Proceedings of the 5th International Conference " Archaeometallurgy in Europe "

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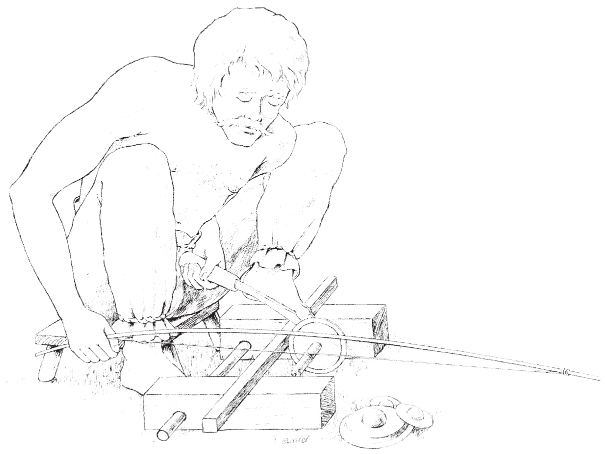

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Michel Feugère

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TABLE OF CONTENT

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Metallographic examination of nine medieval knives from Šepkovčica, Kobilić and Okuje (Republic of Croatia)

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Abstract

Archaeological excavations of the remains of medieval rural settlements conducted in 2006-2010 in Šepkovčica, Kobilić 1 and Okuje (Turopolje region, Zagreb County, Republic of Croatia) yielded in total 88 knives or knife fragments dated to the 11^{th}-14^{th} century. All these artefacts have been investigated by X-radiography and a total of 11 pieces were selected for metallography. Two of these eleven knives have already been analysed and published, revealing the first pattern-welded knife reported among Croatian archaeological finds (Thiele et al. 2017). The other nine knives were analysed for this study and are published here.

The metallographic investigations suggested that three of those nine knife blades show a forge-welded construction deliberately combining iron and steel although none of these was pattern-welded. The remaining blades appear to have been made from a single piece of metal: in particular three blades were found to be iron whereas four were made of steel. All the blades containing steel were hardened by quenching. One of the iron knives was made entirely of phosphoric iron; such blades are reported very rarely. The construction of one of the nine blades (PN_558) is still uncertain. Of the 11 knife blades examined overall (nine here and two previously) only one was found to be pattern-welded and this was one of the two already published. Also, none of the blades had any surviving evidence of inlayed non-ferrous decoration, although three of them bore (punched) maker's marks.

The proportion of good-quality knives, the fact that quenching of blades containing steel was standard, and the relatively high proportion of blades made entirely of steel, might suggest that knives used in the region of Turopolje were predominantly of simple but good quality construction. High-status blades, on the other hand, seem to have been rather rare in the Turopolje region and the single pattern-welded knife was more likely imported than locally produced.

Metallographic examination of nine medieval knives from Šepkovčica, Kobilić and Okuje (Republic of Croatia)

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Jiří Hošek
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Márk Haramza

Introduction

In comparison with medieval short-bladed tools and weapons, there are fewer published studies of medieval knives. This can be explained by their often poor condition, which limits the opportunities for investigations (Cowgill et al. 1987, 78-115; Holl 1994-1995, 159). Fortunately, the progress of archaeometallurgy makes it possible to examine the technological aspects of iron artefacts. Different modes of use led to different knife-types, and in the times of the guilds specialization and the division of labour had speeded up, intensifying the development of quality. As a result, we can distinguish blade-smiths, knife-grinders, and the hilt/grip makers who finished the overall production.

Historical background

The knives that are the focus of this analysis were discovered during the archaeological excavations of medieval rural settlement remains at three sites in the Turopolje region. These sites are Šepkovčica, Kobilić 1 and Okuje. All three sites were excavated as part of archaeological rescue excavations in the period 2006-2010; Šepkovčica and Okuje on the route of the Zagreb-Sisak highway and Kobilić on the route of the Velika Gorica by-pass. The site at Šepkovčica was excavated in 2006-2008 by the Zagreb City Museum. The site at Okuje was excavated in 2008-2009 by Zagreb City Museum and the archaeological company Kaducejd.o.o., and that company also excavated the site at Kobilić in 2010.

The Turopolje region is situated in Zagreb County, south of the city of Zagreb; between the

Sava River at its northern and eastern border and the hilly region of Vukomeričke Gorice to the south. This area covers approximately 600 square kilometres. All three sites were set in the Turopolje plain, the so called Polje (the Field); they are relatively close to each other, forming a triangle of approximately 15 km² (cf. Fig. 1.). The knives came from pits dating from the 11th to the 16th century.

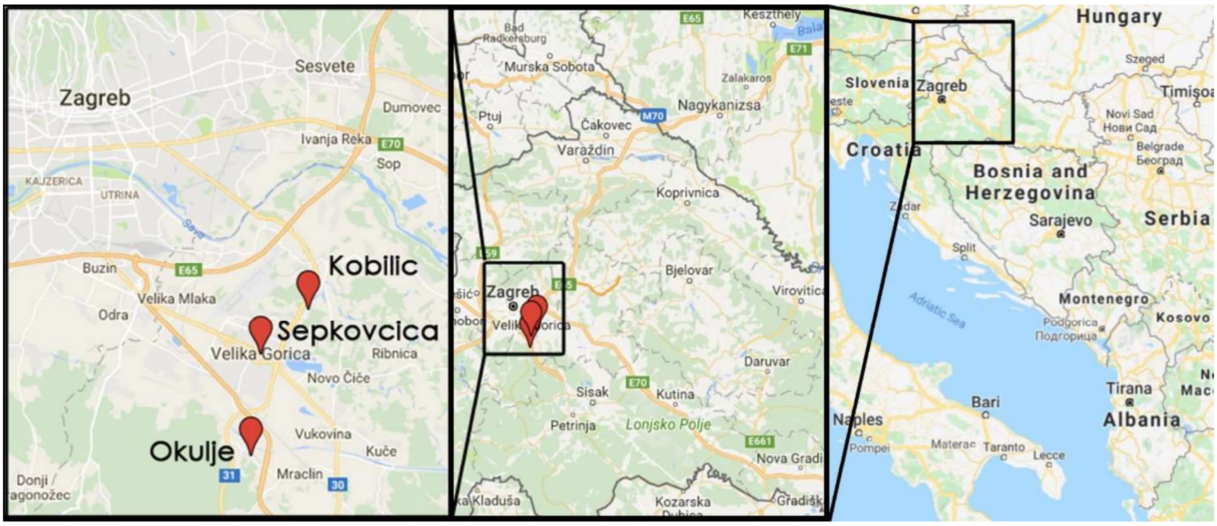

Fig.1: The archaeological sites of Šepkovčica, Kobilić 1 and Okuje.

The scarce written sources do not tell us much about northern Croatia (medieval Slavonia) in general and even less about the Turopolje region in particular prior to the 13th century. The picture is starting to be filled out lately by the data gained through archaeological research.

During the reign of the Croatian King Tomislav, in the first quarter of the 10th century, southern Croatia (Dalmatia) and northern Croatia (Slavonia) were connected as one kingdom for the first time. This connection continued under his successors, but the exact borders of the land ruled by Croatian kings are not known, nor do we have any detailed information about the sort of territorial organization established in the northern part. At the end of the 11th century, Turopolje, like the rest of Slavonia, became part of the Kingdom of Hungary-Croatia, due to the Slavonian campaign of the Hungarian king Saint Ladislaus (1091), and the Croatian enthronement of his cousin, Coloman the Learned (1102) (Kristó 2002, 40-44). More details about this part of Croatian history in the early Middle Ages can be found elsewhere (Klaić 1975; Budak 1994).

From the 13th century on, the history of the area is well known due to the abundance of the extant written sources. In the high and late medieval period, this Field of Zagreb (as it called in the sources) was a densely inhabited rural area with a complex settlement network of villages and estates belonging to different owners. The majority of the noble population were castle-warriors (iobagiones castri), commoners elevated by the king to the rank of petty nobles who owned land hereditarily in return for military service. Besides the villages held by them, there were also the estates of the gentry and high nobility, the bishopric of Zagreb, the Hospitallers etc. (For an overview of the historiography of Turopolje in the high and late middle ages cf. Antonić and Rácz 2017, 256.) Naturally all these estates were inhabited by the serfs and tenant-peasants who worked on them.

Archaeological background

The site at Okuje, on the eastern edge of the present-day village of Okuje, is the biggest medieval settlement excavated in the Turopolje region so far. It was set on three small hills separated by streams. The total excavated area, covering the route of the highway, was 8 hectares (although after extensive field-walking, the total area of the site was estimated to be 15 to 20 hectares). The features found here range in date from the 10th to 17th century.

Work on the abundant material from this site is still in progress. However, what can be said at this stage of research is that different sorts of activities took place in this area through this period; there was indirect evidence of pottery production in the 13th century as well as remains of pottery workshops from the 14th century, dwelling units (16th/17th century) etc. Also, the historical background of the site is very complex. It was not a village of the castle-warriors of Turopolje, but part of a nobleman's estate that can be clearly traced in documents starting in the 15th century. In 1652 it became a property of the Order of Saint Clare of Zagreb (Antonić 2019).

The site at Šepkovčica was set in a separate taxable land holding (cadastre parcel) between the present-day villages of Donja Lomnica and Gradići. The remains of the medieval horizon of the site spread over an area of 1.5 hectares within the strip affected by the new highway. In the investigated area, 823 different features were defined. The date range of the features extended from the 9th/10th to the 15th century.

The site could be divided into two parts, on either side of the old river bed. The majority of the features were found on the southern part of the site. These were remains of settlement features, mostly postholes but also pits of various shapes and sizes, ovens, and fireplaces. They were interpreted as the remains of dwelling units and workshops dating from the 9th/10th to the 13th century. So, across an area of some 7000 m² (0.7 hectares), features created over a few centuries lay densely packed. This is one of the biggest settlements of the Bijelo Brdo culture so far discovered (Bugar 2008, 179-193).

The site on the other side of the stream was smaller, around 3500 m² (0.35 hectares), and the features were less dense. Here, along with some early medieval pits, two wells (13th/14th and 14th/15th century), and ditches and pits dated to 14th and 15th century were found. At that time this was on the edge of Donja Lomnica, one of the most important villages of the castle-warriors of the Turopolje region (Bugar 2011, 161-178; Antonić 2015, 211-228).

The site of Kobilić 1 is on the western edge of the present-day village of Kobilić. Far fewer features were discovered in the medieval levels at this site than at the two above mentioned sites: only 41 features. They can be interpreted as the remains of a working zone on the edge of a village or a smaller private estate. The features were dated broadly to the 13th century. The sparse extant written sources from that period did not allow any conclusion as to the owner of this estate or settlement. It is natural to assume that this belonged to the castle-warriors of Turopolje in the 13th century as it did in the 15th century, but other options remain open (Antonić and Rácz 2017, 256-260).

Despite the small number of features uncovered, this site is important because the highest status knives that have been discovered in the region were found here. These are a pattern-welded knife and an all-steel knife that have already been subjected to analysis (Thiele et al. 2017).

In general, it can be said that the features found at these sites (mainly postholes, pits, fireplaces, ovens and wells) are the remains of both above ground and below ground structures. They were made of wood which was the main building material in medieval Turopolje (especially oak). From both the written sources and the old military survey it is clear that dense woodland covered the area in the past, surrounding the medieval villages. Along with that, there were lots of streams and swamps; this changed only in the 20th century with water management projects. Old stream beds were found on all three sites.

The features are mostly the usual ones found in village excavations. However, as already stated, the Turopolje area was a complex patchwork of villages and estates owned and run in different ways. How the social diversity of the rural settlements of Turopolje was reflected in material remains found by archaeology is an important question for further research. Another important question is the one of local production of metal items. Thus far no workshop that could be dated to the medieval period has been discovered. However, pieces of slag that were occasionally found in pits in Okuje and Šepkovčica point to smithing and hence production here. To both of these questions the analysis reported here can significantly contribute.

Aims and questions

Previous analysis of two knives from Kobilić 1 revealed the first pattern-welded knife reported among Croatian archaeological finds (Thiele et al. 2017). This singular artefact encouraged us to analyse more knives from the archaeological excavations of Kobilić 1, Okuje and Šepkovčica. There was the hope of finding some more pattern-welded or other high status/ decorative blades. Also, what was the general quality of the rural knives used in the region of Turopolje? Were they made of iron or steel, or with a composite forge-welded construction? Traces of heat treatments were also sought.

Investigation of the knives

86 knives and fragments thereof from these three sites were investigated by X-radiography and then nine were selected for metallography (see Tab. 1).

X-radiography

Šepkovčica

In total, 22 knives or their fragments from Šepkovčica, dating from the 9th to 14th centuries, were X-rayed. None of the pieces showed a maker's mark or pattern-welding. In 13 cases a whittle tang (a short, pointed tang of the blade friction fitted into the handle) was revealed (PN_: 109, 112, 141, 144, 235, 238, 256, 258, 353, 357, 359, 372, and 403). There was no reliable evidence for knives with scale tangs (where the handle is riveted to a wide, long tang of the blade from both sides).
Perhaps misleadingly the X-ray image of PN_113revealed four rivet-like holes (see the holes in areas 'A' in Fig. 2a). However, the edge 'B' of the piece looks on the X-ray image rather like the back of a blade and the edge 'C' like a cutting edge; in which case the part in question would not be a scale tang and the holes would be just a result of corrosion. Although we cannot say for certain which alternative is correct, the piece is more likely to be a blade fragment because its overall shape is more consistent with this.

Kobilić 1

Only one knife, a 13th century blade from Kobilić (PN_358), was included in the set investigated here. The blade bears the remains of three identical marks (see Fig. 2b). As already said, two other knives from this site (PN_51, a long war knife, and PN_52, a pattern-welded whittle-tang knife) had been examined and published beforehand (Thiele et al. 2017).

Okuje

Finally, X-ray images of 63 knives or knife fragments from Okuje were taken. These finds date from the 13th to 16th/17th centuries. Out of these, 16 pieces were provided with a whittle tang (PN_: 32, 84, 181, 309, 408, 439, 459, 490, 496, 502, 519, 558, 560, 660, 682, 702), and 12 with a scale tang (PN_: 26, 308, 432, 458, 515, 522, 534, 539, 540, 678, 706, 716). In the rest of the set, tangs were missing or could not be determined.

Although both types of tangs have been recorded in the period given (13th to 16th/17th century), there is a clear tendency for older finds to have whittle tangs and younger ones scale tangs. The 14th century fragment PN_308 is a scale tang, but considering its dimensions and the arrangement of rivets, the tang could also come from a dussack (a form of cutlass or sabre used in Central Europe). Two 16th/17th century pieces (PN_540 and PN_534) were obviously provided with shoulder plates (see Fig. 2c and 2d).

In only two cases was a maker's mark found. The knife blade PN_660 shows a single mark (see Fig. 2e), which is similar to those seen on blade PN_358 from Kobilić 1 (cf. Fig. 2b). The blade of knife PN_520 bears a set of five triangular and rhombic imprints, which were obviously made intentionally (see Fig. 2f).
Neither pattern-welding nor non-ferrous inlays were found; only one blade (PN_558) was provided with a shallow groove originally running along one side of the back extending at least half way down the blade.

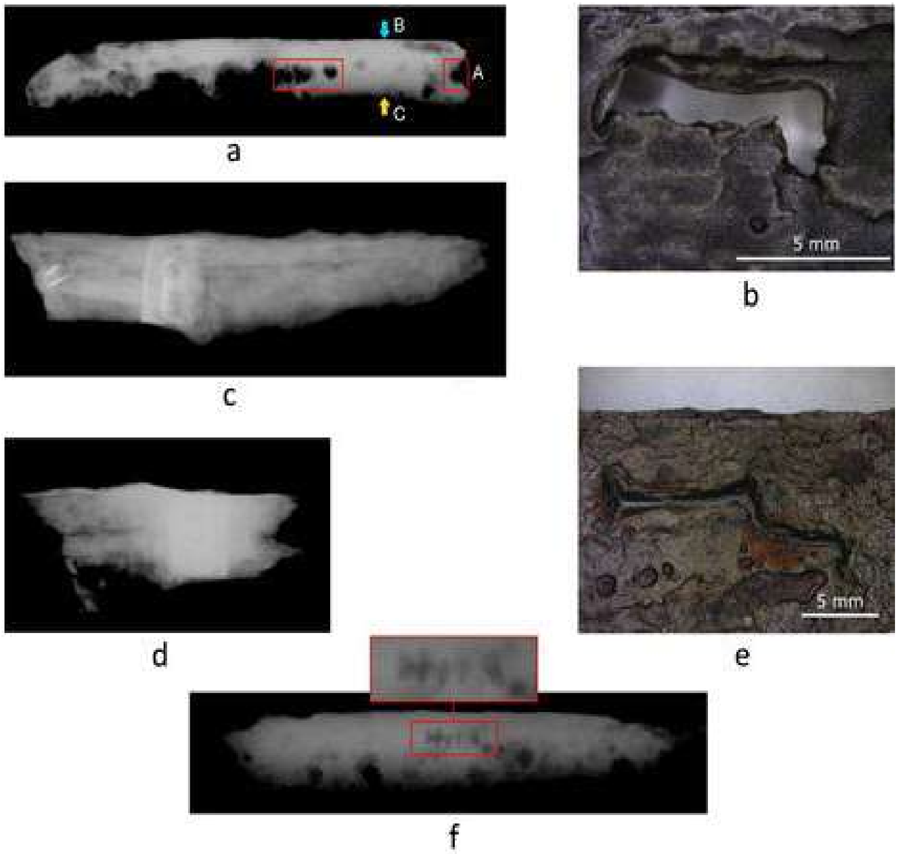

Fig. 2: a) Possible rivet holes on an X-ray image of knife PN_113, b) Maker's mark on a stereo microscope image of knife PN_358, c) Shoulder plates on an X-ray image of knife PN 540, d) Shoulder plates on an X-ray image of knife PN 534, e) Maker's mark on a stereo microscope image of knife PN_660, f) A set of five triangular and rhombic imprints on an X-ray image of knife PN_520.

Metallography

Due to the poor condition of the objects a total of only nine knives was examined metallographically (see Tab. 1 for the dimensions and basic archaeological data on these items).

Samples for this purpose were taken from the objects using a precision cutter (Buehler IsoMet 1000) to avoid overheating. The samples were prepared for metallographic examination using standard procedures. Afterwards they were assessed in a non-etched state (to assess the purity of the metal), and then after etching with 2% Nital (to assess the nature and distribution of the metallographic structures) and Oberhoffer's etchant (to reveal the phosphorus rich iron layers and forge-welding lines). The slag inclusions in the metal were evaluated using the Jernkontoret scale (Js), and the slag content of the surface examined was also assessed in %. Grain size was estimated using the ASTM E112 standard. The Vickers hardness was measured using a Buehler 1105 micro Vickers hardness tester with a load of 0.2 kg and a loading time of 10 seconds.

In the illustrations of the knives examined (Figs. 3-11) the small pictures at the top are the X-ray image of each knife and a picture showing the sampling. The small images that follow show the details revealed in section after sampling. For each sample in turn, those show, from left to right:

- A macro photo of the cross-section in unetched state;
- A macro photo of the cross-section after etching with 2% Nital;
- A macro photo of the cross-section after etching with Oberhoffer's etchant;
- The distribution of the structures and of the main welds across the cross-section;
- The layout of areas described;
- The Vickers micro-hardness distribution chart.

Knife PN_109, Šepkovčica, 11th century (Fig. 3): the blade was made of a single piece of mostly phosphoric iron (SEM-EDS analysis showed 0.8-1.1wt% phosphorus content in Areas I and III and 0.5-0.6wt% phosphorus in Areas II and IV). Although the hardness of the cutting edge corresponds to that of non-hardened eutectoid steel, the blade suffers from brittleness. Therefore, it was designed for non-demanding use only.

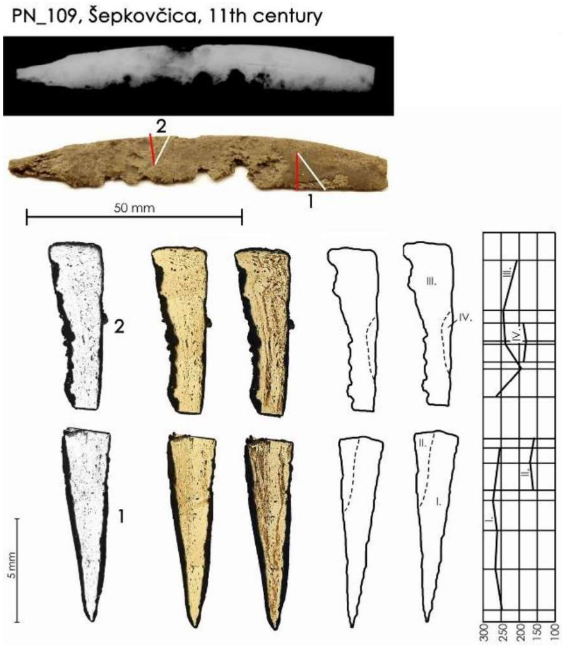

Fig. 3: Metallographic examination of the samples taken from the PN_109.

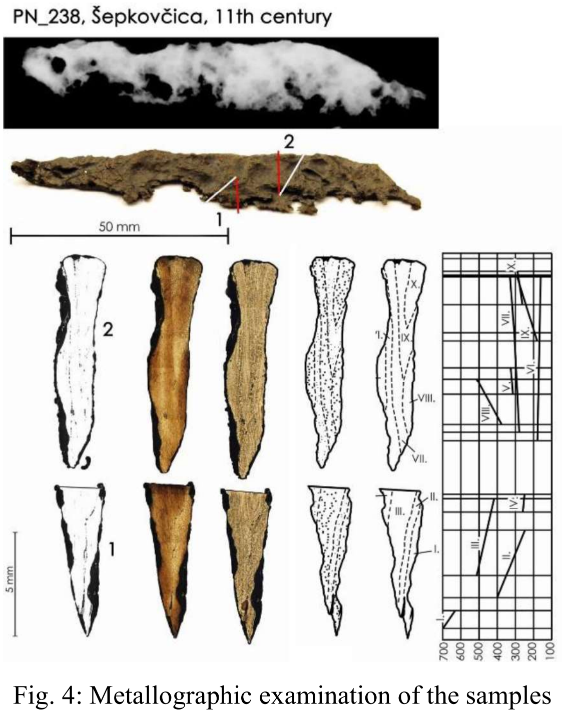

Fig. 4: Metallographic examination of the samples taken from PN_238.

Knife PN_238, Šepkovčica, 11th century (Fig. 4): this non-pattern-welded blade has a banded structure in which areas of high and low carbon content alternate with each other. It has a very heterogeneous microstructure but forge-welding lines cannot be observed between the areas of different microstructures. The bloomery steel out of which the blade was made was homogenised by repeated folding and forge welding. The carbon content in the tip is sufficient for quenching, and the whole blade (not only the cutting edge) was quenched and perhaps tempered at a low temperature (ca. 200°C). This blade is a good quality product.

Knife PN_353, Šepkovčica, 14th century (Fig. 5): the blade has a very heterogeneous microstructure, and a number of forge-welding lines can be observed between as well as inside individual areas of different microstructure. The bloomery steel used for the cutting edge of the blade was probably homogenised by repeated folding and forge welding. The middle part of the blade was made of iron which is forge-welded to the cutting edge and to the back of the blade. The lower part of the back was made of steel to which the upper part of iron is welded. The carbon content in the tip is sufficient for quenching. The whole blade (not only the cutting edge) was quenched but probably not tempered. This blade is another good-quality product.

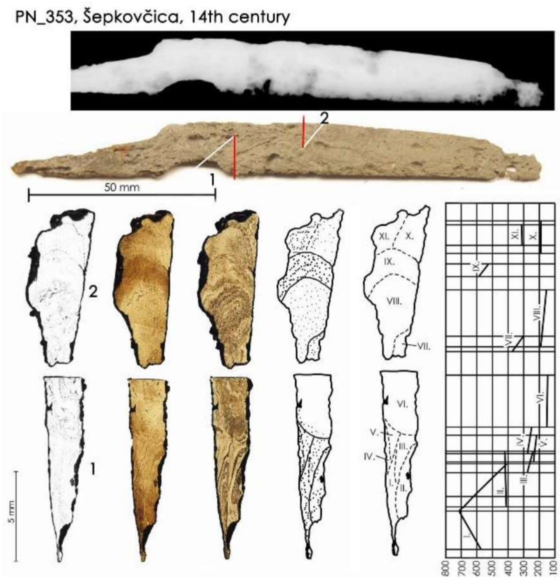

Fig. 5: Metallographic examination of the samples taken from PN_353.

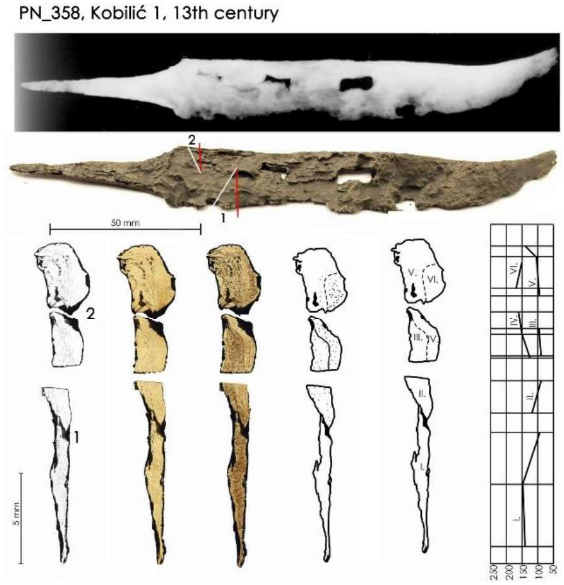

Fig. 6: Metallographic examination of the samples taken from PN_358.

Knife PN_358, Kobilić 1, 13th century (Fig. 6): the whole blade was forged from a single piece of iron, though some welding lines appear in the cross-section. The carbon content of the cutting edge is not high enough for quenching to have any effect. However, the microstructure of Area VI implies that the cooling rate was low. The blade has a very soft cutting edge and corresponds to a simple, low-quality product. Near the back (towards the top in Fig. 6) is the indentation visible evidence for the punching of a mark from one side of the blade.

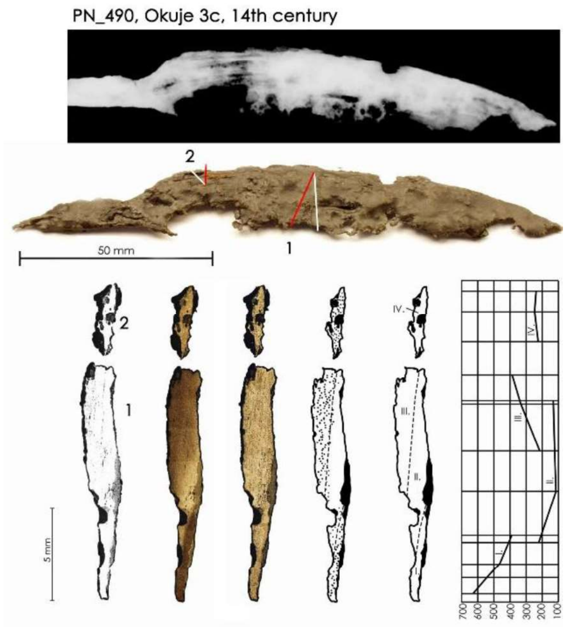

Fig. 7: Metallographic examination of the samples taken from PN_490.

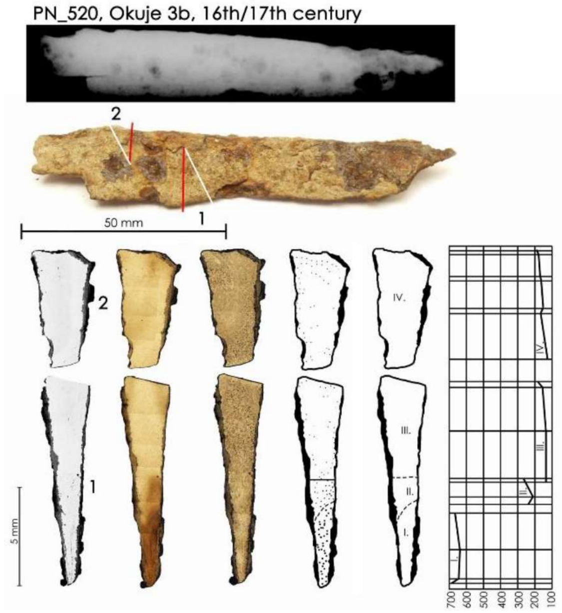

Fig. 8: Metallographic examination of the samples taken from PN_520.

Knife PN_490, Okuje 3c, 14th century (Fig. 7): this blade was probably forged from a single heterogeneous piece of steel. No forge-welding lines were detected in the cross-section. Only the cutting edge of the blade was quenched; and although no traces of tempering were visible low-temperature tempering may have been carried out. This blade is a good-quality specimen.

Knife PN_520, Okuje 3b, 16th/17th century (Fig. 8): this blade has a cutting edge of steel and a back of iron. These were welded to each other; evidence of this being the faint forge-welding line visible between Areas I and II when etched with Oberhoffer's reagent. The whole blade was quenched but no traces of subsequent tempering were detected. This blade has the best mechanical properties among the knives examined in this study. It is a very good-quality product.

Knife PN_558, Okuje 3c, 13th/14th century (Fig. 9): the blade has an unusual structure because the present cutting edge is iron and the back was made of steel. The back near the tang shows a very heterogeneous microstructure and it was probably forge-welded from three or four individual pieces of metal. In contrast the back, further down, is also steel but appears more homogeneous (see the top of sample No. 2). The whole blade was quenched, but only the back of the blade became very hard; the cutting edge remained soft because it was almost carbon-free. As such the blade would have been ineffective because while the back was hardened the cutting edge was soft and easy to blunt.

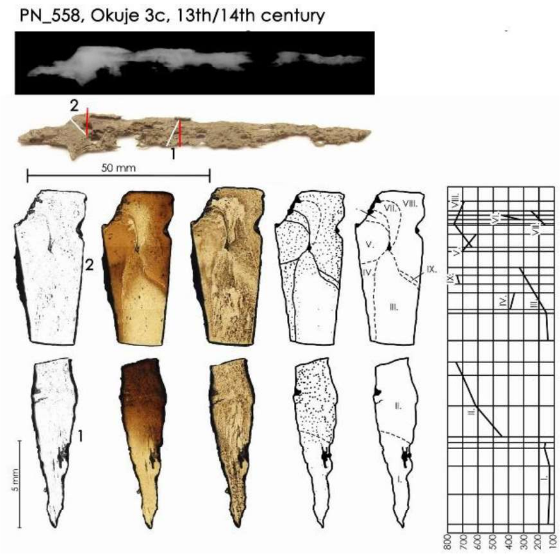

Fig. 9: Metallographic examination of the samples taken from PN_558.

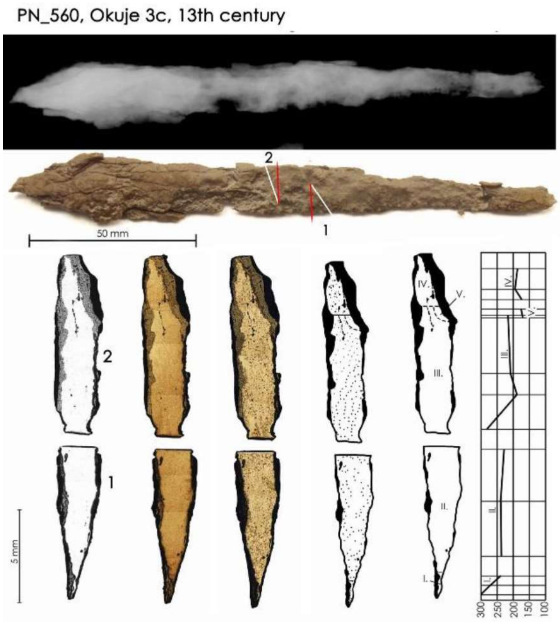

Fig. 10: Metallographic examination of the samples taken from PN_560.

Knife PN_560, Okuje 3c, 13th century (Fig. 10): the blade is homogeneous in structure corresponding to low carbon steel. Only the cutting edge was subjected to quenching followed by tempering. The cutting edge that survives is less hard (approx.300 HV0.2), and it is difficult to determine whether the blade was originally provided with a harder and perhaps welded-on part to the edge or not. Hence the blade was originally of medium to excellent quality.

Knife PN_660, Okuje 3c, 14th century (Fig. 11): this blade was forged from a rather homogeneous piece of iron, and was not quenched. The tip of the cutting edge is soft, and the blade is likely to be a simple, low quality product in terms of effectiveness.

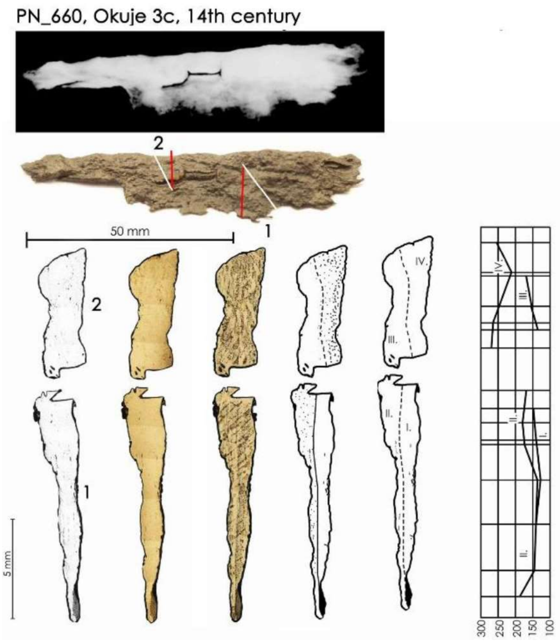

Fig. 11: Metallographic examination of the samples taken from PN_660.

Discussion

Nine knives dating from the 11th to the 16th/17th centuries have been examined metallographically for this study. Figure 12 gives schematic cross-sections of all those knives and the two knives from Kobilić 1 investigated earlier (Thiele et al. 2017).

From the site of Šepkovčica we have two 11th century knives, one (PN_109) made entirely of phosphoric iron, the other (PN_238) made entirely of layered (piled) steel, and one 14th century knife (PN_353) made in the construction scheme 'cutting edge (steel)/centre (iron)/back (steel-iron)'. Both knives with steel in their edge were hardened by quenching.

Five of the knives came from the site of Okuje_3c. The 13th century knife PN_560 is a single piece of steel. The 14th century knife PN_660 is made from a single piece of iron. Another 14th century knife (PN_490) is a single piece varying between steel and iron.

The blade of the 13th/14th century knife PN_558 seems to be heavily worn through long use, therefore we cannot determine its original construction reliably (cf. Kolčin 1959, 54; Terekhova et al. 1997, 41; Blakelock 2012a, 65-66, 247-249). In its present state the blade has a soft cutting edge of iron, but we do not know whether it once had a good-quality cutting edge of steel that has worn off. However, considering the very high hardness of the steel back and the extent of wear, the original (harder) cutting edge may have been lost. But the blade does not show any intentional construction scheme, and it is quite possible also that it was simply made from a single piece (or pieces) of metal varying between iron and steel.

The fifth blade, a 16th/17th century knife (PN_520), was made in the construction scheme 'cutting edge (steel)/back (iron)'. All the blades from Okuje containing steel were hardened by quenching.

Lastly, the 13th century knife from the site of Kobilić 1 (PN_358) consisted of a single piece of iron.

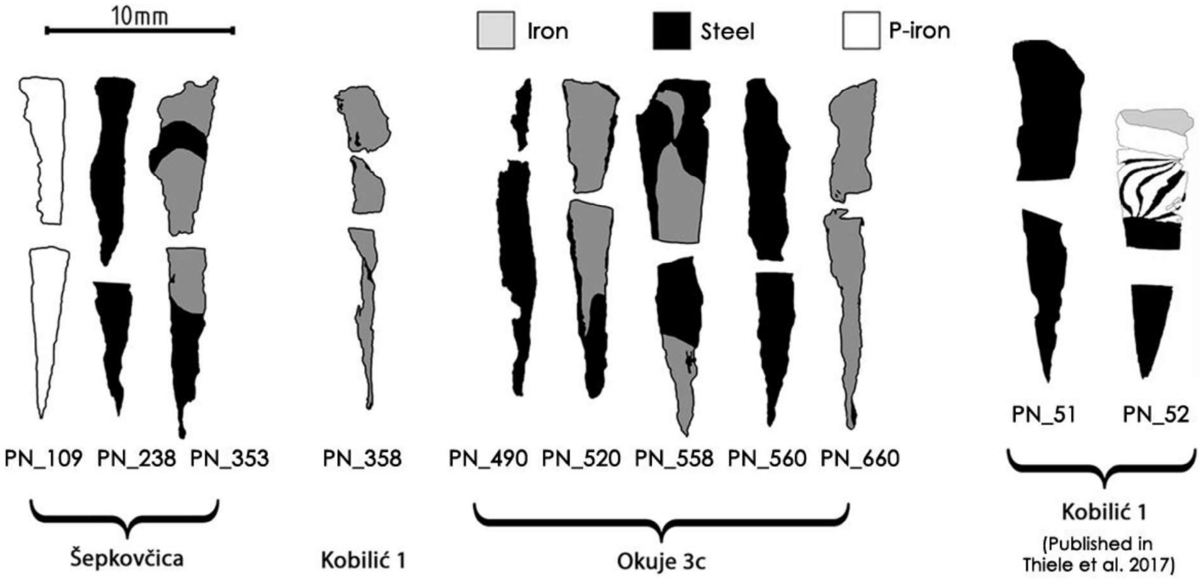

Fig 12: Schematic cross-sections of the knives examined metallographically for this study and the two other knives from Kobilić 1 which were examined and published earlier (Thiele et al. 2017).

We can add to the set of knives examined for this study the two other knives from Kobilić 1 examined and published earlier (see the right side of Fig. 12). One of these knives (PN_51) was made from a single piece of steel, whereas the other (PN_52) was a composite blade made by welding a steel cutting edge to a pattern-welded back. The pattern-welded piece itself consisted of alternate phosphoric iron/iron laminations. Both these knives were hardened by quenching.

If we leave aside knife PN_558, whose construction was not determined reliably, and knife PN_520, which is from the 16th/17thcentury, we have a set of nine knives, which gives us a first (though as yet still preliminary) view of 11th to 14th century knife making in the region of Turopolje.

We can see that only two out of the nine examples show a forge-welded construction deliberately combining iron and steel. The other blades were most likely made from a single piece of metal; in particular, three blades are iron and four were made of steel or material varying between iron and steel. That is perhaps surprising, given the summary data available for knife-making techniques from the Czech Republic (for 9th to 14th century knives: Boháčová and Hošek 2009; Hošek 2006; Hošek and Ottenwelter 2010; 2012; Hošek et al. 2009; Pleiner 1979; 1982; 1993 etc.), Great Britain (for the 9th to 12th century knives: Blakelock

2012b, Tab. 2.12) and medieval Russia (for the 9th to 13th century knives: Terekhova et al. 1997, 265-295).

From those studies, we would expect to find in the Turopolje region, for every five to seven iron/steel welded blades, just one blade made of a single iron piece, and only one or two blades made of a single piece of steel or of material varying between steel and iron.

X-radiography revealed that none of the blades analysed for this paper was pattern-welded or provided with preserved non-ferrous decoration. This would suggest that knives with high status blades were rather rare in the Turopolje region.

Three blades bear maker's marks but without any trace of non-ferrous metal inlay. In general, maker's marks are common for knives from the 14th century onwards, often using metal inlay. Due to the poor state of preservation, we cannot tell whether there were originally any inlays in the case of our knives, or if the marks were just punched. Blades PN_660 from Okuje and PN_358 from Kobilić have marks which seem to be almost identical in form; but it is difficult to determine whether or how they might be related to each other. The motif of the marks is not entirely unique; for example, blades bearing more or less similar marks are known from London and from the Austrian and German region (Cowgill et al. 2003, 21; Holl 1994–1995, 166; Hack 1949; Bajc 2009, 192).

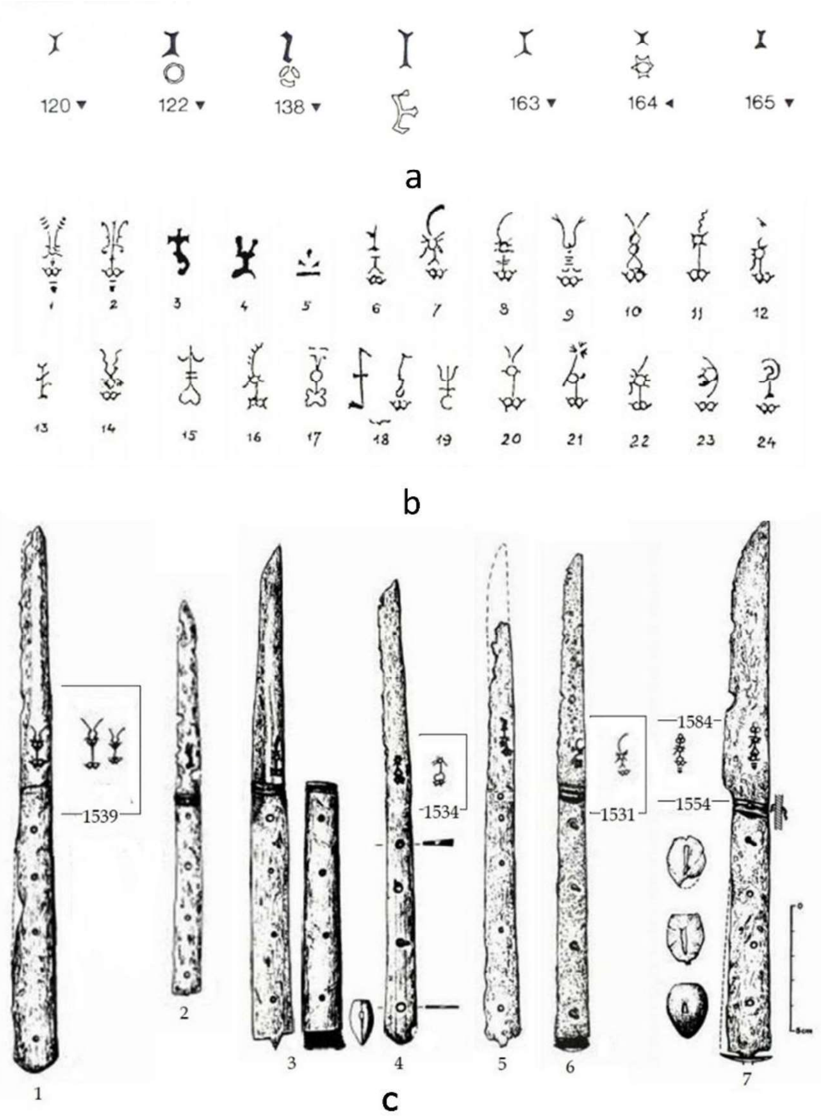

Fig. 13: a) Marks from London (Cowgill et al. 1987, 21), b) Marks from Steyr (Holl 1994–1995, 166: Fig 5), c) Steyr-knives from Hungary – 1: Vác, Szentháromság square; 2: Pomáz, kastély; 3: Hahót-Sárkányszeg; 4–5: Sarvaly; 6: Gyepükaján-Nagykeszi; 7: Nagykanizsa (after 1552) (Holl 1994–1995, 169–177: Fig. 7:3, 7; Fig. 9:2–3; Fig. 10:1; Fig. 12: 7; Fig. 14).

Unfortunately, given the small number of Turopolje knives analysed, we cannot draw any deeper conclusion about the apparent inconsistency with the knife-making techniques recorded in other parts of Europe. Furthermore, we know little how knife-making techniques practised in medieval urban centres might have differed from those in rural settlements. It has been suggested that late medieval knife-production had become an urban industry, and the privilege of burgesses (Holl 1994-1995, 229).

Also, we need more evidence of late medieval technological changes in iron-smithing practices in this region during this period. One major advance was the appearance of water-powered workshops (such as the workshop of the Cistercian monastery in Pilis, or that of the Pauline monastery in Klastrompuszta, cf. Benkő 2010, 693; see also Gerecvich 1985). These can be related to the re-settling of Bavarian and Saxon craftsmen, in the 13th and 14th centuries.

Of course, there are also the general problems associated with metallographic research into archaeological iron objects, such as the state of preservation of the objects studied and the (lack of) recognition of composite, forge-welded construction. For example, the percentage of all-iron blades is likely to be lower than generally assumed; Kolčin (1953, 81), for instance, pointed out that all-iron blades in general show a high degree of wear, thus there was the likelihood that an original harder (steely) part had not survived in most if not all cases. He doubted that all-iron blades were actually produced intentionally. By the same token, the proportion of forge-welded blades could be higher than expected.

But there is also the blade from Šepkovčica, PN_109, which was made entirely of phosphoric iron. Blades made of a single piece of phosphoric iron are reported rarely. Several pieces, dating mostly from the 9th to 13th centuries, come, for instance, from Flixborough, England (Starley 1999), Sieradz, Poland (Piaskowski 1962), Biskupin, Poland (Piaskowski 1966), Ostrov by Davle (Sekanka), Czech Republic (Pleiner 1982) and perhaps also from Coppergate, England (McDonnell 1992).

The blades from Coppergate that consisted solely of phosphoric iron were heavily worn and/or damaged by corrosion; therefore, it was not clear whether or not they had originally been provided with a now missing steel cutting edge.

One question is whether these knives were made intentionally from phosphoric iron; and another is whether they were considered good rather than of low quality given that phosphoric iron can be twice as hard as phosphorus free iron.

However, there is no clear evidence of the systematic use of phosphoric iron for its hardness. For instance, although metallography of finds from Biskupin revealed that some other tools (sickles, an awl) also consisted of phosphoric iron, its deliberate choice could not be confirmed. This is because phosphoric iron was also found in other objects, such as spurs, (Piaskowski 1966). Moreover, the hardness of phosphoric iron cannot compete with the hardness of quench-hardened steels. The brittleness of phosphoric iron can be a problem for long-bladed tools rather more than relatively short knife blades. Therefore, while knives made of phosphoric iron might have been better than blades of plain phosphorus-free iron, they should not be thought of as being of much better quality. Hence, the knife PN_109 from Šepkovčica is regarded simply as an average quality product.

The findings so far indicate that, in the region of Turopolje, knives were generally of good quality with steel standardly quenched and a relatively high proportion of simple (i.e. one-piece), all-steel blades. Even where the evidence is missing (because of corrosion or wear) it seems likely that many, if not most, of the rest consisted of composite iron/steel blades, thus still of relatively good quality. However, these are just preliminary conclusions, which must be refined by further research.

Conclusions

Leaving aside knife PN_558, whose construction was not determined reliably (and therefore is uncertain), and knife PN_520, which is from the 16th/17th century, we can see that only one out of the nine pieces shows a forge-welded construction deliberately combining iron and steel (PN_353), while the other blades were most likely made from a single piece of metal. In particular, three blades consisted of iron (PN_109, PN_358, PN_660) and three of steel (PN_ 238, PN_490, and PN_560). All the blades containing steel were hardened by quenching.

Knife PN_109 was made entirely of phosphoric iron, which is unusual as blades made of a single piece of phosphoric iron are rarely reported. However phosphoric iron can be twice as hard as phosphorus-free iron, but considering their brittleness phosphoric iron knife blades should perhaps not be classified as being of good quality.

The overall proportion of good-quality knives, the fact that the quenching of blades containing steel appears to have been carried out as standard in this region, and the relatively high proportion of blades made entirely of steel together suggests that knives used in the region of Turopolje were predominantly good quality though simply made products.

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#	Archaeological data					Dimensions				
Knife No.	Site	PN	Dating	SU	Feature	Total length (mm)	Blade length (mm)	Blade max. width (mm)	Blade max. thickness (mm)	Blade min. thickness (mm)
1	Šepkovčica	109	11th century	165/166	Pit	89	75	8	2.6	1.3
2	Šepkovčica	238	11th century	1222/1223	Pit	141	70	8	2.6	1.2
3	Šepkovčica	353	14th century	2167/2168	Pit	149	110	16	3.8	2
4	Kobilić 1	358	13th century	2761/2723	Pit	185	132	22	4.7	1.6
5	Okuje 3c	490	14th century?	5836/5837	Pit	148	102	19	3.2	2.8
6	Okuje 3b	520	16th/17th century	4835/4836	Pit	106	94	19	4.5	2.1
7	Okuje 3c	558	13/14th century	4693/4694	Ditch	100	81	10	3.2	1.3
8	Okuje 3c	560	13th century	4761/4762	Pit	170	103	21	7	2.4
9	Okuje 3c	660	14th century	5801/5802	Pit	87	52	8	3	1.5

Table 1: Basic data on the knives examined.

Sample	Metal purity Jernkontoret scale/slag %	Microstructures of the different Areas on the metallographoc cross sections										
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI
109/1	Js 3 / 5,9%	F	F	F	F							
109/2	Js 4 / 7,2%	ASTM 4	ASTM 7	ASTM 4	ASTM 7							
238/1	Js 1 / 2,8%	M (t)	F + B	M (t)	F + B	F + B	F + B	F + B	M (t)	F + B	M (t) + F	
238/2	Js 2 / 4,1%		ASTM 6		ASTM 6	ASTM 6	ASTM 7	ASTM 6		ASTM 7	ASTM 9	
353/1	Js 2 / 4,3%	M	M	F + P	F + P	F + P	F	F + B	F + B	M + B	F	M + B + F
353/2	Js 2 / 4,4%			ASTM 8	ASTM 8	ASTM 8	ASTM 6	ASTM 8	ASTM 8		ASTM 6	
358/1	Js 4 / 6,9%	F	F + P	F + P	Wid. F + P	F	Wid. F + P					
358/2	Js 5 / 8,7%	ASTM 5-8	ASTM 6	ASTM 6	ASTM 3-7	ASTM 3	ASTM 6					
490/1	Js 3 / 5,1%	M	F	F + B	P + c							
490/2	Js 1 / 2,9%		ASTM 9	ASTM 10	ASTM 5							
520/1	Js 1 / 1,9%	M	F + B	F	M + F							
520/2	Js 1 / 1,7%		ASTM 8	ASTM 7	ASTM 9							
558/1	Js 2 / 3,9%	F	M	F	M + B	M + B	M + F	F + P + B	M	M		
558/2	Js 2 / 4,3%	ASTM 5		ASTM 6								
560/1	Js 2 / 3,7%	M (t)	M (t)	F + P	F + P	F + P						
560/2	Js 2 / 4,1%			ASTM 5	ASTM 5	ASTM 9						
660/1	Js 1 / 2,7%	F	F + P	F + P	Wid. F + P							
660/2	Js 2 / 3,2%	ASTM 5	ASTM 8	ASTM 8	ASTM 5							

Table 2: Metal purity and microstructures of the different areas on the metallographic cross-sections of the samples taken from the knives. Abbreviations: F = ferrite, P = pearlite, B = bainite, M = martensite, M(t) = tempered martensite. Below the microstructure ASTM numbers are given (if it was possible to measure).

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