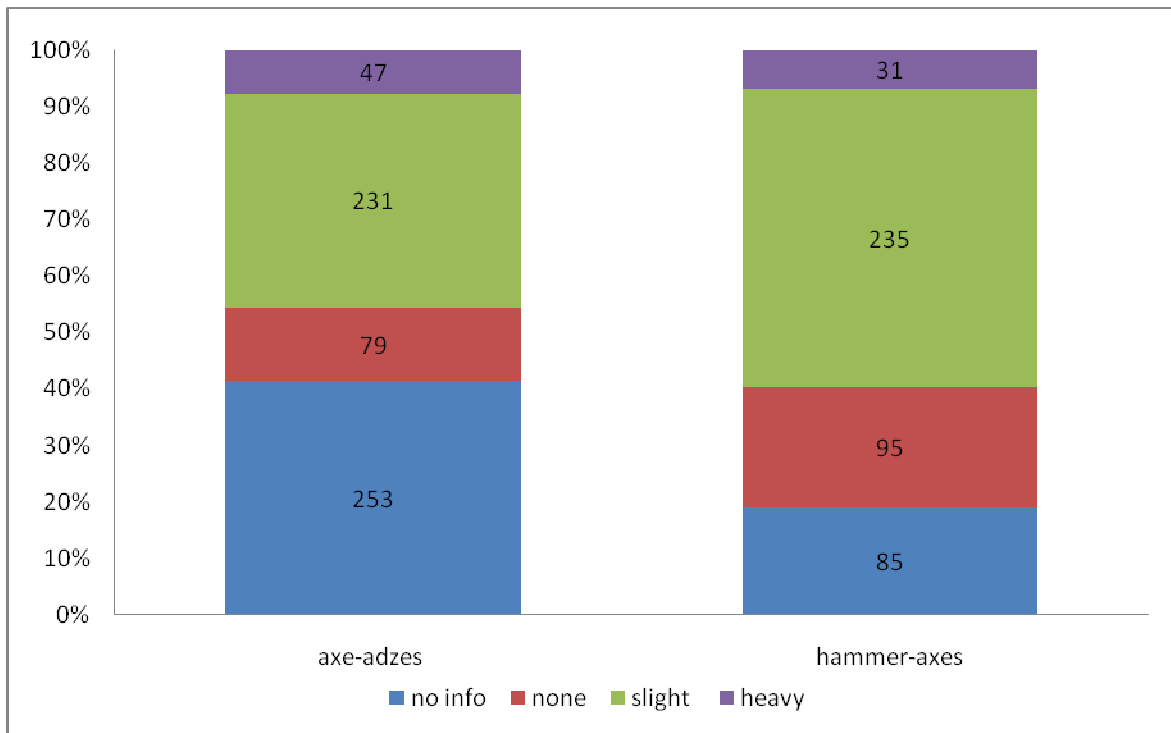


Fig. 88: The difference in the level of wear between hammer-axes and axe-adzes (source: Author)

As can be seen on Fig. 88 there is some difference between the proportions of different levels of wear between the two axe forms. However, it is difficult to say this for certain, as the proportion of axes with no information on the state of wear is much larger amongst axe-adzes than amongst hammer-axes. If one were to assume that the axe-adzes with no information would show similar wear patterns to the known examples, all three proportions would increase. This would lead to the axe-adzes having a slightly larger proportion of heavily worn artefacts, whereas the proportion of objects with no and slight wear would probably be nearer to the numbers seen for the hammer-axes. As this is just based on an assumption, it is not possible to make a conclusive statement on the differential patterns of wear between hammer-axes and axe-adzes.

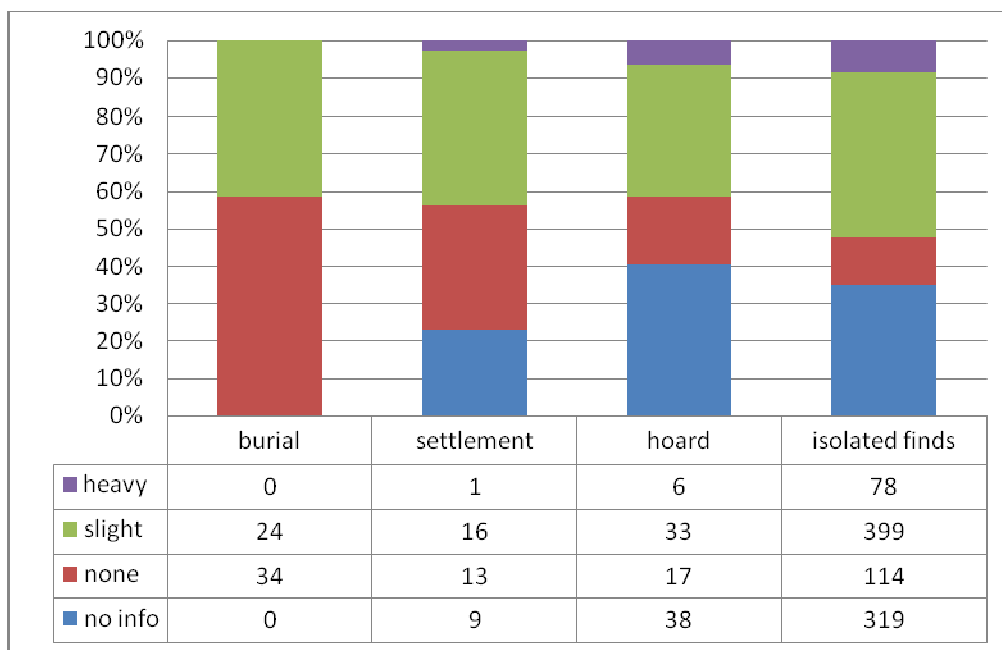


Fig. 89: The difference in the level of wear for the three known contexts of the copper hammer-axes and axe-adzes (source: Author)

When comparing the proportions of different levels of wear between axes coming from, burials, settlements and hoards, and axes which are isolated finds, it is interesting to note that the latter two have a very similar distribution of wear patterns. (see Fig. 89). This could be seen as confirmation that many of the isolated finds might have been hoard finds. However, it is difficult to come to any firm conclusions, as the number of axes without information on wear patterns varies so much between the different contexts. The fact that there are no heavily worn axes from burials might indicate that they were mainly ‘new’ or as good as new, or they were re-sharpened before being deposited in the grave. Of course if the fragmented axes are taken into account as well, four broken artefacts do come from a burial context, which would change the picture entirely, as the proportion of heavily worn objects from burial contexts would be larger than that from settlement contexts. Looking at the spatial distribution of the different wear patterns does not help either to tease any patterns out of the data either (see appendix III), as none of the different stages of wear have a specific spatial concentration. It is only the axes with heavy wear that obviously mirror the distribution of the fragmented axes in the Carpathian Basin.

In general, it is not possible to obtain any clear patterns from the data on the deformation of the axes studied. One could blame the small sample size of axes coming from known contexts. Alternatively, there might actually be no patterns, as the different

stages occur naturally in similar proportions through use, and most axes were used in the same manner. The case is very different for the broken axes, which do seem to show some obvious patterns. Axe-adzes are fragmented considerably more often than hammer-axes, although the specific axe type does not make a difference. In terms of spatial distribution, the 'practice' of fragmentation has a clear concentration in the Carpathian Basin, as hardly any fragmented axes occur south of the Danube. The axe-adzes are most commonly broken across the shaft-hole, as this is mechanically the weakest point during use. When trying to see if there is a relationship between context and fragmentation the evidence is not conclusive. However, the rest of the data clearly show that there is a pattern. The only question is whether this stems from an intentional practice as postulated by Chapman (2000, 100-104), or whether it has some other reason. The fact that most axes break at the shaft-hole through stress and an increasing brittleness could be used as an argument against the intentional fragmentation of these axes, especially as many have early cracks appearing on one or both sides of the shaft-hole. The presence of bismuth has been used to explain the spatial pattern of the fractured axes, although it does not explain why axe-adzes are more often fragmented than hammer-axes unless their stockier shape is taken into consideration. Unfortunately it is not possible to come to a conclusive interpretation, as both an intentional practice, as well as the localised differential qualities of the cast or metal composition might be the cause of the patterns in the data.

10.6 Summary

After looking at the data in the database, five main topics were identified, which were worth exploring in more detail. The first topic 'distribution and context' deals with where the axes were found, and what this might tell us about them in relation to the living practices of the time. The last four focus on the axes themselves. Their composition and dimensions as well as the axe marks and patterns of fragmentation and wear were considered. The analysis of the data has shown that there are two main concentrations in the distribution of the copper axe in question, one in the Carpathian Basin (Alföld and Transylvania) and one around the Middle Danube and the Iron Gates. These two areas actually correspond to regions I (Tisza-Transylvanian region) and II (Middle Danube region) of the Balkan-Carpathian Metallurgical Province as coined by Ryndina and Černych (2002, 29; 2000, 13). Although the axes have a fairly distinct centre of distribution, outliers are found as far as the Baltic Sea Coast and northern Italy, implying indirect networks of long distance exchange (see Chapter 11 for more

details). The apparent clustering of axes along rivers had to be discounted upon closer inspection. Hardly any axes were actually found within one kilometre of a river, but more than half were found within 10km of a river. This confirms the general settlement patterns of the time, and does not necessarily mean that the axes had a direct relationship to waterways.

When looking at the context of the axes, some interesting spatial and possibly temporal patterns can be observed. Whereas hammer-axes come in about equal numbers from settlements, hoards and burials, axe-adzes are mainly found in hoards. Amongst the axes found in graves a further distinction between the two axe forms can be noticed. In the KGKVI and Varna groups only hammer-axes were used as grave goods, whereas the Tiszapolgár and Bodrogkeresztúr cemeteries contained hammer-axes and axe-adzes in equal numbers. This brings us to the spatial patterns in the data. In general finds from burials concentrate in the Carpathian Basin as well as along the Black Sea coast. In the Carpathian Basin, axe finds from burials seem to be a phenomenon occurring throughout the settled area of the Tiszapolgár and Bodrogkeresztúr groups, but south of the Danube they only occur in the cemeteries along the Black Sea coast. Finds from settlements on the other hand occur mainly in the eastern distribution area of the axes, along the western Black Sea board, from the Central Balkans to the Republic of Moldova. Hoards do not show such a distinct spatial pattern. These variations show that there is a clear difference in the living practices between the Carpathian area north of the Danube and the Balkan area to the South. The lack of settlement finds from the Hungarian Plain might also relate to the ephemeral nature of settlements at the time, which is, however, itself a sign of cultural difference between the two areas. There might also be temporal reasons for these differences, as the two regions had their *floruits* at slightly different times. The KGKVI and Varna groups had their peak in the second half of the 5th Millenium BC, and stopped fairly abruptly around 4000 BC. In the Carpathian Basin on the other hand, the main period of use of the heavy copper tools was before and after 4000 BC. Some hammer-axes occur earlier than the appearance of the first axe-adzes. It could therefore be argued that the ‘missing’ axe-adzes in the KGKVI and Varna graves are simply not yet in circulation and use and could therefore not be deposited in a burial context.

The results from the analysis of the available data on chemical composition and dimensions were not particularly insightful for the overall topic. The compositional clusters, especially, did not have a high enough resolution or relevance to the axes from

the overall distribution area. It was therefore only possible to confirm one specific type of copper, which does confirm, however, that there must have been a Copper Age copper mine in the Slovakian Carpathians. The analysis of the morphological data confirmed that axe-adzes tend to be made from less metal for the same length of object. The relationship between the weight and length was able to confirm some of the axe types and the distribution of the weight values is so varied, that a use as currency for the axes can in all probability be discounted.

Towards the end of the production sequence some axes were marked with different patterns, the circular mark being the most common. The marks were probably punched when the metal was still soft or at least hot. It is only the developed axes, which do have marks, and there is no difference in the proportion of marked hammer-axes and axe-adzes. However, there is a difference in the types of marks, which are present on the two axe forms, as on the axe-adzes the 'simple' styles dominate, and on the hammer-axes the more complex or decorative ones. On first sight this might indicate that the hammer-axes were marked for decorative purposes and/or display, whereas the marks on the axe-adzes might be part of the production process. An alternative explanation would be that the marks stem from different metal workshops, a theory, which finds support through the fact that most axes are actually marked on the bottom and not on the top. As the more complex marks occur mainly on the bottom as well, it calls into question their decorative purpose. There is a problem with this interpretation, as the spatial distribution does not really confirm the clustering of the same marks in specific areas. The overall spatial distribution of the marked axes, again illustrates the difference between the two areas to the north and south of the Danube, as they mainly occur within the Carpathian Basin.

Although the data collected on the wear of the axes did not yield any specific or usable patterns, the fragmentation of the axes certainly did. The spatial distribution of the fragmented axes confirms yet again the twofold division of the study area as could be seen in the data on distribution, context and marked axes. Fragmentation occurs mainly amongst the axe-adzes and on those within the Carpathian Basin. The distribution could be seen as an argument that the axes were fragmented due to an intentional practice to the North of the Danube, although alternative explanations have to be considered. Most axes are broken along the shaft-hole, which is the weakest point. The fractures are fairly straight and show no traces of chopping, meaning that they probably occurred as the result of increasing brittleness of the material from repeated use and stress. So why

would this happen in one area and not the other? The distribution of the presence of bismuth in the metal might give an indication, as bismuth increases the brittleness. Axes containing bismuth do actually have a distribution mainly linked to the Carpathian Basin. This makes it tempting to use it as a direct reason for the fragmentation seen within this area. However, it is just one possibility and the debate on intentional versus unintentional fragmentation will be carried on in Chapter 11.

The results from the data analysis summarised above clearly show that we have at least a twofold division in living practices within the study area. The findings will be put into a more general cultural context in Chapter 11, when the axes will be integrated with the larger cultural developments, as well as the everyday lives of people.

11 The copper axes and the living practices of the Copper Age in south-eastern Europe – considerations and conclusions

If we want to assess the role copper hammer-axes and axe-adzes played in the everyday lives of people, it is important to place them in their ‘natural’, ‘social’, ‘cultural’ and ‘technological’ context. As was argued in Chapter 3 terms like ‘technology’ and ‘social’ are laden with multiple and often conflicting meanings (Dolwick 2009, 21-22; Ingold 2000, 321-22). It is also not possible to treat ‘technology’, the ‘social’ and the ‘natural world’ as separate entities; instead, every choice is taken within a specific *meshwork* of social relations, traditions, technical knowledge and the material world (Ingold 2000, 87; Latour 2005, 76). As it is in the everyday choices an individual makes that change is situated, change is determined by the specific *meshwork* in place at the time (van der Leeuw 2008). From the point of view of the individual, the *meshwork* could also be seen as the specific environment of a person when we think of environment as an all-encompassing term, which includes not only the so-called natural world, but also all of humanity with all its interrelations and world views. If such a broad definition is applied, we can argue that every choice or decision a person makes, be it conscious or unconscious, is determined by her or his environment. The perceptions of people are preconditioned by their environment (in its wider sense) but only in so far as their experiences created a unique combination of memories, which will differ for every individual (Halbwachs 1992, 38). These existing patterns can be both conscious and unconscious when people make their choices (see Chapter 3), and it depends on the individual if their choices ‘keep up the traditions’ or ‘break with traditions’.

It is with this understanding of individual choices made within a *meshwork* of connections and relationships between humans, animals, plants and materials that the wider context of the copper axes will be established in the following paragraphs. During the previous chapters it was tried to better understand the possible taskscapes of the copper hammer-axes and axe-adzes. Especially the practical engagement with the casting process itself has greatly enhanced the understanding of the complex techniques and possibilities of production. The results of the experiments as well as from the analysis of the database were used to look afresh at the cycle of metallurgy in the context of the Copper Age in south-eastern Europe. This chapter will use the stages of the diagram below (see Fig. 90) to re-integrate the copper hammer-axes and axe-adze with their wider context and better understand the choices made during their production and use.

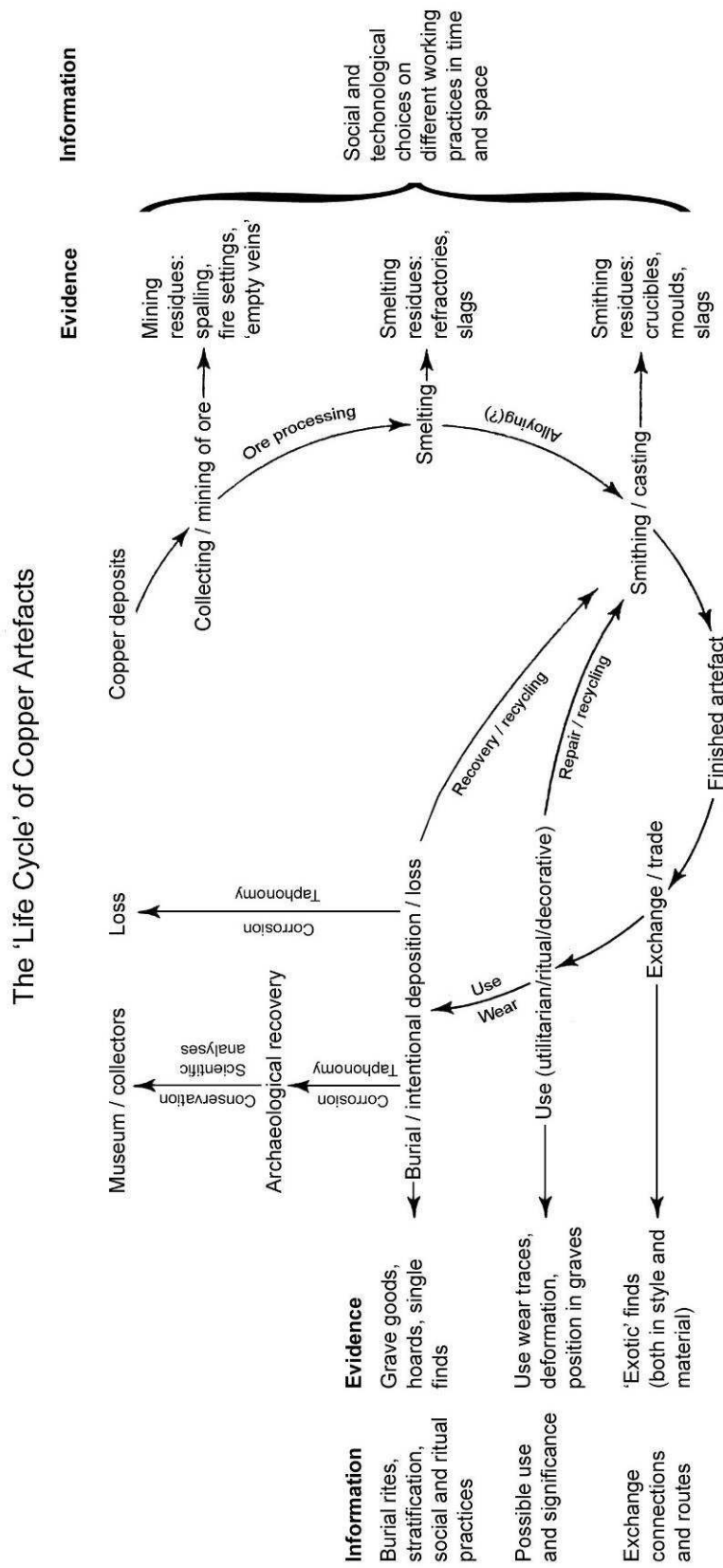


Fig. 90: Illustrating the 'life cycle' of copper artefacts (after: Ottaway 1994, Fig. 1, p. 3)

11.1 Exploitation of the raw material (mining and smelting) – organisation and meaning?

The evidence and methods used to study the mining and smelting of copper have already been presented and, to a certain extent, discussed in Chapter 6. Although the results obtained from the different approaches to the copper axes during this research have not directly brought to light new aspects of the mines and the activity of mining itself, extractive metallurgy is still part of the production chain. It will therefore be discussed in the light of the results obtained during this thesis. Different aspects of mining, including magico-religious ones, will be touched upon and illustrated as a backdrop to the production of the copper hammer-axes and axe-adze.

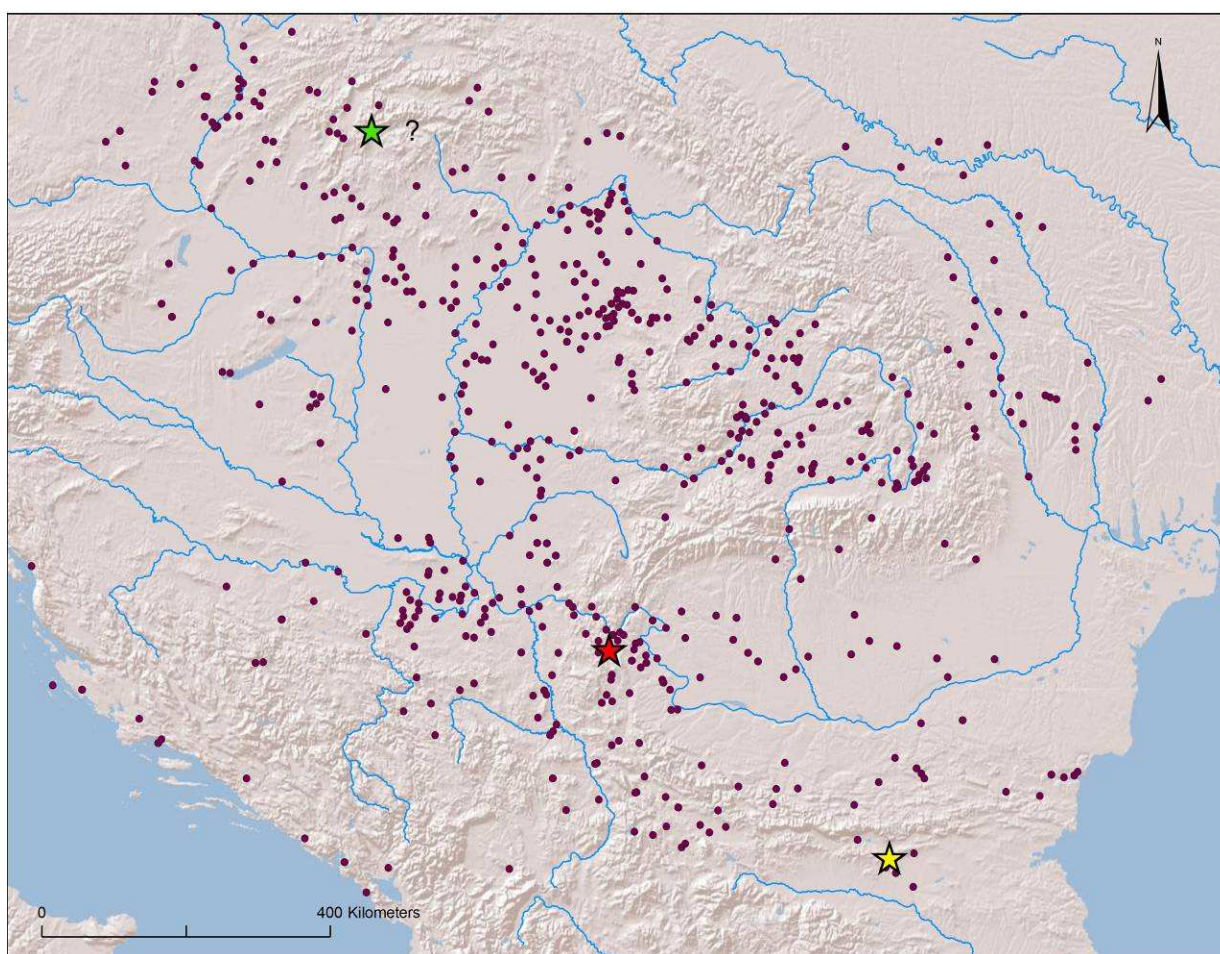


Fig. 91: The two confirmed Copper Age mines of Aj-Bunar (yellow star) and Rudna Glava (red star), as well as the possible copper mine near Špania Dolina (green star) in relation to the copper hammer-axes and axe-adzes (source: Author)

Looking at the distribution of the hammer-axes and axe-adze in relation to the known Copper Age mines (see Fig. 91), it becomes apparent immediately that they are not all

situated near the greatest concentration of axes. Only the mine of Rudna Glava in Serbia is located firmly within the Danubian cluster near the Iron Gates and along the Middle Danube. An analysis of the location of the heaviest axes has been inconclusive, largely due to the small sample size (see Chapter 10), although none of the heaviest axes are situated anywhere near the known copper mines, not even around Rudna Glava. The mine of Aj-Bunar in Bulgaria is hardly surrounded by any of the axes under consideration, although two of them, one hammer-axe (ID 89) and one axe-adze (ID 183) have been found in one of the mine shafts (Černych 1978b, 212). The evidence for Copper Age mining near Špania Dolina in Slovakia is not as clear cut, but, as mentioned in Chapter 10, a mine in the Slovakian Carpathians is also attested through the cluster analysis of the data on chemical composition. Of course these mines were not the only ones used, and in Bulgaria and Serbia alone a number of other copper deposits have been identified as potential Copper Age mines through compositional and lead isotope analysis (Gale *et al.* 2003; Pernicka *et al.* 1997; Schmitt-Strecker and Begemann 2005), but none of them have been corroborated through traditional archaeological evidence.

There is as yet no evidence for a Copper Age mine in the Carpathian Basin, despite the presence of numerous copper deposits, especially in the Transylvanian Ore Mountains north of the River Mureş. This is, in my opinion, not evidence of their true absence, but merely an absence of evidence. Mines are notoriously difficult to find, as many are exploited throughout history destroying all traces of when they were first worked. There have not been any systematic surveys published for this area, and lead isotope analyses of copper mines are virtually nonexistent. Indirect evidence for the start of the more intensive exploitation of ores comes from pollen cores from the north-eastern Hungarian Plain, which is the centre of the highest density of axes in the Carpathian Basin. Around 4000 cal BC, an increasing amount of copper is identified in the cores, which the authors link either to a Copper Age settlement nearby, or to the general exploitation of copper ores in the Carpathians, which would have released copper particles into the atmosphere. They would then reach the basin through rainwater (Willis *et al.* 1995, 44). The date would fit reasonably well with the peak of the heavy copper axes in the area, as they are slightly later in the Carpathian Basin than on the Balkan Peninsula.

Whereas the mining activities in the Carpathians might have had their Copper Age peak fairly late, recent radiocarbon dates have shown that the copper mine of Rudna Glava was possibly beginning to be exploited at the same time as the trapezoidal building phase at Lepenski Vir (around 6000 cal BC), which only lies 30km away from the mine

(Borić 2009, 200). The presence of malachite beads in these layers seems to confirm the possibility of such an early start of the exploitation of Rudna Glava. However, even if we take only the later ‘safer’ C14 dates, the mine was in use well before the large copper axes were in circulation, from the late 6th millennium BC (Borić 2009, 195). The main activity in the mine shafts, happened, however, in the early centuries of the 5th millennium BC (Borić 2009, 206), during the Gradac phase of the Vinča culture. Although this is considerably earlier than the bulk of the hammer-axes and axe-adzes, the hammer-axes from the settlement of Pločnik have recently been re-dated to the first half of the 5th millennium BC (Borić 2009, 214). As the majority of axes come from unknown contexts, it is quite feasible that at least in the region around Rudna Glava, more of these axes were in use at this early point in time. The activities at the mine of Aj-Bunar have been dated to the Maritza (Karanovo V) group and the KGK VI complex (Černych 1978b) placing it firmly within the mid 5th millennium BC.

But how can we relate the mining activities to the lived experiences of people during the Copper Age? The knowledge and memory of mining was surely embedded in the value of the finished axes. The makers and users must have been aware where the raw material came from, even if only through hearsay or mythical stories. Indeed both ethnographic and historical sources throw light on the wealth of belief systems and myths which can be connected to mines and the process of mining itself. There are goblins that have to be appeased and purifying rituals for the miners before they enter the mines (Topping and Lynott 2005, 183-186). In this context, a fairytale from the Ore Mountains in Romania is an interesting example. It speaks of mountain spirits who help the miners find the ore veins. The only condition is that the miners never tell anyone about the spirits, otherwise they might have fatal accidents (Cioca and Cioca 1995). The story implies that secrecy was of utmost importance and that the knowledge of where new veins are situated was probably protected and only passed on to certain other individuals. It has also been noted that many of these stories are used to negotiate the inherent dangers of mining (Topping and Lynott 2005, 185). The very fact of ‘going underground’ might stir superstitions and the danger might have heightened tensions, making the miners more susceptible to ‘other-worldly’ experiences (Topping and Lynott 2005, 190). Mines have also been used for specific rituals and important ceremonies.

As always, these issues are very difficult to attest in the archaeological record. However, both the mines of Rudna Glava and Aj-Bunar have brought to light evidence

of possible rituals and other non-utilitarian uses of the mines. This shows that the Neolithic and Copper Age communities in south-eastern Europe saw the mines as well as the activity of mining as something which had to be explained and ordered through rituals and myths. The burials of two men and a woman in two of the shafts at the Aj-Bunar mine (Černych 1978b, 207, 209) show that the place had some significance for the local population. It is not possible to say if it was imbued with positive or negative connotations. Were the people buried there because they had a special status maybe linked to the mining of copper, or were they outlawed even in death and buried in the mine as a sort of final punishment? We will never know. It nevertheless shows that the relationship between the people and the mine was not a straightforward utilitarian one. The same can be said about the mine of Rudna Glava. Several hoards containing ceramic vessels, stone and bone tools, 30kg of malachite and azurite as well as zoomorphic 'altar' lamps have been found and mostly dated to the early 5th millennium BC (Borić 2009, 197). Thinking back to the historical and ethnographic sources, offerings are often left for the goblins that assist, or to 'tame' the spirits of nature in order to guarantee safe mining activities (Topping and Lynott 2005, 183-186). Although we cannot know if the miners of Rudna Glava left the hoards to appease the spirits, we can say again that the mine as a place had a special significance, which warranted special rituals and offerings.

The 'special status' of mines might also have varied between the mines themselves, as lead isotope studies have shown that the majority of copper ore and objects from settlements around Rudna Glava, for example, did not come from this local mine (Gale *et al.* 1991; Gale *et al.* 1997; Pernicka *et al.* 1997; Pernicka *et al.* 1993). Was the copper from Rudna Glava destined for a 'special' market, or have there simply not been enough analyses done? Only future work might produce further pieces of the puzzle. An analysis of the ores from settlements around the Aj-Bunar mine show that they probably came from Aj-Bunar (Ottaway 1981, 144). The finished objects from the same villages, on the other hand, could not be matched to Aj-Bunar (Ottaway 1981, 145). Ottaway proposes that the metallurgy was controlled by an elite with its headquarters probably around Varna (Ottaway 1981, 145). The copper ore was transported away from Aj-Bunar to some central processing area, together with ores from other mines (Ottaway 1981, 145). There the objects were made, and found their way back to the settlements around the Aj-Bunar mine (Ottaway 1981, 145). It is an interesting model, which again needs further investigation.

It is always difficult to get to the past engagement between the people and the material we as archaeologists study. However, in the cases of Aj-Bunar and Rudna Glava it is clear that mines and mining was imbued with rituals and myths which ordered the exploitation of copper ore. These myths must have been in some way attached to the finished copper axes as they were exchanged, cared for and used.

There are also other issues to consider, like craft specialisation as well as gender and craft divisions during the production sequence of the copper axes. This is probably just as difficult as getting behind the rituals and beliefs of prehistoric people. An ethnographic/historic example from the Ore Mountains of Romania illustrates that the mining, but especially the processing of the ore was done by an entire community. A series of old photographs taken in the early 20th century around the mining town of Roşia Montană show how the ore was carried down the mountain by boys of about 8-12 years in wicker backpacks, how a woman separated charge through flotation, and how an old man washed the gold (Dordea 2003). Although this is a comparatively modern example of the exploitation of gold, copper mining and ore processing in prehistory really might have been a multi-generational and multi-gendered activity.

The early dates for the first exploitation of copper ore at the mine of Rudna Glava are complemented by the earliest European dates for the smelting of copper in the same region. As mentioned in Chapter 1, the earliest evidence so far for the smelting of copper comes from Belovode, a Vinča settlement in Serbia around 5000 cal BC (Borić 2009, 238; Radivojević 2007). This date confirms the early exploitation of the mine at Rudna Glava not only through the general availability of the technical knowhow, but lead isotope analyses of some copper objects from Belovode indicate that the raw material actually did come from the mine of Rudna Glava (Radivojević 2007, 109). The origin of the raw material was probably steeped in myths, stories and secrets. Did the extraction of the metal also have such connotations? The very act of transforming rock to glowing metal does seem ‘magical’ or unexplainable enough to suggest that this might have been the case. In non-literate societies, many complex processes are still to this day passed on and remembered as stories or even spells (Budd and Taylor 1995, 139). It is tempting to see the Copper Age smelters as magicians or alchemists, who transform the stone to metal. However, this is difficult to corroborate with archaeological evidence, mainly due to a lack of finds related to the smelting of copper which clearly imply ritual activities, unlike the mining sites of Rudna Glava and Aj-Bunar.

At most sites with evidence for the smelting of copper there are no specialised areas for this activity. This would mean that it happened very much in a household context, making it difficult to imagine a ‘magic’ status for the people involved in smelting. It is possible, however, that the process itself did have a ritualised structure or protocol. Although most evidence does suggest a household context, the recent smelting evidence from Belovode does come from a single area. The ‘cold’ metallurgical activities like malachite bead making on the other hand were happening across the whole site in household contexts (Radivojević *et al.* 2010, 2784). This could imply that at least at Belovode, smelting and also casting were separate activities. It is, however, difficult to ascertain if they were simply separate in the spatial organisation of a settlement or whether it also entailed a division in knowledge and practice amongst the inhabitants. Although ethnographic analogies as well as European fairytales and myths indicate that the smelting of metal quite likely had magical connotations, and ritual protocols (Budd and Taylor 1995), it is impossible to prove these archaeologically. Whatever world view was connected to smelting, it surely became a remembered part of the finished objects. It is therefore possible to say that the copper axes under consideration might not only have evoked the myths and stories connected to the mining of the raw material, but also the specific (magic) processes of the transformation from stone to metal.

11.2 Melting and casting – where is the archaeological evidence and how was it done?

There are also plenty of myths recounting the special status and magical abilities of smiths (Budd and Taylor 1995). Again, in a prehistoric context, it is difficult to demonstrate such beliefs, particularly with hardly any evidence at all for the actual process of melting and casting. The case is similar to the smelting of copper, in that hardly any special refractory ceramics are known in the archaeological record. That large amounts of copper must have been melted in order to cast heavy copper axes of up to 3kg in weight is proven by their very presence. The only question is ‘how’? In Chapters 6, 7 and 8 many aspects, like the missing moulds, and the production technique of the shaft-hole have been already discussed in detail as part of the description and examination of the axe blank and its possible meaning as well as the experimental and metallographic results. I will therefore concentrate on the evidence for melting the copper prior to casting, before discussing the results and evidence for the production in general terms, and putting it into a wider context.

In terms of furnace structure, a simple hole in the ground would suffice, and leave no more traces than a hearth. In the actualistic outdoor casting experiments carried out as part of this research, the pit was lined with clay (see Chapter 7). However, other experiments have shown that even this is not necessary. A simple earthen pit filled with charcoal is enough to melt copper (Jochum Zimmermann, pers. com.). The act of melting copper is to a certain extent determined by the laws of nature. Copper melts at 1083 °C so it was therefore necessary to supply a constant airflow in order to achieve temperatures high enough to melt copper in a pit in the ground. How this airflow was achieved would have been a matter of choice for the prehistoric casters bearing in mind the materials available to them. Blow pipes have been used successfully to melt small amounts of copper but are not efficient enough to melt larger quantities (Rehder 1994, 349-350). A set of two bellows, made entirely of organic materials (see experiments in Chapter 7), are very efficient and do not leave any traces in the archaeological record. The only parts which have to be made from clay are the tuyères, which lead the air directly into the fire.

If we look at the archaeological record for the Copper Age of south-eastern Europe, there have hardly been any such finds. However, when looking through some of the literature and excavation reports, I repeatedly came across small clay objects which had been interpreted as phalli (see Fig. 10) (Childe 1939, 127; Cucuş 1999, 284). I was unfortunately unable to view any of these objects, in order to establish any secondary burning. However, in my mind it is certain that we are dealing with tuyères. They are fairly small compared to the large L-shaped tuyère used in my experiments, which was based on a Bronze Age artefact. Future experiments would have to establish how these small tuyères are best used. Due to the size it would be impossible to connect leather bellows directly to these tuyères, as the proximity to the fire would be too close. Such small tuyères might point to casting being a group activity, as they must have been used in larger numbers, possibly surrounding the entire casting pit. In the experiments clay tubes were used to connect the tuyère to the bellows (see Chapter 7) but these could equally well be made from wood. When the bellowing is done properly, meaning the achievement of a constant airflow into the fire without a backflow through the tuyères, there would be no problem with overheating any part of the bellow system. This has also been confirmed through the experiments. Experiments, as well as the archaeological record, have shown how the temperatures for melting copper could have been achieved in the past. A rigorous re-examination of the available ceramic material

from all Copper Age sites would be necessary in order to find more evidence for the process of melting and to establish whether similar equipment and methods were used throughout south-eastern Europe. At the moment the small tuyères used in combination with a number of bellows surrounding the furnace is the most likely scenario for the production of the large copper hammer-axes and axe-adzes.

When we look at the possible crucibles which might have been used to hold the copper during the melting process, a similar problem becomes apparent immediately. The known crucibles from the Copper Age of south-eastern Europe are all of a similar small size. Although it might be possible to melt a few hundred grams of copper in these it would be impossible to melt much more than 1kg of copper as my experiments have shown. As there are many axes which weigh more than 1kg, and some considerably more, it is difficult to imagine how these large amounts of copper were melted. As there are a number of smaller crucibles surviving, larger ones would have surely also survived if they existed. This can of course not be used as an argument that larger crucibles did not exist, but it makes it highly unlikely. As mentioned before (see Chapter 7), a larger crucible would have been very difficult to handle, as they become too heavy to be used steadily by a single person. When trying to explain how larger amounts of copper were melted, we might have to try and think outside the box. The traditional image of the single, itinerant metal smith cannot account for the casting of the heavy axes. Instead, the small crucibles point to a group activity as was suggested for the use of the small tuyères above, which must have been highly choreographed. Several crucibles were probably used for melting enough metal to cast one of the large axes under consideration. The timing must have been crucial in order for several people to pour their metal into a single mould. Only future work and more experiments will be able to come closer to answer this aspect of the production of the large copper axes for certain. However, the taskscape which is emerging for the copper axes involves an entire group of metal-workers, who shared the same technical skill and knowledge. The processes are therefore likely to have been firmly rooted within the communities of specific settlements.

The missing moulds have been discussed in some detail above and for now it will be assumed that the axes were cast either in sand moulds or in unfired clay moulds (see Chapter 7). When looking at the whole assemblage of axes, it is especially their variability by type and diversity in shape and size which becomes apparent (see Chapter 9). There are no two axes which can be identified as coming from the same mould. This

is mainly due to the fact that they were forged after casting, a process which is highly individualised as it is impossible to forge two objects which are identical. The axe types probably had specific moulds and/or patterns, but the differences between the variants are surely caused by the forging necessary to finish these axes. A further reason for this diversity, besides the choices of the people, is probably the mould material. Sand and unfired clay moulds are the most likely materials used and neither can be re-used. This means that a new mould would have had to be created for each axe, again leaving room for small changes by the individual metal-worker. There was no one standardised way of producing hammer-axes and axe-adzes. Their macromorphology betrays a variety of techniques used, depending not only on the axe shape but also on the type. Both the mould shape and the shaft-hole production technique varied between the different axe types (see Table 15). The axes with punched shaft-holes, for example, must have been cast in open or partly open sand moulds, as otherwise it would not be possible to punch through the soft metal. The oxide distribution seen in the experimental axes cast in open sand moulds compared to the axes cast into closed moulds also seems to indicate that even the Jászladány axes might have been cast in open moulds (see Chapter 8).

Table 15 The possible production techniques for the different axe types (source: Author)

Pločnik	Cast, probably in open mould with shaft-hole in place or drilled(?) later, finished through forging
Vidra	Cast, probably in open or partly open mould with shaft-hole in place or drilled(?) later, finished through forging
Crestur	Cast, probably in closed mould with shaft-hole in place, finished through forging
Szendrő	Cast, probably in open (sand) mould, shaft-hole punched through when metal still liquid, finished through forging
Székely-Nádudvar	Cast, probably in closed or partly open mould with shaft-hole in place, finished through forging
Handlová	Cast, probably in closed or partly open mould with shaft-hole in place, finished through forging
Mezőkeresztes	Cast, probably in closed or partly open mould with shaft-hole in place, finished through forging
Čoka	Cast, probably in open or closed or partly open mould with shaft-hole in place, finished through forging
Širia	Cast, probably in closed or partly open mould with shaft-hole in place, finished through forging

Mugeni	Cast, probably in closed or partly open mould with shaft-hole in place or drilled (?), finished through forging
Tg. Ocna-Nógrádmargal	Cast, probably in open or partly open mould with shaft-hole in place or punched through when metal still liquid, finished through forging
Jászladány	Cast, probably in closed or partly open mould with shaft-hole in place, finished through forging
Kladari	Cast, probably in closed or partly open mould with shaft-hole in place, finished through forging

The extent of the forging could unfortunately not be tested experimentally. Metallographic analysis has been used to estimate the extent of forging, but the results are not always in agreement. Whereas Kienlin and Pernicka argue only for a final surface finish through forging (2009), Ryndina and Ravich talk about different techniques, with reductions in thickness through forging varying between 80-90% and less than 50% (2000, 10). Some objects do show that substantial forging must have taken place (see Fig. 92 and 93).



Fig. 92: The shaft-hole of an axe-adze with clear forging marks (photo: Author)



Fig. 93: The axe cutting edge split open, which indicates that it was forged together (photo: Author)

Fig. 92 illustrates that the axe and hammer/adze arms in a number of axes were forged up and together, creating small triangular depressions either side of the shaft-hole. This indicates that the raw cast was probably not very close to the final shape. These depressions are visible on a number of axes of most developed types. Further evidence for substantial forging which must have been used to shape some of the axes is seen in Fig. 93. The axe blade was clearly forged or folded together. This is mainly seen in hammer-axes of Mezökeresztes and Székely-Nádudvar type, but one potential axe-adze of the Jászladány type also shows this pattern. The Jászladány axes are the most common axe type, but they are not as homogeneous in their macro-morphology as the other axe forms and types. It is interesting to observe that some examples do show these heavy signs of forging, whereas others look as if they really were cast into their final shape. Not one axe of another type actually looks as if it was cast in its final shape. It is unfortunate that most axes are isolated finds, as the Jászladány axes almost look as if they came from two different horizons, with some early heavily forged ones and others, which are later, cast into their final shape. More experiments and metallographic analyses are necessary to substantiate such a claim, as differential taphonomic processes and state of preservation might also play a role in the appearance of the objects.

Ryndina and Ravich were able to sample a comparatively large number of axes and other copper objects for metallographic analysis from the Republic of Moldova and Bulgaria (Ryndina and Ravich 2000, 2001). They identify two stages, the first one

encompassing Gumelnița, Varna, Salcuța I-III, Vinča-Pločnik II, Tiszapolgár, Lengyel III, and Cucuteni A-Tripolye A (mid 5th Millennium BC). This stage they claim is mainly dominated by early hammer-axes (Ryndina and Ravich 2000, 11). The second stage is connected with the following cultural groups: Bodrogkeresztúr, Cucuteni A-B and B, Tripolye BI-BII, BII, CI and Cernavoda I-Pevec (around 4000 cal BC) (Ryndina and Ravich 2001, 2). The diagnostic axes are argued to be the Jászladány axe-adzes, as well as the developed hammer-axes like Mezökeresztés and Székely-Nádudvar (Ryndina and Ravich 2001, 2). In stage I they identify two metallurgical centres (Varna and Gumelnița) which although contemporary, made different choices regarding their forging and finishing techniques. The Gumelnița metal-workers, for example, mostly worked with forging temperatures of between 900 - 1000°C, whereas the Varna metal-workers mainly worked with temperatures of between 300-500°C (Ryndina and Ravich 2000, 14). A further possible difference between the two centres is the use of cold working. The sampled axes from Varna contexts show that they were work-hardened only along the cutting edges. The objects from Gumelnița sites, on the other hand, are work-hardened along the cutting edges as well as along the axe body and inside the shaft-hole (Ryndina and Ravich 2000, 14-15). For the second stage such differences between the regions were not evident; the authors state that the cold working, especially of the cutting edges, increased during this period, and that the centre of metallurgy firmly shifted to the Carpathian Basin (Ryndina and Ravich 2001, 6-7). As discussed above, the ability to reconstruct the annealing and forging temperatures through grain size is questionable, which means that these claims are not necessarily very reliable. A further problem with these results is that the increasing importance of cold working of the cutting edges of axe-adzes could not be corroborated by Kienlin and Pernicka's study (2009) in which they sampled six Jászladány axe-adzes. These did not show any evidence of cold working along the cutting edges. As the axes in the latter study came from the western Carpathian Basin (Kienlin and Pernicka 2009, 261) and the axes for the former analyses from the eastern most area, this difference in cold working techniques could in fact be a sign of different choices made in two cultural areas. However, such a claim would have to be confirmed through more analyses. The example above shows the potential of analysing the microstructure of archaeological axes. If done on a large enough scale, different choices taken by metal-workers in space and time can be identified. For a clearer picture much more work of this kind is necessary, in combination with experimental work. The problem with the two studies above is that they could not back up their claims through controlled experiments.

One last aspect to consider is the fact that the process of melting and casting is not a purely metallurgical one. It is often forgotten that many parts of the equipment needed are made from clay and organic materials. One of the values of experimental archaeology is therefore to illustrate that metallurgy is very much a composite skill or practice, which has obvious implications for the organisation of work. No matter what the status of the metal smith or metalworking group might have been in the past, he would have had to work together with other craft specialists in order to complete his task. The copper axes under consideration reflect a myriad of production techniques and choices made by the metal-workers and their communities. Parts of the *chaîne opératoire* can still not be explained, like the melting of the metal itself. Other aspects, like the moulds used, the forging and finishing of the artefacts have to be confirmed through further work. However, it looks as if we are dealing with a non-standardised form of production. Different methods were tried and working techniques were developed. This is not surprising when one considers that these are the first large metal objects from anywhere in the old world.

11.3 Shape, size, decoration and use – human choices and the functionality of objects

As mentioned in Chapter 9, the majority of axes are either hammer-axes (a combination of an axe end and a hammer end) and axe-adzes (a combination of an axe end and an adze end). Any combination of cutting or hammer arms is a possibility, both now and in the past, so why are these two shapes so dominant? The choice must have had something to do with their function which was not only determined by the utilitarian use of these axes, but also the traditions and customs which went hand in hand with the production and use. The repertoire of the coppersmiths was part of a specific *meshwork* (see Chapter 3) in which the decision-making processes were determined by the environment in its wider sense (see above) and the objects were suitable for their purpose.

So far I have considered the production of the axes from the perspective of the producer purely through the steps necessary to achieve the final result. However, the final shape of the axes and, therefore, their production techniques are also dependent on the user. I am not using the word consumer, as this implies modern notions of supply and demand, which are not relevant to prehistory. The user must have been involved in the final steps

of production, if not directly then indirectly through their wishes. It was the people who used the axes, whether as tools, weapons or ritual objects who knew what qualities they wanted in an axe. This implies that the production was carried out by groups of specialists, creating this duality between the producer and the user. As there is evidence for the specialised production of pottery from Copper Age settlements (Marinescu-Bîlcu and Bolomey 2000, 180), the production of metal objects can surely also be seen as a specialised craft. As mentioned above, the casting of copper was probably also carried out within a settlement context by a group of highly skilled artisans. The relationship between these skilled metal workers and their customers cannot be reconstructed but it is likely that the dynamics consisted rarely of straight forward linear connections. The dynamic networks between the producers and the users are the place where inventions are turned into innovations (van der Leeuw 2008, 242-243). Inventions happen on a local scale (van der Leeuw 2008, 242), in the very process of production (see Chapter 3) or as a direct result of a request from a user. It becomes an innovation when there are enough users who have an interest in this new invention (van der Leeuw 2008, 243). This needs a much larger network of relationships and associations, as the ideas spread over large distances to regional and even supra-regional scales.

Table 16: A summary of the spatial distribution of the different axe types (source: Author)

Pločnik	The stocky A and B variant occur mainly in the Carpathian Basin and Serbia, the slender C and D variant occur within the entire distribution area, particularly in the cemetery of Varna
Vidra	The stocky A variant occurs mainly North of the Danube, the slender B variant mainly to the South
Crestur	Crestur axes concentrate along upper Tisza and lower Körös
Szendrő	No difference between the two variants, the axes of Szendrő type concentrate in northern Hungary and Slovakia
Székely-Nádudvar	Occur mainly North of the Danube, only variants A and B show distinct distributions, concentrating in the western Carpathian Basin and Transylvania respectively
Handlová	Very distinct concentration in the Slovakian Carpathians
Mezőkeresztes	Found mainly around the Tisza and Körös Rivers with some occurring along the middle and lower Danube
Čoka	No clear concentrations

Şiria	Concentrate along middle Danube and Tisza
Mugeni	Occurring throughout south-eastern Europe, but three distinct clusters in Transylvania, around lower Sava and to the south-east of the Iron Gates
Tg. Ocna-Nógrádmargal	Present in entire study area, but there are distinctions between variants. Variants A1 and A2 show a clear concentration in eastern Transylvania. Variants B, C1 and C2 occur mainly in the western Carpathian Basin and along the lower Danube
Jászládány	Present in entire study area. Variants A1-A3 absent from Transylvania, variant A2 clusters around the Iron Gates. No other clear patterns
Kladari	Clusters occur mainly in northern Croatia and northern Serbia

If we therefore accept that the user also determines the shape and size of the axes, the spatial distribution of the different types and variants (see Table 16) gains an extra dimension. Whereas some axe types occur within the entire distribution area, straddling different cultural groups (eg. Jászládány, Mugeni and Pločnik), others occur mainly within one cultural tradition as defined through the pottery (eg. Mezökeresztes and Székely-Nádudvar). Some axes have an even more localised distribution, like the Handlová axes of the Slovakian Carpathians. There were clearly different levels of practice in action. Especially the Jászládány axes show that there must have existed a supra-regional aesthetic or function, which meant that they occur in the whole of south-eastern Europe, not ‘respecting’ the boundaries of conventional ceramic traditions. The axe types occurring only in certain regions indicate that some values and choices were related to the specific tradition of a culture or even sub-culture. It is difficult to imagine what the reason for these different levels of decision-making might be. There might, of course, be a temporal dimension as well, which is unfortunately not possible to ascertain due to the lack of context. However, the distribution of the different axe types shows that the producers as well as the users of these axes were influenced not only by their local environment (in its wider sense) but also their cultural group at large, and even if indirectly by supra-cultural developments.

The axe marks already discussed in Chapter 10 show a similar pattern, with a clear division between the areas to the north and the south of the Danube. As this division is also visible in the axe types, it must have had a special significance. Why did the metal smiths decide to mark their axes in the Carpathian Basin? Or might it be more suitable to ask why the users of the axes who lived North of the Danube wanted their axes

marked? Might they have marked them themselves? It is so far not possible to say what these marks meant. As discussed above, most of them occur on the bottom of the axes, making it unlikely that they were meant to be seen.

The same goes for the function of these axes. Although often discussed, there is still no consensus what these objects were used for. The softness of copper has often been used to argue for a non-utilitarian function of the axes, although this cannot be substantiated, and Kienlin and Pernicka have shown that the presence of the (Cu+Cu₂O)-eutectic increases the hardness of the objects without the need to cold-work them (2009, 266). There seem to be three main suggestions which can be found in the literature: tools, weapons and status/ritual objects (Bognár-Kutzián 1972, 139; Patay 1984, 18-19; Popescu 1944, 30; Vulpe 1975, 16-17). Obviously these categories can be split up even further, with tools being potentially used on a variety of different materials. Within the last ten years, some of the first experimental studies of use-wear analysis on metal have been carried out on flat axes from the Alpine region, and socketed axes from Britain (Kienlin 1998; Roberts 2003). The authors carried out their experiments on wood, and were able to distinguish between light, medium and strong use (Roberts 2003, 130-131). However, there are some serious issues regarding the preservation of use-wear traces on metal, as the objects are normally too corroded. This leaves a small sample size, which is not necessarily representative. Particularly the copper shaft-hole axes are usually heavily corroded. More research could build up an experimental reference collection, but even if it were successful, it would only ever show the last activity the axe was used for. Thinking about the prevalence of the two major shape combinations, the hammer-axes and axe-adzes (see above), it is safe to say that they had something to do with the function of the axes. Although it will always be speculation, the axe-adze for example might be perfectly suited for woodworking tasks, especially the building of houses, as one only really needs an axe and an adze blade to carry out most of the tasks involved. Experiments would be a useful way of establishing the likelihood of such an explanation. The most likely function is probably a bit like a Swiss army knife. It is a very useful tool and indeed weapon, but can serve at the same time as a status symbol or a prop in a ceremony. In any case, finding out the sole function of the axes is not possible. They most certainly had different and even changing meanings for each person, as the perceptions and memories of people depended on the individual *meshworks* in place (Olick and Robbins 1998; van der Leeuw 2008).

A non-utilitarian function, which takes into account the changeability of meaning, has been proposed particularly for the axe-adze by Chapman (2000, 100-103). This practice is known as ‘fragmentation’ and was briefly introduced in Chapter 10. Although problems with this theory were exposed regarding the copper hammer-axes and axe-adzes, there so far is no definitive explanation for the strange pattern seen in the fragmentation of the axe-adzes. The proportion of fragmentation amongst the axe-adzes from the Carpathian Basin is considerably higher than in other regions (see Chapter 10). I will therefore examine the theory of fragmentation in more detail, and discuss how it might affect the axes in question.

The theory was born out of the feeling that there was no awareness in Balkan archaeology “of the structural relationships between people, objects and places” (Chapman 2000, 4). Chapman develops a multiplicity of relationships between humans, objects and the landscape: it is the movement of objects and to a certain extent people, which are the subject of his book on fragmentation (Chapman 2000, 5). He claims that “enchainment and accumulation are the two main practices which sustain social relations” (Chapman 2000, 5), although he focuses rather more on enchainment through fragmentation, in order to explain the large amount of fragmented objects in south-eastern Europe (Chapman 2000, 37). The evidence for the use of fragmented objects in enchainment practices is the absence of at least one part of the broken object, as it would have been taken by one of the two or more people who sealed a social relationship or a transaction by breaking the object (Chapman 2000, 6). While this absence of object parts is easily detectable in published grave contexts (2000, 52), Chapman’s attempt at applying the same methodology to settlements (2000, 56) seems difficult as settlements in south-eastern Europe are rarely excavated completely, and vast numbers of sherds are usually thrown onto the spoil heap. In her undergraduate dissertation Wood tried to improve the methodology for the detection of enchainment by fragmentation by excavating a complete settlement but found it still difficult to prove its existence (Wood 2004).

In a more recent book, some of the criticisms have been addressed as the author’s acknowledge that the excavation methodology has an impact on the missing parts of fragmented objects (Chapman and Gaydarska 2007, 71). The re-fitting of fragments from the same sites and from different sites is therefore proposed as a way forward to identify deliberate fragmentation (Chapman and Gaydarska 2007, 176). The numerous good case studies show that in certain contexts it is possible to identify fragments from

the same object in separate locations (Chapman and Gaydarska 2007, 153, 177-178). However, this is still no direct evidence for deliberate breakage, never mind a practice of enchainment. Examples like the shell rings from grave context in Varna and Durankulak make deliberate fragmentation likely (Chapman and Gaydarska 2007, 153) but I find it difficult to explain the whole of the south-eastern European Copper Age through a social practice of deliberate fragmentation simply because there are so many fragments present, which is after all a common phenomenon on archaeological sites.

Despite stressing the difference between metal objects and ceramics, and proposing metals for a social practice of accumulation due to their physical and possible social properties (2000, 44), Chapman uses the case study of copper axe-adzes and hammer-axes to propose a regional practice of enchainment through the fragmented copper axe parts (Chapman 2000, 103). However, his only evidence is the increased proportion of fragmentation of axes from modern day Romania (Chapman 2000, 100). As was shown in Chapter 10, this is not entirely true, as the practice (if it is one) seems to occur throughout the Carpathian Basin. Even so, there is a clear difference between the proportion of fragmentation from the Carpathian Basin and the rest of the distribution area of the axe-adzes, which cannot be easily explained. That the axes do tend to break at their weakest point does not explain why they break more frequently in a certain geographical region. The presence of bismuth was therefore proposed as a possible reason for this pattern, as bismuth makes the metal more brittle. However, this is so far just a theory, and more work would need to confirm this. The possibility of some social practice which might account for this geographically distinct pattern of fragmentation has to be an alternative explanation, although it does not necessarily have to be a theory of enchainment. There could be a number of other practices which could result in this pattern. It is therefore in my mind not helpful to speculate in such definitive terms about a possible practice of enchainment in prehistory.

11.4 Trade and Deposition

The results from lead isotope analysis have brought up some intriguing patterns of possible trade links and routes of supply for copper ore within south-eastern Europe. The two known copper mines Aj-Bunar and Rudna Glava seem to have played different roles in the supply of the raw material. Whereas a number of objects and ore samples from various sites can be linked to Aj-Bunar, there was, until recently, no evidence for objects having been made from Rudna Glava copper (Iliev *et al.* 2007, 13; Pernicka *et*

al. 1993, 37). Although there now is evidence that a number of objects and ore samples from Belovode and the Varna region came from Rudna Glava (Iliev *et al.* 2007; Radivojević 2007), the majority of samples from the Balkans cannot be related to Rudna Glava, despite the traces of its large scale exploitation.

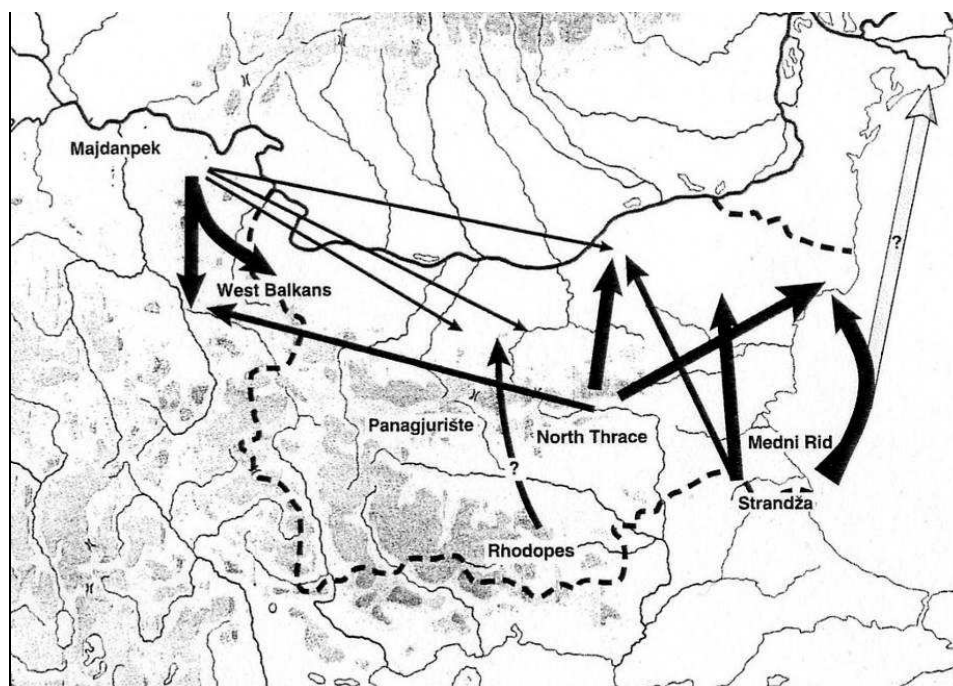


Fig. 94: The possible supply routes of copper in the Balkans (source: Pernicka 1997, p. 145, Fig. 30)

The possible supply routes have been summarised on a map by Pernicka *et al.* (Pernicka *et al.* 1997, 145) (see Fig. 94) although the recent evidence for the exploitation of Rudna Glava is not yet included. However, the map shows a rather complex net of interactions, with very close links between the Central Balkans and the Black Sea Coast. As the authors state themselves, this network is based on evidence from the second half of the 5th millennium BC and even later. As the recent C14 dates from Rudna Glava have shown that the mine was in use only during the first half of the 5th millennium BC, it might not be surprising after all that there are so few objects which can be related to its lead isotope signature, as the samples mainly date to the second half of the 5th millennium BC. It is interesting to observe that within the territory of Bulgaria, the main copper deposits come from regions with hardly any finds of copper axes. The ore-producing communities must have had no interest in or were not allowed to participate in the ownership and use of these large copper items. It is unfortunate that these detailed

supply routes can so far only be investigated south of the Danube, as there has been no work done on any of the objects or ores from the Carpathian Basin. We therefore need to look at the objects themselves for any wider trade links which might have been in existence.

The distribution map of the finished objects makes it possible to look at some of the potential long-distance exchange networks. Two axe-adzes have been found around the Baltic coast of northern Germany and Denmark (Klassen 1997; Klassen and Pernicka 1998). One was made from 'Balkan' and one from Slovakian copper deposits (Klassen 1997, 191). In his work on the copper finds in the Northern Funnel Beaker Culture (TRB), he argues that the import of the earliest copper objects went hand in hand with the uptake of farming (Klassen 1997, 192), which would confirm the theory of the spread of metallurgy with the 'Neolithic package' also in other parts of Europe. Of course, in the original theory, it was only the 'cold' metallurgy (bead making, and cold hammering of native copper) which was meant to have been introduced with agriculture. But as the Neolithic way of life reached the Baltic area only when 'hot' metallurgy had been developed within south-eastern Europe, it is not surprising to find cast copper objects, which have made it so far North. The question is whether we can really talk about long-distance trade. It is probably more likely that it illustrates indirect exchange networks, with many intermediate stops and interruptions. It is unlikely in my opinion that a metal smith from Serbia, or even Slovakia, produced an axe with the intention of trading it with a 'customer' on the Baltic Sea coast. Other long distance exchange pathways must have existed to the alpine region and the Pontic steppe area (see Fig. 93). The axes found along the Balkan Adriatic coastline are a different matter. They occur quite frequently, and are close enough to the core distribution area of the axes to argue for intentional trade with these areas.

When thinking about networks of exchange through the distribution of objects one has to remember that the axes we know today are but a fraction of the original number in circulation. If we divide the total number of axes present in my database (1313) by 500 (the probable time period in years most axes were in use), the result is 2.6, which would mean that in the entire area of south-eastern Europe, only 2.6 axes were made per year. This is of course a very crude calculation with many unknown factors, but it highlights the fact that archaeologists today are dealing with an extremely small sample size of the

original assemblage, probably less than 1% ⁶. It is likely that many more regions were indirectly connected to the metallurgical cultures of south-eastern Europe, but the evidence has simply not been found or does not exist anymore, as the objects were recovered and recycled. The missing context of the axes which were found away from the main distribution area means that it is not possible to interpret their meaning through the way the people deposited the axes intentionally or unintentionally. This is of course also a problem in the main distribution area when we are trying to reconstruct practices of deposition. However, as already mentioned in Chapter 10 there are a number of axes from known contexts which can be used for looking more closely at the practices of deposition of the copper hammer-axes and axe-adzes.

The deposition of an object, whether intentional or unintentional, is the last action of an individual or group in prehistory which the archaeologist can see and interpret. Of course there are other indirect ways of throwing light on certain actions and choices of individuals, like untangling the production sequence or history of use of an object, but the deposition is better suited to the interpretation of attitudes and values which past people projected on to the object and the circumstances of deposition. There might have been a different value or association attached to hammer-axes and axe-adzes, as the former occur in about equal numbers from settlements, burials and hoards, whereas axe-adzes occur mainly in hoards (see Chapter 10). This pattern might also be due to a difference in time and/or space, as about a third of hammer-axes from known contexts are of Pločnik type, which are thought to be older than the axe-adzes. However, as there are a number of axe-adzes coming from burials and settlements, it is difficult to interpret this pattern conclusively. What is more obvious is the difference in deposition practices in space. Whereas settlement finds occur mainly in the eastern area (Bulgaria and the Republic of Moldova), burial finds concentrate along the Black Sea coast and in the Carpathian Basin. Hoards have been found in about equal numbers throughout the distribution area of the axes. In order to highlight the deposition practices in more detail, a few specific examples will be considered below, starting with two axes found in settlement contexts.

⁶ As proposed by Timothy Taylor in the session on social aspects of metallurgy at the TAG meeting in Exeter 2006

Settlement

Unfortunately, for most settlement finds, not much detail is known about the specific *in situ* context within the settlement. Two examples from Bulgaria may be used as examples. The tell at Hotnica in the county of Veliko Tŕrnovo was partly excavated, and the uppermost layer was dated to phase III of the KGK VI complex (Todorova 1981, 17). A hammer-axe was found in one of the burnt-down houses belonging to the upper layer, next to a man who died together with his family in the fire (Todorova 1981, 37). This might be one of the rare examples where an axe was left in a situation of ‘daily life’, meaning it was found where it was used every day, before it could be recycled, or deposited in a grave or hoard context. There was no indication if the house or the inventory implied a comparatively high status of the inhabitants. However, a considerable number of tells have been excavated and finds of hammer-axes and axe-adzes are very rare. This would imply that it was not common to own one of these large axes, and that the man must have had some sort of status within the settlement. It could be argued, on the other hand, that most axes were recycled or deposited in some other context before the houses were abandoned, and that the hammer-axe from Hotnica only survived because the house burnt down accidentally. However, the second example shows that many houses on Copper Age sites burnt down so this might not be a convincing argument. The hill settlement of Teliš in the county of Pleven has three layers and a Jászladány axe-adze was found in the middle layer, dated to the later Krivodol-Sălcuța complex. The axe was found in the remains of a burnt-down house with about twenty pots. Axes within a settlement context are difficult to interpret regarding the intentions of the people who left them. It might be intentional (although in that case the axe would take on a more hoard-like character) or it might be unintentional. In either case it demonstrates that they clearly belonged very much within the daily domestic lives of people.

*Hoard*s

The majority of axes which are found in hoards are found together with only other hammer-axes or axe-adzes. It might be the case that some of these ‘hoards’ are in fact not hoards at all, as there are examples of ‘hoard creation’ when a number of axes come from the same findspot without further contextual information. At the turn of the 19th and 20th centuries, it was sometimes simply assumed that it must be a hoard find if all the objects came from the same place. Although this has to be kept in mind it does not

necessarily mean that this is the explanation for the large number of hoards with only hammer-axes and axe-adzes. It might in fact demonstrate a real trend in the data, in which case the choice to deposit only hammer-axes and axe-adzes together had a particular reason, rooted in the customs and traditions at the time. Were they offerings or were they hidden in times of conflict? It is not necessary to open up the debate about the meaning of hoards, as we will never know what the people in the past thought and meant when they were depositing these objects. However, there are some examples which seem to suggest at least a thematic meaning.

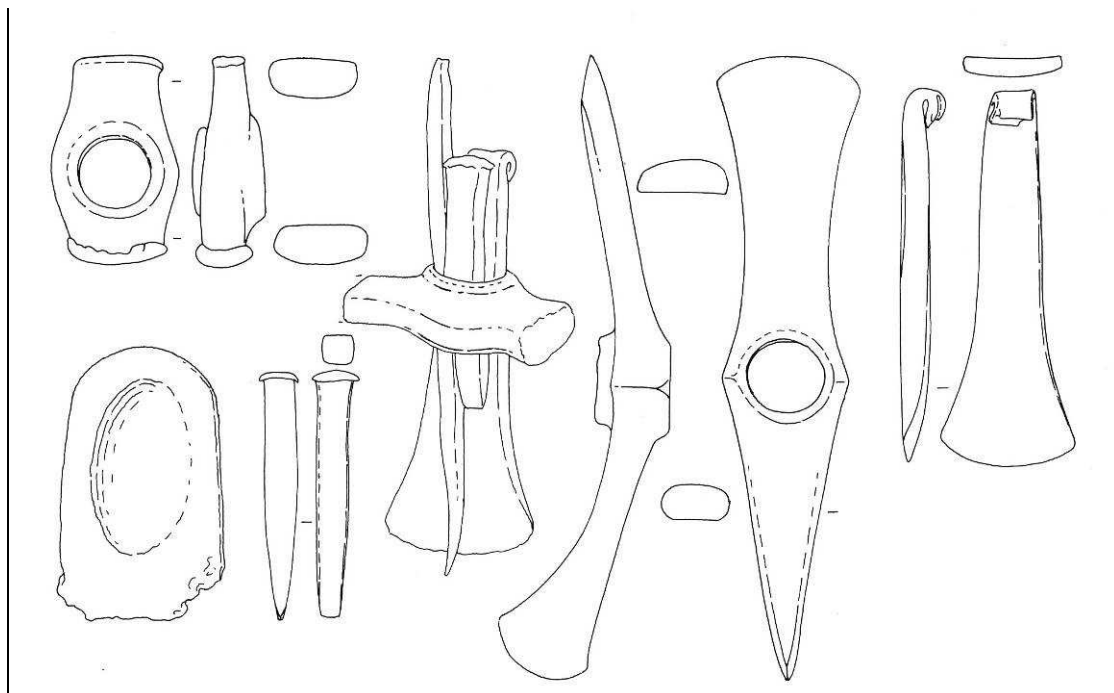


Fig. 95: The hoard find from Szeged, Szillér (source: Patay 1984, Plate 68)

The hoard find from Szeged, Szillér (Patay 1984, 21) contains objects which look very much as if they might relate to the production of the axes or at least the copper objects themselves (see Fig. 95). A chisel and an awl as well as a flat axe have been inserted inside the shaft-hole of a broken hammer-axe or axe-adze. There is a possible crucible as well as a further broken axe, a chisel, a flat-axe and a large axe-adze. The crucible is again too small to have been used for melting more than 500-1000gr. of copper, so it is interesting to see it in a hoard context together with a large axe-adze. Although this hoard does have a theme, it is still not possible to say why it was deposited. That it might have had something to do with a copper smith can be assumed, but any further

interpretations are difficult to substantiate. That a number of hammer-axes and axe-adzes are found in hoard contexts shows that they were valued and had ascribed meaning, which made them worth being deposited in such a way. The composition of the hoards seems to suggest that there were different deposition practices at work, as most hoards only consist of hammer-axes and/or axe-adzes, whereas others have a clear theme or contain more decorative elements like beads. In general one could say that a hoard opens a window onto which sorts of objects had a 'special' value, be it practical or ritual.

Burial

A similar argument can be made for objects coming from graves. They too must have had some significance. The difference from hoard finds is that objects in graves are linked in one way or another to the person they are associated with after death. As mentioned in Chapter 10, hammer-axes and axe-adzes mainly occur in graves in the Carpathian Basin and along the Black Sea coast. In the Carpathian Basin, both hammer-axes and axe-adzes are provided as grave-goods. In the KGK VI groups, specifically in the Varna cemetery, only hammer-axes have been found in graves and cenotaphs. This might point to a difference in function between the two axe forms, alternatively it could be due to the earlier date of the hammer-axes, as the cemetery of Varna partly predates the classic period of the axe-adzes. The reason for this difference is difficult to ascertain, but the cemetery of Varna is a special case within the Copper Age of south-eastern Europe. It contains some of the richest graves in the prehistory of Europe and the first major assemblage of gold artefacts in the world (Renfrew 1978, 199). Even in the Black Sea area it is unparalleled. Although unsuitable as an example for the entire region of south-eastern Europe, it has to be discussed in more detail due to its significance for the region and the debates which have centred on it in recent decades. However, the deposition of copper axes will also be examined in the context of the burial practices within the Carpathian Basin, as they do not fit the generally accepted view of a so-called stratified society of the Copper Age.

Unfortunately, the excavations of the cemetery of Varna have never been fully published⁷, but a number of articles have covered the subject, and axes which come from the cemetery have been listed in the PBF volume on Bulgaria (Todorova 1981).

⁷ Vladimir Slavchev, curator at the Museum of Varna, is working on a final publication of the site at the moment.

About half of all copper hammer-axes from the cemetery of Varna come from 'normal' inhumations, whereas the other half comes from cenotaphs. It is not necessarily the copper axes which make Varna so sensational, but the large number of gold artefacts, occurring together with other high value objects. As cemeteries in other parts of Bulgaria are fairly rare, other rituals relating to the dead must have been in use at the same time. This is also confirmed by the fact that some graves at Varna contain only disarticulated bones (Renfrew 1978, 199). The lack of other rich cemeteries together with the extreme wealth of the Varna burials has been used repeatedly to argue for its supraregional importance and hierarchical nature (Chapman *et al.* 2006, 160; Lichter 2001, 111-113; Ottaway 1981, 146-7; Renfrew 1978, 200). The cemetery is therefore thought to serve as an elite burial place for a wider area (Chapman 1991; Renfrew 1978, 201-2). This idea seems to be confirmed through lead isotope analysis of the copper objects from Varna, as they come from a large variety of copper deposits over a wide geographic area (Gale *et al.* 2003, 169). However copper finds from settlements show a similar variety of copper sources which might be due to the overall supply networks of copper. Renfrew argues that the social differentiation seen at Varna is surprising as the Copper Age, especially the settlement evidence, had, until the discovery of Varna, been seen as a mainly egalitarian period, before the greater social differentiation in the Bronze Age (1978, 201).

Indeed the evidence from Varna can be interpreted in different ways. Some papers still argue for its supraregional importance and hierarchical differentiation, while at the same time extrapolating these so-called new social relations to all of Balkan Copper Age society (Chapman *et al.* 2006); others take a more careful stance. In his analysis on the burial rites of south-eastern Europe in the Neolithic and Copper Age, Lichter argues that the cemetery of Varna is not inevitably of supraregional importance and does not necessarily contain any evidence of hierarchical differentiation (Lichter 2001, 111-113). Only one of the burials of the two richest grave categories are in fact real burials, as the rest are all cenotaphs. Cenotaphs cannot be used in interpretations on hierarchical structures, as we simply do not know who or what they were meant for. The remaining burials can just as well be explained as the outcome of a kinship structure, in which status is not hereditary but tied to age and personal achievement, which would speak against the so-called hierarchical nature of all of Copper Age society. Instead Lichter explains the extreme richness of Varna as being caused by its geographic location near to one of the major trading posts. It is a localised phenomenon of local groups having

the opportunity to create lavish graves for their elders or persons with special abilities and achievements (Lichter 2001, 113). This would fit much better with the evidence from the rest of south-eastern Europe. Lichter has also analysed the burials of the Tiszapolgár and Bodrogekereztúr groups and came to the conclusion that different groups can be identified according to the grave-goods (Lichter 2001). One of these groups, are the richer male graves, which are usually connected with axes. However, to belong to this group only age and personal achievement were needed and not hereditary status (Lichter 2001, 344-348).

Although the so-called stratified society, as showcased by the cemetery of Varna, is not a certainty, there was a development which was more clear-cut and visible throughout south-eastern Europe. This development was the increasing archaeological visibility of the individual. Although woman and children were regularly buried within a settlement or house context during the Neolithic, male individuals only become visible in the formal inhumation cemeteries of the Copper Age, both along the Black Sea coast and in the Carpathian Basin. The burial evidence can, of course, not be directly translated as evidence for a matriarchal Neolithic and the development of a patriarchal society in the Copper and Bronze Age. This would be too simplistic and the reconstruction of gender roles through material culture and burial evidence is highly problematic. However, there does seem to be a change occurring during the Copper Age, as individuals (both male and female) are buried in a different way, displaying their position in society through grave-goods deposited during the burial ritual. Some of the richest graves at Varna are cenotaphs and it is not possible to interpret them as either male or female. The rich inhumations with copper axes are all male, and copper axes together with stone shaft-hole axes do tend to occur in male graves, both at Varna and in the Carpathian Basin. There are also rich female graves, but they are not usually connected with axes.

This crystallization of a male burial cult with symbols of power and prestige is interesting to look at in the light of the developments in the Bronze Age (Harding, 2007; Treherne 1995). By the Middle and Late Bronze Age, European society became more and more complex in terms of status, wealth and power and, later on, state formation, which is visible through the numerous rich individual burials sometimes called warrior graves (Jensen 1999, 96). Treherne (1995, 112-113) generalizes the trend from disarticulated (the individual is destroyed) burials in the European Neolithic to individual inhumation burials (the individuality is pronounced) in the Bronze Age as a move from more communal societies to societies of warrior elites. The self-image of

men itself changed during the Bronze Age, making them self conscious of their appearance as an outward marker of identity, as seen in the grave-goods including weapons, ornaments and toilet articles (Treherne 1995, 127). Treherne (1995, 130) describes the changes as a new lifestyle of a warrior elite, which experienced itself through warfare and winning glory, beauty and eternal remembrance. J. Whitley (2002, 217) has criticised the notion of a Bronze Age hero, claiming it only emerged in the Iron Age, although he does say that the “grave goods should be seen as a metaphor for a particular kind of identity and ideal”. He states that grave goods cannot be seen as proof of biographical facts (Whitley 2002, 219). Harding (2007 141) emphasises the fact that so-called gender specific objects, are often found in both male and female graves. However, he does argue for the emergence of the ‘warrior’ in the Bronze Age (Harding 2007, 143).

For the Copper Age it would be somewhat misleading to interpret the copper axes as grave-goods for an emerging warrior elite. There is simply not enough evidence to substantiate such a claim. The deposition of axes in grave contexts does indicate, however, that they were connected in some way to male individuals, and that they had some wider significance in this respect. This ‘male link’ is only visible in burials. The deposition in hoards and settlements does not betray any gender-specific relationships, but the male connections in cemeteries make it likely that also in daily life it was mainly men who used and owned copper axes. All three deposition practices show, however, that copper hammer-axes and axe-adzes had a deep ritual significance.

11.5 Conclusions

This thesis has pulled together a lot of evidence both on the background as well as on the actual production, use and deposition of the copper axes with central shaft-holes from south-eastern Europe. It has also enabled the first supra-national database of known axes, combining the material of all major PBF volumes on axes from south-eastern Europe, as well as more recent finds. The marked axes were, for the first time comprehensively recorded and classed into different categories (see appendix I) and the typology of the axes was modified (see Chapter 9). Experiments and metallographic analysis have helped to throw light on production. Although as always, many questions remain unanswered for now, there are a number of issues concerning the integration of

the axes with their cultural background, their production, as well as their deposition that this work has helped to understand better.

What were the factors influencing the development of the large copper axes as well as the changes we see in the rest of material culture from Copper Age south-eastern Europe? The appearance of formal cemeteries is often seen as direct evidence for increasing stratification of society, which in turn is often linked to the emergence of metallurgy or vice versa. The case is not as clear-cut as often portrayed, even at the cemetery of Varna. In the eastern regions of the distribution area of the axes, around the Black Sea, the nature of settlement does not change considerably with the emergence of formal cemeteries. This means that a complete overhaul of living practices is unlikely. In the Carpathian Basin on the other hand, the settlement pattern does change (see Fig. 96), but becomes more dispersed with the appearance of formal cemeteries, which is also difficult to explain through the advent of increased stratification.

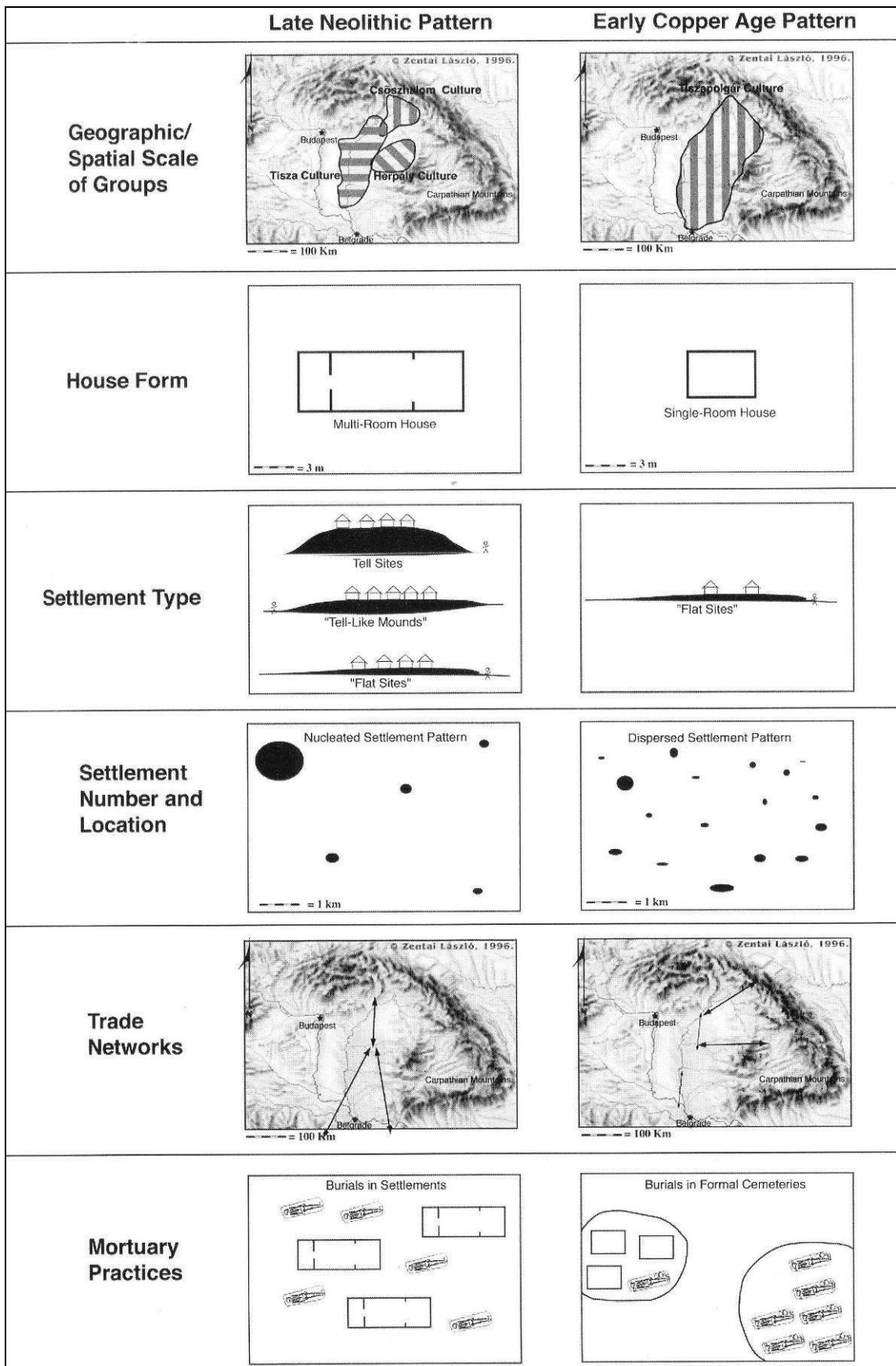


Fig. 96: The changes in settlement structure and burial practice between the Neolithic and the Copper Age (source: Kienlin 2009, p. 273, Fig. 13)

At least in the Carpathian Basin the changes in settlement structure go hand in hand with a change in subsistence strategies. The milking of cattle and sheep had been practiced already for centuries but the recent use of traction (Russell 2004, 329) can be linked to the dispersal of settlements. This could be seen as evidence that the plough enabled heavier soils to be cultivated, and previously unoccupied areas were settled. On the other hand, it has been suggested that the Carpathian Basin was dominated by semi-nomadic cattle breeders during the Copper Age, which might also explain the ephemeral nature of the settlements (Parkinson 2006). Whatever the changes in the Copper Age looked like they seem to have had a visible impact on the landscape, as pollen evidence shows a second period of intense burning and clearing in northern Hungary during the Middle and Late Copper Age. There is some evidence from Transylvania that the hilly areas away from the river terraces were also increasingly settled during the Copper Age. In fact, the copper axes themselves might have played a role as agricultural tools, as the adze blades, especially of some of the larger examples, are ideal tools for breaking up harder soils. They could even have been fixed to some sort of plough, although this is all speculation, and until an axe is found *in situ* hafted to a wooden plough, we will never be able to know.

One of the central questions is whether the changes in living practices were caused by the availability of metallurgy and metal objects, or whether these changes only made the development of metallurgy possible. As stated above, the first evidence for the smelting and casting of copper is older than the first indication for a change in the way people lived and treated their dead. This would suggest that metallurgy itself as well as the availability of metal objects were at least partly responsible for these changes. Initially it might have been organized on a household level, although the evidence from Belovode does suggest some specialization in the production sequence of copper objects very early in the 5th millennium BC. As metallurgy is highly labour-intensive this is no surprise. Whether it was only carried out seasonally is not possible to ascertain. It could be argued that it was the very production sequence which necessitated a division and, therefore, a specialization of labour. This does sound very simplistic and somewhat deterministic, but the data currently available are best interpreted in this way. With the development of large cemeteries and a ritual of display through grave goods, the interest in metal objects increased and might have led to the 'boom' in the second half of the 5th millennium BC. The more ephemeral nature of the settlement evidence in the Copper Age of the Carpathian Basin is difficult to relate to the changes seen in burial contexts

and material culture. However, in the light of the increasing importance of the individual as seen in grave contexts, the smaller settlements could be interpreted as showing a decrease in the importance of communality, relying instead on smaller units and an increase in competition between these smaller settlements (Kienlin and Pernicka 2009, 273).

Although the changes in settlement patterns are not as pronounced in the eastern Balkans and along the Black Sea coast as they are in the Carpathian Basin, the copper hammer-axes and axe-adzes are, across all of south-eastern Europe, in some way connected to the increasing visibility of the individual in the archaeological record. This is particularly evident in the numerous formal cemeteries. Although these changes are visible in the archaeological record, when looking at the evidence from an archaeologist's point of view, the timescales are extremely long, and it is unlikely that these changes were experienced in the lifetime of an individual. Many changes, especially those concerning the everyday living practices and customs, probably happened so slowly that they were not experienced as change by people. The discovery of smelting and casting, on the other hand, probably happened quite suddenly and unexpectedly. This would mean that a drastic new invention or discovery was developed and taken up within one or two generations. Although the resulting changes were probably not experienced consciously, as they happened over a long period of time, the invention of hot metallurgy might have had a strong impact on the memories of Neolithic people.

Against this backdrop of local innovation of metallurgy, and changing settlement, burial and agricultural practices, the copper axes with central shaft-holes must have played a major role in the everyday lives of people. It is only when we look at the production, use and deposition that we can get closer to the individuals behind these objects, and the choices they made. As the embodied approach to experimental archaeology has shown, it is not possible to melt and steadily cast enough copper for the majority of axes by a single person (see Chapter 7). The small crucibles which have so far been found (Cucoş 1995, Fig. 10) confirm these findings. It is much more likely that the casting of these large objects was carried out in a highly choreographed group activity. It is the subsequent finishing of the axes through forging, which probably leaves the most room for individual changes and choices to be made. These small changes can lead to major changes, as was discussed in Chapter 3. They can be both conscious and unconscious and depend on the choices, memories and surrounding *meshwork* of the individual

worker. There are some axe types which seem to have been made according to a clear tradition, with hardly any variability visible between the axes, as with, for example, the Handlová axes. There are only very few axes which belong to this type but nevertheless their production seems to have been controlled very closely leaving little room for changes to be made. The Jászladány axes, on the other hand, show great internal variability, indicating that their final shape was not as heavily controlled, leaving more room for the individual to bring about small conscious or unconscious changes to the overall shape of the objects. As the Jászladány axes are distributed over a much wider area, this is not surprising, but it shows again the different spheres of practice which were at play in the Copper Age in south-eastern Europe.

As described in Chapters 9 and 10, it was not only the axe shapes which varied greatly, but also the very production techniques, like the creation of the shaft-hole or the mould shape (open/closed). This variability in shape and casting techniques shows that the production was not standardised, as can be seen later in the Bronze Age with the countless examples of bronze axes coming from the same mould. The production might be described as experimental as new techniques and shapes were tried and became established on a local or regional level. The different geographical levels, which seemed to influence the decision-making processes in relation to technique and shape were described in Chapter 12 and above. Some types like the Jászladány axes occur throughout the distribution area, whereas other types occur only in an extremely localised area. It is interesting to observe that the types do not necessarily respect the Copper Age cultural groups as defined through the ceramic traditions. This means that there must have been other networks of aesthetics and functionality which influenced the decision-making regarding the morphology of the copper axes. In any case, it is difficult to establish what part of the surviving material culture should be taken as the best indication for the feelings of cultural affinity of an individual. As we have seen, the typologies of the metal artefacts and the ceramics do not always match spatially. We should therefore question the use of ceramic types for the creation of ‘cultural groups’. But what aspects of the daily traditions and material culture made people feel to belong to a certain group in a specific region? These questions are impossible to answer; however, what we can say is that there certainly were different levels of ‘belonging’ to a certain group, as well as different *meshworks* of practice at play in the Copper Age.

One of the clearer divisions must have been the River Danube. On either side of the Danube there are significant differences in axe types, the presence or absence of marks

and fragmentation, as well as different settlement structures. The difference in spatial distribution between marked and unmarked, as well as fragmented and unfragmented axes, illustrates this division most noticeably. The fact that it was mainly the axes within the Carpathian Basin which were marked shows that it was a practice going beyond the boundaries of traditional archaeological cultures, but not over the entire distribution area of the copper axes with central shaft-hole. The marking of axes must have been intentional, although we cannot say if it had a decorative or utilitarian reason, but the increased proportion of fragmentation amongst axes found to the North of the River Danube might not necessarily be intentional (see Chapter 10). Even if the increased fragmentation is not intentional but related to the quality of the metal used or the function of the axes, it means that there was an area of shared technologies and possibly values north of the Danube, which influenced the choices of the people living there.

However, when we try and imagine how these shared values or aesthetics might have been disseminated over a comparatively large area, issues of inter-communal organisation and relationships have to be considered again. As was shown above it is unlikely that the society of the Copper Age was heavily stratified. The settlements and cemeteries do not show any evidence for permanent hierarchies. This is not to say that some individuals did not have a higher status, as this is clearly visible in the burial evidence. However, this status was probably not hereditary but obtained simply through age and achievement. Parkinson (2006) and, more recently, Kienlin and Pernicka (2009, 272-274) have proposed a tribal kinship-based structure for the Carpathian Basin. This poses the question how the shared values and different spheres of influence so visible in the data on the copper axes with central shaft-hole were maintained if there was no 'control from above'. Despite the variability, axe types like the Jászladány axes are found over the entirety of south-eastern Europe, meaning that there must have been some control mechanisms at work consciously or unconsciously, which maintained the overall shape of this type. Kienlin explains this through the kinship structure, as the access to metallurgical knowledge was passed down the family (Kienlin and Pernicka 2009, 274). The knowledge was then dispersed over a wide area, as the 'metallurgical lineages' travel and/or intermarry, taking with them the norms and non-verbal knowledge they have grown up with (Kienlin and Pernicka 2009). Although this might answer some of the questions, it certainly cannot be applied to all of south-eastern Europe and does not account for the variations which were not linked to archaeological

groups. Some axe types are distributed all over south-eastern Europe, others can be related to an archaeological group, whereas some only occur in a localised area. The practice of marking and ‘fragmentation’ is only found in the Carpathian Basin, whereas axes found within settlements contexts mainly occur along the eastern parts of the distribution area. These are just a few of the different levels or spheres of influence visible in the data. It is not possible to find definitive answers for this phenomenon, and I am not sure if it will ever be possible, but future work on all aspects of these enigmatic objects, and Copper Age society at large, should hopefully be able to close at least some of our gaps in knowledge.

11.6 Future work

There are several areas of research which require more work. Although it would be helpful if the Database started as part of this research were completed, as some data (especially that for the weight of axes from Bulgaria) is still missing, there are other more important issues to be considered in detail. The results obtained from the database as well as through mapping the queries using GIS, cannot be improved or added to significantly. This is mainly due to the fact that the vast majority of axes are isolated finds without context. This is a limiting factor when analysing the database, and is therefore not of high importance for future work. The natural and cultural background have been considered in some detail, and although future work is essential to better understand the dynamics of the Copper Age in general, for the axes under consideration, it is not of vital importance. There are three areas which have most potential for further unravelling the story of these axes. These are the continuation of an experimental approach into all aspects of production, the identification of misinterpreted or so far unknown refractory ceramics across south-eastern Europe, and the furthering of compositional and lead isotope analyses in the entire distribution area of the copper axes.

Although experimental archaeology was used as a method as part of this thesis, it could only scratch the surface of the potential it really has. This has to do with the time and resources necessary for experimental archaeology. It is also not possible to answer many questions with just one experiment. One original question often has to be addressed through several experiments to achieve acceptable results. More experiments are necessary looking at the possibilities of melting large enough amounts of copper for casting larger axes. The mould material and shape is another important area for a

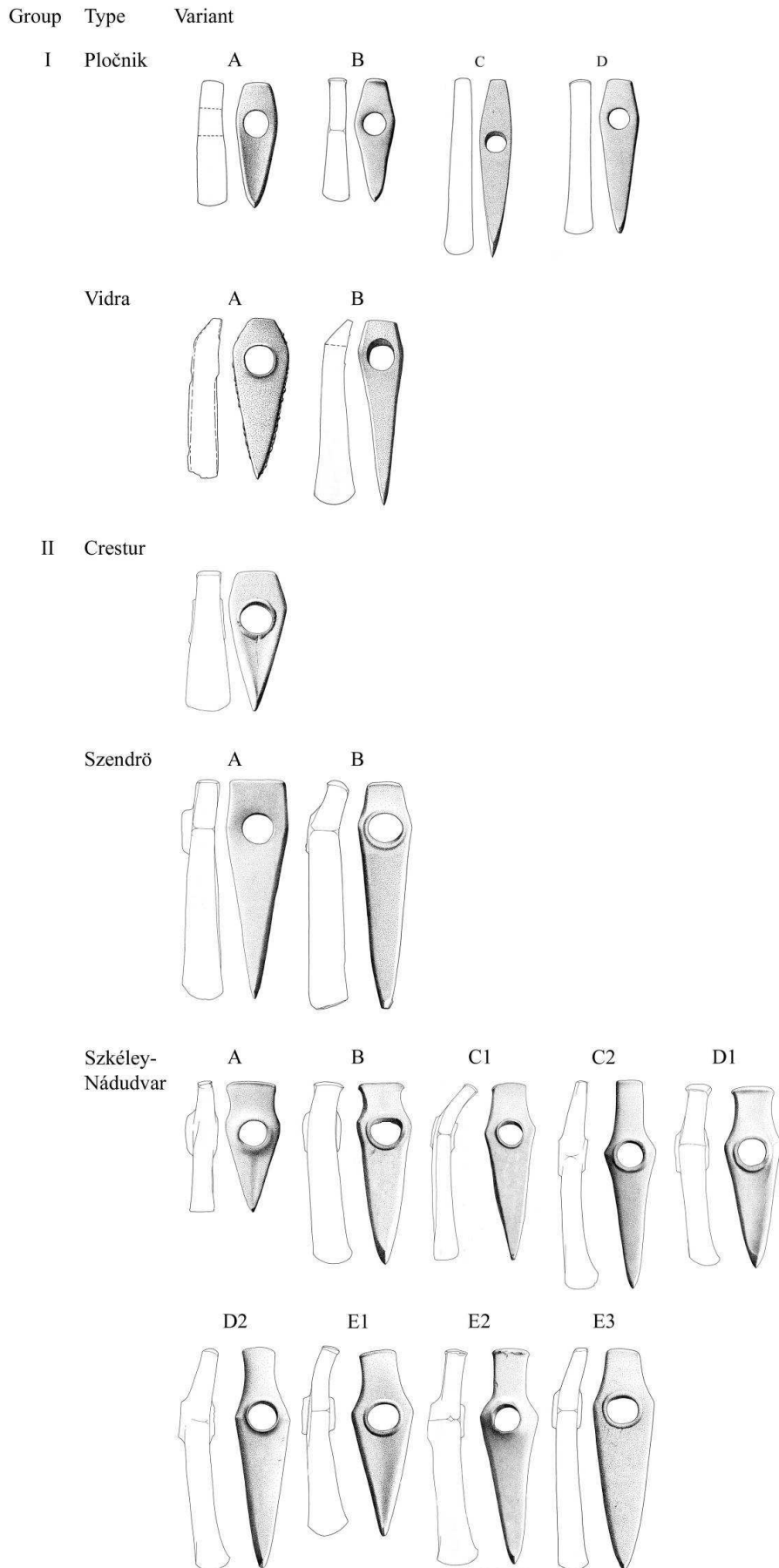
detailed experimental exploration. The shaft-hole production was the topic of the experiments carried out as part of this thesis, but there is still potential for future work. Most importantly, in my mind, are experiments looking at the working stages after casting, including annealing and forging, in combination with metallographic analysis.

The other area with a great potential for future work is the study of ceramics from Copper Age sites in south-eastern Europe. Ideally, all ceramic assemblages ever excavated should be gone through in order to identify possible refractory ceramics and traces of secondary burning. As was shown by the examples of the misidentified tuyères, there are probably scores of pieces in the deposits of various museums which have been misidentified, or never even catalogued. Although this work would be tedious and time consuming, the potential insights for the Copper Age *tasksapes* would be staggering.

Last but not least, the compositional analyses carried out so far should be re-evaluated for the entire distribution area (see Chapter 12) and, more importantly, the work done on lead isotope analysis in Bulgaria and Serbia, should be carried out in Hungary, Slovakia and Romania too. Only after a thorough characterization of all copper ore deposits, slags and objects, regarding their composition and lead isotope ratios will it be possible to come to firmer conclusions about the copper sources used, as well as the routes of supply of the raw material.

Appendix I

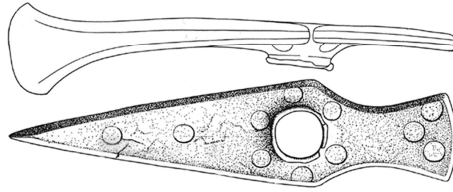
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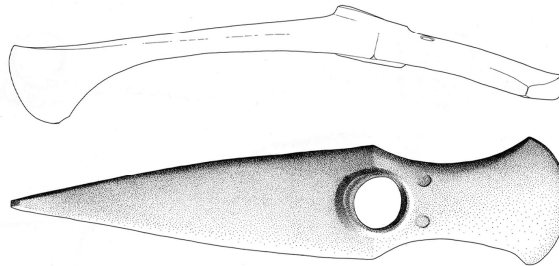
Hammer Axes (Category 1)

Group Type

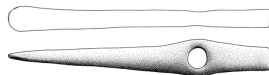
III Handlova



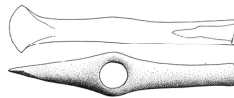
Mesökeresztes



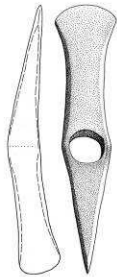

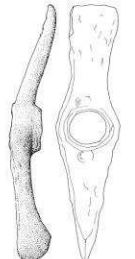
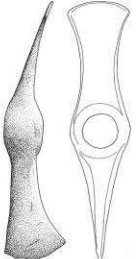

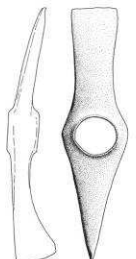


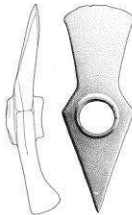
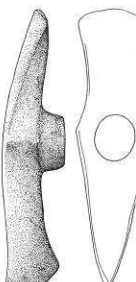
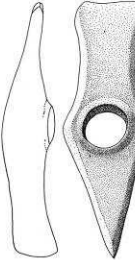
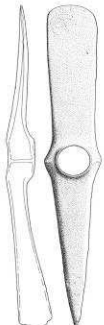
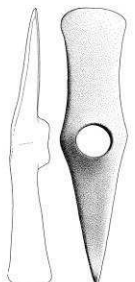
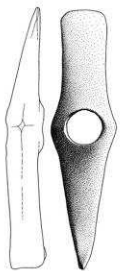
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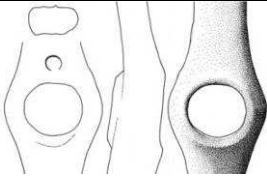
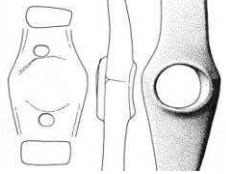

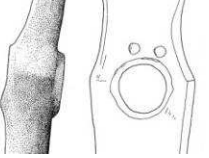
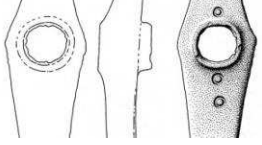

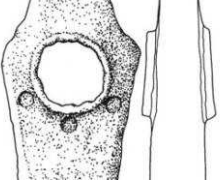
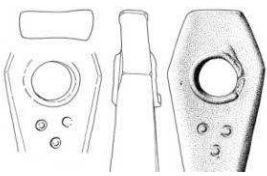
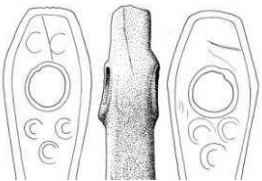
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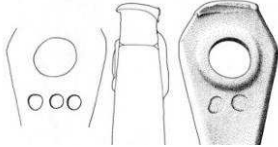
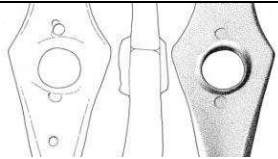
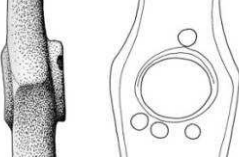
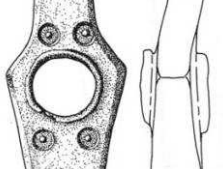
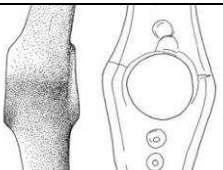
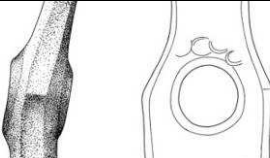

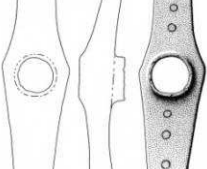
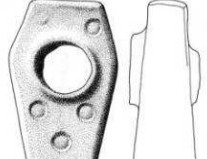


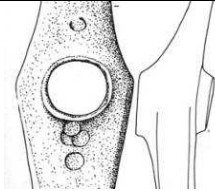
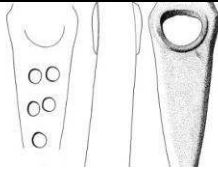
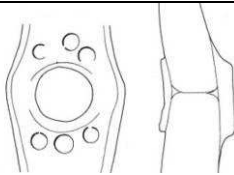
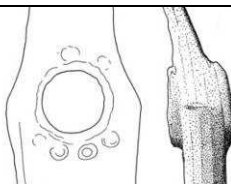
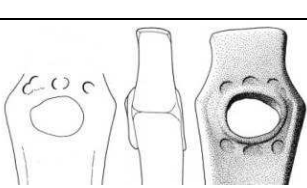
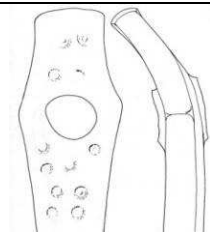
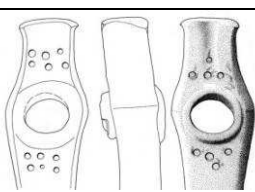
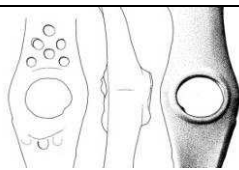
Axe Adzes (Category 2)


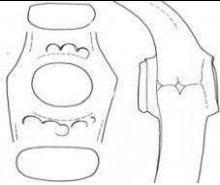
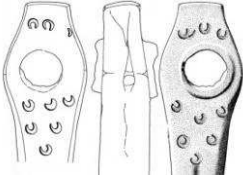
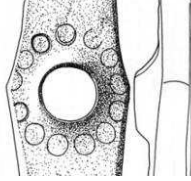
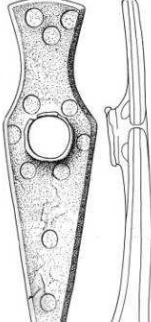

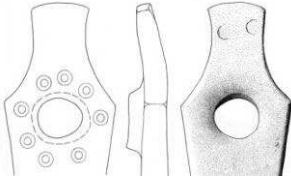
Group	Type	Variant
I	Mugeni	
II	Jászladány	<p>A1  A2  A3  B1  B2 </p> <p>B3  C </p>
	Kladari	
III	Tg. Ocna-Nógrádmargal	<p>A1  A2  B  C1  C2 </p>

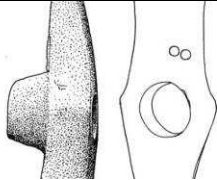
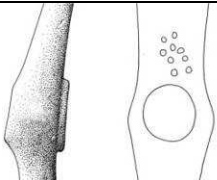
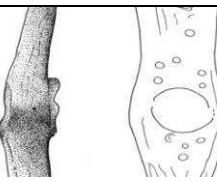
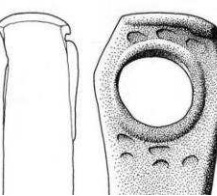
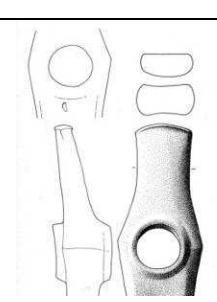
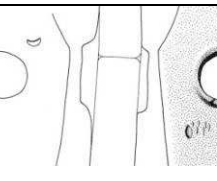

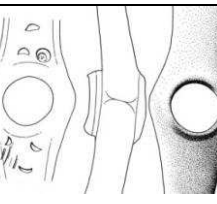
Appendix II

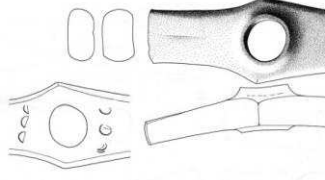
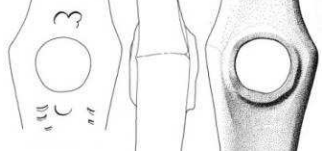
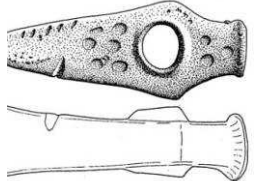
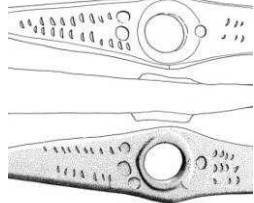

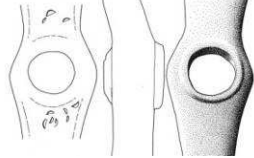
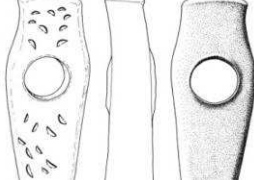
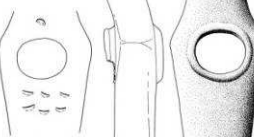
Code (amount)	Description	Example
1a (13)	One circle	
2a (52)	Two circles, one on each side of SH	
2b (1)	Two circles, one on each side of SH on upper and lower axe side	
2c (7)	Two circles on only one side of SH	
3a (3)	Three circles distributed on both sides of SH in a line	
3b (10)	Three circles distributed on both sides of SH in a triangle	
3c (7)	Three circles on only one side of SH	
3d (1)	Three circles on only one side of SH on upper and lower axe side	
3e (1)	Three circles on only one side of SH in triangle on one axe side and five circles distributed on both sides of SH 2:3 on other axe side	

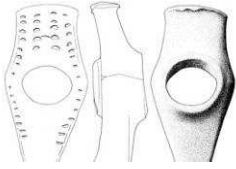
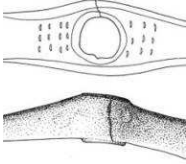
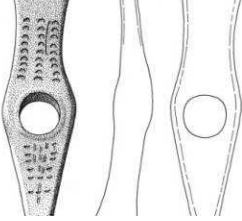
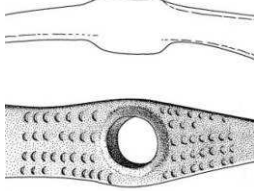
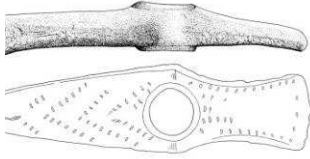
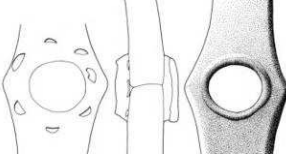
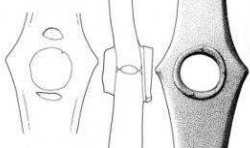
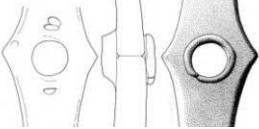
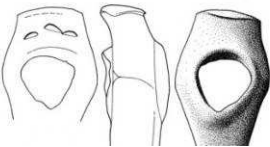
3f (1)	Three circles on only one side of SH in line on one axe side and two circles distributed on only one side of SH on other axe side	
3g (1)	Three circles distributed on both sides of SH on one axe side and two circles distributed on both sides on of SH on other axe side	
4a (6)	Four circles distributed on both sides of SH 3:1	
4b (12)	Four circles distributed on both sides of SH, 2:2	
4c (1)	Four circles distributed on both sides of SH, 2:2	
4d (2)	Four circles on only one side of SH	
5a (4)	Five circles distributed on both sides of SH, 3:2, round	
5b (1)	Five circles distributed on both sides of SH, 3:2, linear	
5c (1)	Five circles distributed on both sides of SH, 3:2, triangle	

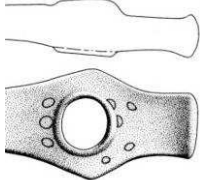
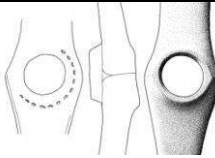
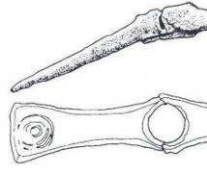

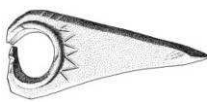
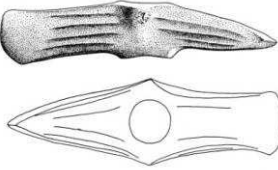
5d (1)	Five circles distributed on both sides of SH,1:4	
5e (1)	Five circles on only one side of SH	
6a (14)	6 circles distributed on both sides of SH 3:3	
6b (1)	6 circles distributed on both sides of SH 2:4	
6c (1)	6 circles distributed on both sides of SH 3:3 upper hammer axe side, and four circles on one side of SH on lower hammer axe side	
7a (1)	12 circles distributed on both sides of SH, 4:8	
7b (1)	8 circles distributed on both sides of SH 4:4 on upper hammer axe side, 12 circles distributed on both sides of SH 6:6 on lower hammer axe side	
7c (1)	9 circles distributed on both sides of SH 6:3 on lower axe side	

7d (1)	7-8 circles distributed on both sides of SH 2:5-6 on lower axe side	
8a (6)	Unevenly distributed circles on both sides of SH, sometimes overlapping each other ⁹	
9a (1)	9 half-finished circles distributed either side of SH 3:6 on both hammer axe sides	
10 a (5)	Between 6 and 15 circles surrounding the SH (more or less evenly spaced)	
10b (1)	Six circles surrounding the SH as well as three circles on hammer end, and two on axe arm	
10c (1)	Six circles surrounding the SH as well as three circles on hammer end (upper side), and seven on axe arm	
10d (1)	Six circles surrounding the SH as well as two circles on hammer end (upper side)	

11a (1)	Two small circles on only one side of SH	
11b (1)	Nine small circles on only one side of SH	
11c (1)	10 small circles distributed on both sides of SH, 4:6	
12a (1)	8 ovals distributed on either side of SH 3:5 on one axe side	
13a (1)	1 half-moon on one side of SH the lower axe side	
13b (1)	1 half-moon on one side of SH the lower axe side, and 1 oval mark on one side of SH on upper axe side	
13c (1)	2 half moons on only one side of SH on lower axe side	
14a (1)	1 circle and 5 half moon marks distributed either side of SH 3:3 on lower axe side	

14b (1)	3 circles in line on one side of SH and 3 half moons in line on other side of SH, both on lower axe side	
14c (1)	3-4 circles distributed on both side of SH 3(4):1 and 5 half moons on one side of SH, all on lower axe side	
14d (1)	8 circles distributed either side of SH 3:5, 1 oval mark and 5 half moons on one side of SH, all on one axe side	
14e (1)	3 circles and 27 half moons (6:21) distributed either side of SH on one axe side and 4 circles (1:3) and 27 half moons (11:16) distributed either side of SH on other axe side	
14f (1)	8 circles distributed on both sides of SH 4:4 and 34 half moons distributed on both sides of SH 14: 20	
15a (1)	10 half moons distributed randomly on both sides of SH 3:7 on lower side of axe	
15b (1)	19 half moons distributed randomly on both sides of SH 9:10 on lower side of axe	
16a (1)	7 half moons distributed on both sides of SH 1:6, on lower axe side	

16b (1)	41 half moons distributed both sides of SH 15:26, on lower axe side	
16c (1)	21 half moons distributed both sides of SH 9:12, on upper axe side	
16d (1)	42 half moons distributed both sides of SH 14:28, on lower axe side	
16e (1)	63 half moons distributed both sides of SH 32:31, on lower axe side	
16f (1)	81 nicks distributed both sides of SH 45:36, on lower axe side	
17a (1)	7 'sunken' circular marks around SH, partly hidden by SH lip on lower axe side	
17b (1)	2 'sunken' circular marks either side of SH, partly hidden by SH lip on lower axe side	
17c (1)	2-3 'sunken' circular marks either side SH, partly hidden by SH lip on lower axe side	
17d (1)	3 'sunken' circular marks on one side of SH, partly hidden by SH lip on lower axe side	

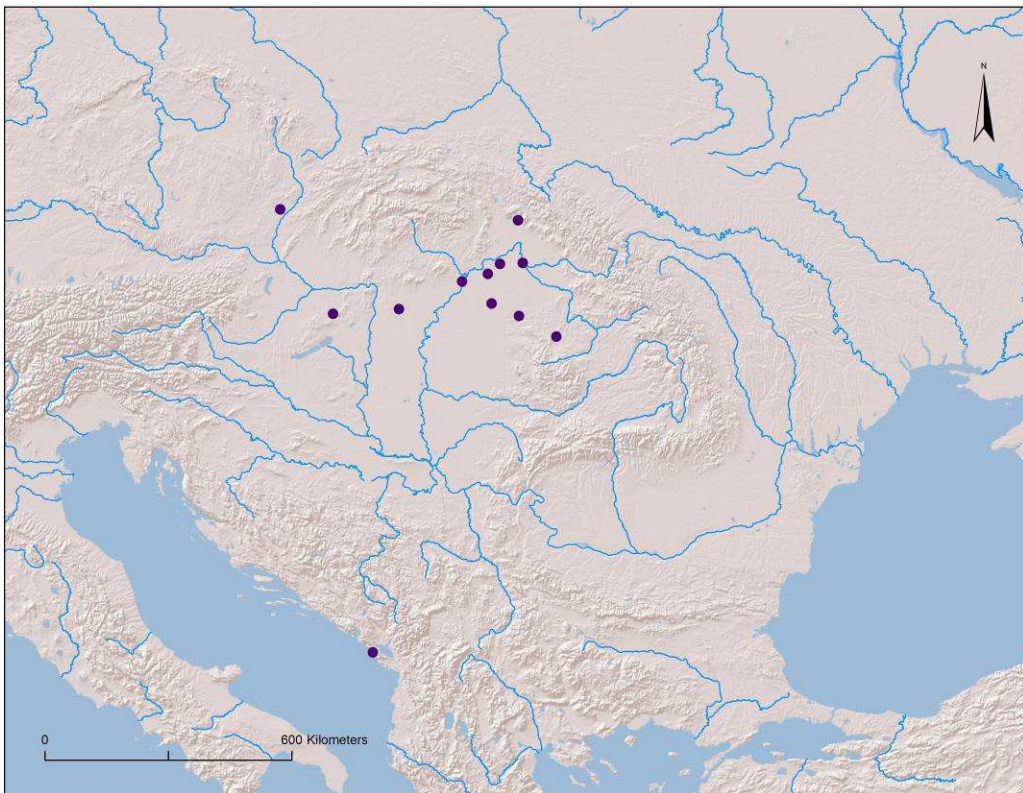
17e	2 'sunken' circular marks on one side of SH, partly hidden by SH lip and 6 circular/oval marks distributed on both sides of SH 3:3, on lower axe side	
18a (2)	Small nicks surrounding SH on lower axe side	
19a (1)	Concentric circles on lower adze arm	
20a (1)	Zigg zag lines on both sides of SH on upper axe side	
20b (1)	Zigg zag lines around SH	
21a (1)	Grooves on axe sides	

Appendix III

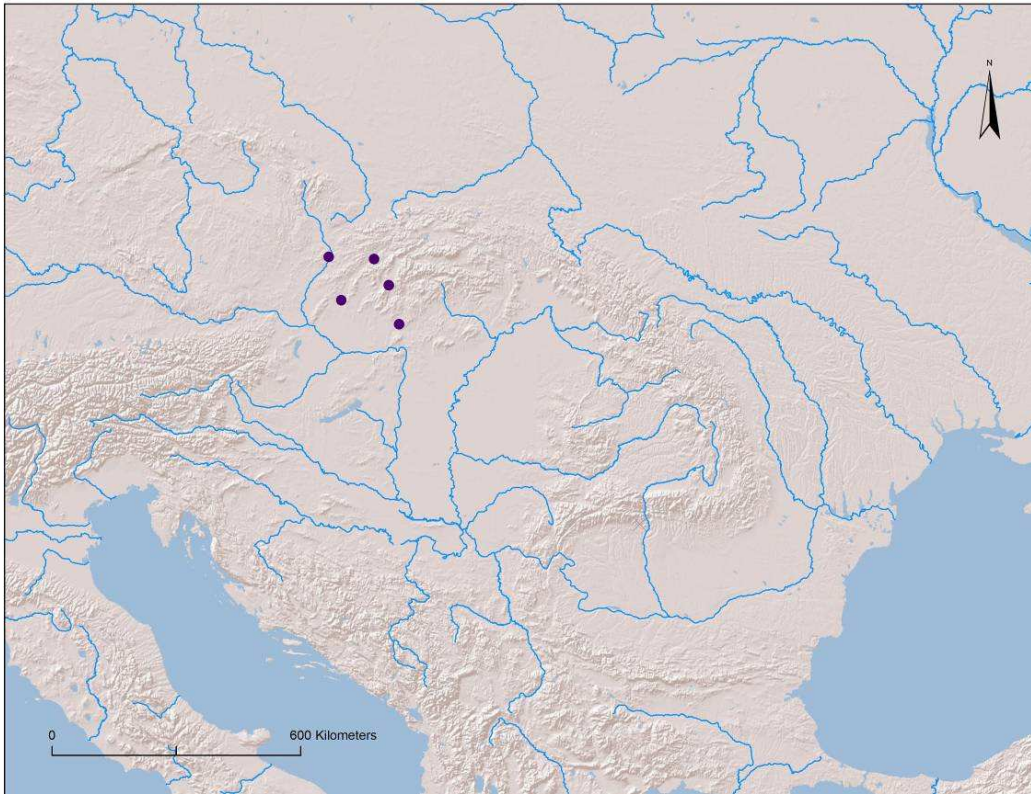
Distribution maps



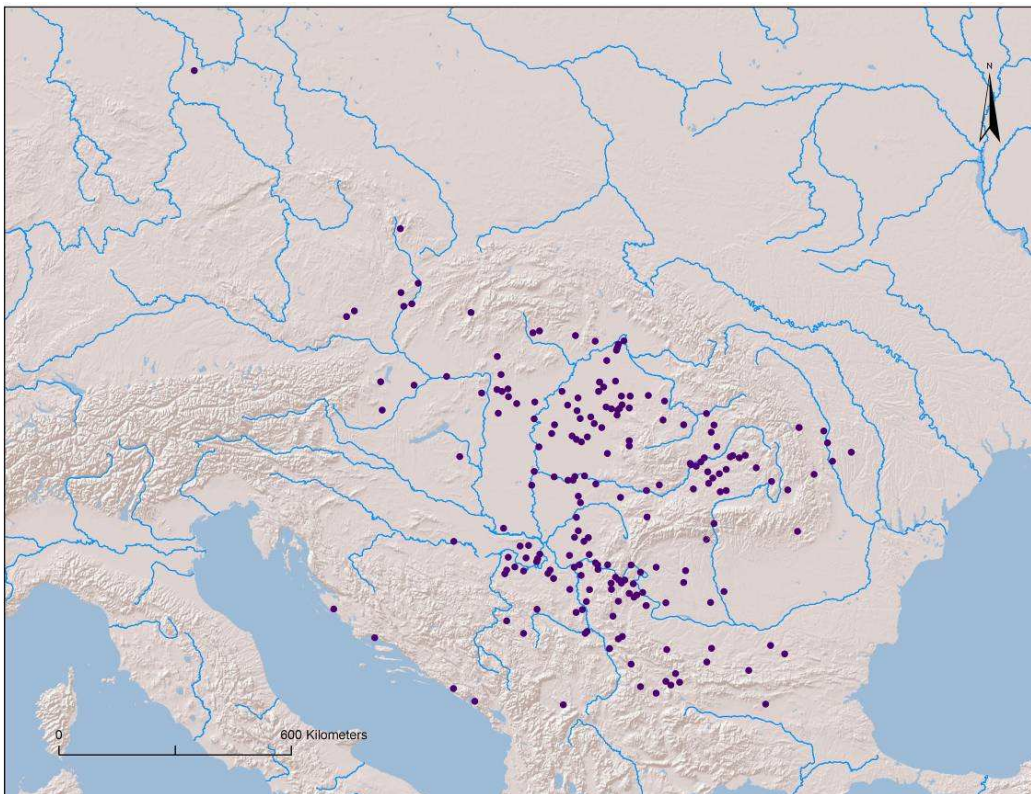
Map 1: Axes of type Čoka



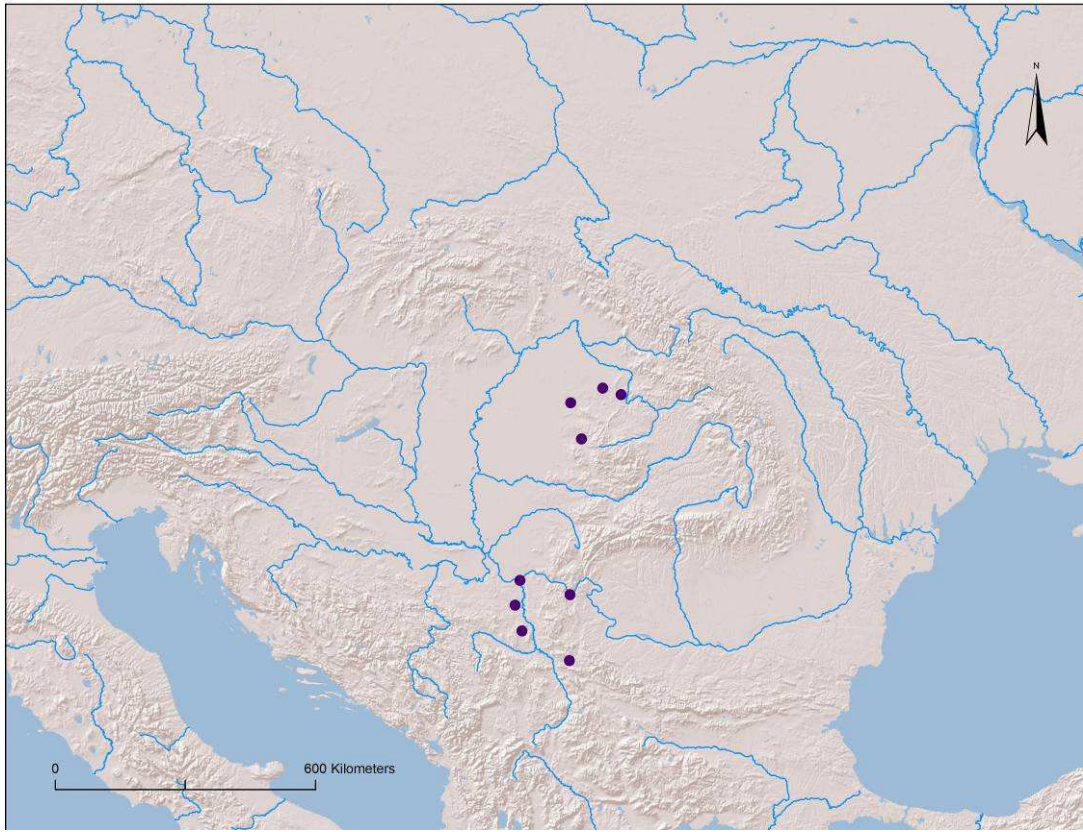
Map 2: Axes of type Crestur



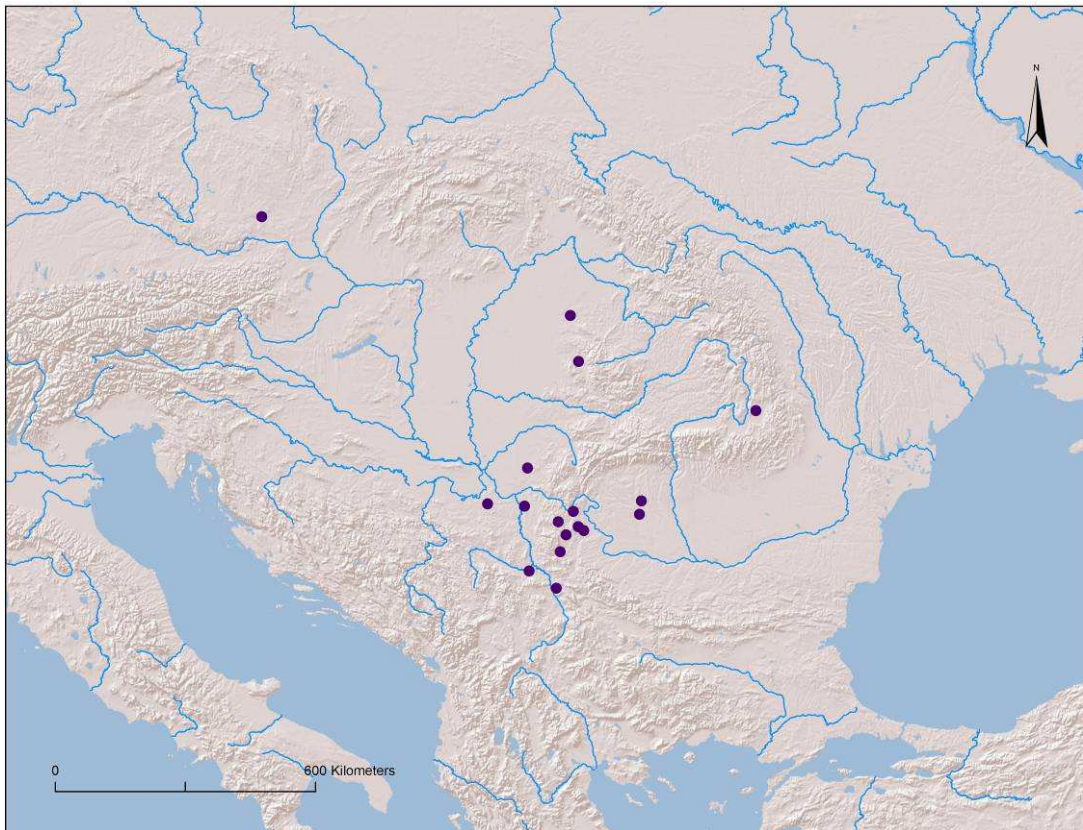
Map 3: Axes of type Handlová



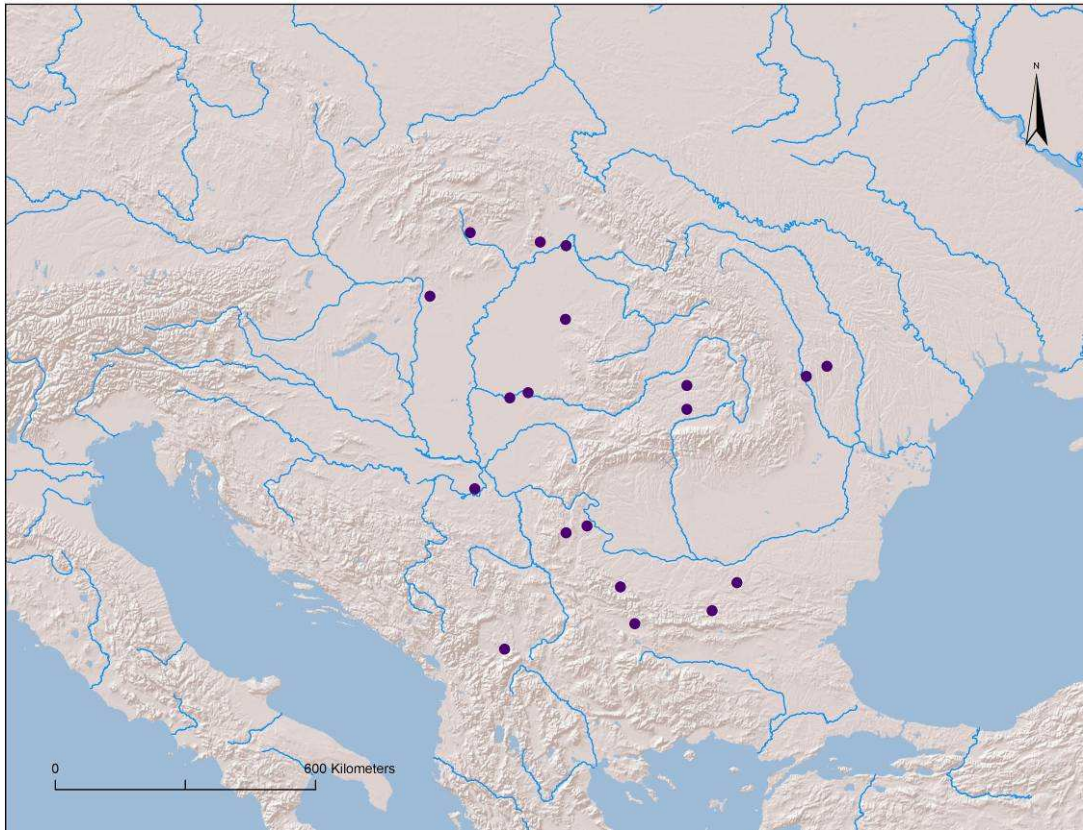
Map 4: Axes of type Jászladány (all variants)



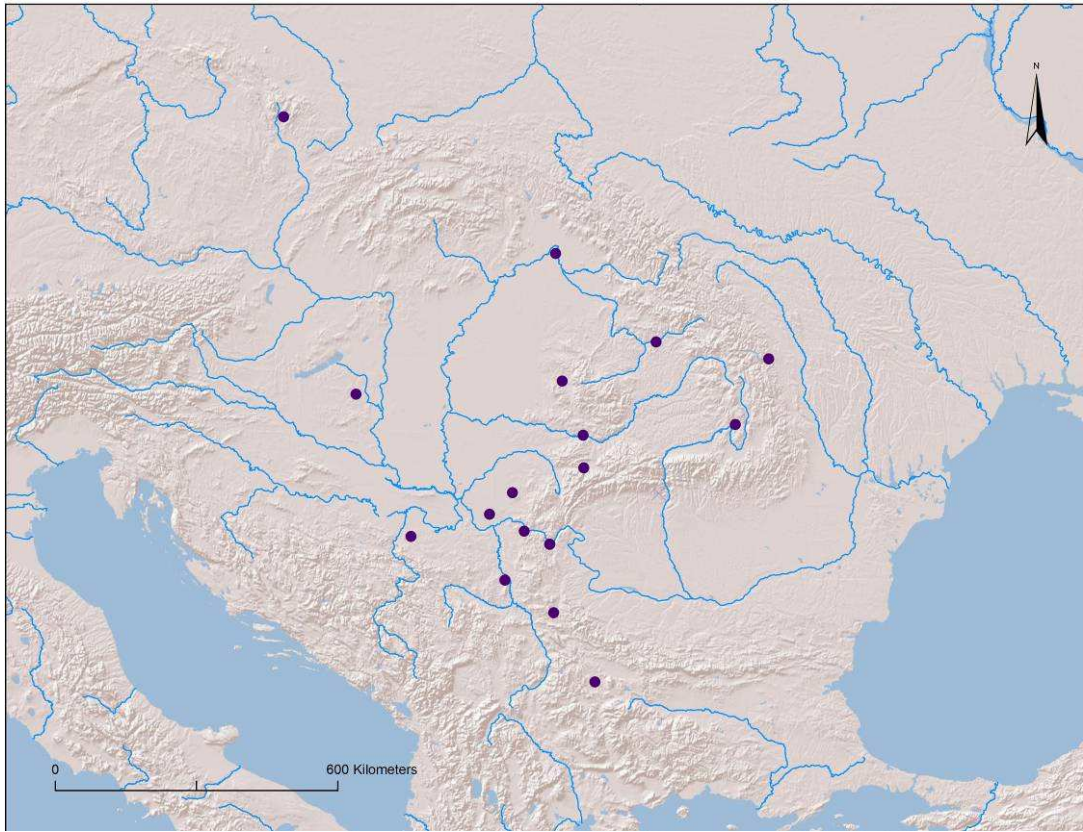
Map 5: Axes of type Jászladány A1



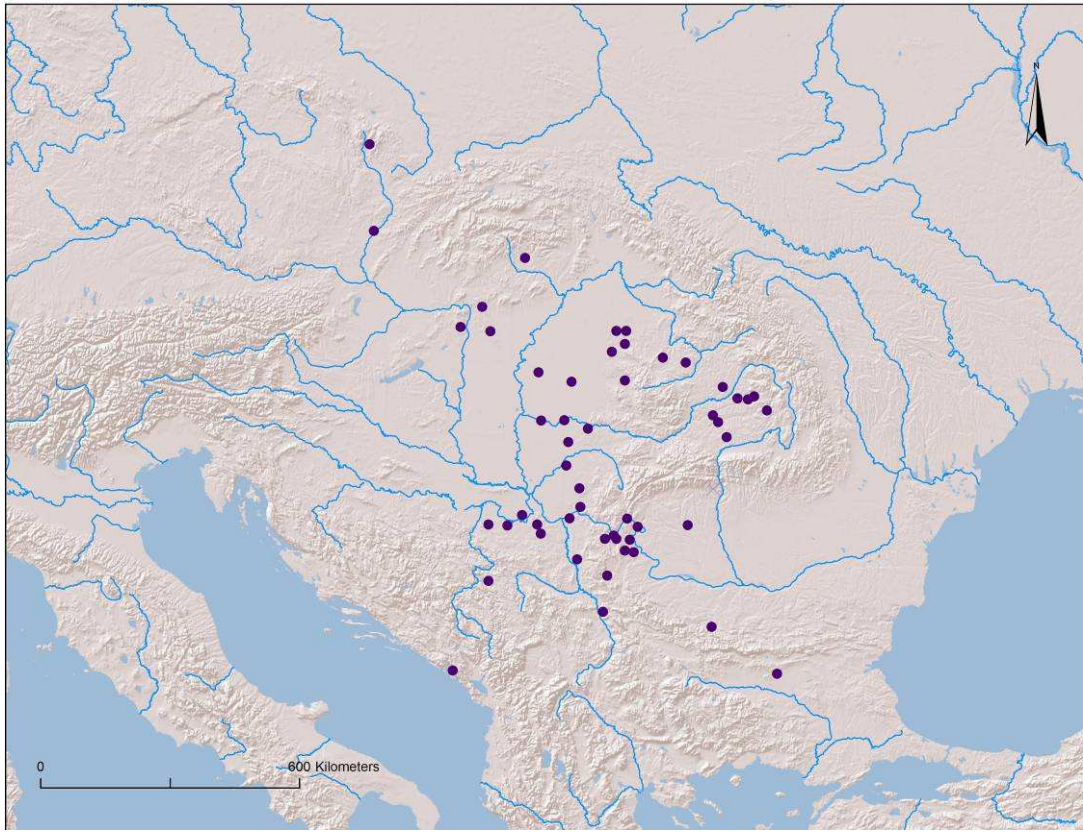
Map 6: Axes of type Jászladány A2



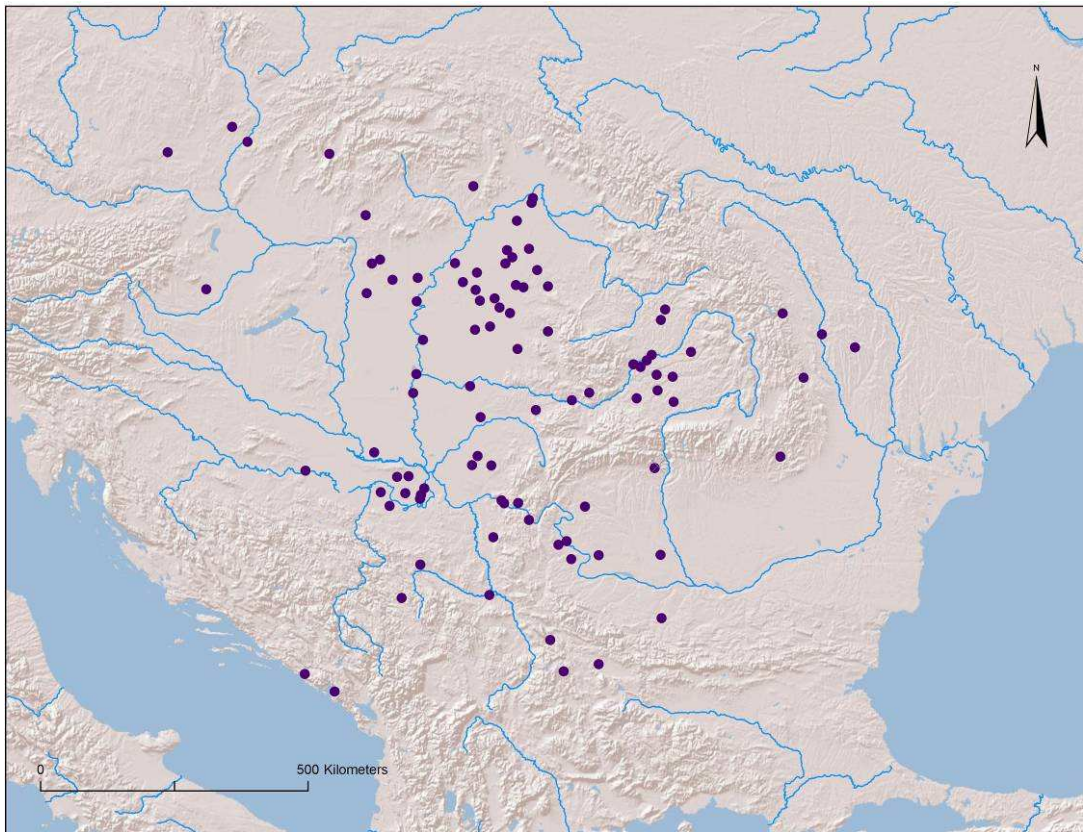
Map 7: Axes of type Jászladány A3



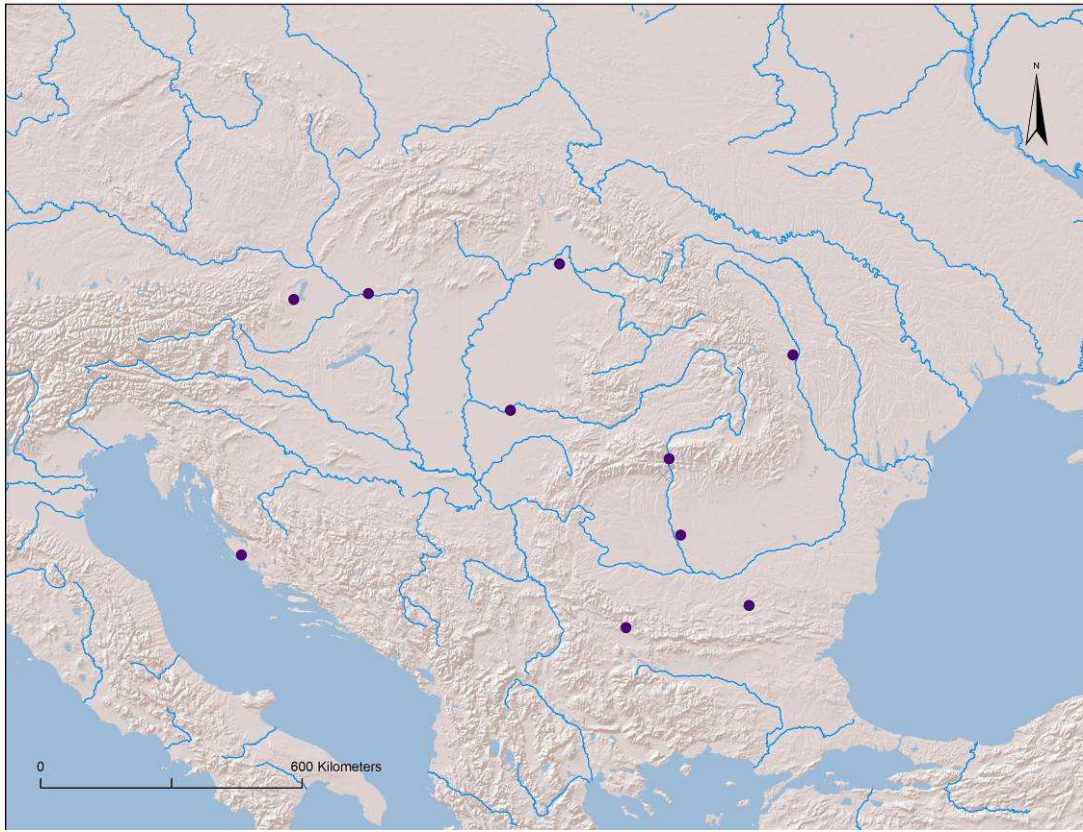
Map 8: Axes of type Jászladány B1



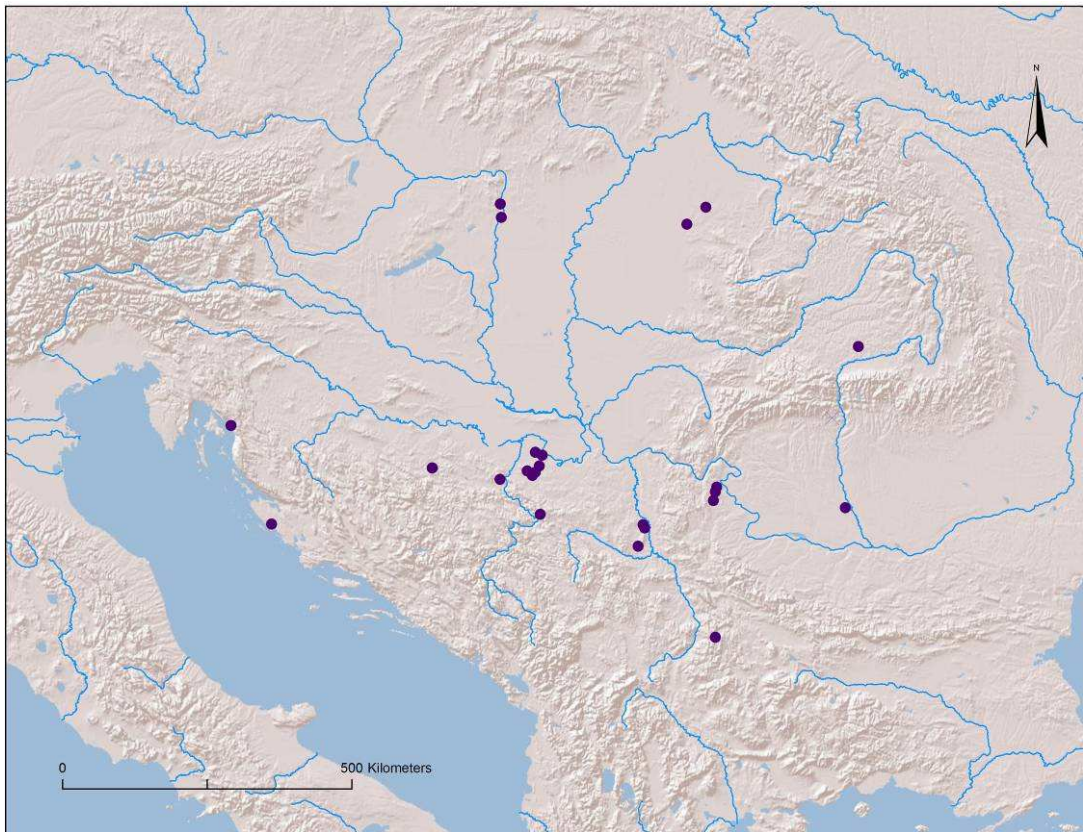
Map 9: Axes of type Jászladány B2



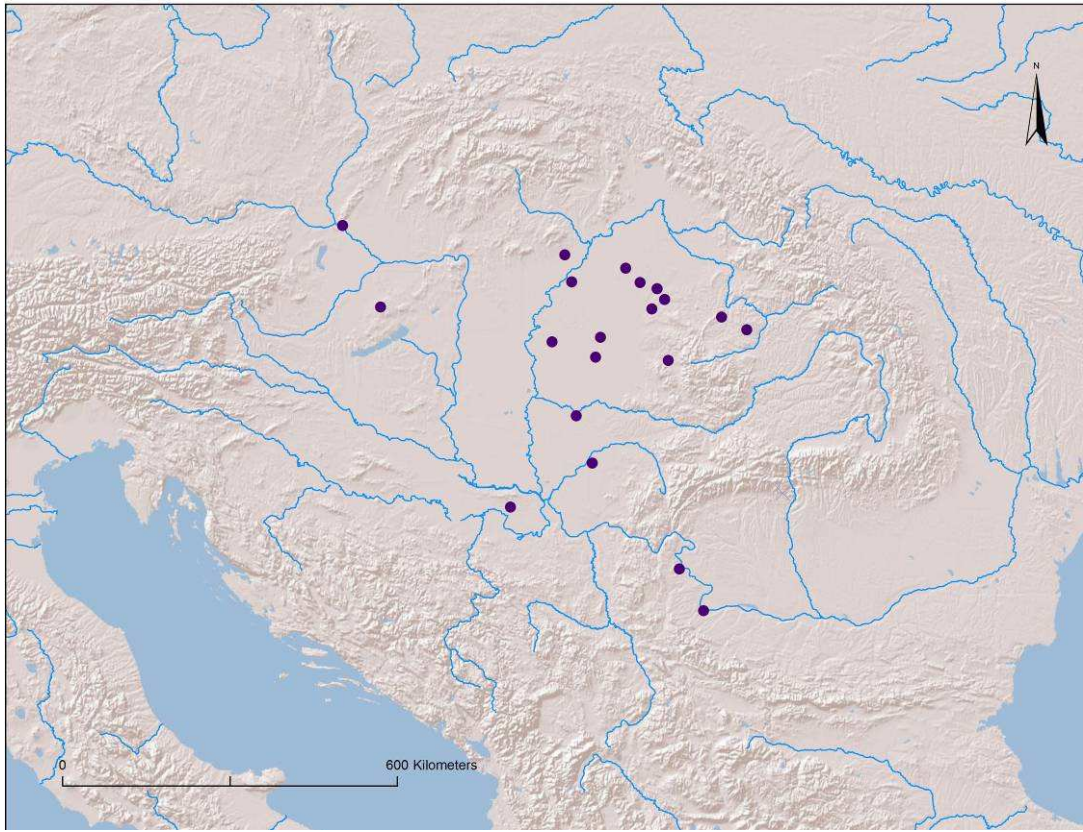
Map 10: Axes of type Jászladány B3



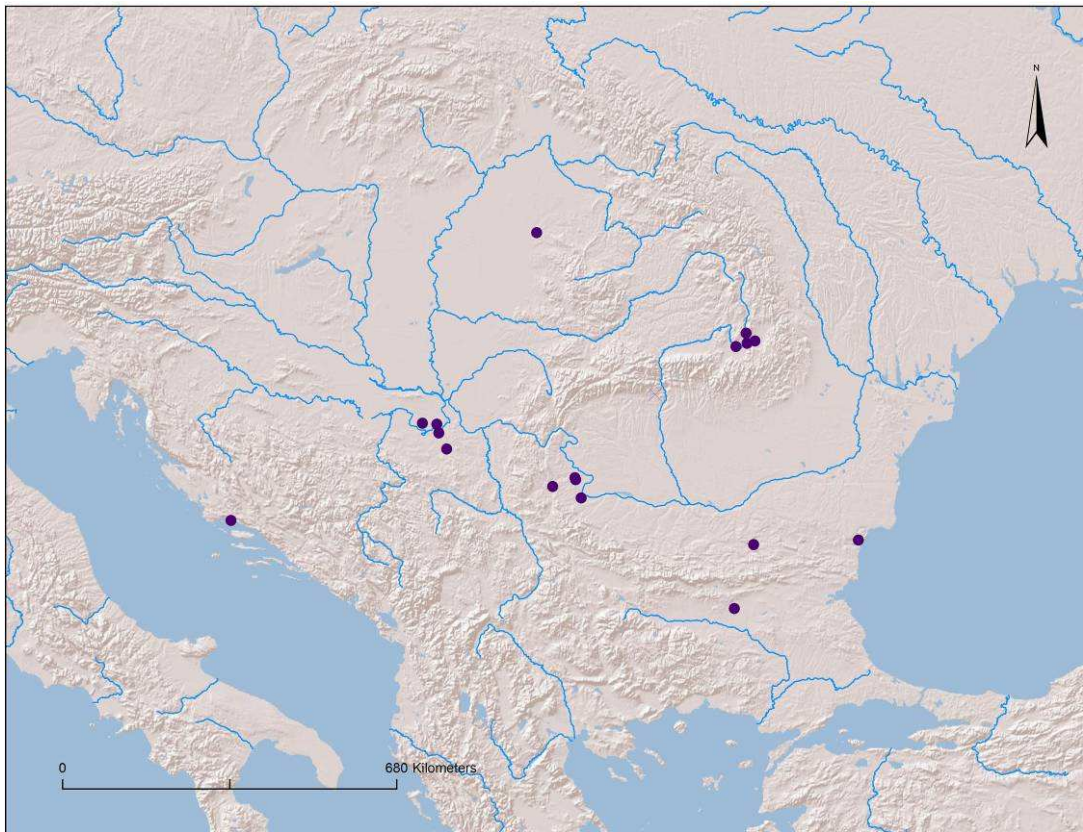
Map 11: Axes of type Jászladány C



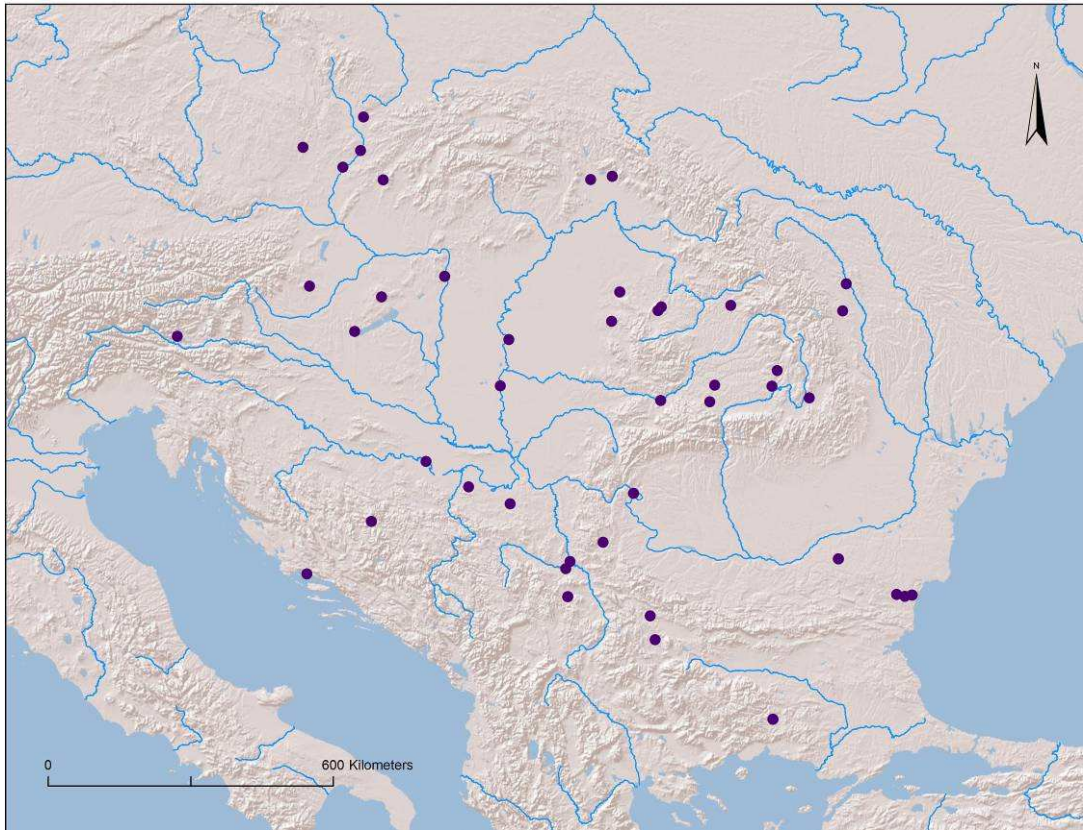
Map 12: Axes of type Kladari



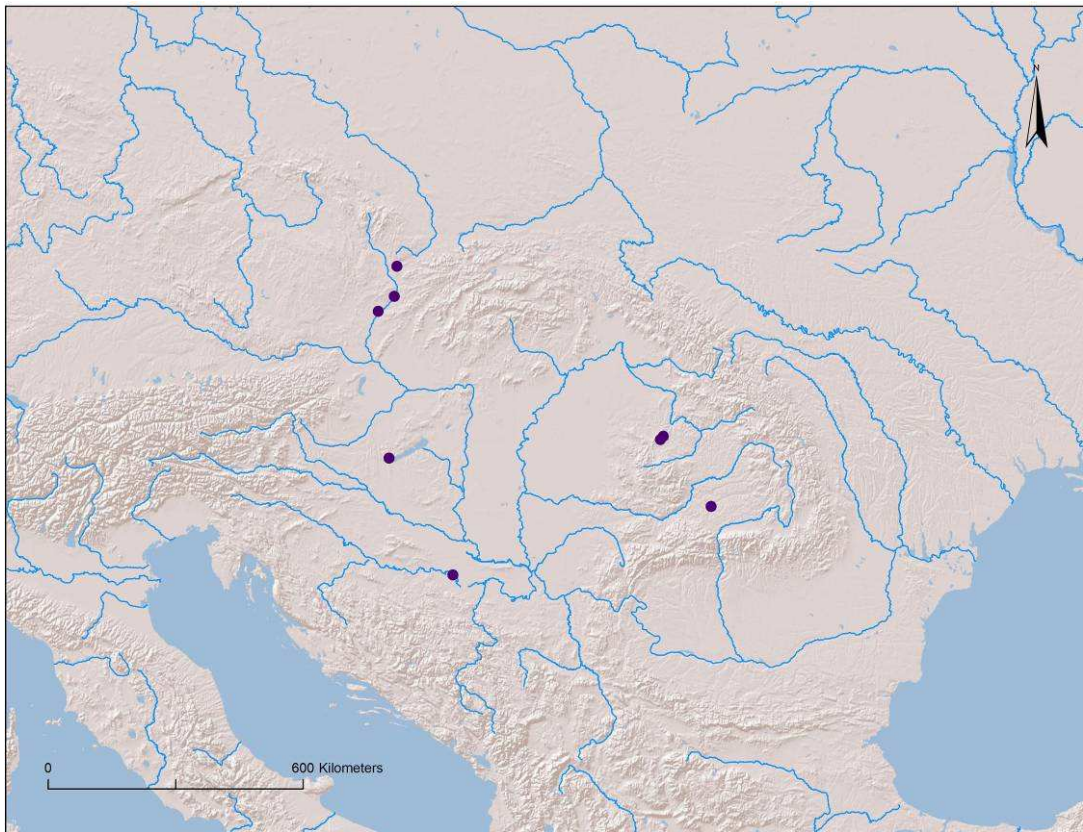
Map 13: Axes of type Mezökeresztes



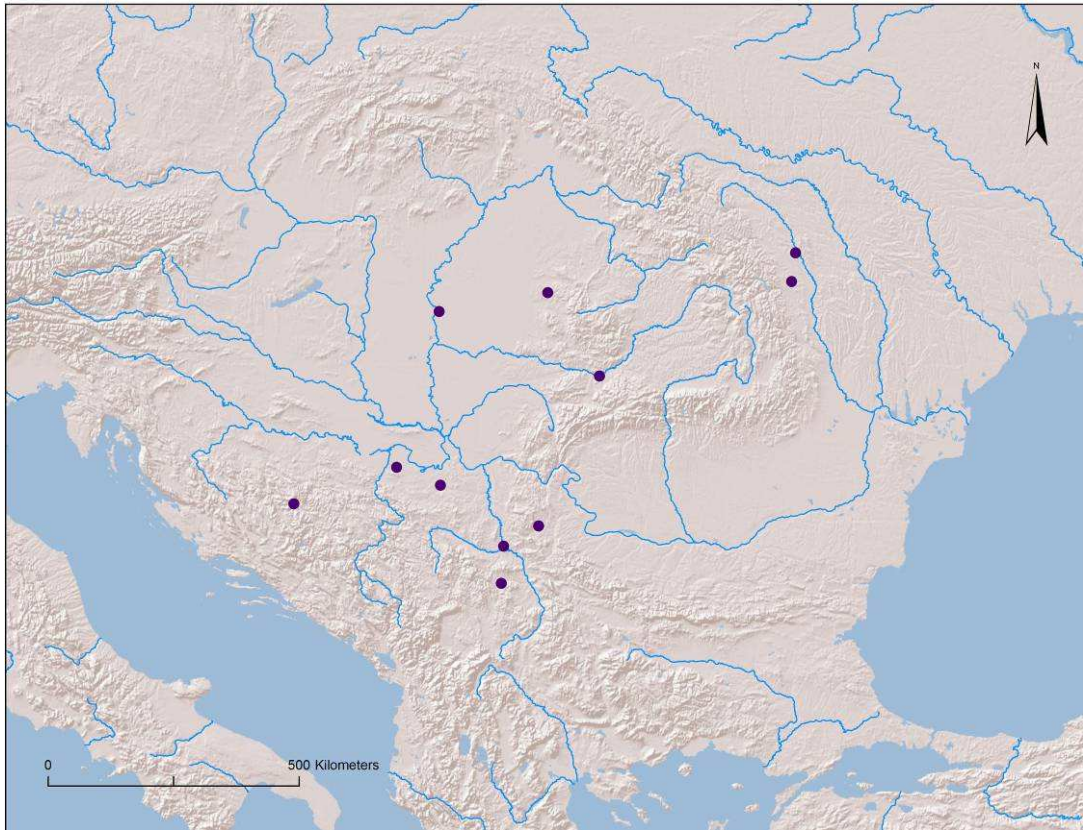
Map 14: Axes of type Mugeni



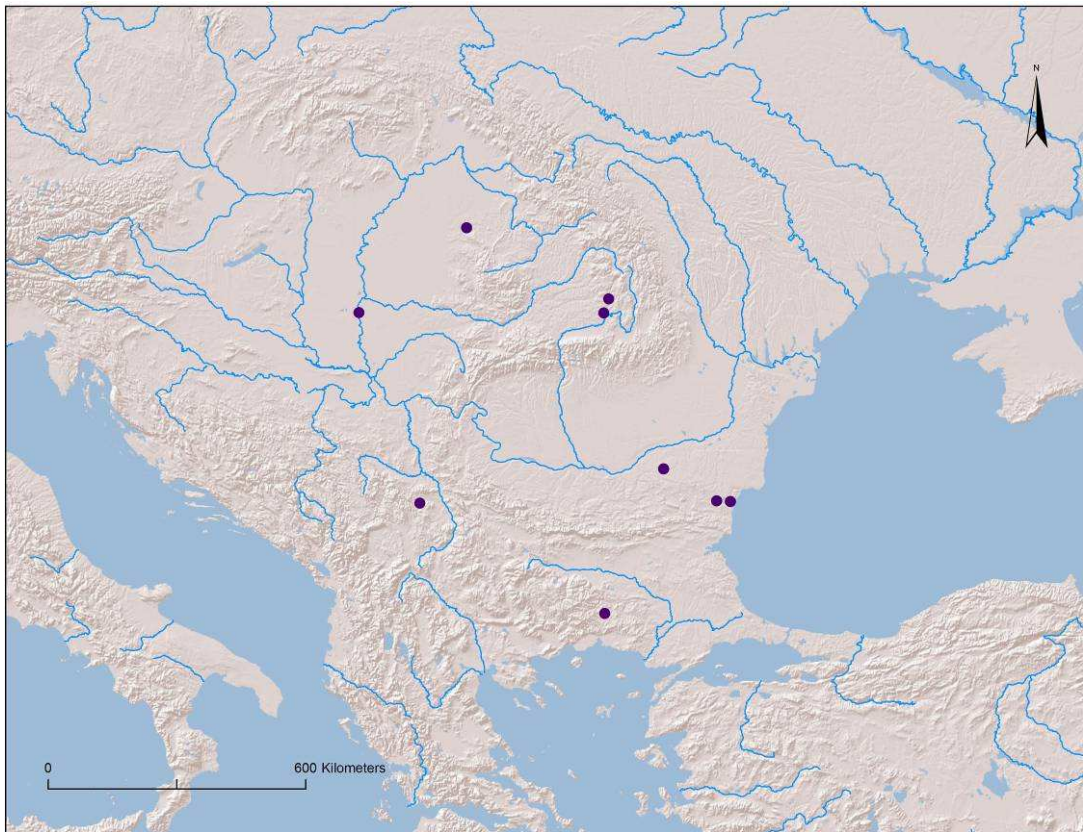
Map 15: Axes of type Pločnik (all variants)



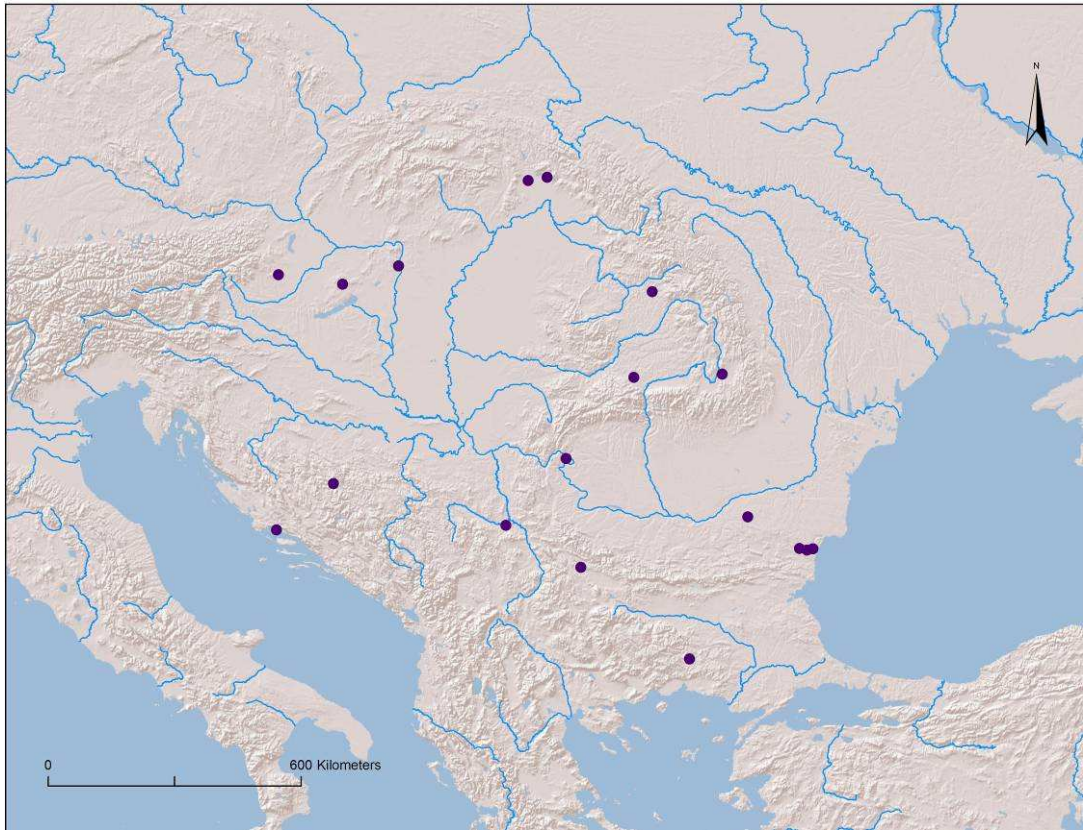
Map 16: Axes of type Pločnik A



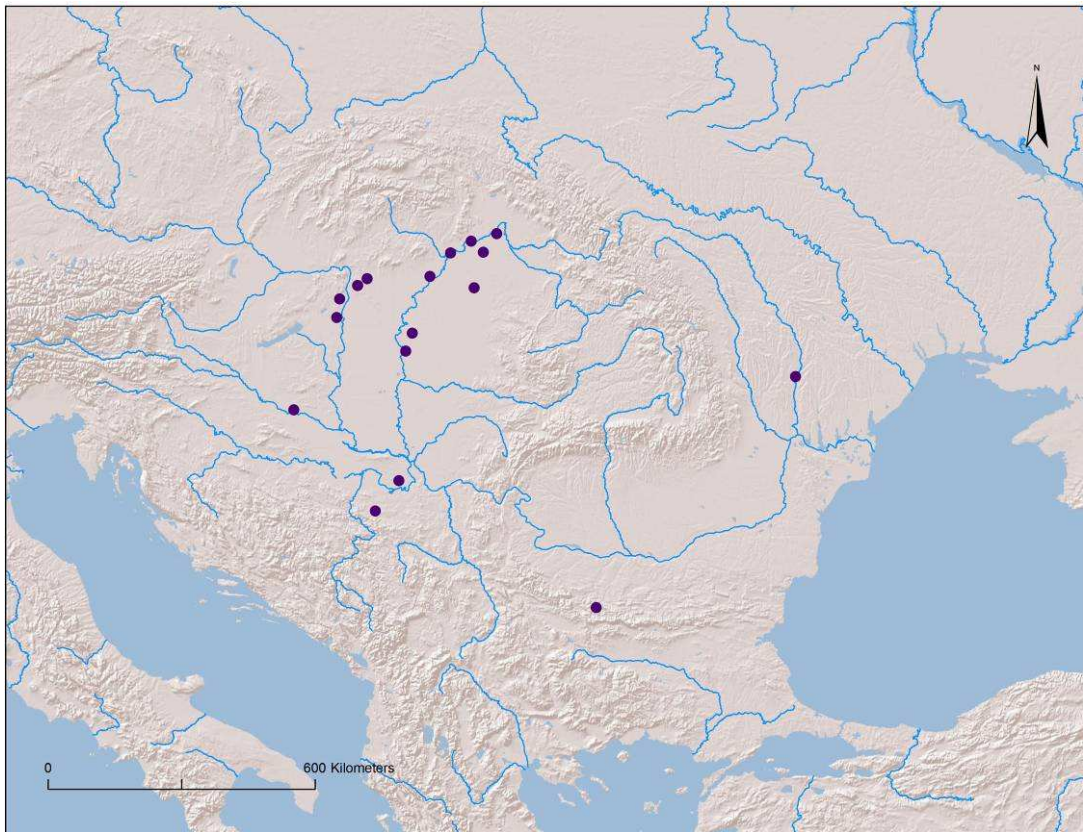
Map 17: Axes of type Pločnik B



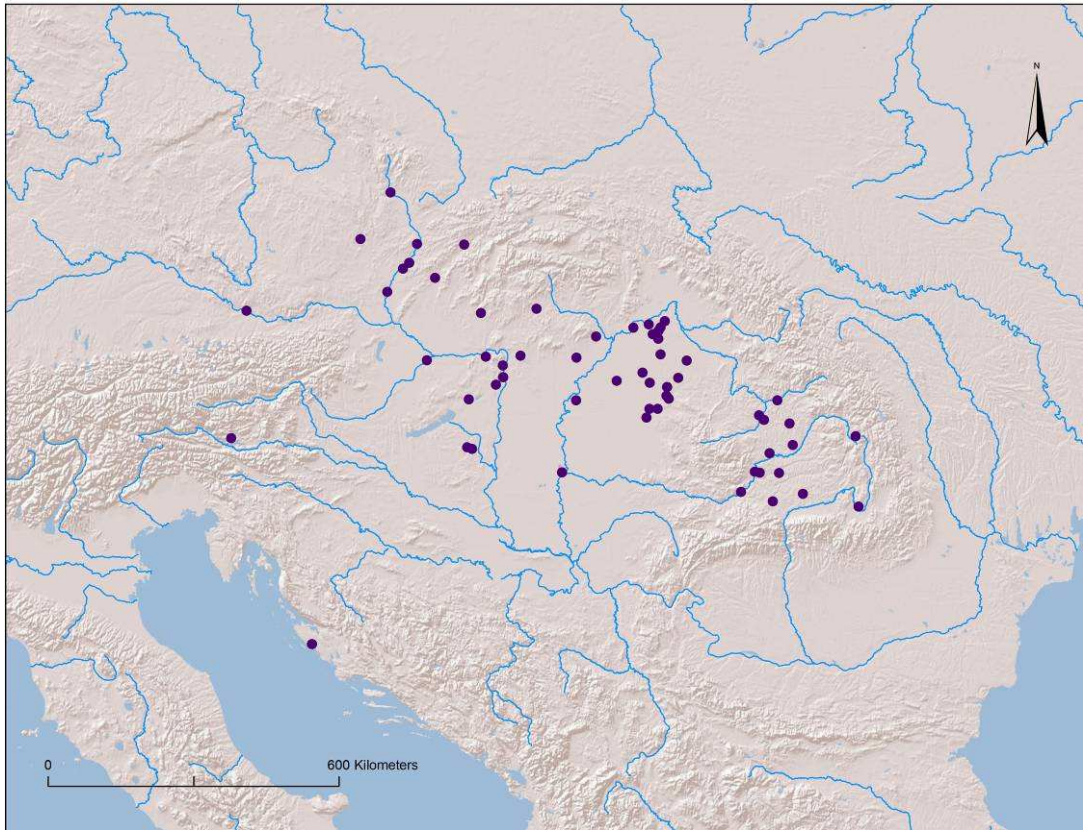
Map 18: Axes of type Pločnik C



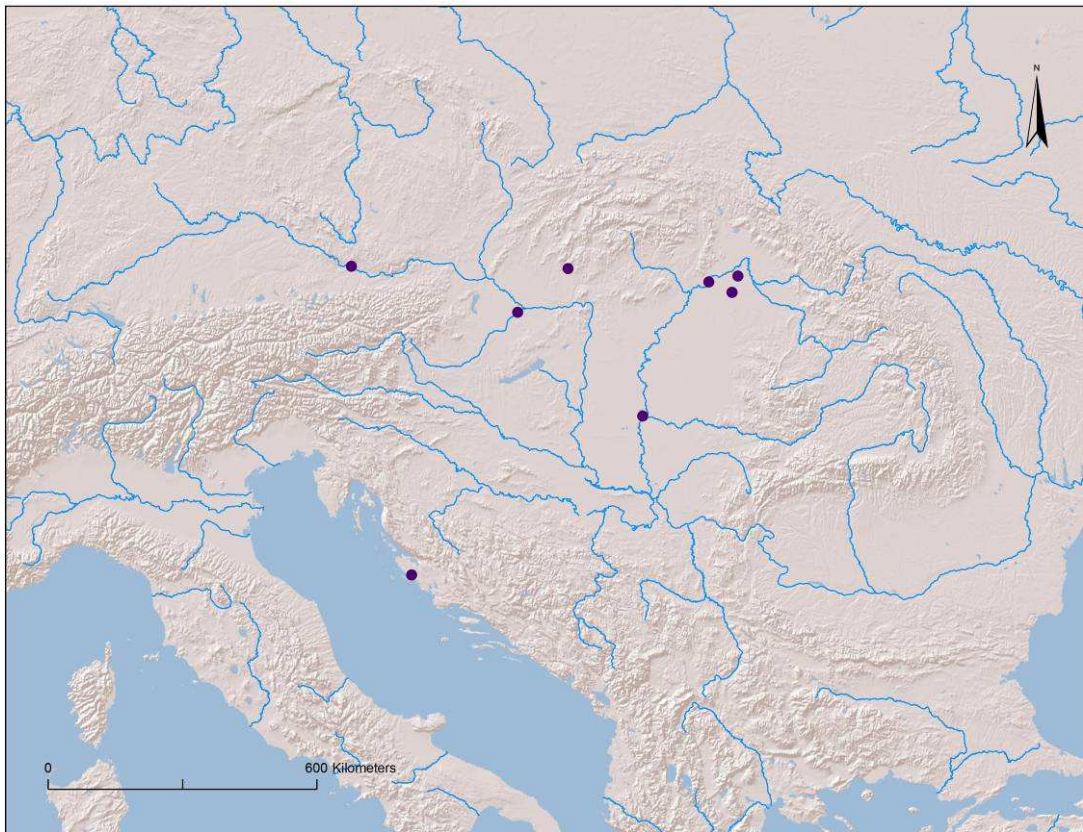
Map 19: Axes of type Pločnik D



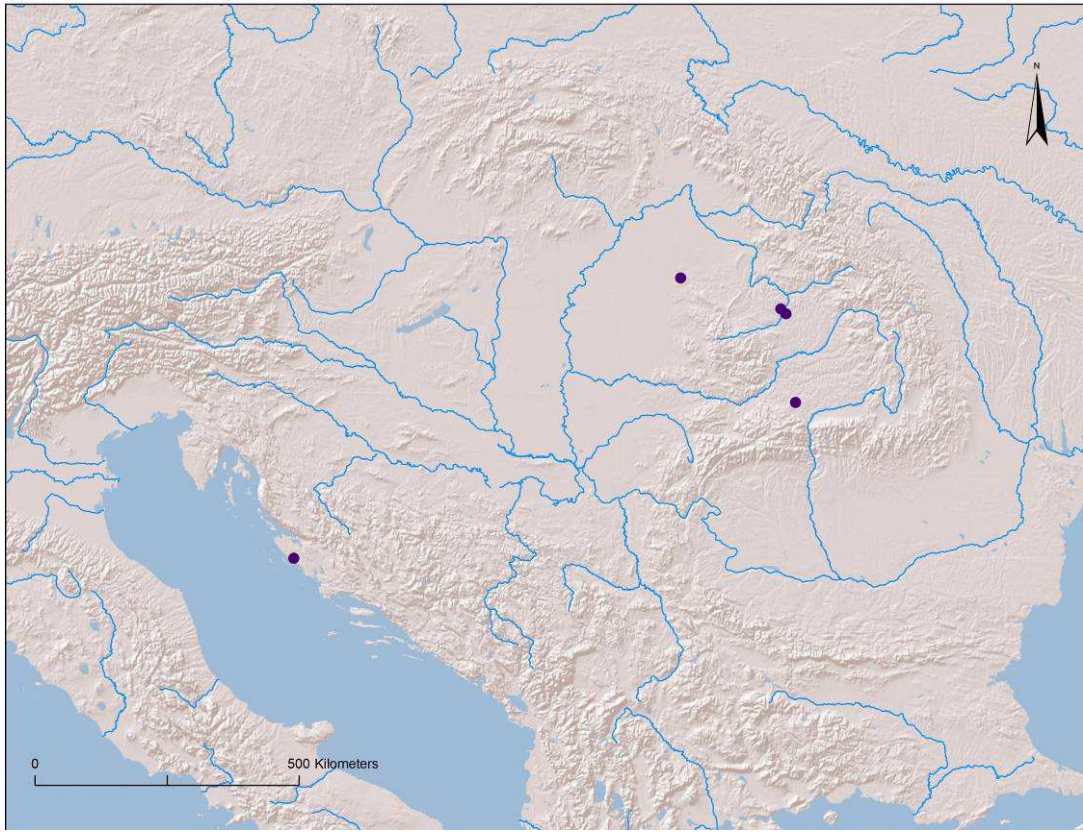
Map 20: Axes of type Şiria



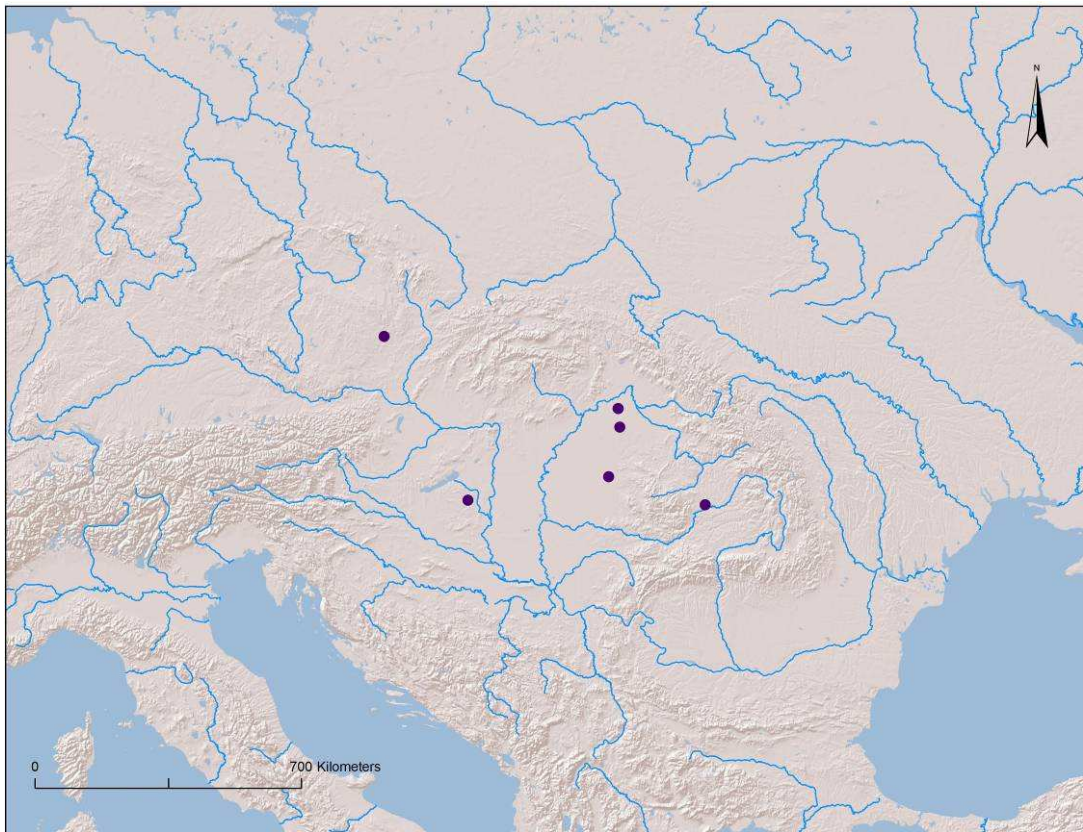
Map 21: Axes of type Székely-Nádudvar (all variants)



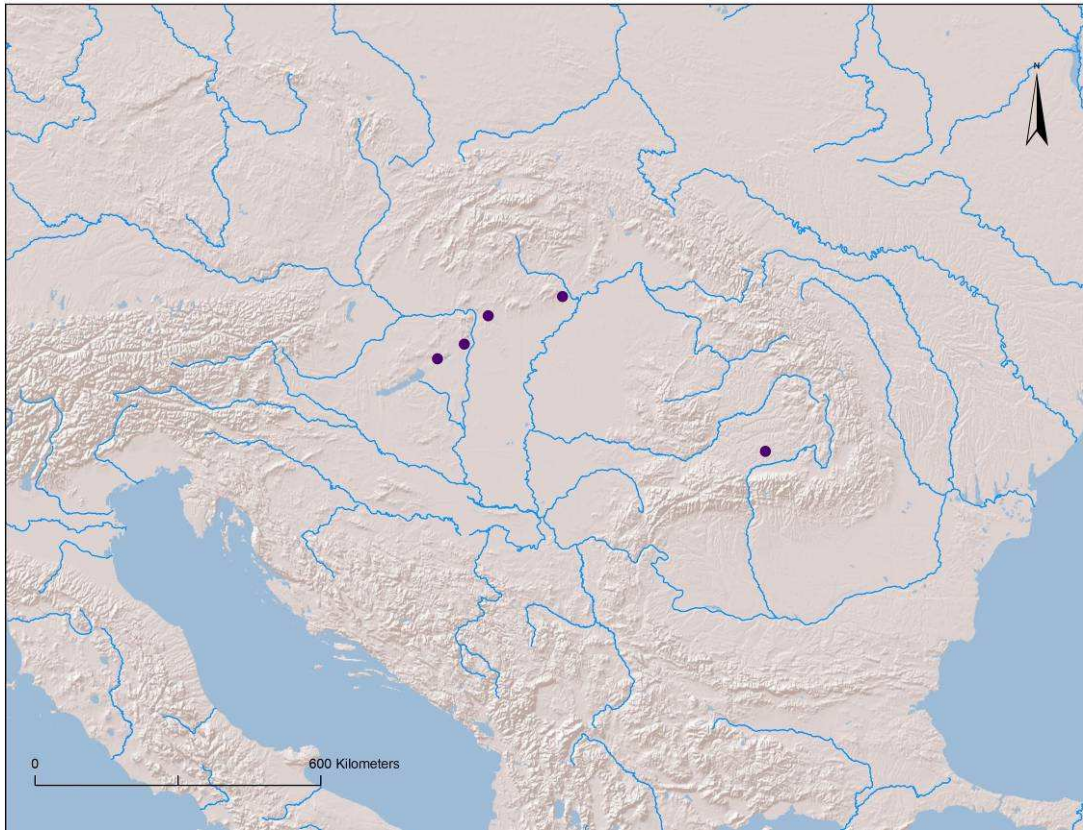
Map 22: Axes of type Székely-Nádudvar A



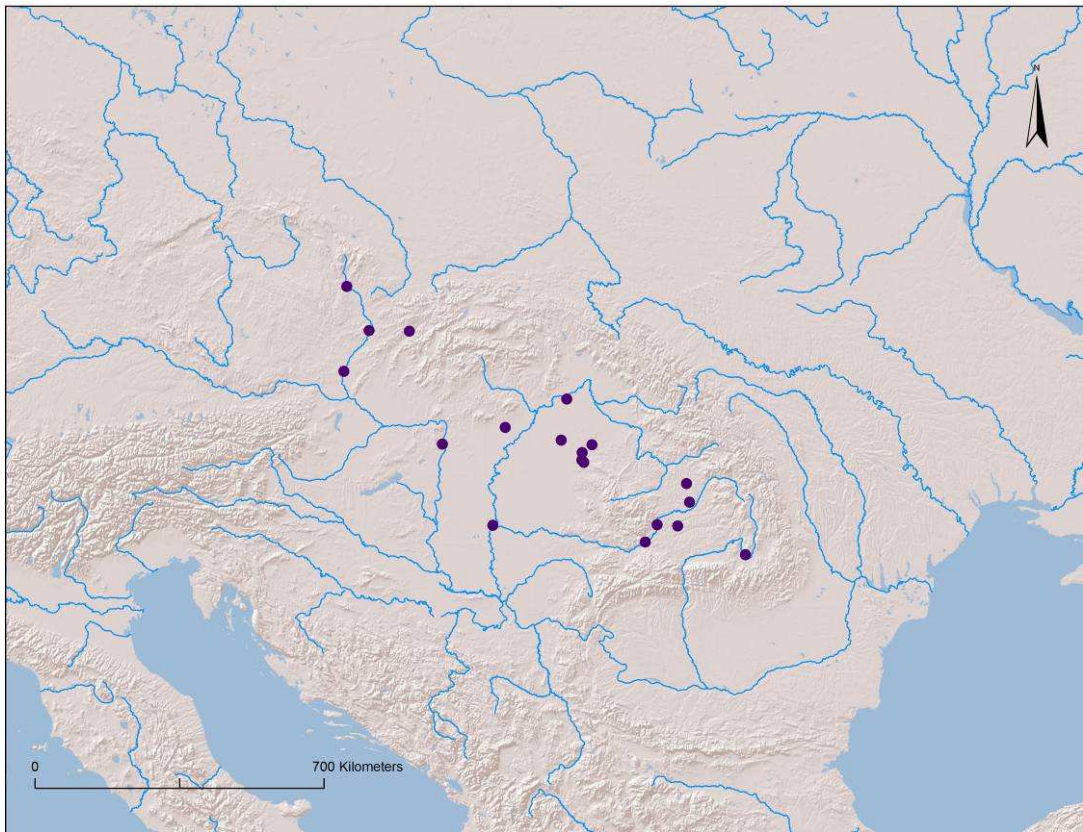
Map 23: Axes of type Székely-Nádudvar B



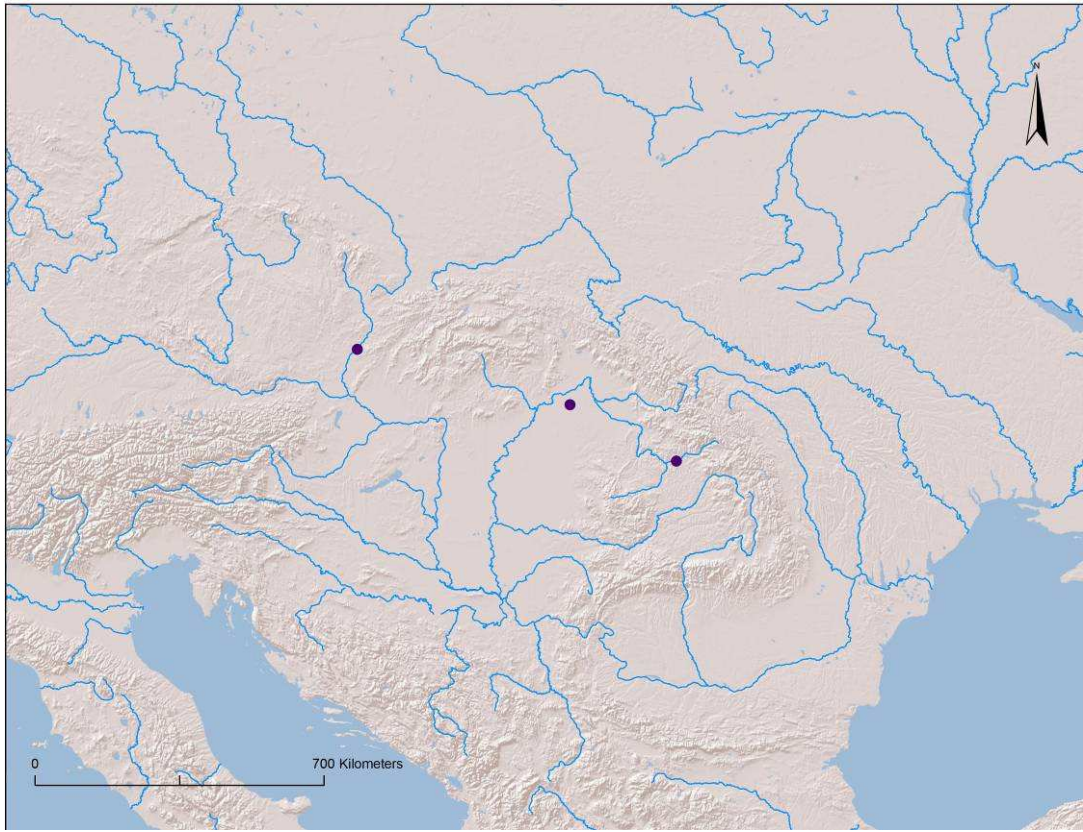
Map 24: Axes of type Székely-Nádudvar C1



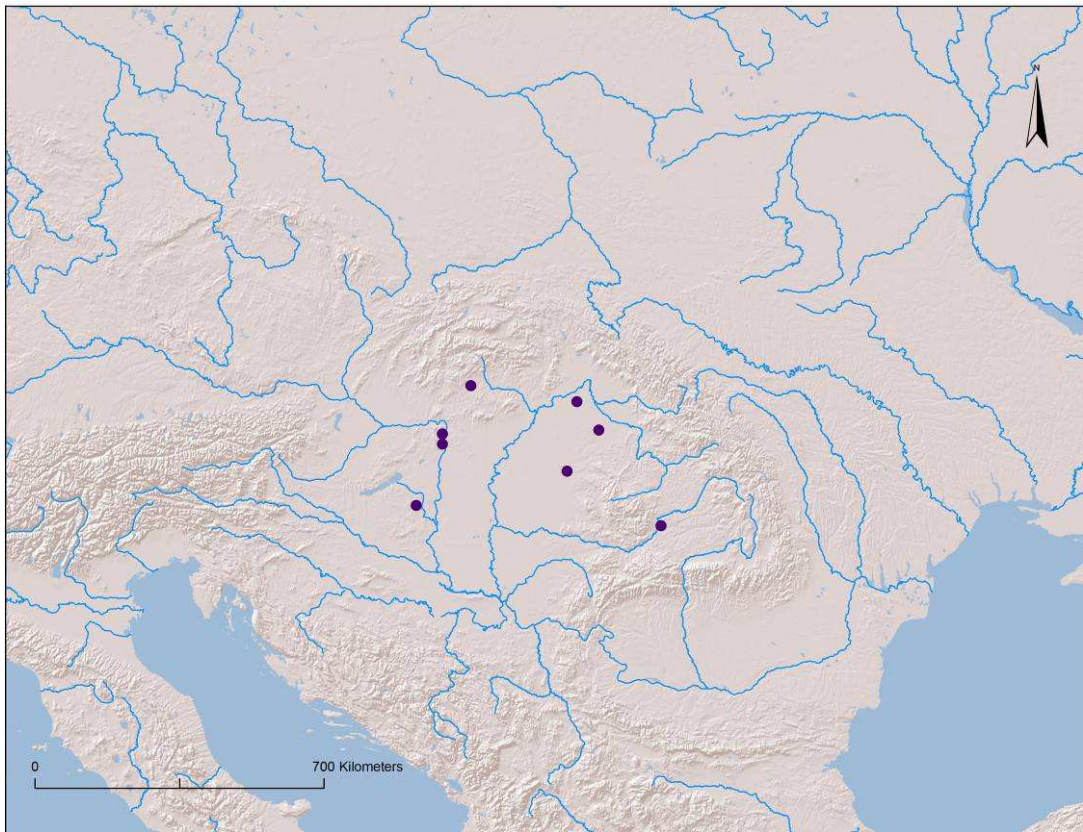
Map 25: Axes of type Székely-Nádudvar C2



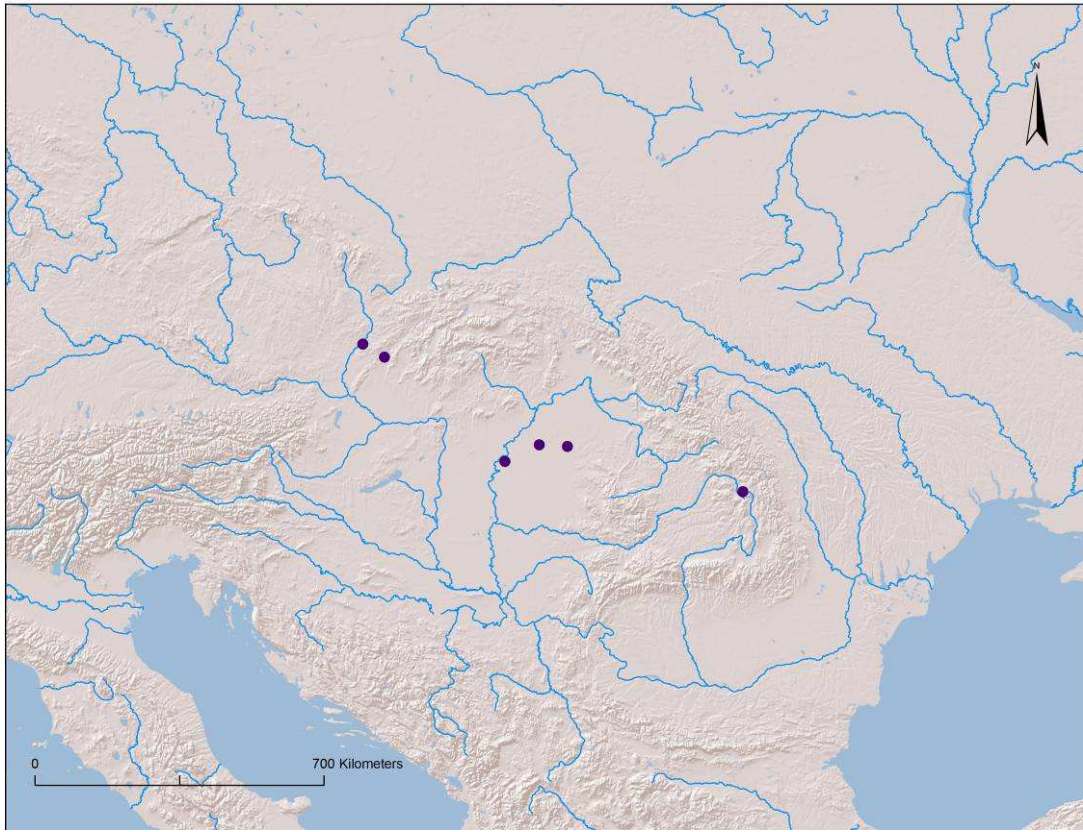
Map 26: Axes of type Székely-Nádudvar D1



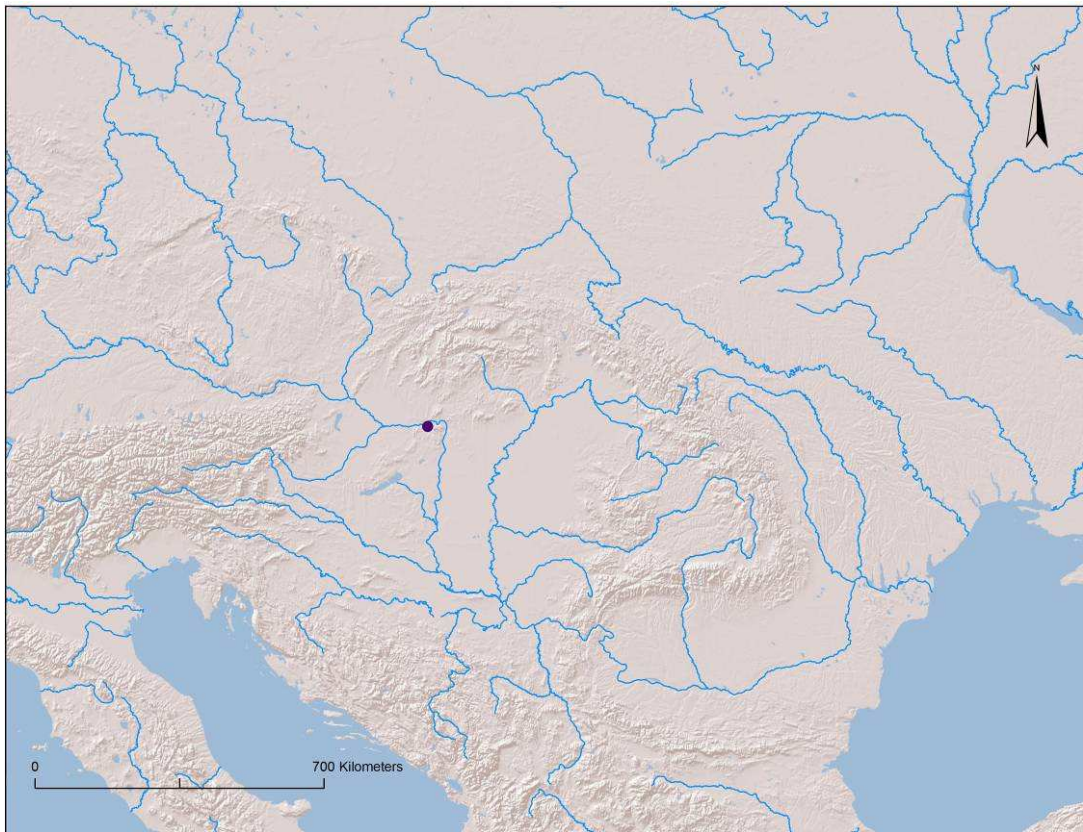
Map 27: Axes of type Székely-Nádudvar D2



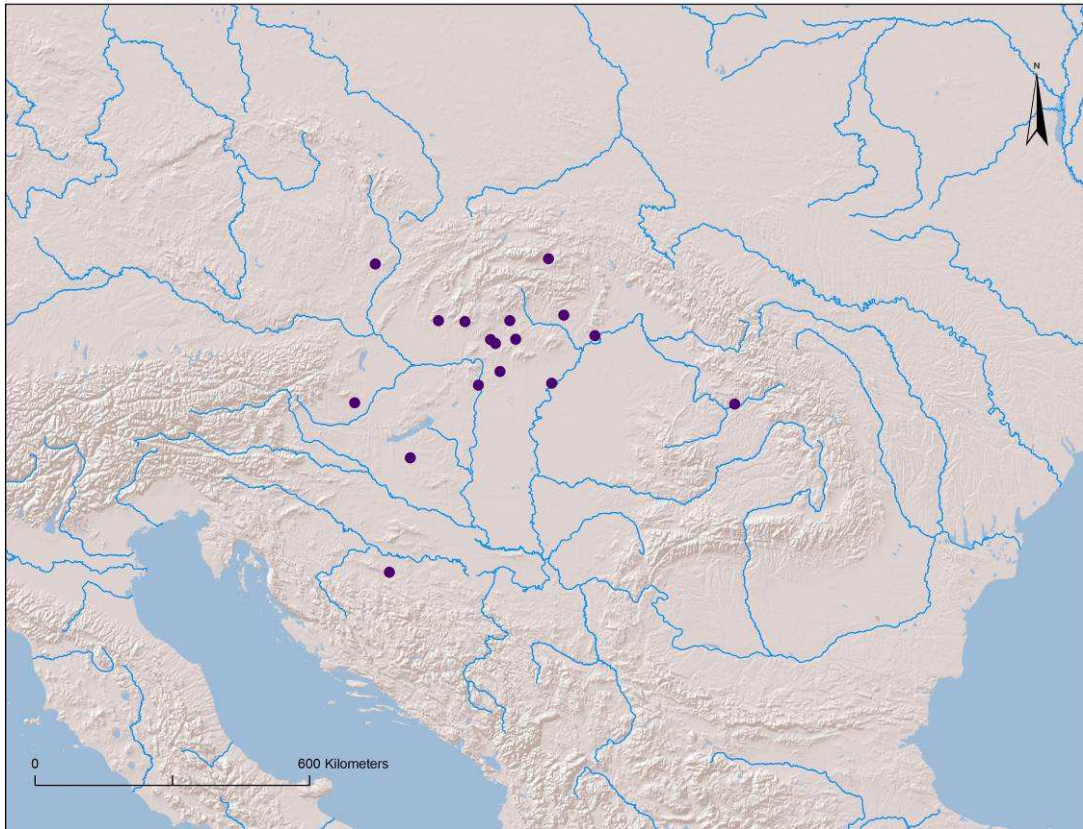
Map 28: Axes of type Székely-Nádudvar E1



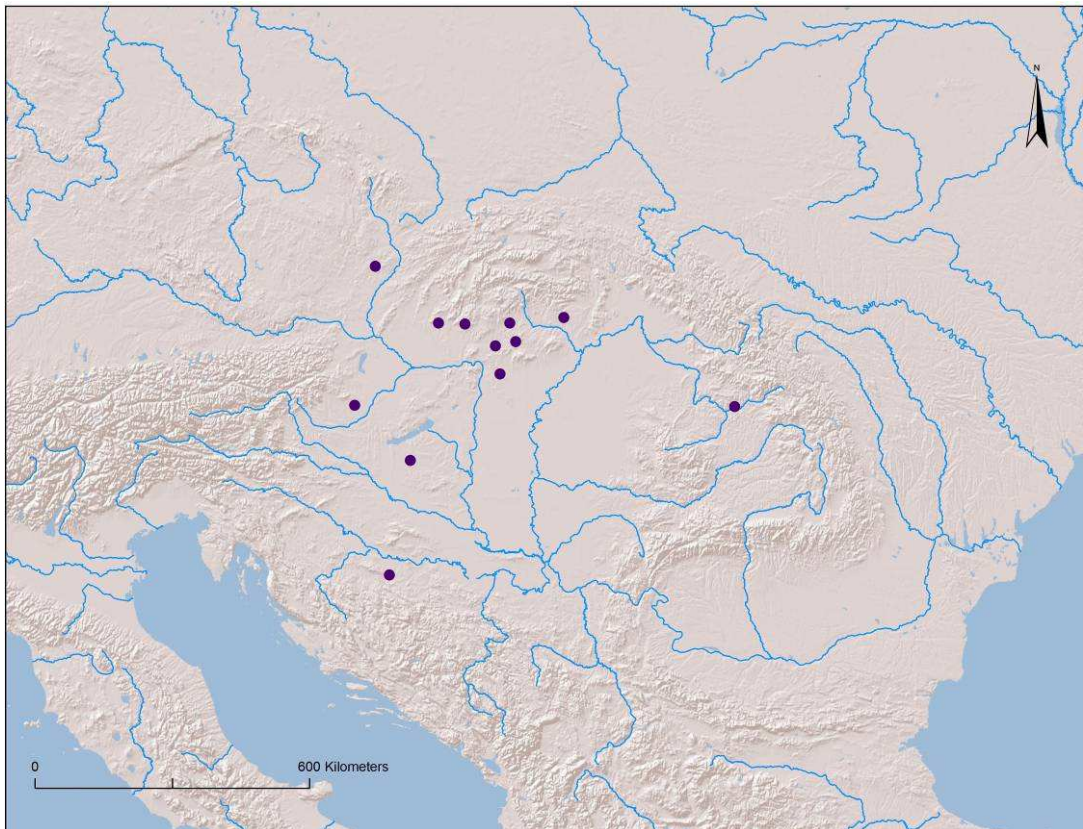
Map 29: Axes of type Székely-Nádudvar E2



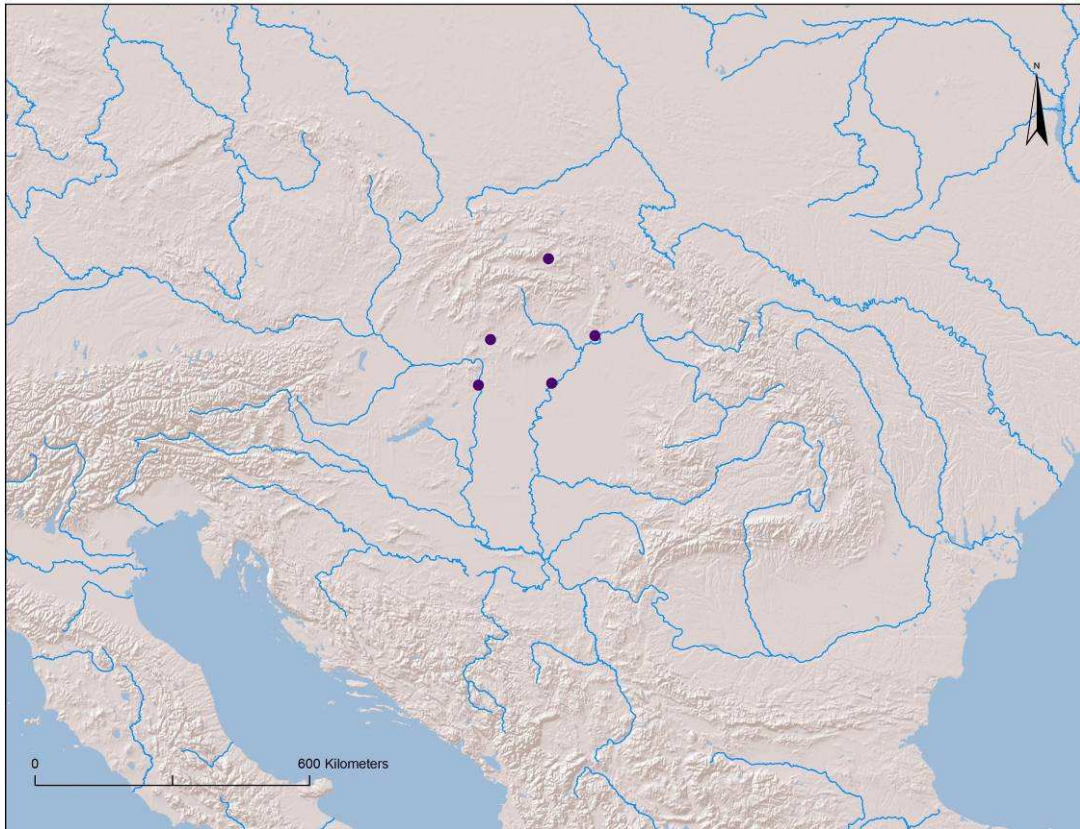
Map 30: Axes of type Székely-Nádudvar E3



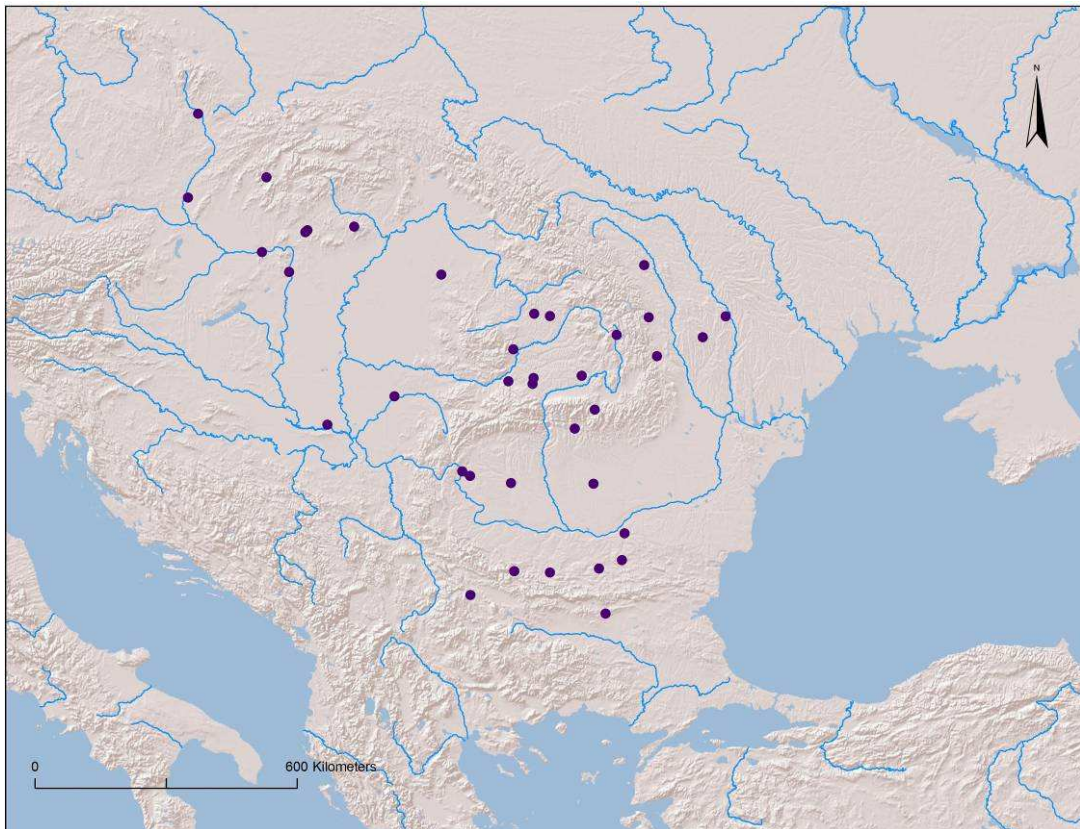
Map 31: Axes of type Szendrő (all variants)



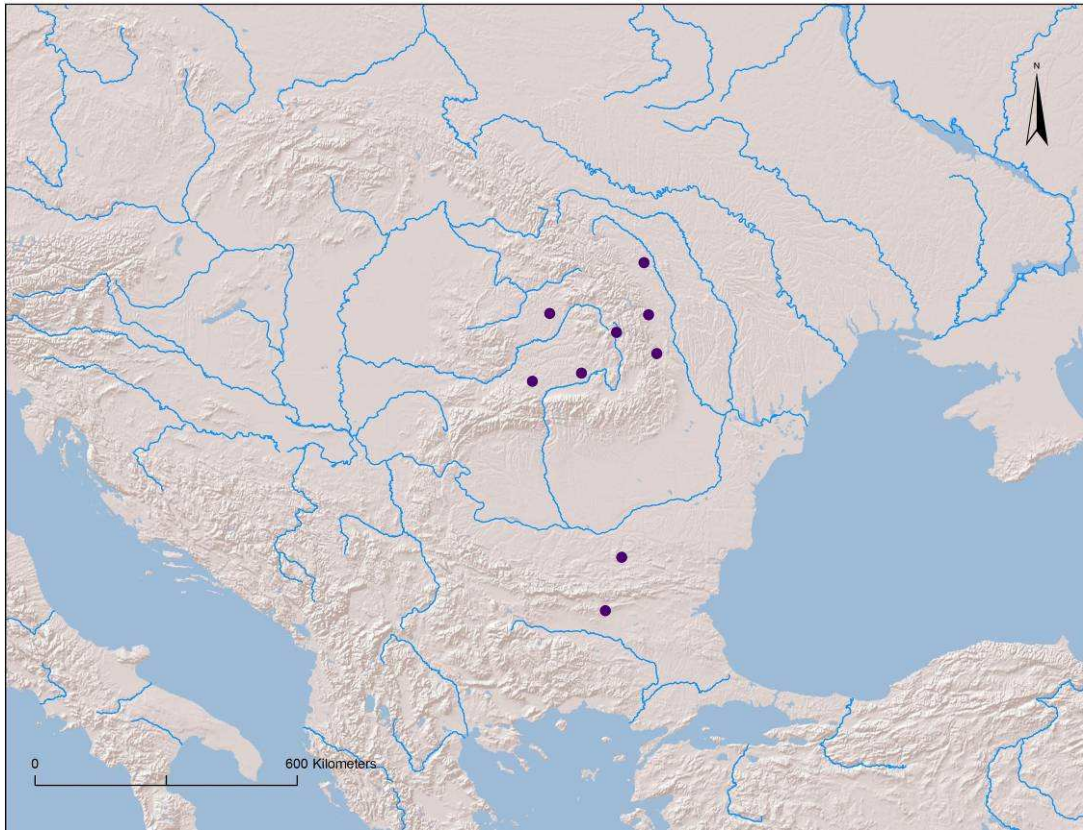
Map 32: Axes of type Szendrő A



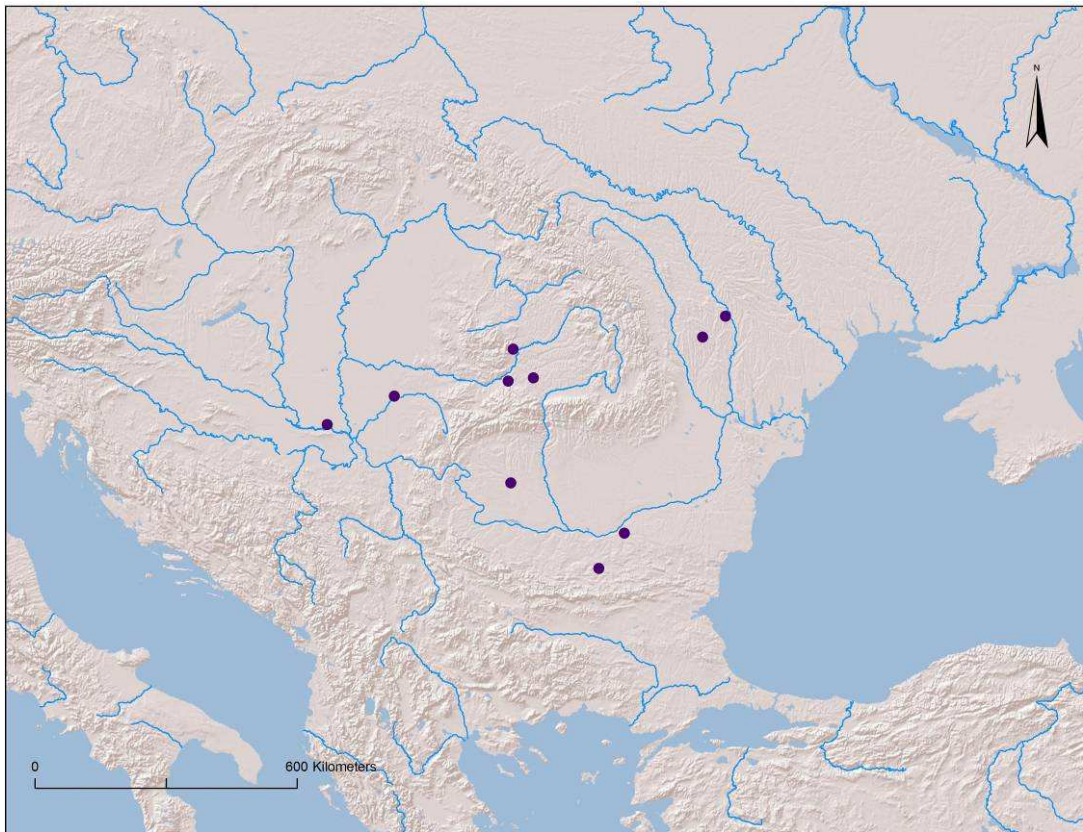
Map 33: Axes of type Szendrő B



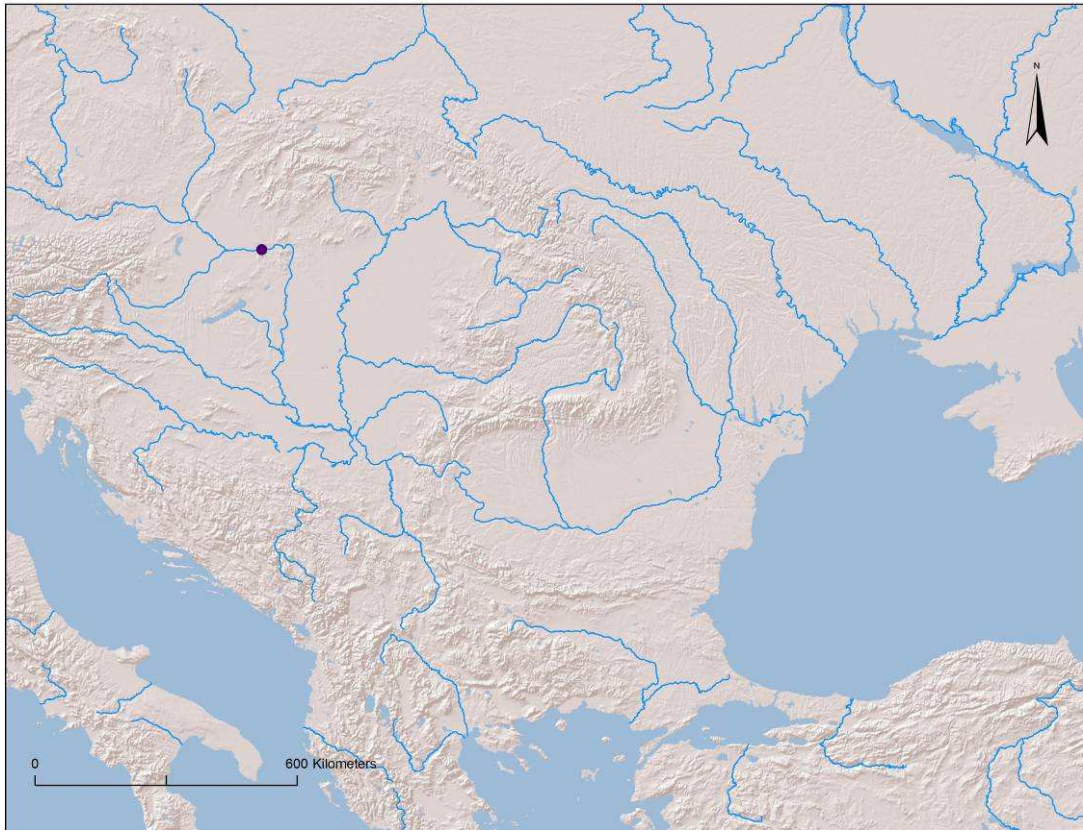
Map 34: Axes of type Tg. Ocna-Nógrádmárcal (all variants)



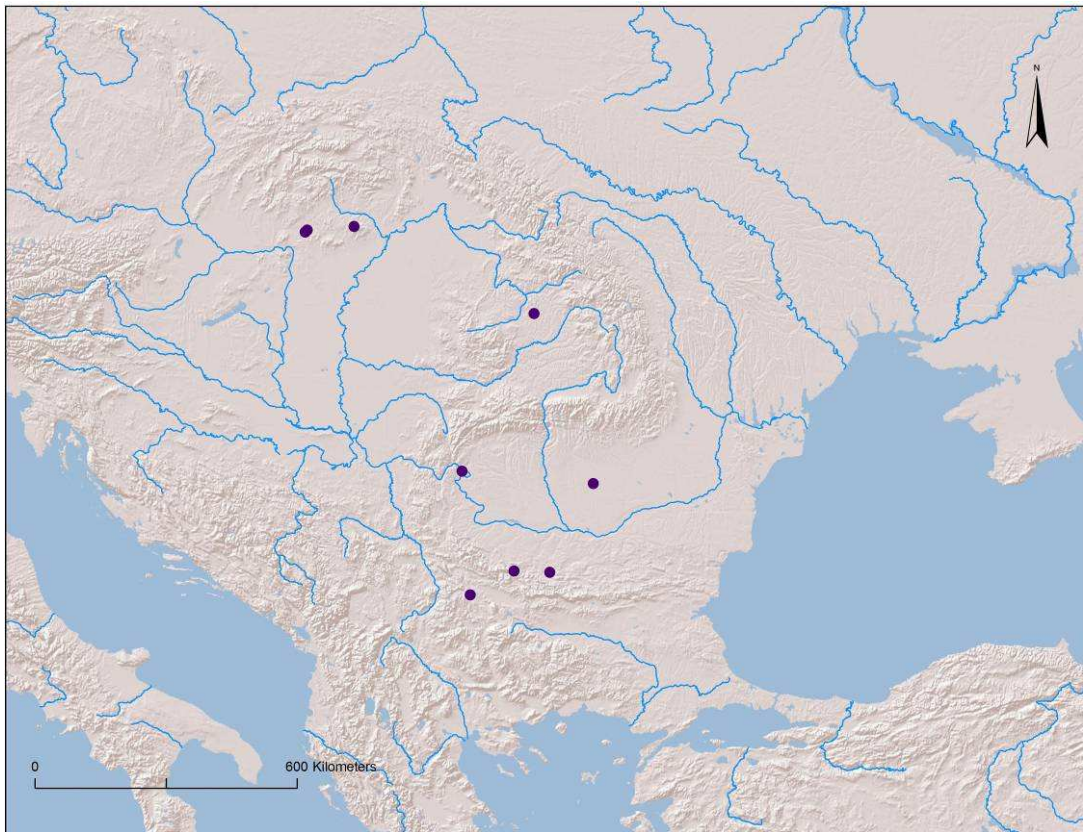
Map 35: Axes of type Tg. Ocna-Nógrádmargal A1



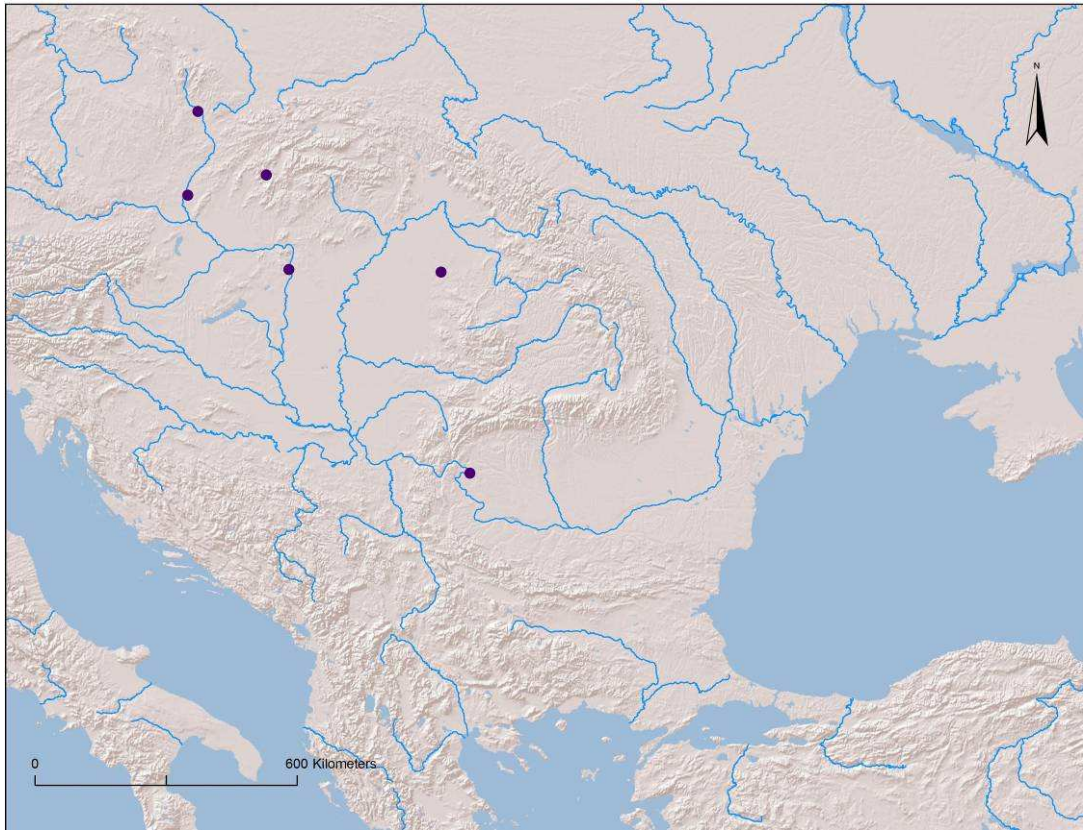
Map 36: Axes of type Tg. Ocna-Nógrádmargal A2



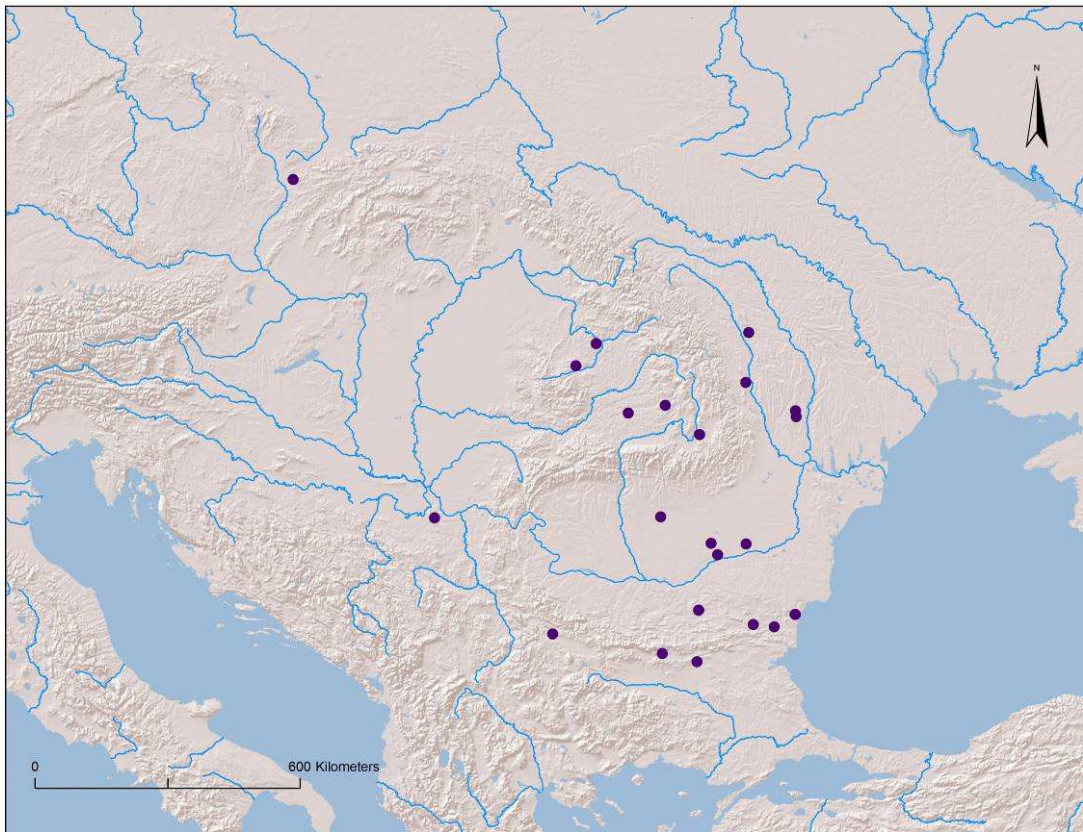
Map 37: Axes of type Tg. Ocna-Nógrádmárcal B



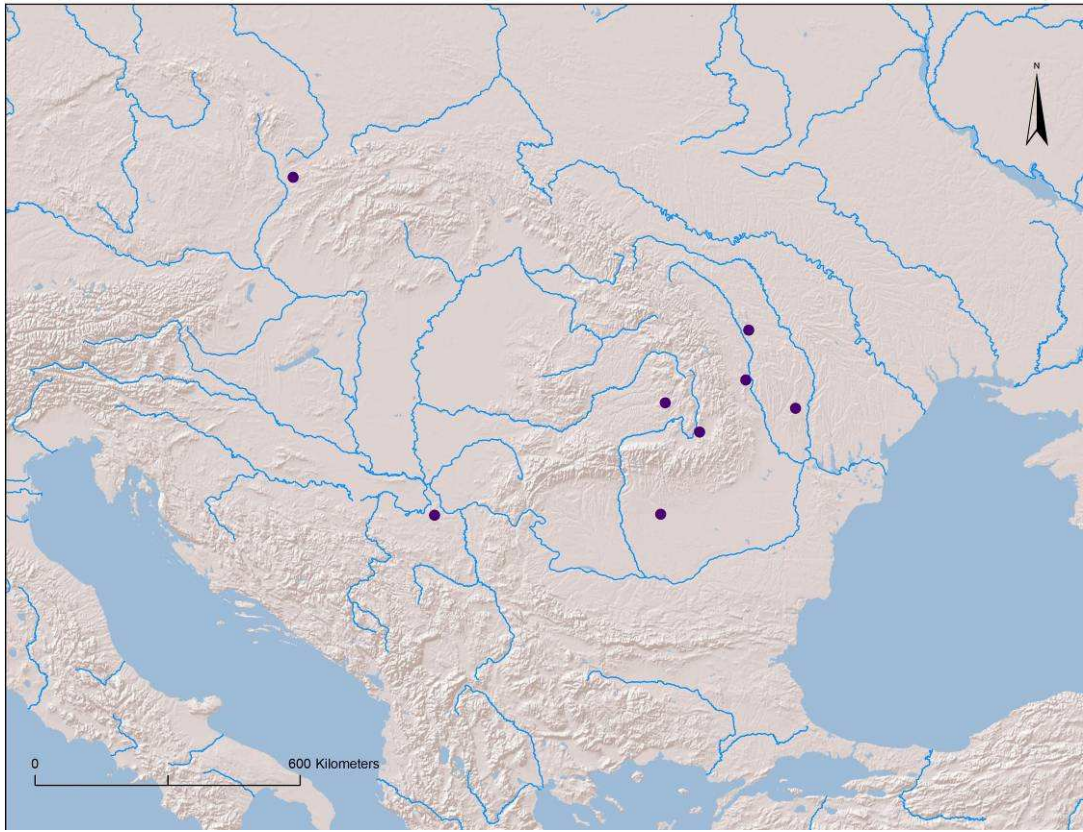
Map 38: Axes of type Tg. Ocna-Nógrádmárcal C1



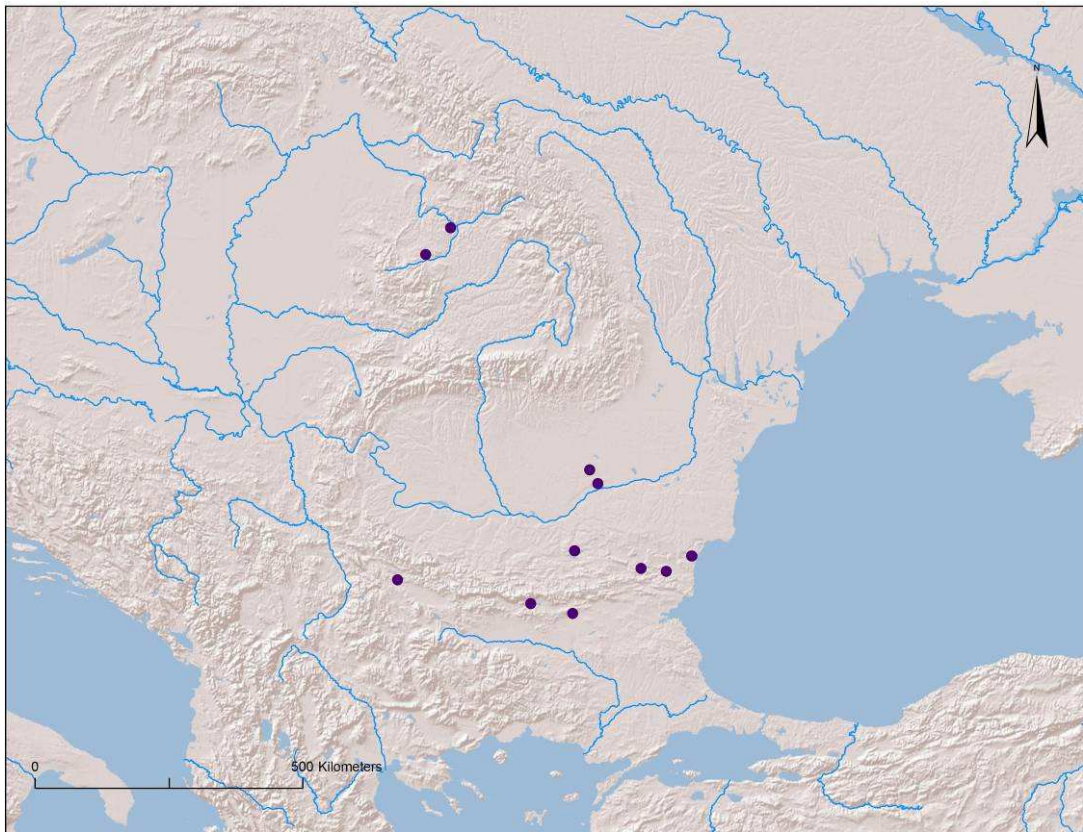
Map 39: Axes of type Tg. Ocna-Nógrádmargal C2



Map 40: Axes of type Vidra (all variants)

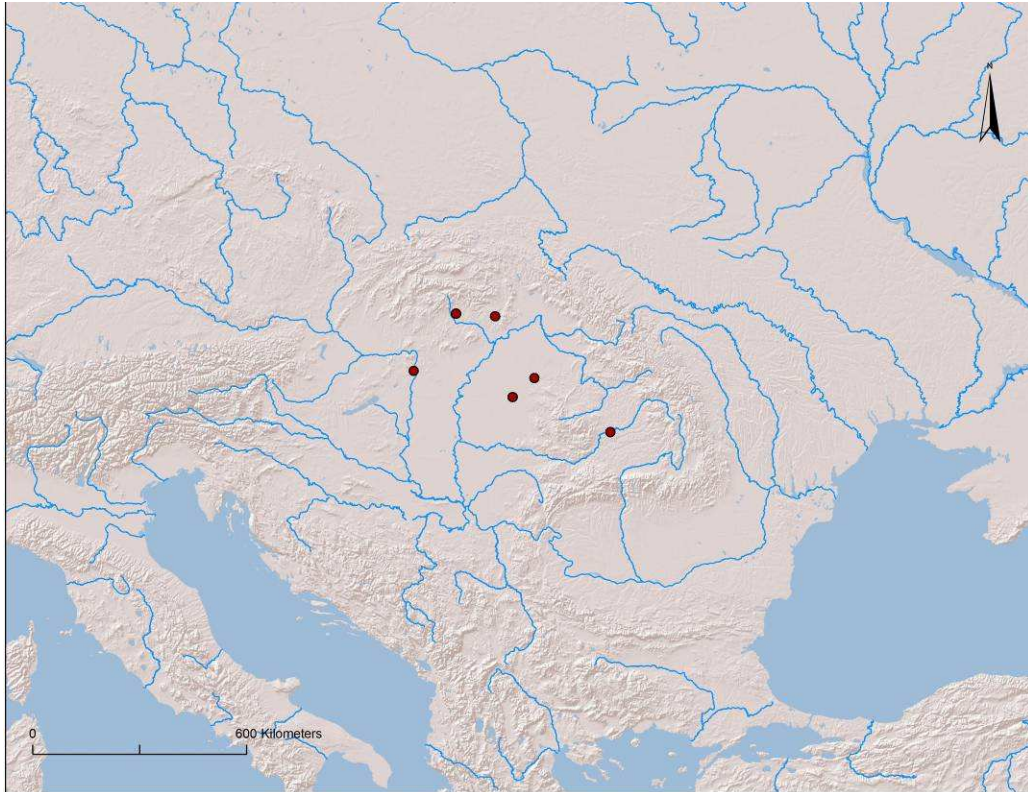


Map 41: Axes of type Vidra A

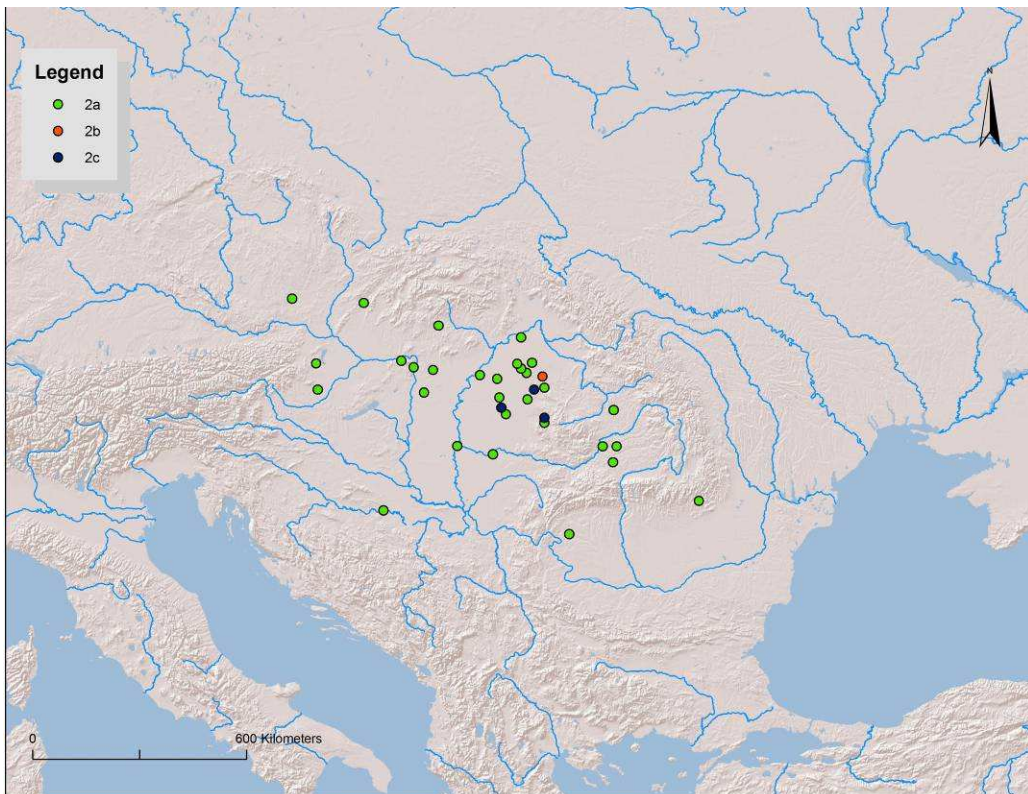


Map 42: Axes of type Vidra B

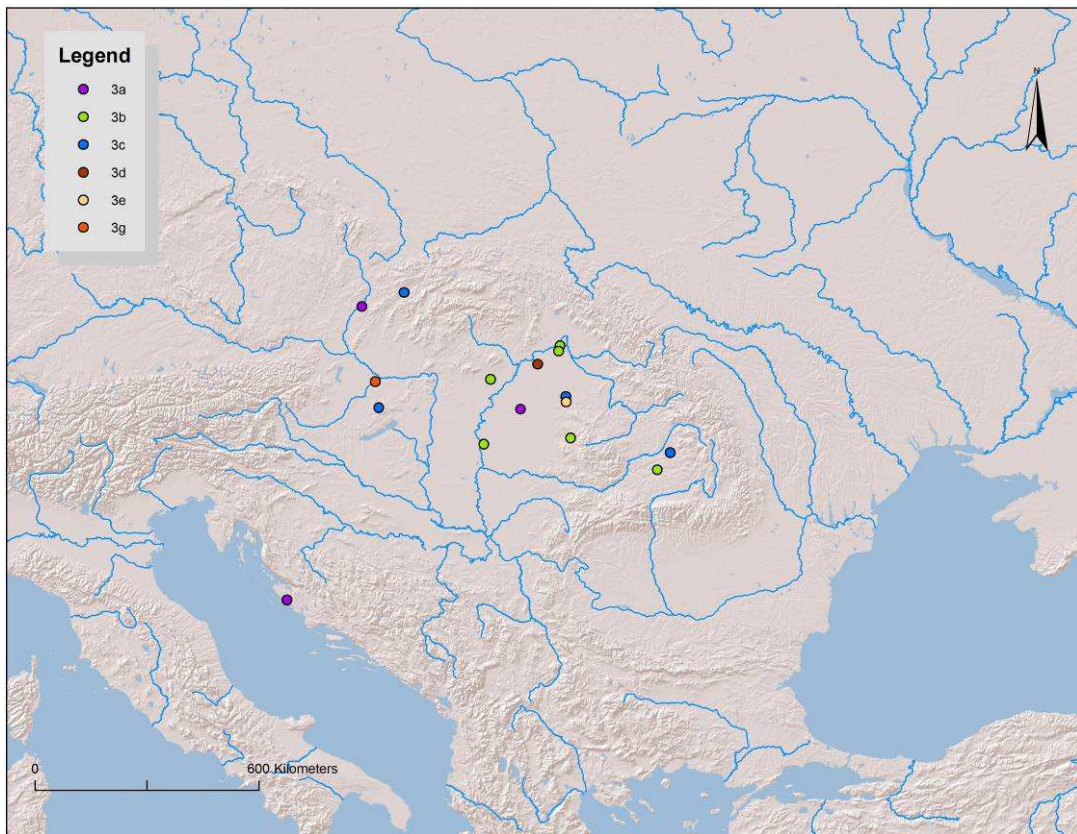
Axe marks



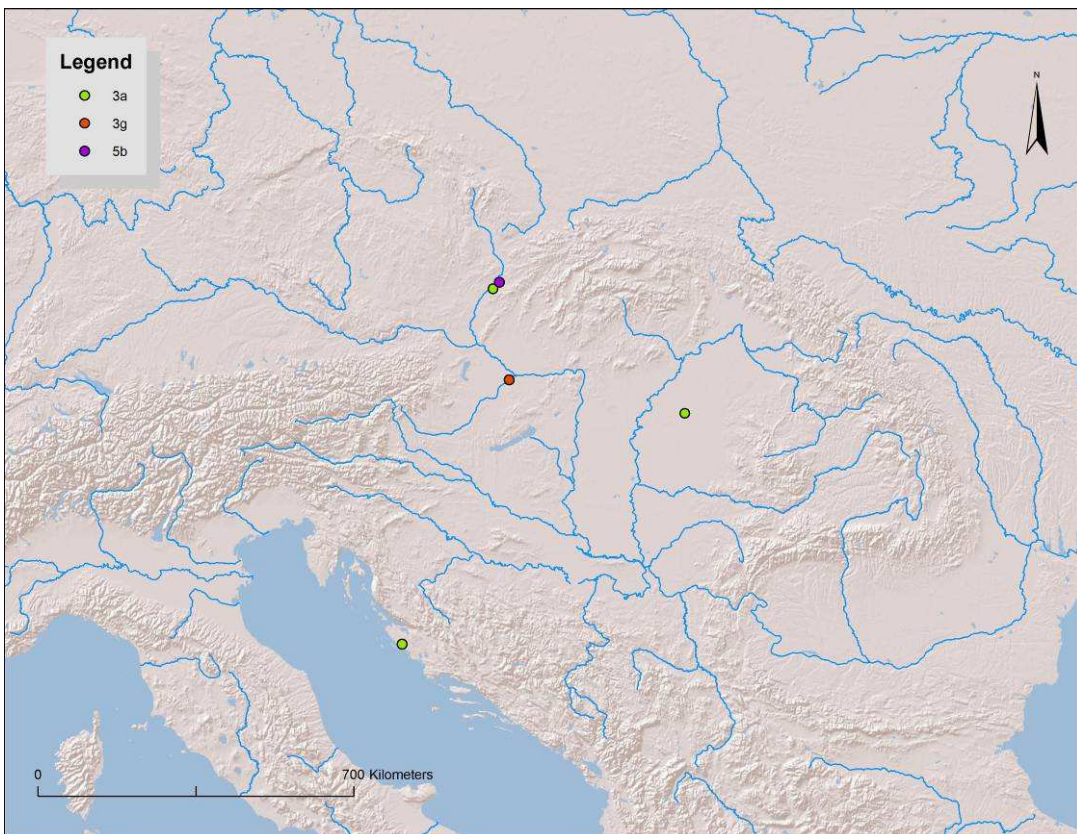
Map 43: Axe marks of code 1a



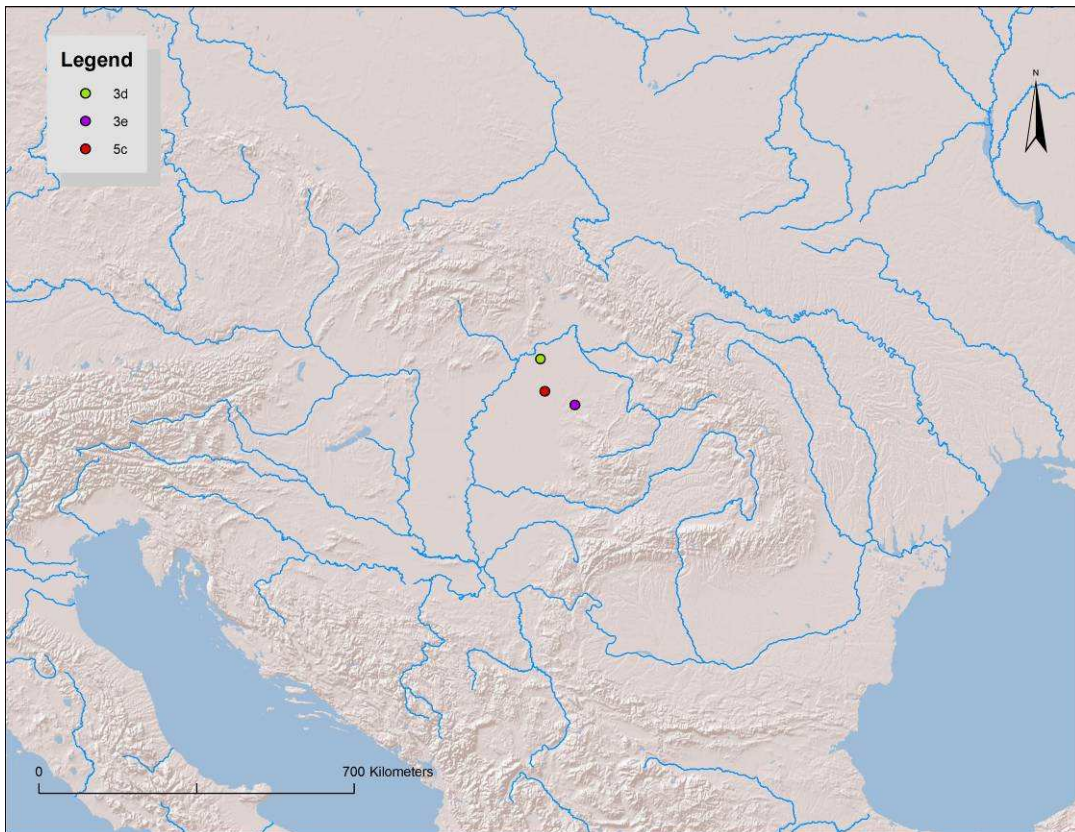
Map 44: Axe marks of code 2a,2b and 2c



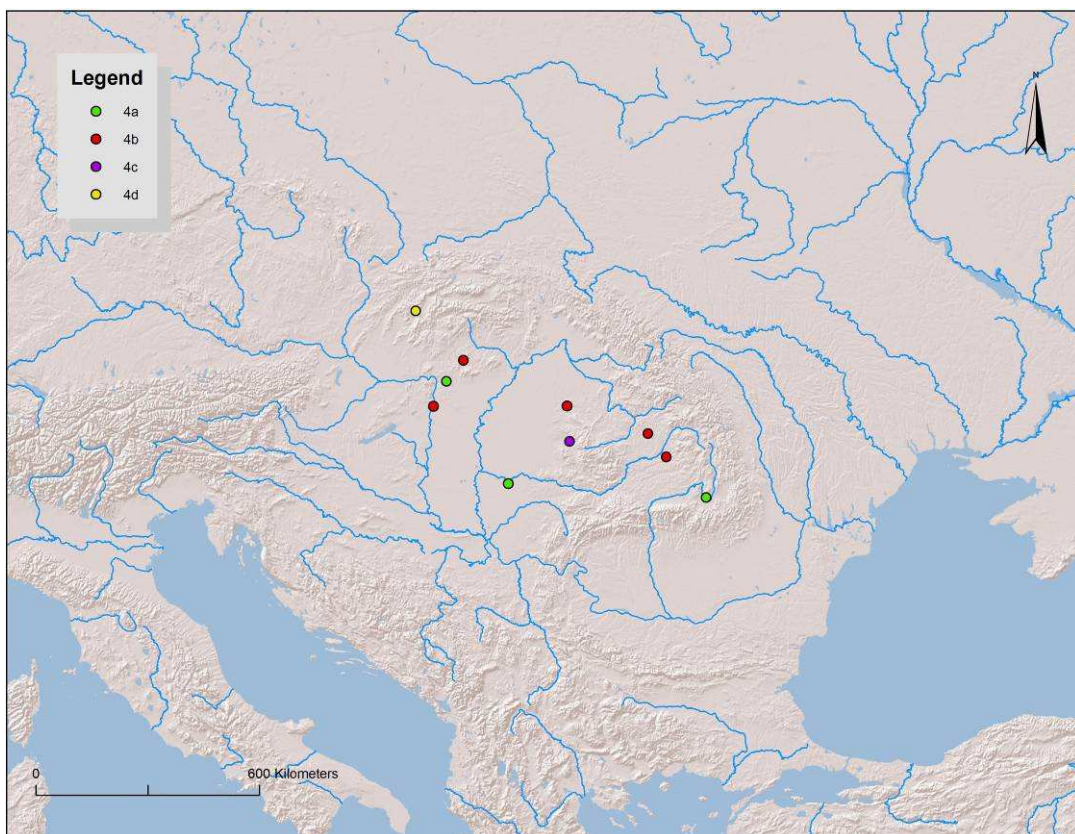
Map 45: Axe marks of code 3a, 3b, 3c, 3d, 3e, 3g



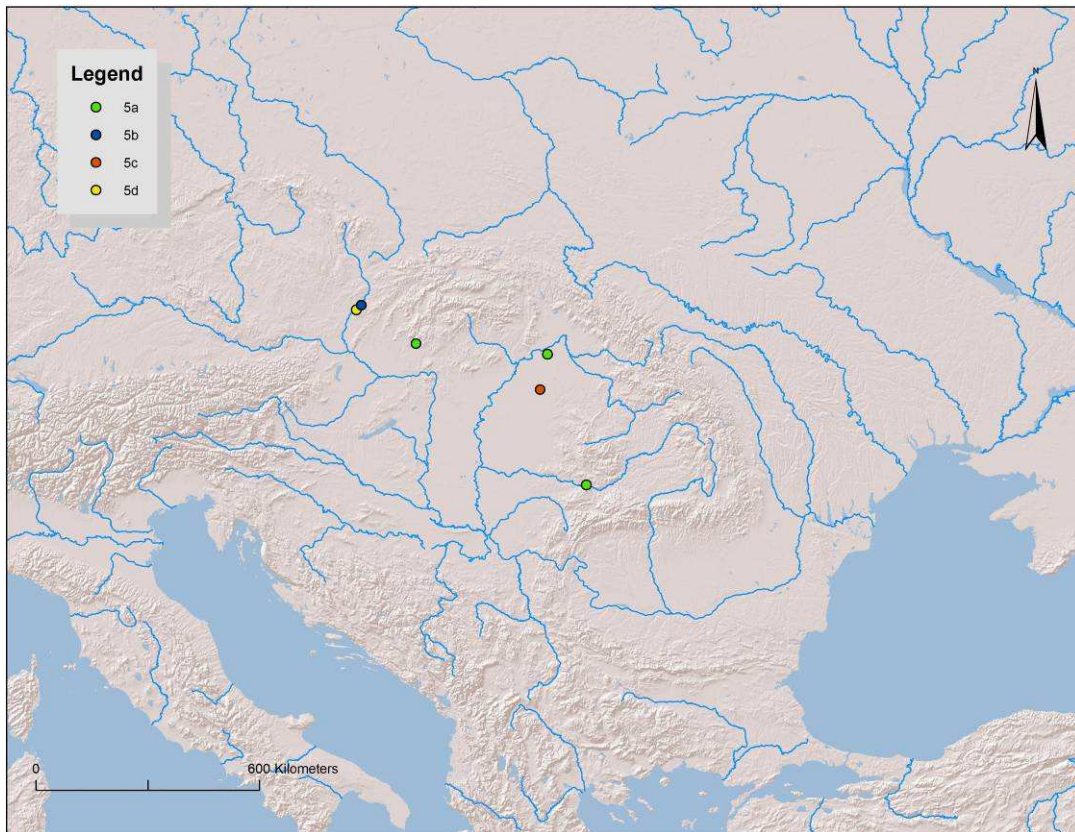
Map 46: Axe marks of code 3a, 3g and 5b



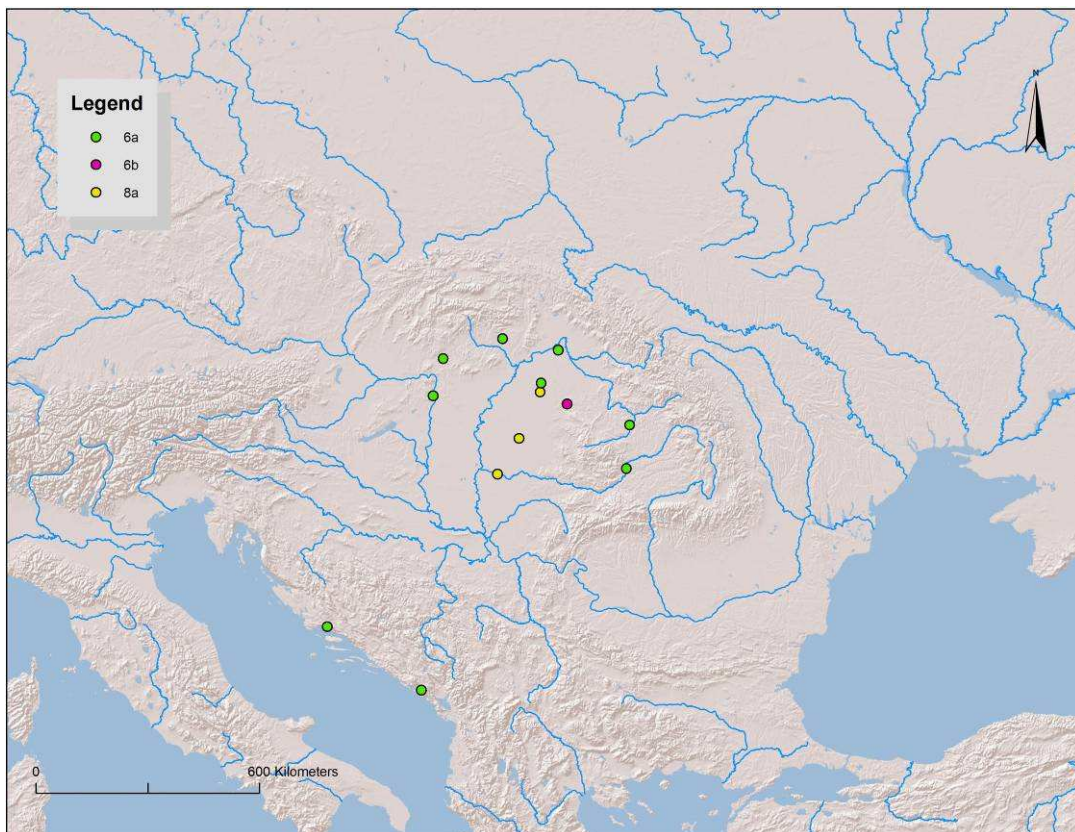
Map 47: Axe marks of code 3d, 3e and 5c



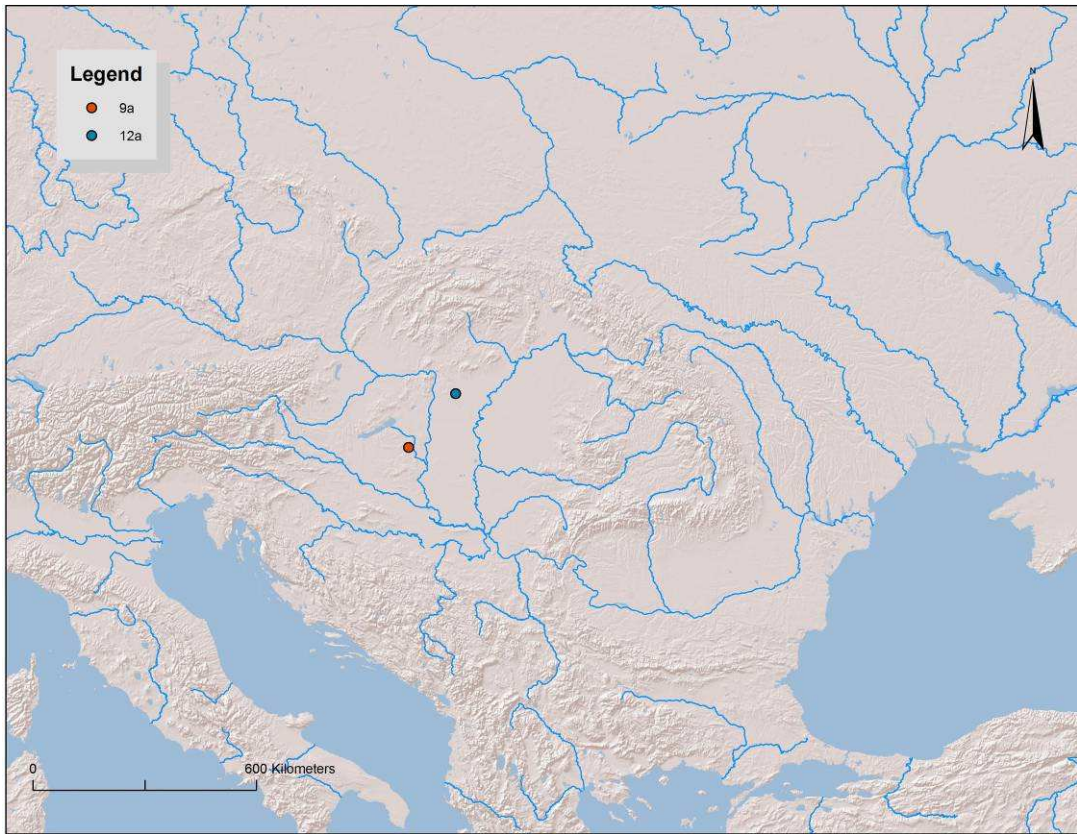
Map 48: Axe marks of code 4a, 4b, 4c and 4d



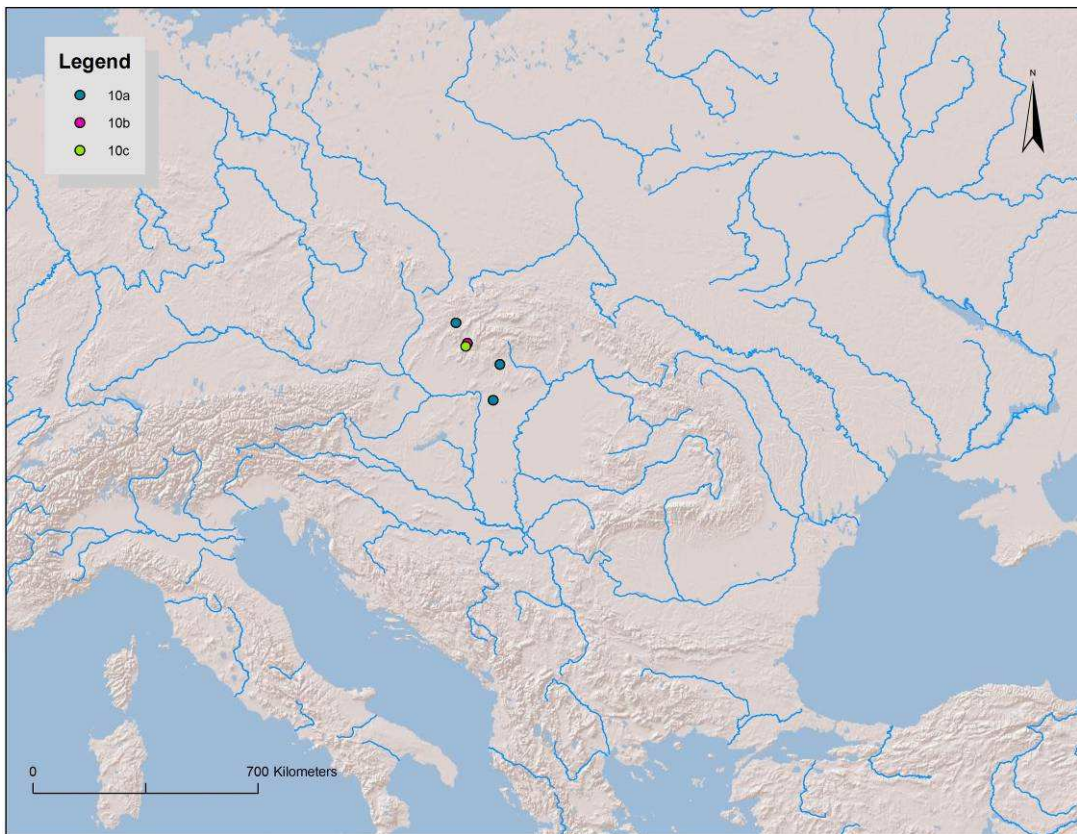
Map 49: Axe marks of code 5a, 5b, 5c and 5d



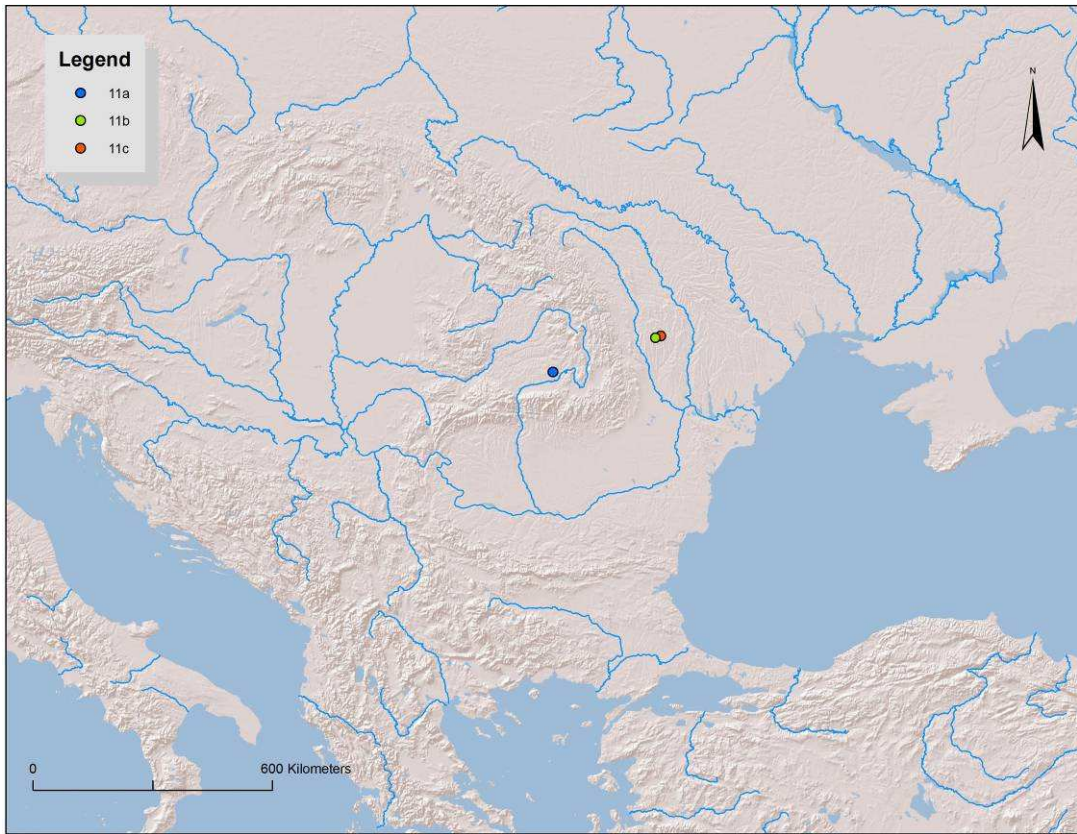
Map 50: Axe marks of code 6a, 6b and 8a



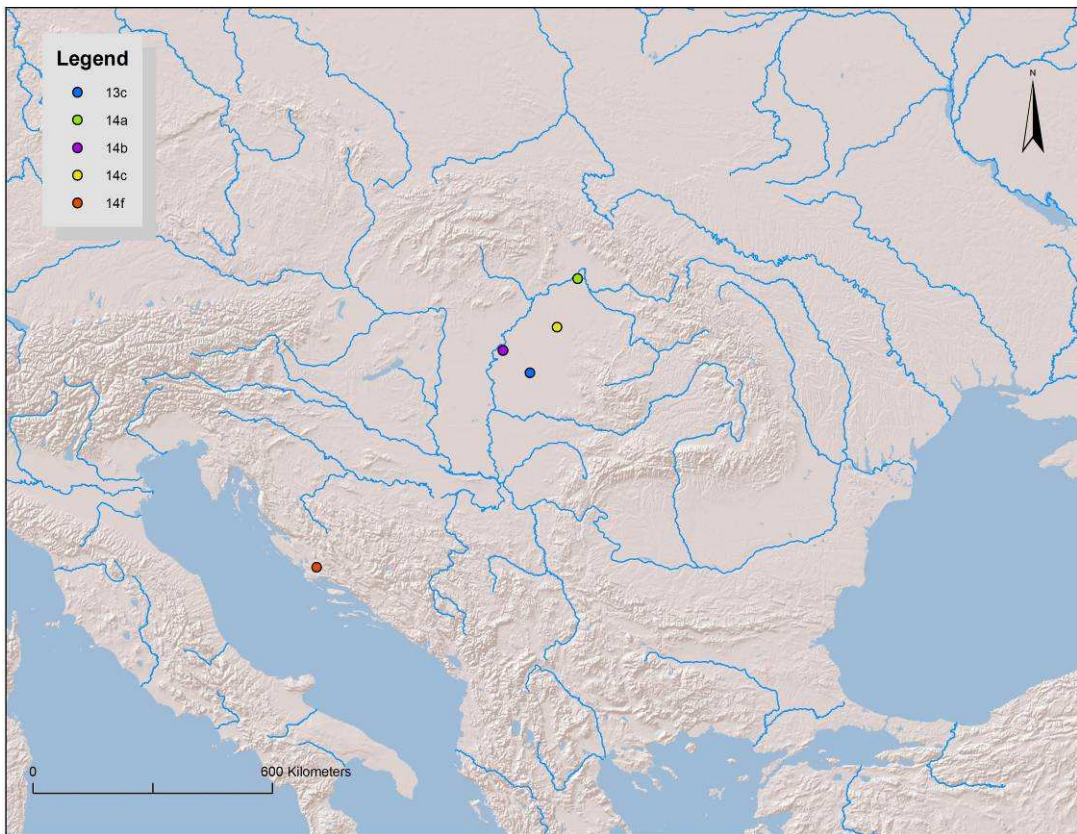
Map 51: Axe marks of code 9a and 12a



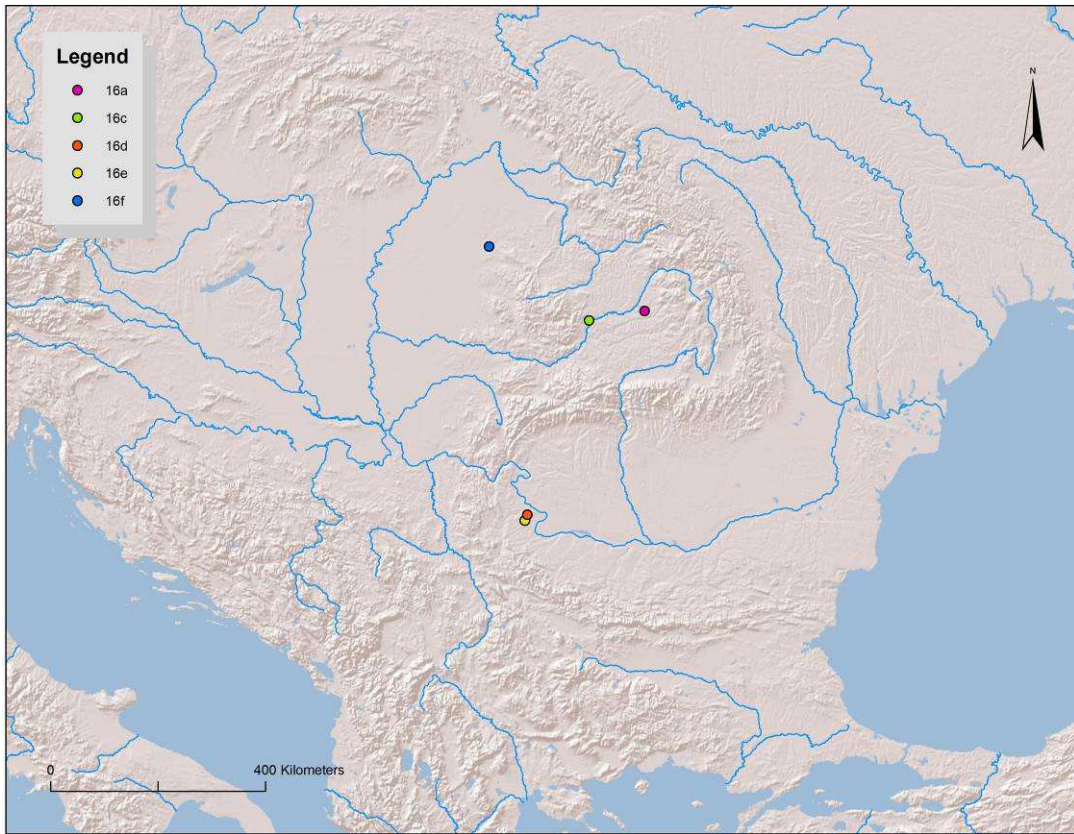
Map 52: Axe marks of code 10a, 10b and 10c



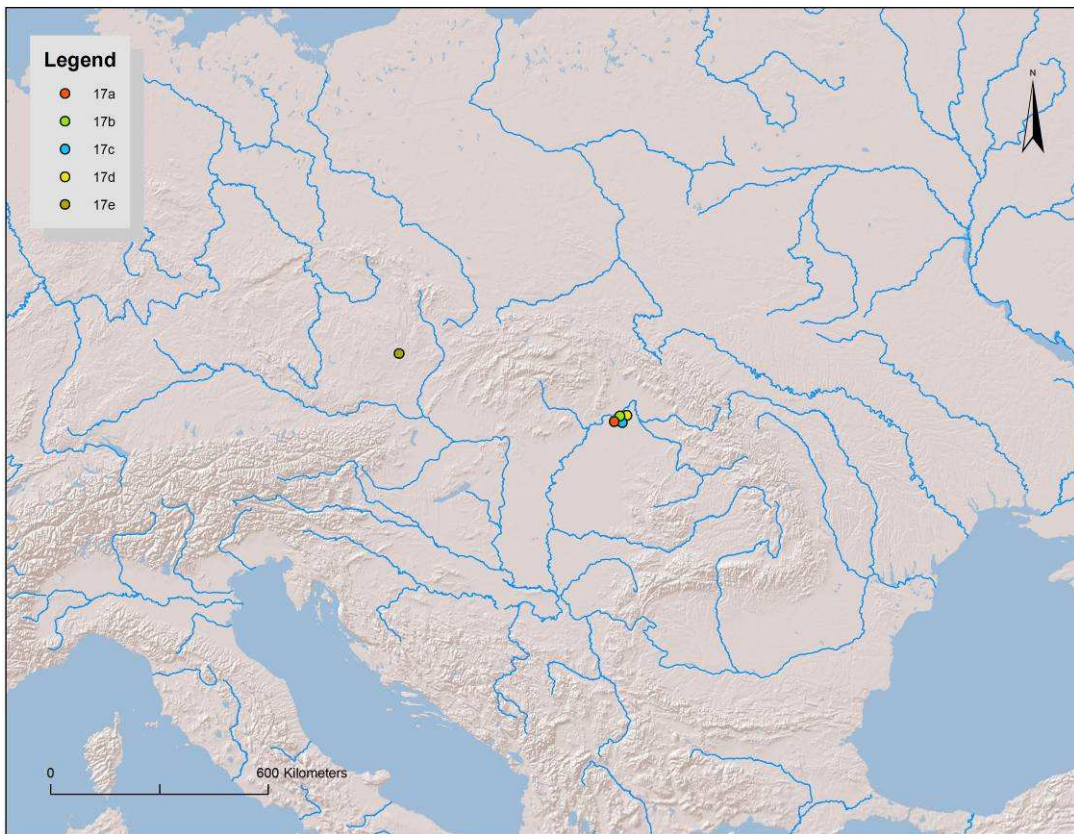
Map 53: Axe marks of code 11a, 11b and 11c



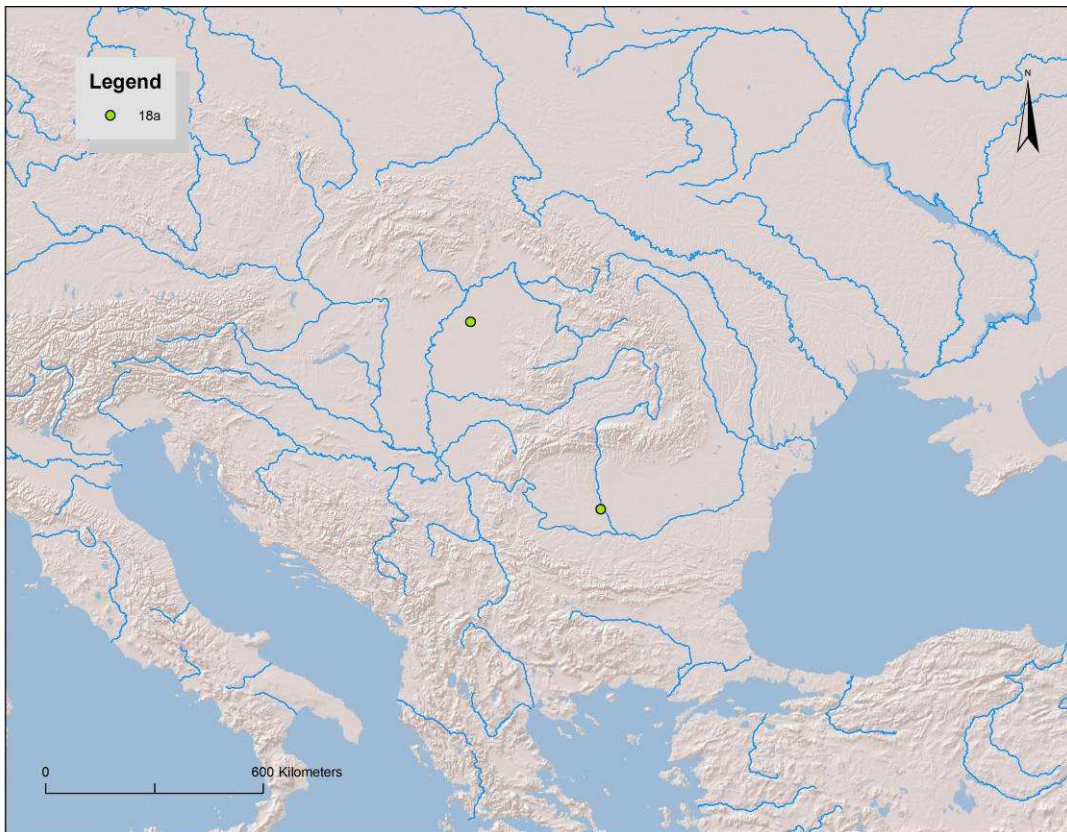
Map 54: Axe marks of code 13c, 14a, 14b, 14c and 14f



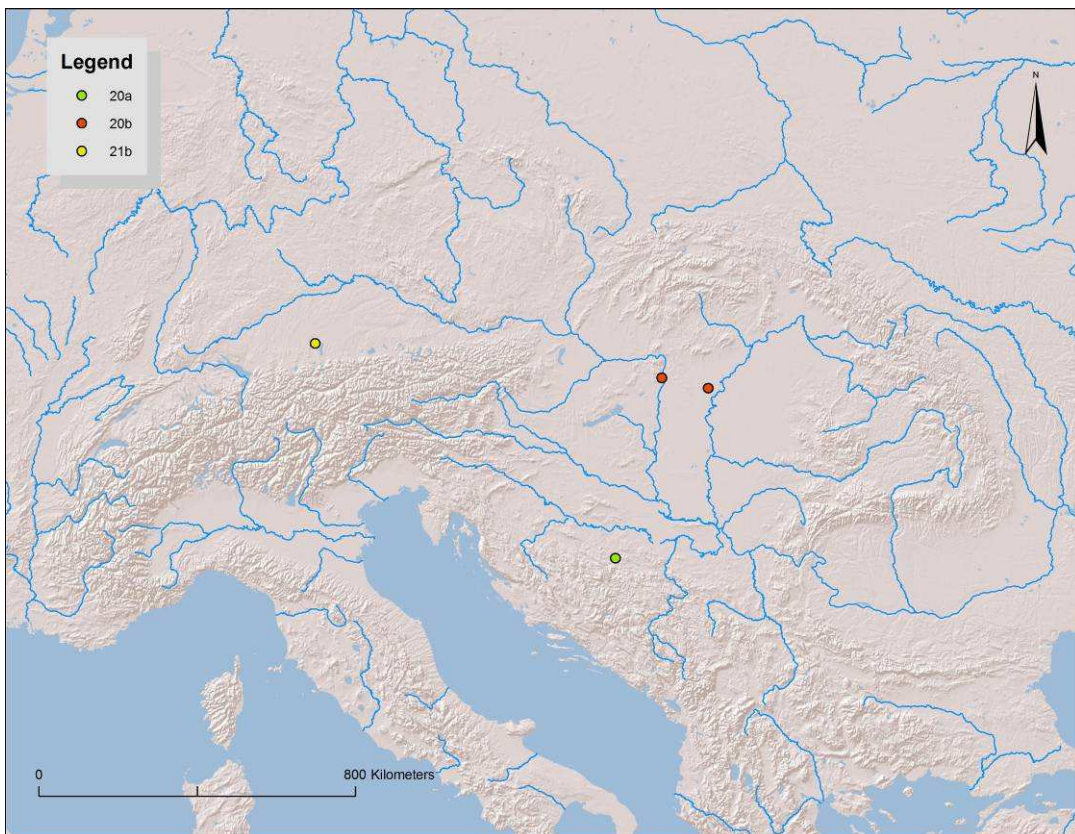
Map 55: Axe marks of code 16a, 16c, 16d, 16e and 16f



Map 56: Axe marks of code 17a, 17b, 17c, 17d and 17e



Map 57: Axe marks of code 18a



Map 58: Axe marks of code 20a, 20b and 21b

Appendix IV

Cluster distribution maps (from Krause 2003)



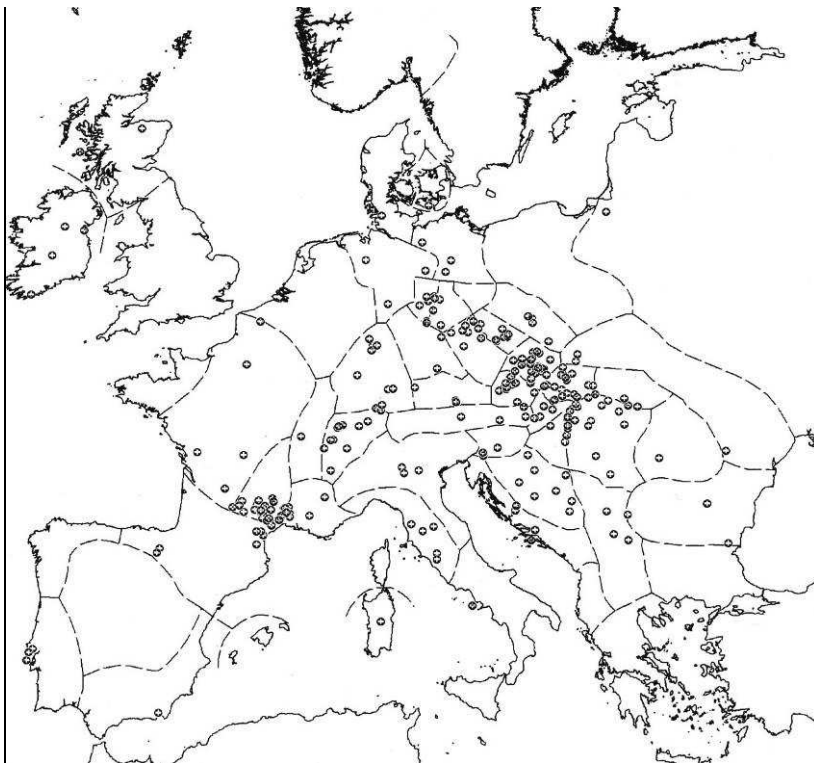
Map 1: Distribution of cluster 3 from Krause 2003, p.127, fig. 88



Map 2: Distribution of cluster 5 from Krause 2003, p, 125, fig 84



Map 3: Distribution of cluster 6 from Krause 2003, p. 128, fig. 89



Map 4: Distribution of cluster 7 from Krause 2003, p. 126, fig. 86

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