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METALLOGRAPHIC ANALYSES OF MILITARY ITEMS FROM THE EARLY MEDIEVAL INHUMATION CEMETERY IN RADOM, SITE 4

Introduction

The cemetery in Radom is one of the best studied Early Medieval burial sites in the area between the Rivers Pilica, Wisła, Kamienna and Czarna, for which the name of the Land of Radom (*terra radomiensis*) came into use in Late Medieval historiography¹. It was first excavated in 1923, and later in 1942. The materials obtained in these years were published by Jerzy Gąssowski. The cemetery was once more subject to fieldwork in 1966, when it was necessary to carry out rescue excavation, directed by Wojciech Twardowski. In total, 126 graves were uncovered, including 82 in the last season. However, one should bear in mind that the burial area has not been examined completely and many graves have been destroyed.

During the period of formation of the early Piast state, the discussed cemetery was a part of a larger settlement structure, including a stronghold called „Piotrówka”, dating back to the 2nd half of the 10th century, along with nearby settlements², the stronghold chapel of St. Peter³ and at least one more inhumation cemetery⁴.

¹ J. Gąssowski, *Cmentarzysko w Końskich na tle zagadnienia południowej granicy Mazowsza we wczesnym średniowieczu*, „Materiały Wczesnośredniowieczne”, Vol. 2, 1950, p. 75; M. Wilczyńska, *Ziemia radomska między Mazowszem a Sandomierzem w średniowieczu*, „Kwartalnik Historii Kultury Materialnej”, Vol. 15, Fasc. 1, 1967, p. 105-117; Z. Lechowicz, *Dzieje ziemi radomskiej w średniowieczu. Okręg grodowy w Skrzynnie*, Radom 2010, p. 25-26, 65-75, Fig. 3; Idem, *Problematyka przynależności historycznej ziemi radomskiej. Korelaty archeologiczne*, [in:] *Radom. Korzenie miasta i regionu*, Vol. I: *Badania 2009*, eds. A. Buko, D. Główka, Warszawa 2010, p. 31-53, Fig. 1; B. Fuglewicz, *Osadnictwo wczesnośredniowieczne ziemi radomskiej*, [in:] *ibidem*, p. 74-79.

² In the 11th century or at the beginning of the 12th century, one of them (Site 3), situated in the Old Town of Radom, changed from a regular household settlement into a market place (B. Fuglewicz, *Wczesnośredniowieczne grodzisko Piotrówka w Radomiu na podstawie badań archeologicznych i źródeł historycznych*, [in:] *Radom i region radomski w świetle badań archeologicznych*, eds. M. Cieślak-Kopyt, K. Solarska, „Biuletyn Kwartalny Radomskiego Towarzystwa Naukowego”, Vol. 44/1-4, Radom 2010, p. 117).

³ However, no remains of any of them have been found so far (B. Fuglewicz, *Wczesnośredniowieczne grodzisko ...*, pp. 117, 119).

⁴ Recent works on this subject include B. Fuglewicz, *Wczesnośredniowieczne grodzisko ...*, p. 112ff.

On the basis of the grave goods, especially coins, and of some features of the burial rite, it can be assumed that the cemetery in question was used in the period from the last quarter of the 11th c. to the end of the 12th c.

During the above-mentioned post-war research, archaeologists found two interesting burials containing military items: an axe and a spearhead. A separate chronological and typological analysis of these items has already been conducted⁵. Thus, this article will be limited to the most basic findings concerning the context of the discovery and the artefacts themselves, the main focus being on the discussion of metallographic and technological issues.

Description of the graves

The spearhead was discovered in Grave 41. It is the only one at the discussed cemetery in which traces of wooden structures, namely sawn or hewn boards (?), were found. In the middle of the pit, there was a skeleton in the supine position, with the skull pointing to the east. It was impossible to determine the sex and age of the dead person. The spearhead was discovered approximately 10 cm from the left shinbone, and the tip of the leaf-shaped blade pointed to the feet. Between the left hand and the chest as well as above the collarbone at the level of the skull, fragments of wood were found. They lay along the skeleton (from the socket to the skull), on the basis of which they can be interpreted as remains of the shaft. The grave goods included also clay vessels, an iron buckle with a bronze prong and a knife.

By contrast, the axe was discovered in Grave 29. The grave pit was damaged to a large extent. The deceased was buried in the supine position, with the head to the west, with the face to the north. In the light of an anthropological analysis, the bone remains belonged probably to a man who died at the age of *maturus* (?)⁶. The axe head lay with the blade directed towards the outside of the pit, and was located near

⁵ T. Kurasiński, K. Skóra, *Militaria z wczesnośredniowiecznego cmentarzyska szkieletowego w Radomiu, stan. 4*, „Acta Militaria Mediaevalia”, Vol. 8, 2012, pp. 69-89.

⁶ The anthropological analysis of the burials from Radom was conducted by Wiesław Kapła, whom we would like to thank for making the results of the study available to us.

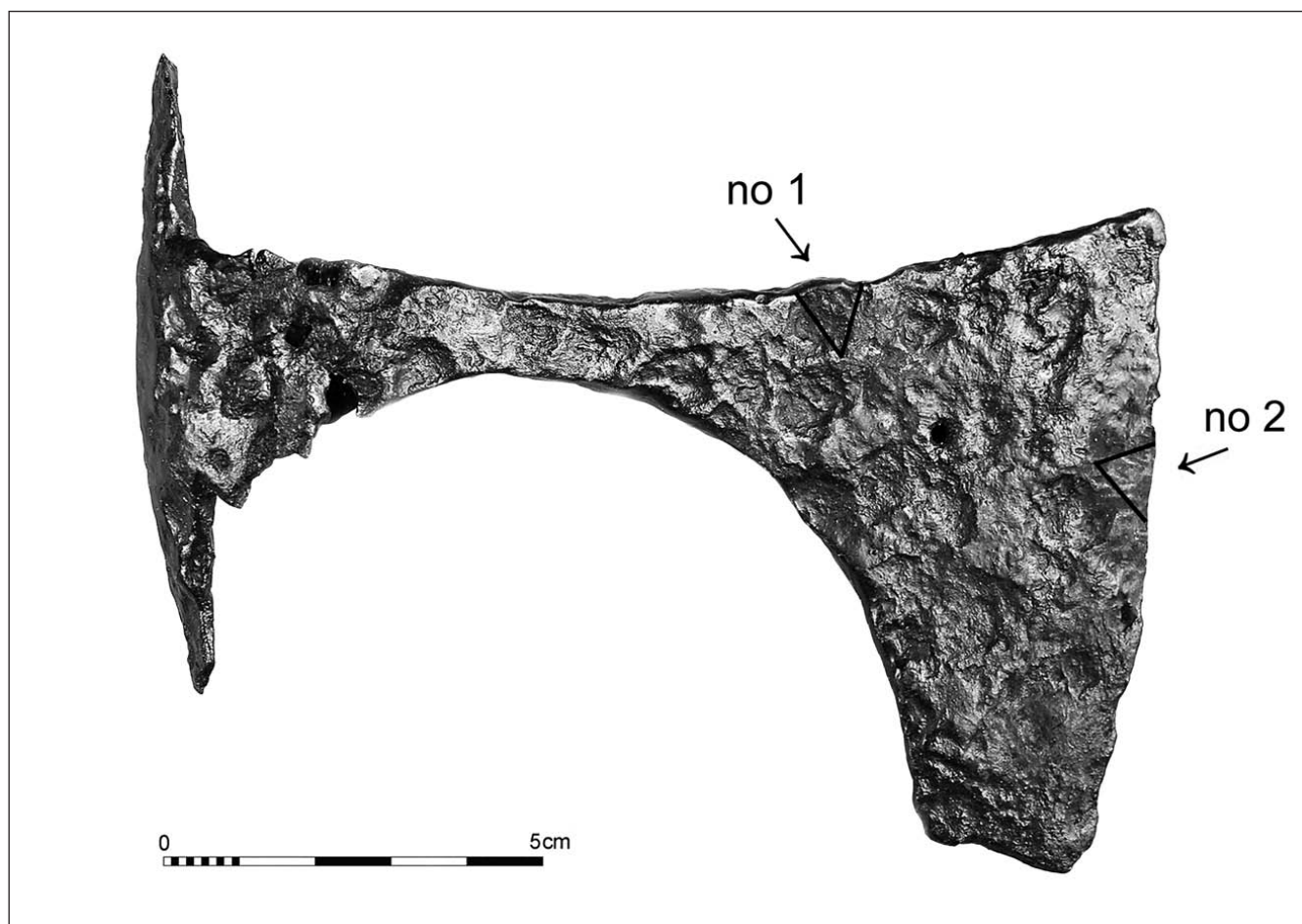


Fig. 1. Radom, Grave 29. Axe head with marks where samples were taken.

the right tibia. Moreover, there was a fragment of a coin (cross denar from circa 1050-1075) in the right hand of the dead person⁷. Between ten and twenty centimetres behind the skull, there was a stave bucket. The grave goods probably included a whetstone as well⁸.

Description of the military items

Axe

The axe head from Grave 29 has a beard (perhaps broken), lugs (considerably damaged) and a prominent cap (Fig. 1). Moreover, it has a suspension hole. On the basis of these features, it can be classified as Variant a of Type V according to A. Nadolski's typology⁹. The artefact has the following dimensions: total length – around 140 mm, (preserved?) blade width – around 90 mm, minimum neck width – 10 mm, (preserved) height of the eye with the lugs

– around 35 mm, cap height – 90 mm, eye hole diameter – 25 mm. Weight 210 g.

There are numerous axes of Type Va among materials from Poland and they are frequent elements of grave goods. Due to an intensification of research on this form of weapon, the number of known items gradually increased¹⁰ and at present, including the artefact from Radom, we have information on over 50 such items. They occurred mainly in Central Poland, Lesser Poland and Masovia. They include

⁷ The coins from the cemetery in Radom were studied by Mateusz Bogucki, PhD of the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Warszawa. We would like to thank him for making the results available to us.

⁸ According to the *Excavation journal*, this artefact was located in a cut near the grave.

⁹ A. Nadolski, *Studia nad uzbrojeniem polskim w X, XI i XII w.*, Łódź 1954, p. 45.

¹⁰ E.g. P. N. Kotowicz, M. Świątek, *Mittelalterliche Streitäxte aus den Sammlungen des Regionalmuseums in Jasło. Ein Beitrag zur Kenntnis der Bewaffnung in den polnischen Karpaten*, „Acta Archaeologica Carpathica”, Vol. 41, 2006, p. 119, Fig. 3; A. Drozd, A. Janowski, *Wczesnośredniowieczny topór inkrustowany z miejscowości Pień na ziemi chełmińskiej*, [in:] *Wojskowość ludów Morza Bałtyckiego. Materiały z II Międzynarodowej Sesji Naukowej Dziejów Ludów Morza Bałtyckiego, Wolin 4-6 lipca 2006*, eds. M. Bogacki, M. Franz, Z. Pilarczyk, Toruń 2007, p. 111, Fig. 4; P. Kotowicz, *Wczesnośredniowieczny topór z miejscowości Kryniczki*, „Silesia Antiqua”, Vol. 44, 2008, p. 170, Fig. 2; A. Janowski, *From the North-Eastern to Central Europe. Silver-inlaid Axe from the Early Medieval Chamber Grave in Pień in the Land of Chełmno (Poland)*, [in:] *Arkheologiya i istoriya Pskova i Pskovskoy zemli*, Vol. 55, ed. V. V. Sedov, Pskov 2010, p. 166, Fig. 5; T. Kurasiński, K. Skóra, *Wczesnośredniowieczne cmentarzysko szkieletowe w Lubieniu, pow. piotrkowski*, Łódź 2012, pp. 44-46.

both full-size and miniature items. A little more than a half of them were discovered at cemeteries¹¹, and most of them are dated to the period from the 11th c. to the beginning of the 12th c. The wide occurrence of the axes in question is also confirmed by finds from settlements and strongholds as well as stray finds¹².

On the basis of the finds of axes with a beard, lugs and a cap in the Polish lands, it seems possible that they appeared as early as in the 10th c. The item from Radom is dated on the basis of a cross denar minted in the 3rd quarter of the 11th c. Therefore, the origin of the discussed axe should probably be associated with the 2nd half of this century.

Spearhead

The spearhead has a long leaf-shaped blade distinctly flaring towards the socket. The section of the blade is lenticular, transitioning into quadrangular near the tip (Fig. 2). The total length of the artefact is 410 mm, of which the length of the socket is circa 125 mm (the diameter of the mouth being 17-21 mm). The maximum width of the blade amounts to 33 mm. Weight 224g. There are numerous defects on the edges of the blade and on the bottom parts of the socket, which makes it somewhat difficult to classify the spearhead typologically. However, on the basis of the identified features, especially the considerable length, the relatively gentle but distinct transition of the socket into the blade, and the quadrangular section of the latter in the tip area, it can be classified as Type II according to Andrzej Nadolski's typology¹³. The excavation documentation includes information on "an impression of a cord on the surface of the socket of the spearhead." Unfortunately, at present, due to conservation work, it is impossible to conduct a verification analysis. Therefore, it is difficult to determine whether in the case of the discussed item, the element was used to attach the fabric of a pennant or the reason for its presence is different¹⁴.

Including the item analysed here, we know 32 finds of this type, from Masovia, Central Poland, Greater Poland, and Cuiavia. A single item was found in Western Pomerania. They are known mainly from cemeteries, although such military items are not often placed in graves. As far as we know, only 14 items from 9 cemeteries have been discovered. On the basis of the chronology of the cemeteries or isolated grave complexes, it can be concluded that all the artefacts of the type in question got to the graves in the 11th and 12th centuries. The finds of spearheads of Type II are not limited to cemeteries¹⁵.

¹¹ More on this issue T. Kurasiński, K. Skóra, *Militaria...*, pp. 69-89.

¹² *Ibidem*, pp. 77-78.

¹³ A. Nadolski, *Studia nad uzbrojeniem...*, p. 54.

¹⁴ For more on this issue, see T. Kurasiński, K. Skóra, *Militaria...*, pp. 76-77.

¹⁵ Cf. *ibidem*, pp. 73-76.

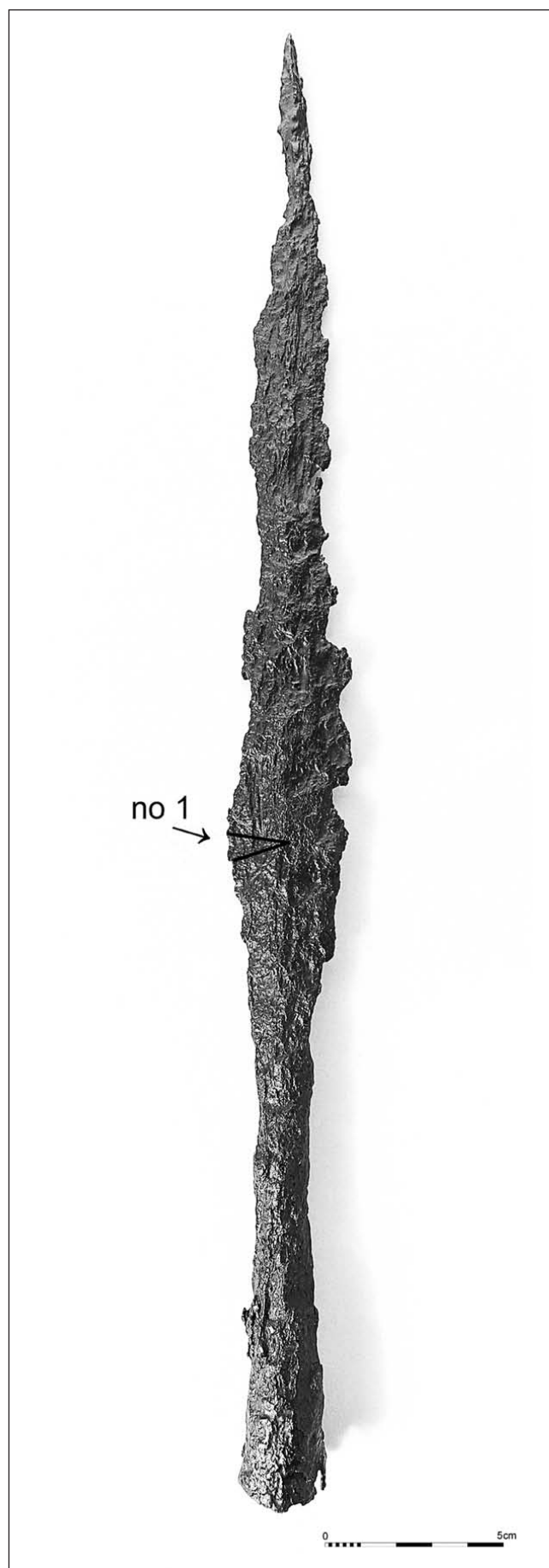


Fig. 2. Radom, Grave 41. Spearhead with a mark where a sample was taken.

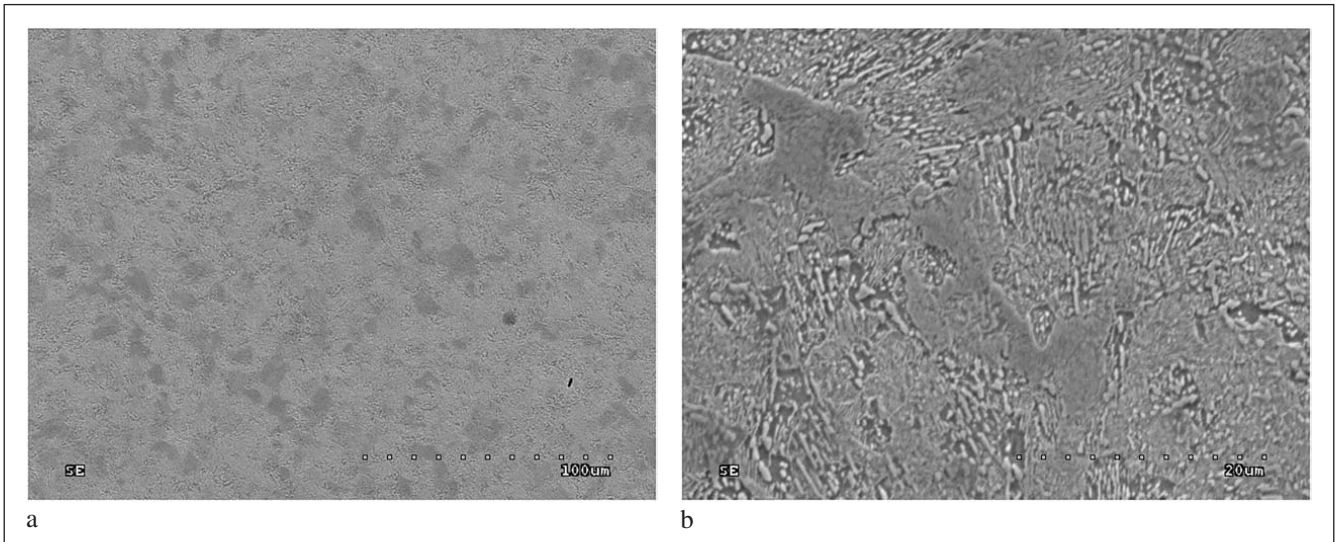


Fig. 3. Axe – Sample No. 1 (neck). A scanning microscope image of the structure.

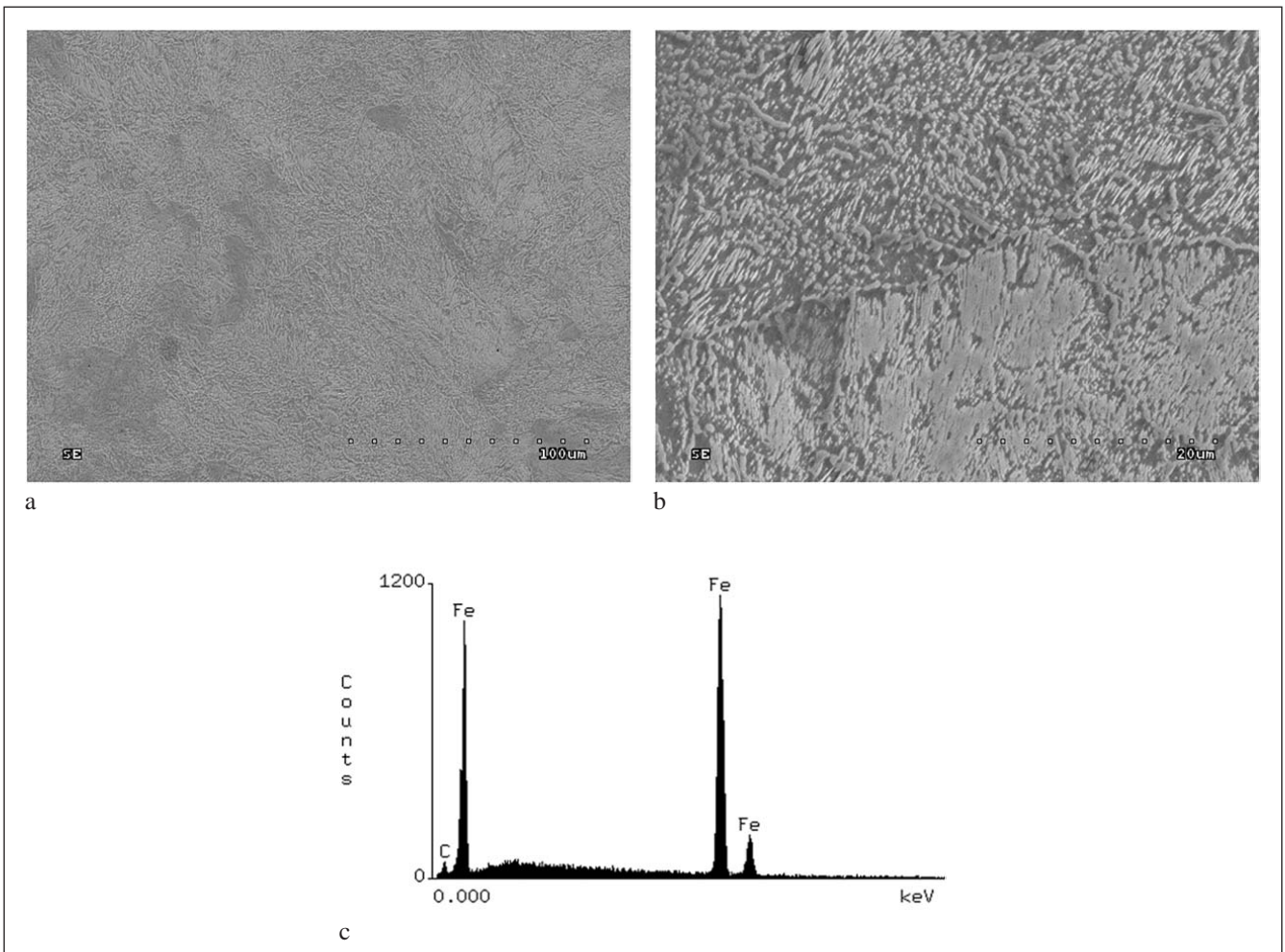


Fig. 4. Axe – Sample No. 1 (neck). Scanning electron microscope images in various magnifications (a, b) and an X-ray spectrogram of the sample surface (c).

Moreover, it should be emphasised that the spearhead form discussed here was quite widespread in Europe, but there was quite a distinct concentration in the northern part of the continent. Thus, the discussed item would mark the southern

limit of the occurrence of this type of weapon, extending to the borderland between Lesser Poland and Masovia. However, its foreign origin is not certain, as the spearhead from Radom, unlike most northern European artefacts, does not bear traces

of encrustation, pattern-welding or other ornamentation. This indicates rather local production, although probably inspired by foreign models. The spearhead was probably manufactured in the 11th c., when such spears were most popular¹⁶.

Specialist analyses

Both the artefacts in question were subject to X-ray, chemical composition and metallographic analyses. A palaeobotanical species identification of the preserved remains of the shaft of the spearhead was carried out.

X-ray analysis

Both artefacts were subject to an X-ray analysis, which revealed defects, in the case of the spearhead, on the edges of the blade and at the lower part of the socket, and as for the axe head, a damage to a part of the blade was found. Unfortunately, neither traces of ornaments, nor details of the structure of the weapons were detected¹⁷.

Chemical composition analysis

Also a spectrometric analysis of the chemical composition of both artefacts was carried out¹⁸. Apart from iron (98.26%), the sample taken from the axe was found to contain several elements, probably coming from bog iron ore (Al – 0.22%; Si – 0.4%, P – 0.05%; S – 0.43%; Cr – 0.63%; Mg – 0.03%); even though they occur in small quantity, they may influence the properties of the product. Although nowadays, aluminium, silicon and manganese, called standard components of steel, are sometimes added in the process of production in order to deoxidise and desulphurise the steel¹⁹, it seems doubtful that Early Medieval blacksmiths introduced them consciously to improve the quality of the alloy. The percentage of silicon of the order of 0.4% discovered by the analysis corresponds to the present metallurgical norms²⁰. When it amounts to 0.5-1%, it increases the strength of ferrite²¹.

Undesirable elements in steel include sulphur, which dissolves in iron but only to a small degree, and phosphorus. According to the modern norm, the content of sulphur and phosphorus should be below 0.05% each, and for high quality steel, between 0.02-0.03%²². Sulphur forms ferrous sulphide, which has an adverse effect on steel strength and

on the possibility of hot working²³. By contrast, the presence of phosphorus on the one hand increases the brittleness of the alloy, but on the other hand, it increases its hardenability and resistance to cracking²⁴. Nowadays, neither phosphorus nor sulphur is removed from the alloy for economic reasons²⁵. Chrome, which was found in the sample, is an element which considerably enhances the hardenability of steel. Nowadays, it is applied also due to the fact that it increases resistance to corrosion and oxidation²⁶.

As for the samples from the socket and blade of the spearhead, the chemical composition analysis revealed differences in weight, but also in the number of elements. Therefore, it can be assumed that these two elements were made separately from two different bog iron ores. The socket contains elements which were not detected in the blade such as sulphur, manganese, magnesium and nickel (0.02%, 0.13%, 0.02%, 0.08% respectively, as well as 99.39% Fe, 0.02% Al, 0.24% Si, 0.07% P, 0.01% Cr). The composition of the blade sample is as follows: 99.51% Fe, 0.14% Al, 0.06% Si, 0.29% P, 0.01% Cr²⁷. The presence of a small quantity of several elements has a better influence on the hardenability of steel than the presence of a large quantity of just one element²⁸.

Metallographic analysis of the military items

Two wedge-shaped samples were taken from the axe head: from the blade and the part where the cutting edge transitions into the neck (Fig. 1). In the case of the spearhead, one sample was taken from the middle part of the blade, at its widest and best preserved part (Fig. 2)²⁹.

The separated fragments were embedded in Struers POLYFAST thermosetting resin. Then, the surface of the specimens was ground with sandpaper with different grit sizes, from 120 to 2000. After the grinding process, the surface was polished by means of diamond paste with a grain size of 0.25 µm. Subsequently, the samples were etched with the reagent MiIFe. Each element was subject to a metallographic analysis with the use of a Nikon MA100 optical microscope and a HITACHI S-3000N scanning electron microscope. The device was also used to determine the chemical composition by means of an energy dispersive X-ray microanalysis (EDS). The analysis was performed using a THERMONORAN Pioneer X-ray detector mounted on the scanning electron microscope and working

¹⁶ *Ibidem*, p. 76.

¹⁷ Cf. *ibid.*, p. 82, Fig. 8.

¹⁸ The spectrometric analysis was conducted with the use of a PGT AVALON 8000 spectrometer at the Central Archaeometric Laboratory of the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Warszawa. Preliminary discussion in *ibid.*, pp. 81-82.

¹⁹ K. Przybyłowicz, *Metaloznawstwo*, Warszawa 2003, p. 175; M. Blicharski, *Inżynieria materiałowa. Stal*, Warszawa 2004, p. 126.

²⁰ Cf. M. Blicharski, *op. cit.*, p. 127.

²¹ *Ibid.*, p. 127.

²² K. Przybyłowicz, *op. cit.*, pp. 191-192.

²³ *Ibidem*, p. 191.

²⁴ *Ibidem*, p. 192; M. Blicharski, *Inżynieria...*, p. 128.

²⁵ K. Przybyłowicz, *op. cit.*, pp. 175, 190.

²⁶ M. Blicharski, *op. cit.*, p. 130, see also L. A. Dobrzański, *Metaloznawstwo z podstawami nauki o materiałach*, Warszawa 1998, p. 401, Table 6.15.

²⁷ T. Kurasiński, K. Skóra, *Militaria...*, p. 80, fig. 7.

²⁸ M. Blicharski, *op. cit.*, p. 110.

²⁹ We would like to thank Grzegorz Żabiński, PhD of the Institute of History of Jan Długosz University in Częstochowa for taking the samples.

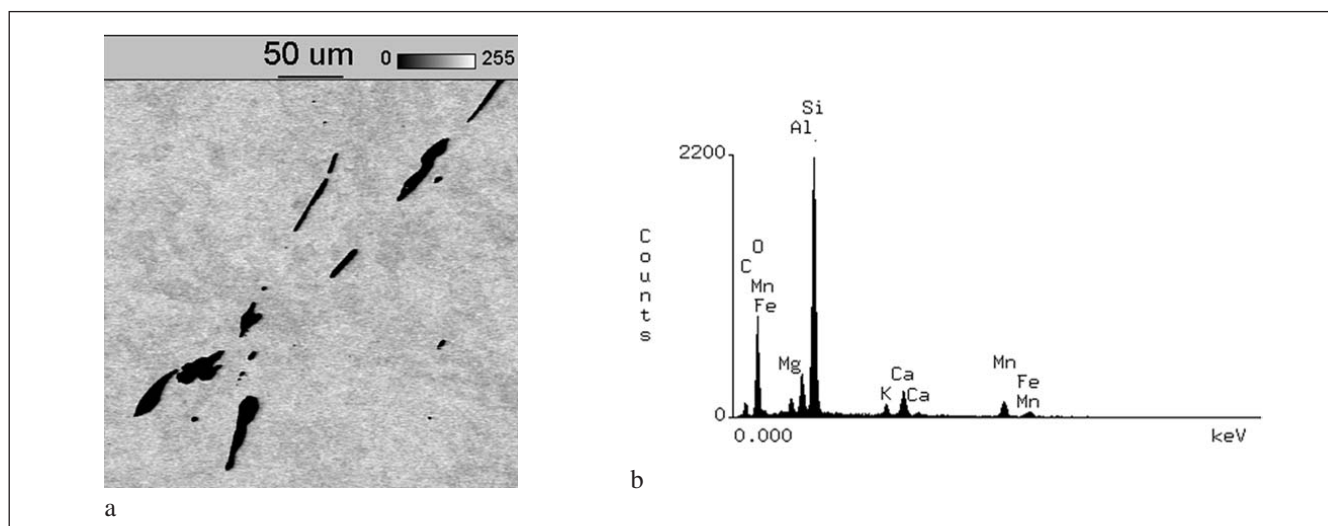


Fig. 5. Axe – Sample No. 1 (neck). A microscope image of a non-metallic inclusion (a) and a spectrogram of the inclusion (b).

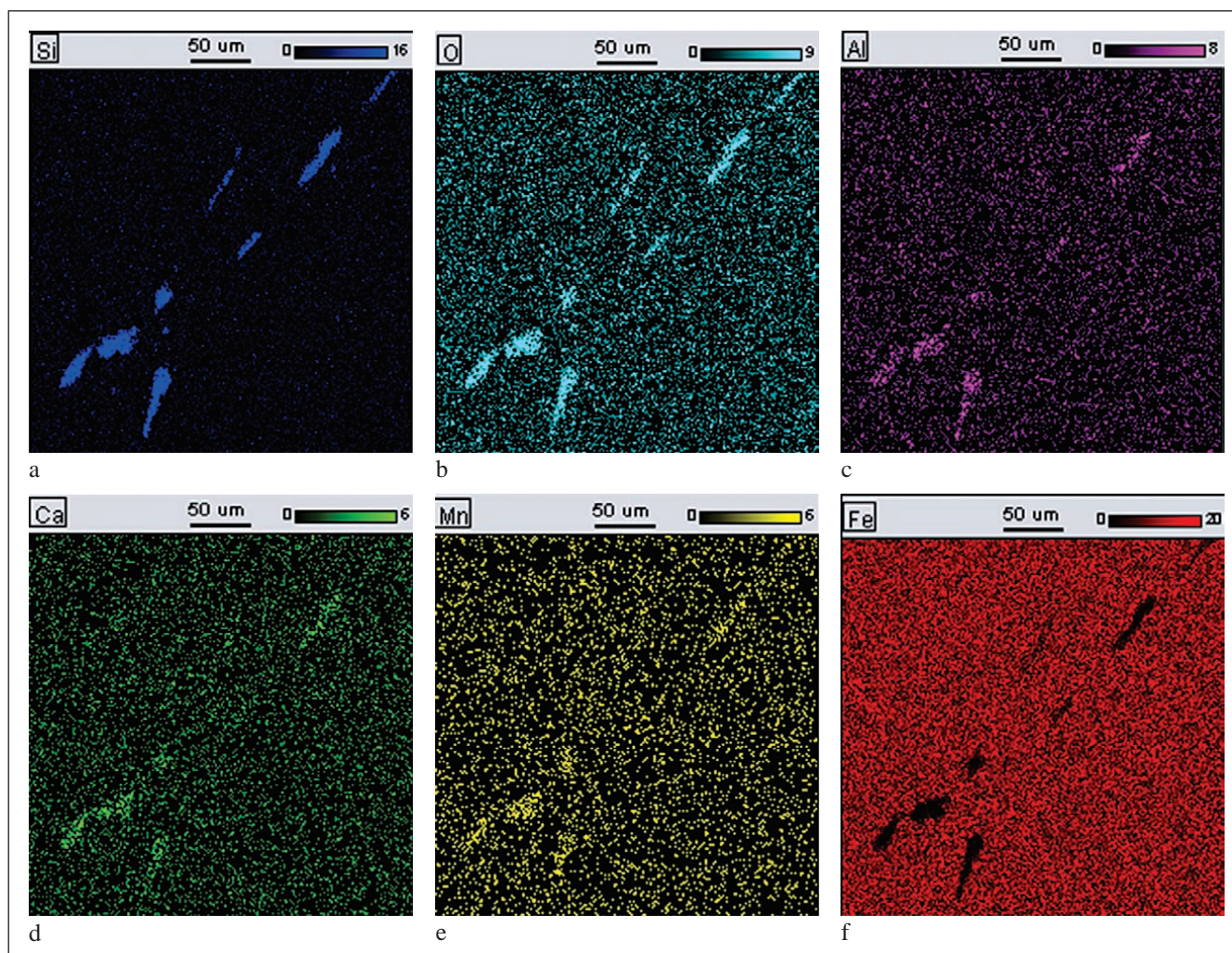


Fig. 6. Axe – Sample No. 1 (neck). Surface distribution of silicon (a), oxygen (b), aluminium (c), calcium (d), manganese (e), and iron (f) in the area presented in Fig. 5a.

with it. Element distribution analysis was carried out for a specific place on the surface of each sample. Microhardness measurements were taken according to the Vickers method using a CLEMEX tester with a load of 0.5 N.

AXE – NECK AND BLADE (SAMPLES NO. 1 AND 2 – Fig. 3-11)

The chemical composition of the samples was analysed with another method as well, namely, X-ray microanalysis (Fig. 4c), which revealed the presence of iron and carbon.

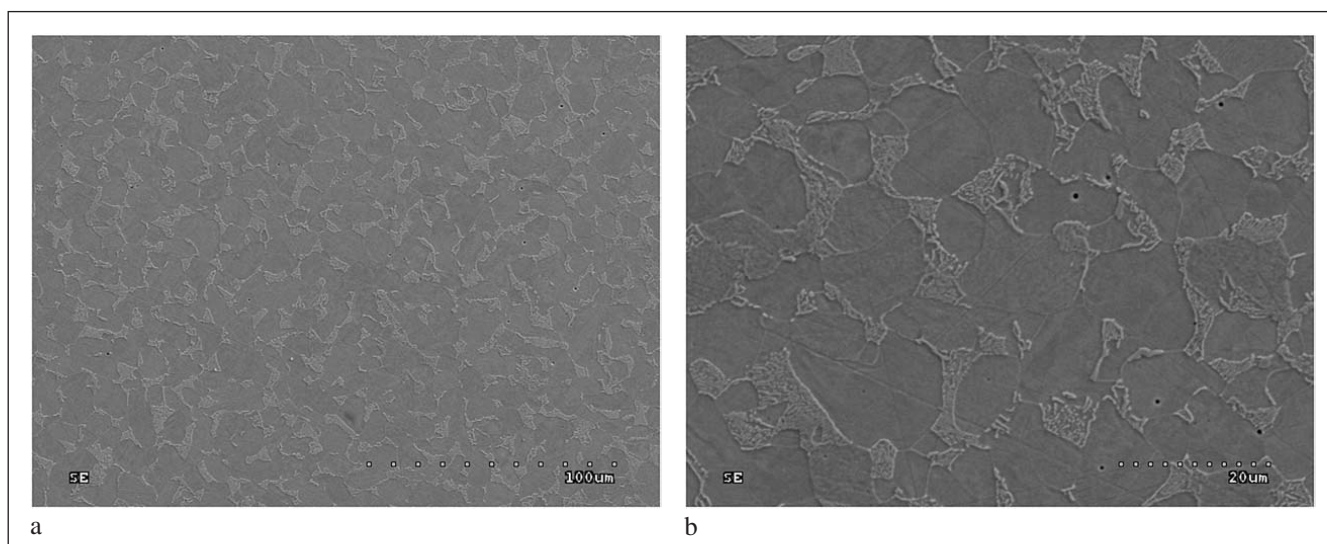


Fig. 7. Axe – Sample No. 2 (blade). A scanning microscope image of the structure.

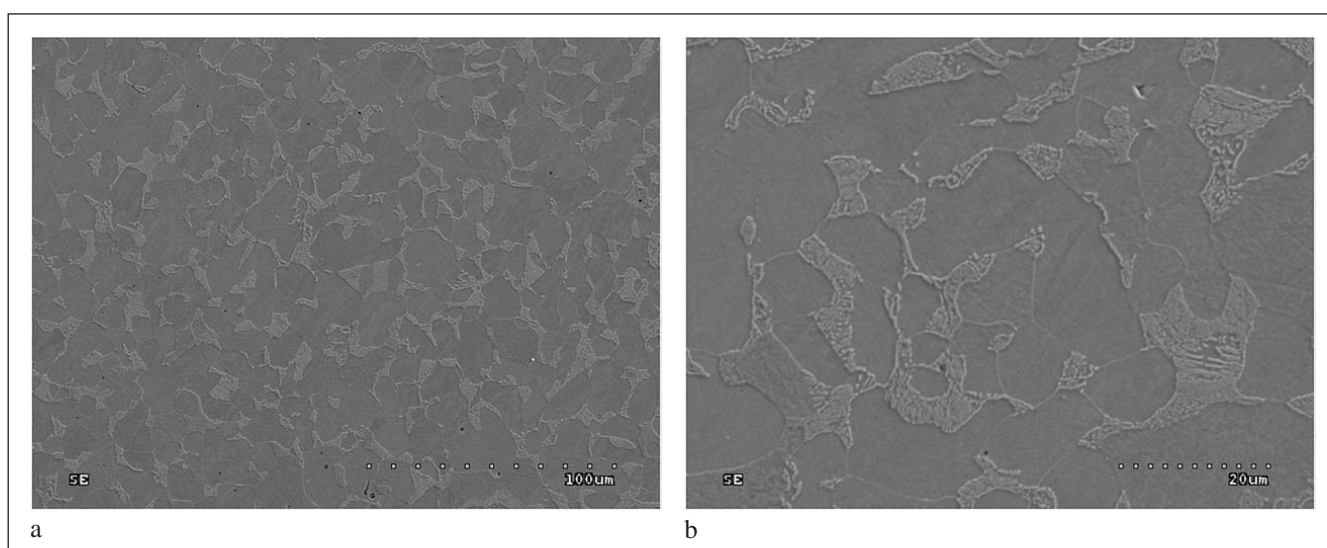


Fig. 8. Axe – Sample No. 2 (blade). A scanning microscope image of the structure.

The structure of the axe turned out to be diverse. At the transition into the neck (Sample No. 1), there is virtually pearlitic structure with a low ferrite content. By contrast, in the blade (Sample No. 2), there is definitely more ferrite and only a small amount of pearlite. It indicates a difference in the carbon content in these areas. Places with a greater amount of pearlite have a higher carbon content. Considering the percentage of pearlite and ferrite areas, it is possible to estimate the carbon content in the blade at 0.25% and at the transition into the neck at 0.7%.

Ferrite grains present in the structure are quite equiaxed, without a visible oriented deformation. In the analysed areas, also non-metallic inclusions forming bands were detected (Fig. 5a, 7a-b). The X-ray microanalysis of these inclusions revealed the presence of the following elements: O, Si, Al, Ca, Mn (Fig. 5b). Surface distribution maps of elements in the area of the inclusion show that its main components are Si, Al and O. Thus, they are probably siliceous impurities,

which remained due to an imperfect purification of the ore or got into the metal during the metallurgical process.

The average hardness of the structure of the axe neck was 195 HV1, and of the blade 171 HV1. The differences in hardness resulted from different amounts of ferrite (soft) and pearlite (harder).

On the basis of the conducted analyses, it is possible to conclude that the axe was made of iron with quite a high carbon content. The different content in different places may have resulted from decarburisation that occurred during forming it by hot forging. During heating for working, the worked areas (blade) may have undergone decarburisation in the presence of air. The metallographic structure indicates that the axe was made by means of plastic deformation, there is no structure characteristic of casts from this type of materials (Widmanstätten structure). The more or less equiaxed grains, without clear deformations, point to hot forging, above the recrystallisation

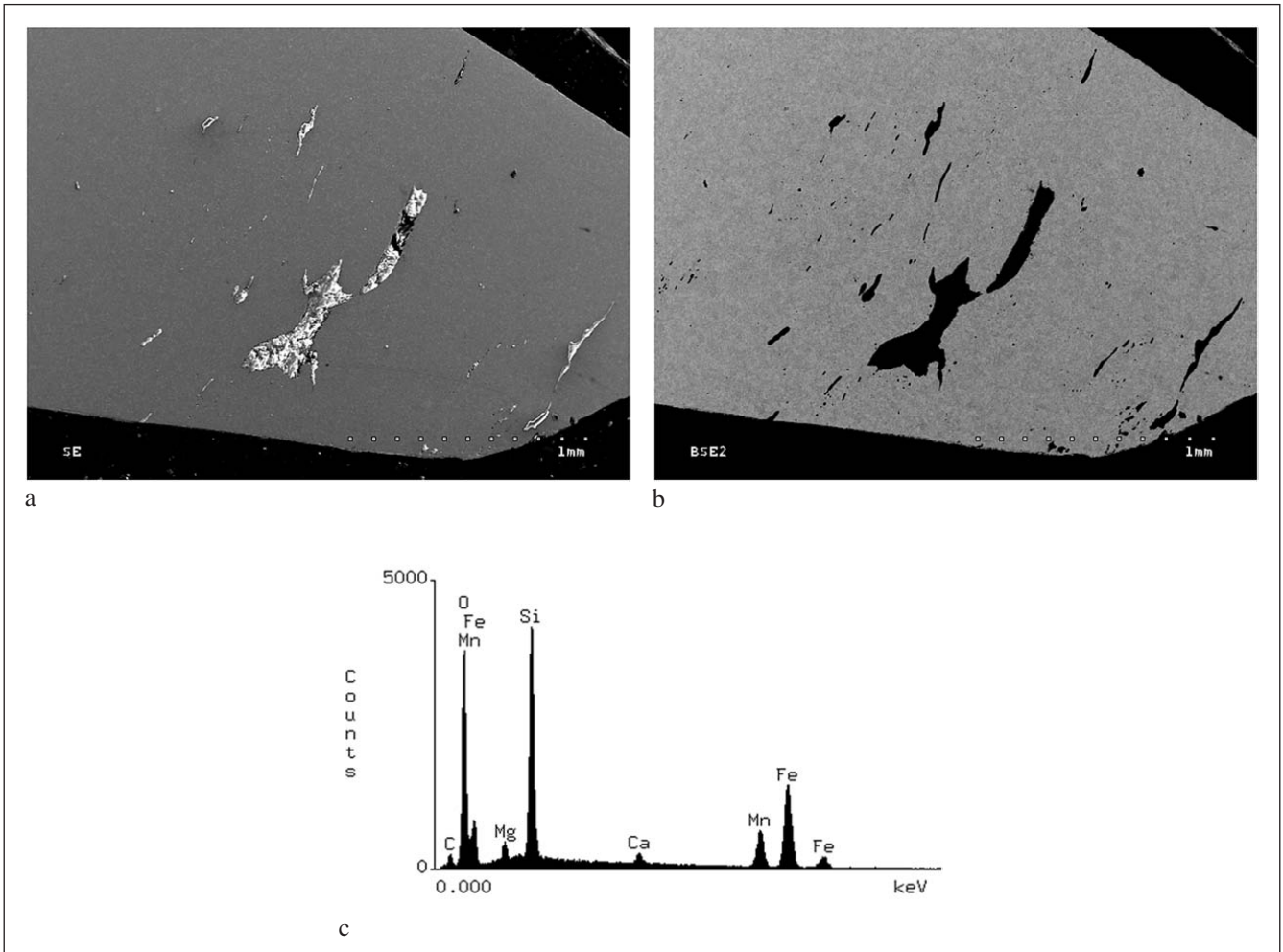


Fig. 9. Axe – Sample No. 2 (blade). Scanning electron microscope images of the area with inclusions: a) secondary electron image, b) back-scattered electron image (material contrast), c) X-ray spectrogram of the inclusion.

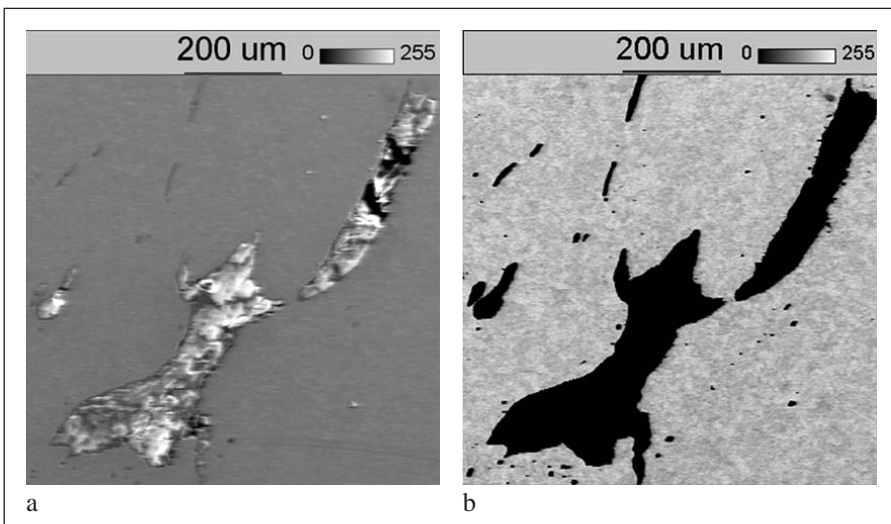


Fig. 10. View of a non-metallic inclusion: a) secondary electron (SE) image; b) back-scattered electron (BSE) image.

temperature, which is approximately 500°C for this type of material.

SPEARHEAD – LEAF-SHAPED BLADE (Fig. 12-17)

As far as the chemical composition of the sample is concerned, the X-ray microanalysis (Fig. 12c) detected only the presence of iron. The structure of the sample is ferritic,

with regular grains (grain size 200-300 μm). No oriented deformations of these grains are visible. No cementite was observed in the structure, which means that the carbon content is very low, below 0.01%.

In the analysed fragment of the spearhead, also non-metallic inclusions forming bands were detected (Fig. 13, 14 and 16). The X-ray microanalysis of these inclusions

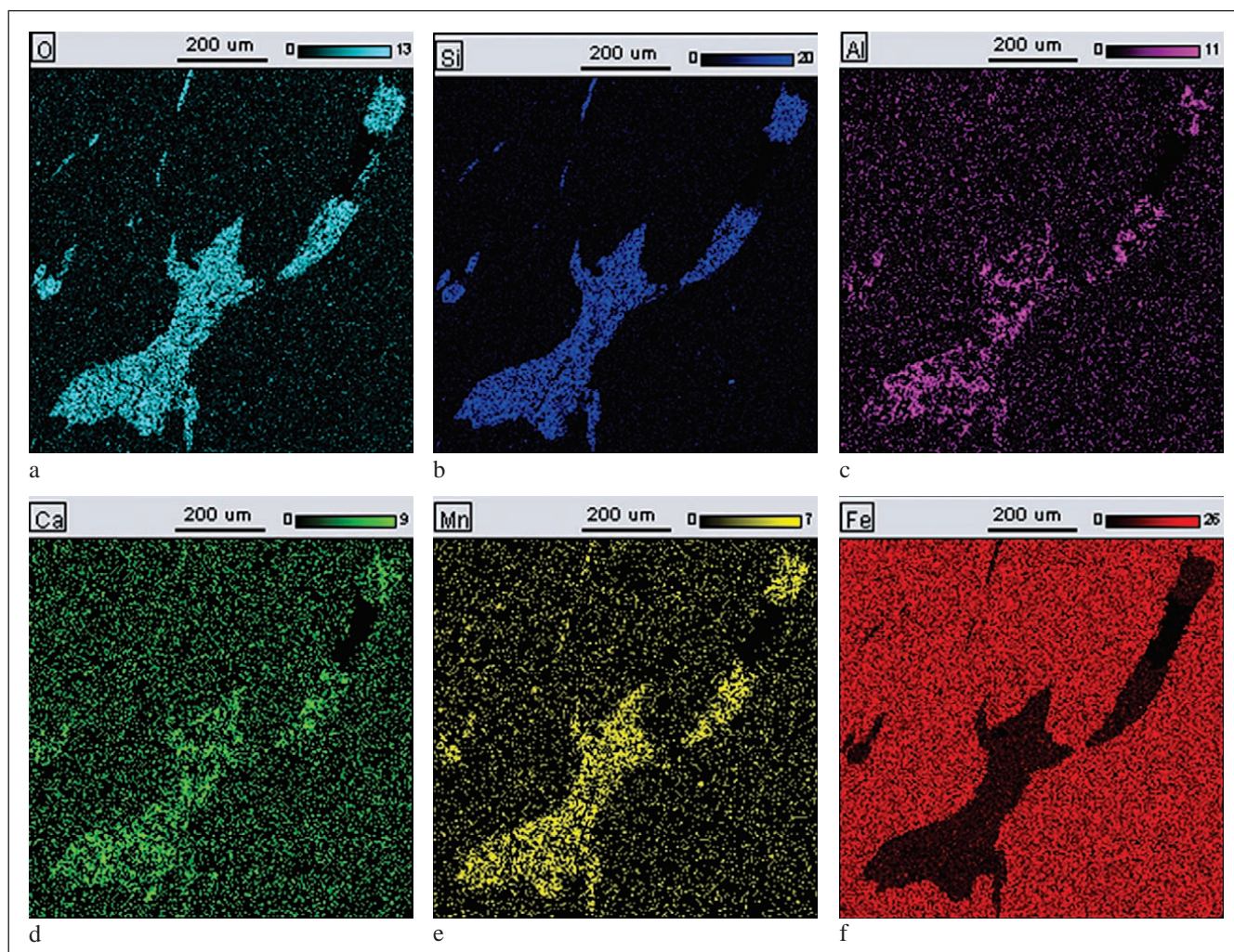


Fig. 11. Surface distributions of elements in the area of the inclusion: a) oxygen; b) silicon; c) aluminium; d) calcium; e) manganese; f) iron.

revealed mainly the presence of the following elements: O, Si, Al (Fig. 13c). A surface distribution map of elements in the area of an inclusion shows that its main components are Si, Al and O, which can most probably be interpreted as a result of a siliceous impurity (insufficient purification of the ore or contamination of the metal during the metalworking process). The average hardness of the analysed sample was 137 HV1. Such hardness is characteristic of ferrite structure that has not been subject to hardening.

On the basis of the conducted analyses, it may be concluded that the spearhead was made from almost pure iron. The metallographic structure indicates that the method of plastic deformation was applied, there is no structure characteristic of casts from this type of materials (Widmanstätten structure). The more or less equiaxed grains, without clear deformations, suggest that it was hot forging, above the recrystallisation temperature, which is approximately 500°C for this type of material.

Technological assessment of the military items from Radom

The results of the conducted metal science analyses suggest uneven carburisation, and because of that, varying

hardness (HV1) of the axe head. The sample taken from the blade (No. 2) with an estimated carbon content of 0.25% seems to indicate that low-carbon steel or carburised iron was used³⁰. By contrast, in the sample from the upper part of the axe (No. 1), carbon content was 0.7%, which would mean that it was high-carbon steel³¹. Such an amount of this element facilitates plastic deformation by forging and quenching, but it is rather untypical of axe blades. An increase in carbon content improves strength but reduces plasticity³². In the blade, no structure indicating the application of quenching was observed.

And as the working part of the weapon, it should be harder. In the Early Middle Ages, additional measures were taken to improve the cutting qualities of the axe

³⁰ It is assumed that in that period, charcoal with an addition of powdered animal bones, skin and hooves was used for carburising (J. Peets, *On Forging Technologies of Estonian Iron Age and Medieval Axes*, [in:] *Prehistoric and medieval Direct Iron Smelting in Scandinavia and Europe. Aspect of Technology and Society*, ed. L. Ch. Nørbach, Aarhus 2003, p. 115).

³¹ K. Przybyłowicz, *op. cit.*, p. 191.

³² *Ibidem*, p. 191.

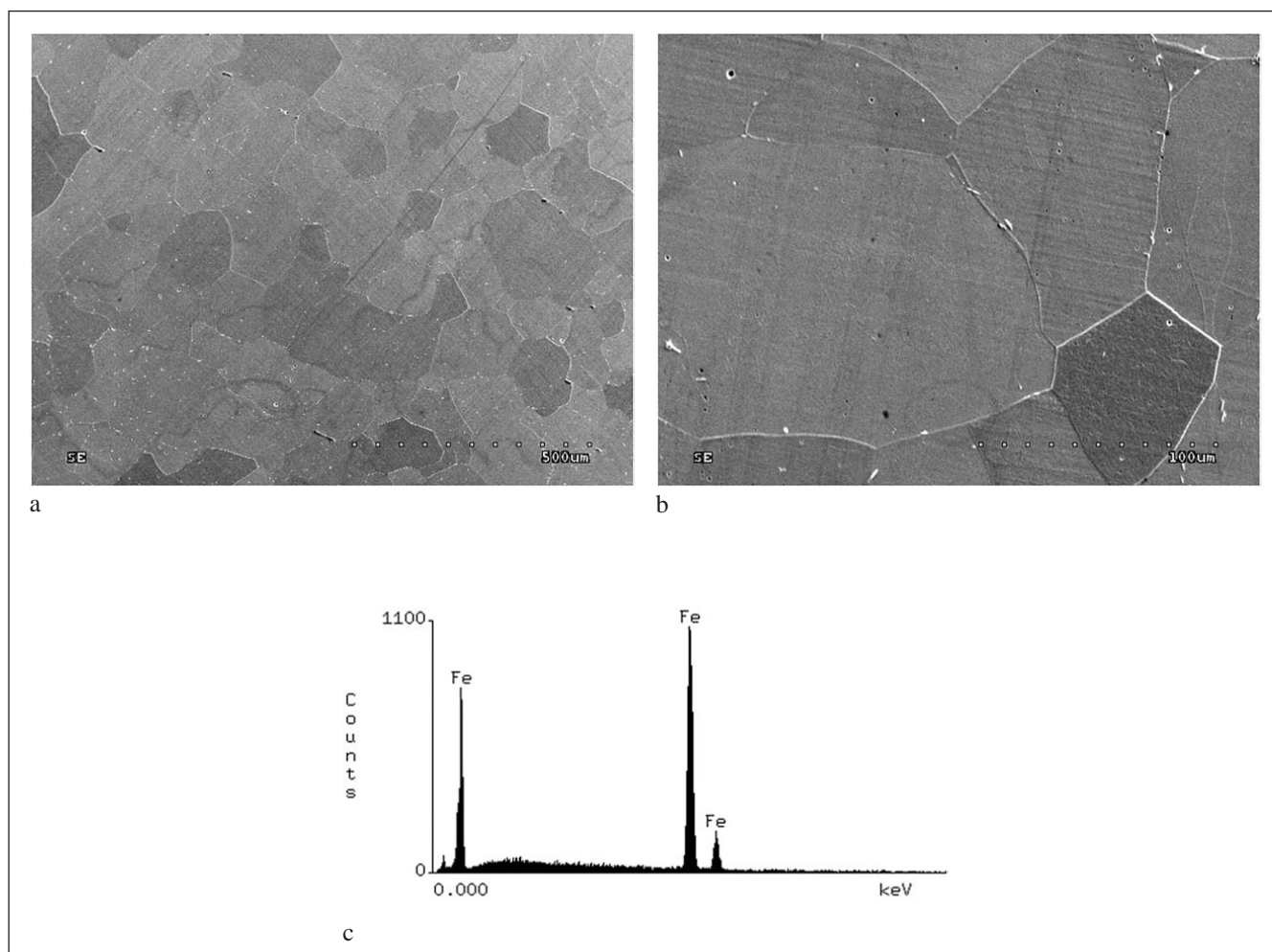


Fig. 12. Spearhead – Sample No. 1 (leaf-shaped blade). Scanning microscope image of the structure in various magnifications (a, b) and an X-ray spectrogram of the sample surface (c).

head, namely carburising or welding together the iron core and steel edges³³. The upper edge of the axe head has better strength parameters, although theoretically, it could be more elastic than the blade, i.e. with a lower carbon content. On account of that, it is impossible to determine the way the axe head was produced. For the Middle Ages, two techniques of manufacturing axe heads are confirmed. One consists in forming a rectangular iron plate, folded into a U-shape or a hook, and subject to further heat treatment. Sometimes, steel inserts were added as well. The other method is more complicated and consists in welding together multiple steel and iron elements with different qualitative parameters³⁴. This technique should rather be ruled out on the basis of the structure of the samples. However, it remains an unanswered question whether the observed differences in carbon content

should be attributed to using a portion of unevenly carburised material or the worse parameters of the blade are a result of the above-mentioned decarburisation during processing or an effect of other factors, e.g. corrosion. Finally, it is worth adding that the material used to manufacture the discussed weapon has a low phosphorus content – 0.05%³⁵.

Also the spearhead is interesting technologically. It, or at least the blade, from which the sample was taken, was made from iron with the carbon content estimated at less than 0.01%. The chemical composition analysis of the weapon revealed that the blade has worse parameters than the socket (see above). Within the analysed sample, no strengthening procedures were observed. The use of such material caused the product to have a low hardness, assessed at approximately 140 HV1. Perhaps the results of the analysis were influenced by the poor state of preservation of the spearhead, thus, the microanalysis of the sample provided information only on the structure of the core of the blade. In the light of the available data, spearheads and javelin heads were subject to additional procedures aimed at improving

³³ Cf. J. Piaskowski, *Metaloznawcze badania wyrobów żelaznych*, [in:] A. Nadolski, A. Abramowicz, T. Poklewski, *Cmentarzysko z XI wieku w Lutomierniku pod Łodzią*, Łódź 1957, pp. 115-118; J. Peets, *op. cit.*

³⁴ H. Drescher, *Axt – III. Technologisches*, [in:] *Reallexikon der germanischen Altertumskunde*, Vol. 1, eds. H. Beck et al., Berlin-New York 1973, p. 561, Figs. 120-123.

³⁵ T. Kurasiński, K. Skóra, *Militaria...*, Plate 1.

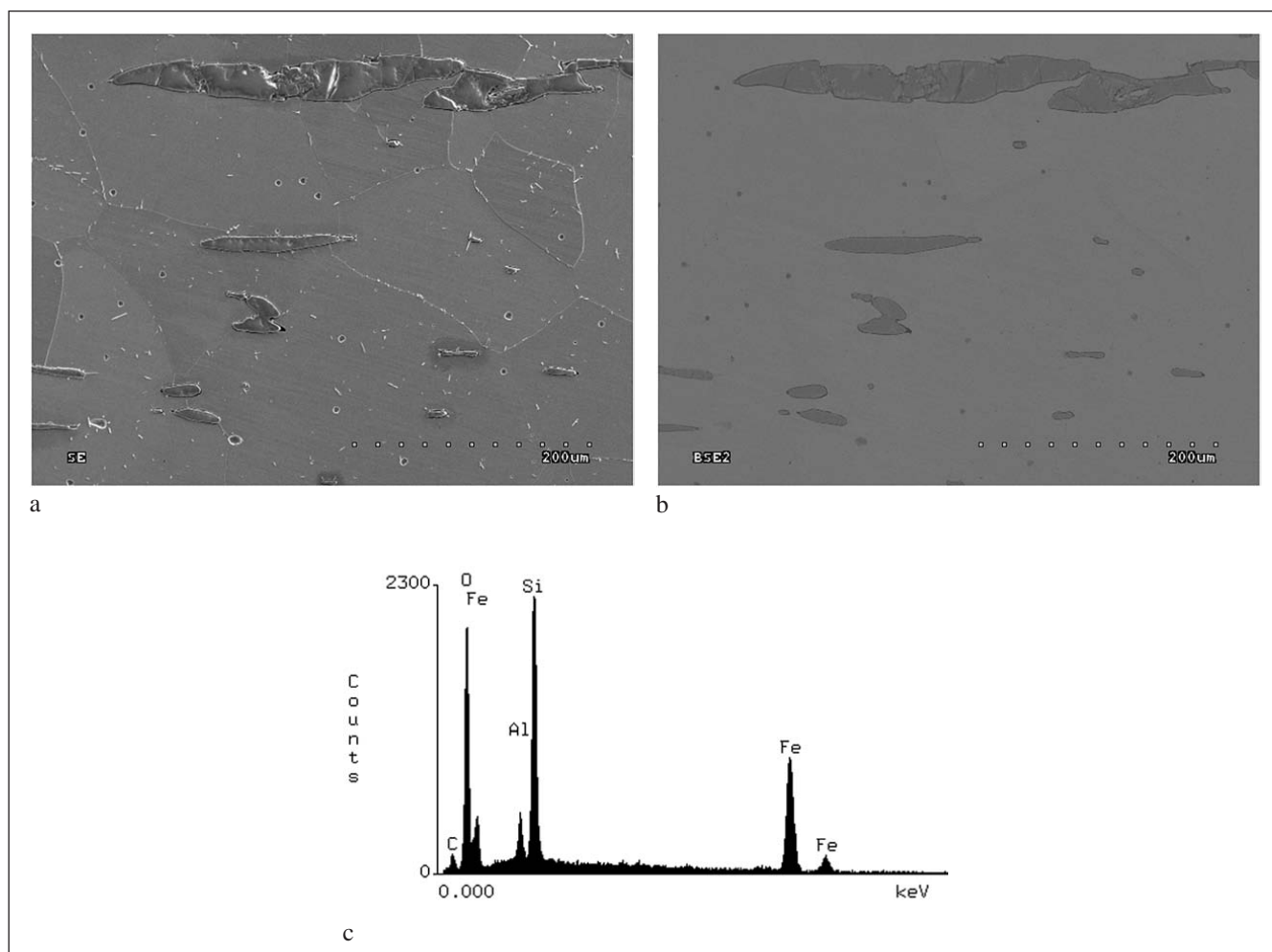


Fig. 13. Spearhead – Sample No. 1 (leaf-shaped blade). Scanning electron microscope images in various magnifications of the area with non-metallic inclusions (a, b) and an X-ray spectrogram of an inclusion (c).

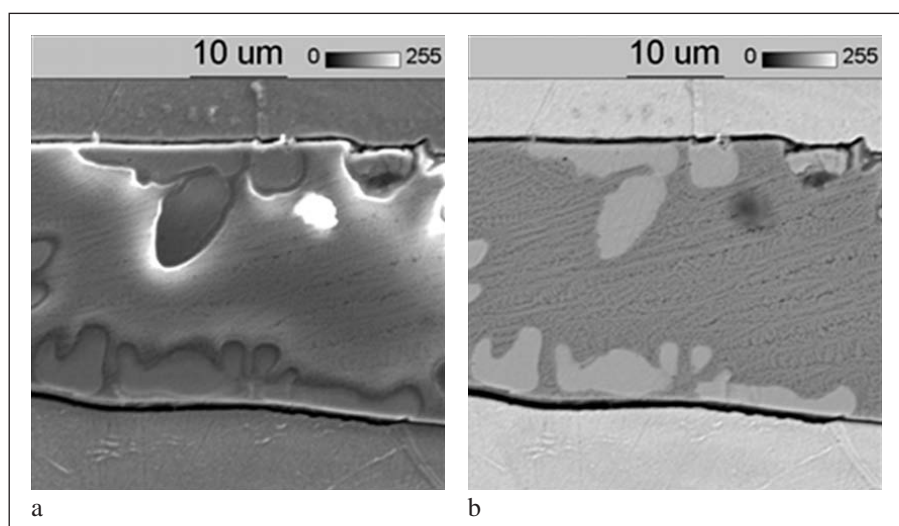


Fig. 14. Microscope view of the spearhead: a) secondary electron (SE) image; b) back-scattered electron (BSE) image.

their battle qualities. The simplest technology involved forging soft iron and then, carburising it³⁶. More often, more

elaborate production techniques were used, consisting in the application of steel blade inserts, which were welded

³⁶ See: M. Husár, *Hroty kopijí/oštepov z obdobia včasného stredoveku v Karpatskej kotline z hľadiska metalografie*, [in:]

Veda v praxi – prax vo vede, eds. E. Bútorová, E. Kováčová, Nitra 2009, p. 207.

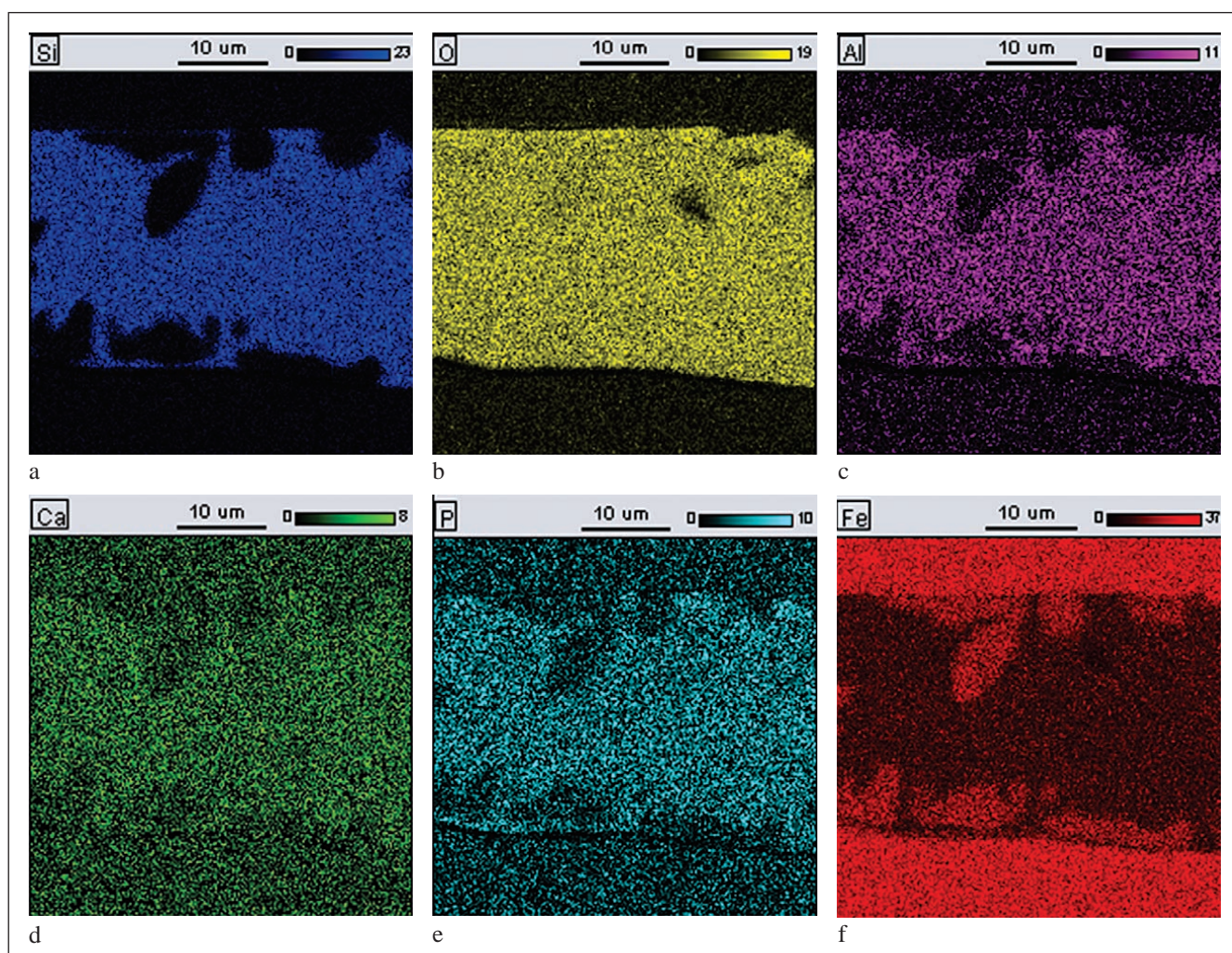


Fig. 15. Surface distribution of silicon (a), oxygen (b), aluminium (c), calcium (d), phosphorus (e), and iron (f) in the area presented in Fig. 14.

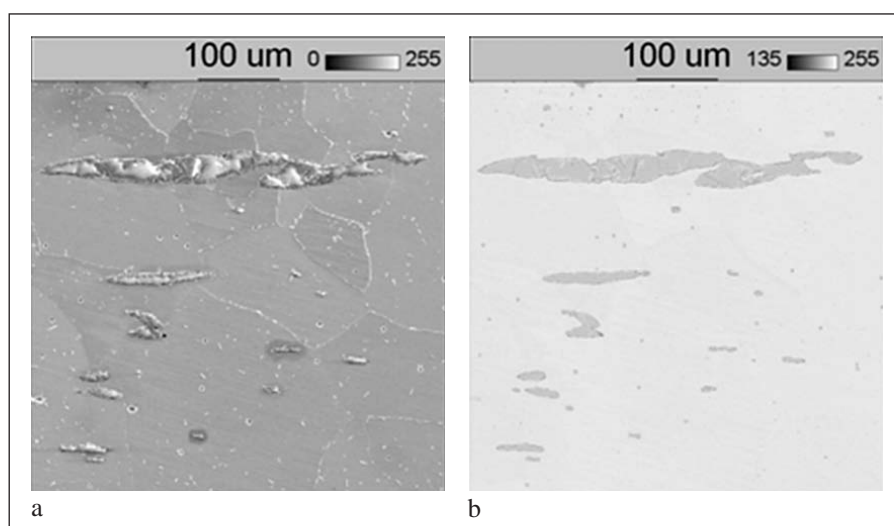


Fig. 16. Microscopic image of: a) metallic inclusion and b) spectrogram of the inclusion.

to the iron core directly or indirectly through a structurally different insert³⁷. Even if soft iron with a low carbon content was used to manufacture a spearhead, the producer

tried to improve its mechanical strength by means of steel strips welded to the blade parallel with its edge³⁸.

³⁷ J. Piaskowski, *op. cit.*, pp. 118-121.

³⁸ P. Pudło, M. Rychter, *Grot oszczepu znaleziony na stanowisku nr 2 w Ostrowitem, pow. Chojnice, „Pomorania Antiqua”*, Vol. XXIII, 2010, p. 230-231, fig. 3-5.

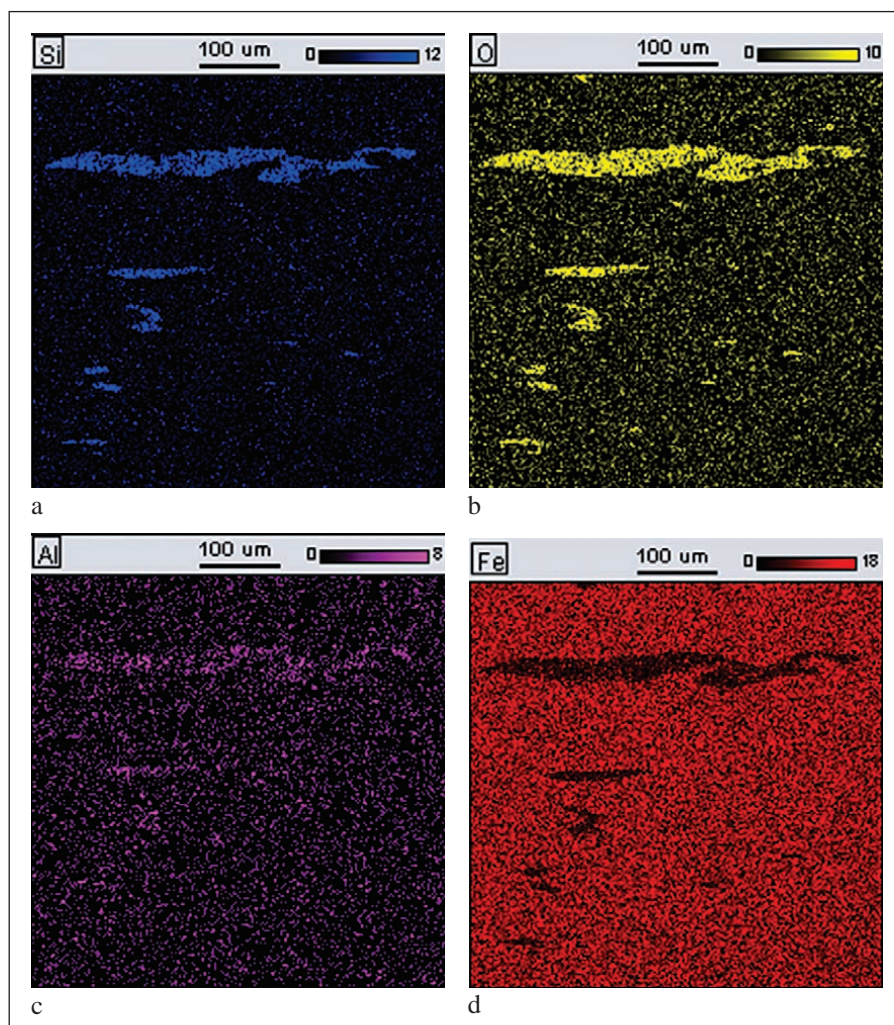


Fig. 17. Surface distribution of silicon (a), oxygen (b), aluminium (c), and iron (d) in the area presented in Fig. 7.

Spearheads that are the most sophisticated technologically are pattern-welded ones³⁹. In our case, the X-ray and metal science analyses did not demonstrate such structures and construction details. Like in the case of the axe, also in the case of the spearhead, it is impossible to determine whether it was made from one iron billet or the blade and the socket were made of materials of different origins. The latter possibility would be indicated by a different element content in both spearhead parts, although it may have resulted from an

³⁹ E.g. A. Anteins, *Nakonechniki kopiy iz svarochnoy uzorchatoy (damasskoy) stali, naydennye v Estonii*, „Izvestia Akademii Nauk Estonskoy SSR”, Vol. XI, Seriya obshchestvennykh nauk, no. 4, 1962, pp. 354-362; Idem, *Nakonechniki kopiy sposerebrennyimi vtulkami v drevney Pribaltike i issledovanie damaskirovaniya ikh per'ev*, „Acta Universitatis Wratislaviensis”, no. 56, „Studia Archeologiczne”, Vol. II, 1967, p. 289-305; Idem, *Damasskaya stal' v stranah basseyna Baltiyskogo Morya*, Ryga 1973, pp. 64-124; J. Ypey, *Flügelanzlen in niederländischen Sammlungen*, [in:] *Vor- und frühgeschichte des unteren Niederrheins. Rudolf Stumpffuß zum Gedächtnis*, ed. G. Krause, Bonn 1982, pp. 241-267; M. Husár, *op. cit.*, pp. 208-209; S. Eichert, M. Mehofer, R. Baier, *Archäologische und archäometallurgische Untersuchungen an einer karolingerzeitlichen Flügelanzlenspitze aus dem Längsee in Kärnten/Österreich*, „Archäologisches Korrespondenzblatt”, Vol. 41/1, 2011, p. 141.

uneven corrosion process or a varied distribution of components in the ore obtained from the same deposit⁴⁰.

While discussing the spearhead, it seems necessary to comment briefly on the way of attaching the shaft to the socket. Due to the partial destruction of this part of the artefact, it is possible only to a certain extent. The socket of the analysed weapon is not forge-welded. Therefore, the shaft was most probably attached to the spearhead when it was hot and the socket was closed with the edges overlapping. Due to the fact that the lower part of the socket is partly damaged, one cannot rule out an additional use of a rivet or a nail in order to improve the stability of the socket.

In the case of the axe, no traces of wood were found in the eye. By contrast, in the socket of the spearhead and beside the body, remains of the shaft were found. Due to a good state of preservation of the analysed remains, it was possible to determine the species of the wood, which was identified as yew (*Taxus baccata*)⁴¹.

⁴⁰ T. Kurasiński, K. Skóra, *Militaria.....*, p. 82.

⁴¹ We would like to thank Maria Michniewicz, from Institute of Archaeology and Ethnology of Polish Academy of Sciences, Warsaw for a botanical analysis of the preserved organic remains from the cemetery in Radom.

The results of the palaeobotanical analyses conducted so far indicate that hardwood species were preferred materials for the production of shafts, mainly ash and beech, and less frequently other species, such as oak⁴². However, yew may have been used as material for shafts, because it has good technical and functional parameters, especially as far as durability and resistance under varying humidity conditions are concerned⁴³. An additional advantage of it was the red-brown colour, producing a wonderful visual effect⁴⁴. It is not without reason that there were attempts to prevent excessive exploitation of habitats of this species. For example, the importance of this species of tree in medieval England is confirmed by edicts issued by the rulers concerning the protection of yew forests and the necessity of planting new ones to supply this valuable material⁴⁵.

Instead of a conclusion

The results of the conducted metal science analyses are difficult to assess. Both the spearhead and the axe head are characterised by a lack of more sophisticated manufacturing techniques aimed at improving the battle qualities of the discussed weapons⁴⁶. Above all, the analyses of the working parts did not reveal either structures resembling welded-on edges, or procedures (quenching or carburising) improving the quality of the weapon. However, it is worth noting that the results may have been influenced by the above-mentioned factors including the state of preservation and the course of the metallurgical process⁴⁷. In the case of Early Medieval butt and pole weapons, especially from the Polish lands, the comparative base concerning specialist material science analyses is still modest⁴⁸. Hence the difficulties in establishing the degree of representativeness of the discussed weapons against a broader background.

Translated by G. Żabiński

Streszczenie

Badania metalograficzne militariów z wczesnośredniowiecznego cmentarzyska szkieletowego w Radomiu, stan. 4

W artykule zaprezentowano zagadnienia związane z technologią produkcji uzbrojenia we wczesnośredniowiecznej Polsce na przykładzie grotu włóczni (typ II wg A. Nadolskiego) i topora (odmiana a typu V wg A. Nadolskiego), odkrytych na wczesnośredniowiecznym cmentarzysku w Radomiu.

Stanowisko to należy do najlepiej archeologicznie rozpoznanych wczesnośredniowiecznych cmentarzysk na obszarze pomiędzy Pilicą, Wisłą, Kamienną i Czarną,

który w późnośredniowiecznej historiografii zaczął być określany jako ziemia radomska (*terra radomiensis*). Nekropolia ta w okresie formowania się państwa wczesnopiastowskiego wchodziła w skład większej struktury osadniczej, obejmującej gród zwany „Piotrówką”, którego początki sięgają 2. połowy X stulecia, wraz z okolicznymi osadami, kaplicą grodową św. Piotra oraz z co najmniej jeszcze jednym cmentarzyskiem szkieletowym.

Na podstawie wyposażenia pośmiertnego, zwłaszcza monet, a także uwzględniając niektóre cechy obrządku pogrzebowego, można przyjąć, że na omawianym cmentarzysku zmarłych chowano w okresie między ostatnią ćwiartką XI a końcem XII w.

W niniejszym artykule ograniczyliśmy się do podania najbardziej podstawowych ustaleń dotyczących kontekstu odkrycia i samych zabytków, główną uwagę koncentrując na omówieniu kwestii metalograficzno-technologicznych. Oba interesujące nas zabytki poddane zostały badaniom rentgenowskim, składu chemicznego oraz metalograficznym. Zachowane pozostałości drzewca grotu włóczni

⁴² Cf. T. Stępnik, *Średniowieczne wyroby drewniane z Ostrowa Lednickiego – analiza surowcowa*, „Studia Lednickie”, Vol. 4, 1996, p. 273, Plate 5; E. Opravil, *Holz aus frühmittelalterlichen Gräberfeldern in Mähren*, [in:] *Studien zum Burgwall von Mikulčice*, Vol. 4, ed. L. Poláček, Brno 2000, pp. 174-175; L. Poláček, O. Marek, R. Skopal, *Holzfunde aus Mikulčice*, [in:] *Studien zum Burgwall von Mikulčice*, ed. L. Poláček, Brno 2000, p. 198; W. Tokarski, *Militaria – broń miotająca, obuchowa i drzewcowa, oraz elementy rzędu końskiego i oporzędzenia jeździeckiego*, [in:] *Wczesnośredniowieczne mosty przy Ostrowie Lednickim*, Vol. I: *Mosty traktu gnieźnieńskiego*, ed. Z. Kurnatowska, Lednica-Toruń 2000, p. 85; M. Husár, *Niektóre aspekty včasnostredovekých kopijí a oštepov z územia Slovenska – otázky násad a odtlačkov textílií*, „Archaeologia Historica”, Vol. 33, 2008, p. 457-461, 468, Plate 1; T. Kurasiński, K. Skóra, *Wczesnośredniowieczne cmentarzysko...*, p. 50). However, there is evidence of using yew to produce wooden parts of weapons, including shafts, in earlier periods (P. A. Thomas, A. Polwart, *Taxus baccata L.*, „Journal of Ecology”, Vol. 91/3, 2003, p. 515; earlier literature there).

⁴³ B. Molski, *Gatunki drewna używane w średniowiecznym Szczecinie do wyrobu przedmiotów codziennego użytku*, „Archeologia Polski”, Vol. 13, Fasc. 2, 1968, p. 494.

⁴⁴ J. Kaźmierczyk, *Wczesnośredniowieczne wyroby bednarskie z Ostrowka w Opolu*, „Kwartalnik Historii Kultury Materialnej”, Vol. 13, Fasc. 3, 1965, p. 473.

⁴⁵ P.A. Thomas, A. Polwart, *op. cit.*, p. 515.

⁴⁶ Cf. M. Husár, *Hroty kopijí/oštepov...*, p. 206.

⁴⁷ Cf. e.g. J. Piaskowski, *Untersuchungen der frühmittelalterlichen Eisen- und Stahltechnologie der Slawen in der Gebieten zwischen Weichsel und Oder*, „Archaeologia Polona”, Vol. XV, 1974, p. 80.

⁴⁸ The situation has not changed much since the first attempt at a summary of the state of research (see W. Świętosławski, *Technologia produkcji uzbrojenia w Polsce średniowiecznej w świetle źródeł archeologicznych*, [in:] *Pamiętnik XIV Powszechnego Zjazdu Historyków Polskich*, Vol. 2, Toruń 1994, pp. 317-321).

przekazano do paleobotanicznej oceny gatunkowej (cis – *Taxus baccata*).

W przypadku topora, wyniki przeprowadzonych badań metaloznawczych sugerują niejednorodny stopień nawęglania, a w związku z tym zróżnicowaną twardość (HV1) żeleźca. Uzyskana średnia twardość struktury jego szyjki wynosiła 195 HV1, zaś dla ostrza – 171 HV1. Próbkę pobrana z ostrza (nr 2) o szacowanej zawartości węgla 0,25% wskazywałaby na użycie stali niskowęglowej lub nawęglonego żelaza. Natomiast w wycinku pozyskanym z górnej partii topora (nr 1) stwierdzono obecność zawartości węgla na poziomie 0,7%, co oznaczałoby stal wysokowęglową. W ostrzu nie udało się zaobserwować struktury, która wskazywać mogłaby na zastosowanie hartowania.

Z kolei grot włóczni wykonano z żelaza, w którym zawartość węgla oszacowano na mniej niż 0,01%. W obrębie pobranej próbki nie zaobserwowano żadnych zabiegów wzmacniających. Użycie takiego surowca wpływało na

uzyskanie wyrobu o niewielkiej twardości, określonej na około 140 HV1.

Wyniki przeprowadzonych badań metaloznawczych wymykają się jednoznacznej ocenie. Zarówno grot włóczni, jak i żeleźce topora charakteryzują się brakiem bardziej zaawansowanych technik wykonania, mających na celu zwiększenie czy poprawę walorów bojowych omawianej broni. Przede wszystkim jednak nie udało się stwierdzić na częściach pracujących struktur w rodzaju nakładek. Nie zaobserwowano też zabiegów hartowania czy nawęglania, polepszających jakość oręża. Warto jednak zauważyć, że na uzyskanych wynikach zaważyć mogły wspomniane czynniki, związane m. in. ze stanem zachowania i przebiegiem procesu metalurgicznego. W przypadku wczesnośrednio-wiecznej broni obuchowej i drzewcowej, zwłaszcza z ziem polskich, dysponujemy skąpą bazą porównawczą w zakresie specjalistycznych badań materiałoznawczych. Stąd trudno o ocenę reprezentatywności omawianego oręża.

