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A POSSIBLE ROMAN PERIOD SWORD FROM GRZYBOWO (GRZYBOWEN), MASURIA, NE POLAND. THE ARCHAEOLOGICAL AND TECHNOLOGICAL CONTEXT

UNA POSIBLE ESPADA DE PERIODO ROMANO DE GRZYBOWO (GRZYBOWEN), MASURIA, NE. DE POLONIA. CONTEXTO ARQUEOLÓGICO Y TECNOLÓGICO

POR

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Abstract - Resumen

The paper discusses a recent stray find of a sword fragment with a possible stamp from Masuria in NE Poland. It was found close to a Roman Period cemetery of the Bogaczewo Culture. On typological grounds, the sword can be classified as a Roman Period weapon. However, the results of metallographic examinations suggest that the find may have been made either from very clean bloomery steel (or hypoeutectoid crucible steel) or from mass-made Industrial Age steel (Bessemer, Thomas, Siemens-Martin, etc.). On the other hand, the chemical composition of the sword would rather imply a pre-Industrial Period steel. In conclusion, it is carefully suggested that the weapon may be a genuine Ancient sword, although its final recognition as a Roman Period weapon could only be verified by finds made from similar metal in undoubted Roman Period contexts.

En este trabajo se analiza el fragmento de una espada con posible sello de Masuria hallada en el NE de Polonia. Fue encontrada cerca de una necrópolis romana de la Cultura Bogaczewo. Tipológicamente es una espada romana. Sin embargo, los resultados de los análisis metalográficos sugieren que fue fabricada o bien con un limpio hierro forjado (o hipotéticamente con hierro fundido) o con acero preindustrial (Bessemer, Thomas, Siemens-Martin, etc.). Por otro lado, la composición química de la misma implicaría el empleo de acero pre-industrial. Para concluir, se sugiere, con cautela, que la espada puede ser una espada antigua, pero esta conclusión solo puede verificarse si aparecen hallazgos similares del periodo romano.

Keywords - Palabras Clave

Sword; stamps on swords; Roman Period; bloomery steel; crucible steel; Industrial Period steel; archaeometallurgy; Masuria; Poland.

Espada; sellos en espadas; periodo romano; hierro forjado; hierro colado; acero del periodo industrial; arqueometalurgia; Masuria; Polonia.

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INTRODUCTION

The sword and its origins[1]

In Summer 2012, archaeologists received information on a stray find of a "dagger" or "sword"[2] in Grzybowo (Grzybowen), the Ryn District, possibly from the west bank of Lake Dejguny (Fig. 1: A, D). The place of discovery was examined for traces of previous settlement, but with no conclusive result.[3] However, it seems probable that the sword is related to a local cremation cemetery of the Bogaczewo Culture from the Roman Period (see Appendix 1).

Figura 1. A - location of Grzybowo (Grzybowen) on the map of Poland. B - Lake Dejguny and the land estate of Grzybowo (Grzybowen) in a map from 1947 (1: 25000). C - Grzybowo (Grzybowen) on a present-day map. D - find place of the sword (photo T. Nowakiewicz).

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[1] The authors are indebted to Peter Crew and the reviewers for reading the paper and for making many valuable suggestions.

[2] Information from Mr Jacek Wielgus, a detectorist with many years' involvement in saving the country's archaeological heritage.

[3] For this information, the authors are indebted to Mr J. Ciastek, Mr M. Piątkowski, Mr D. Rembecki and Mr J. Wielgus.

Only the hilt with the upper part of the blade survived (Fig. 2). The blade tapers gently towards the point of breaking. It seems difficult to assess whether the breaking occurred in result of combat or as part of ritual destruction of the weapon. There are some nicks and gouges on the edges which may have originated during the use of the sword. The cross-section of the upper part of the blade is flattened rhombic. The shoulders of the tang are almost right-angled. The tang is wide near the blade and then it strongly tapers towards its end, where a small rhombic iron plate is riveted. There is also a putative stamp on the tang (Fig. 2).

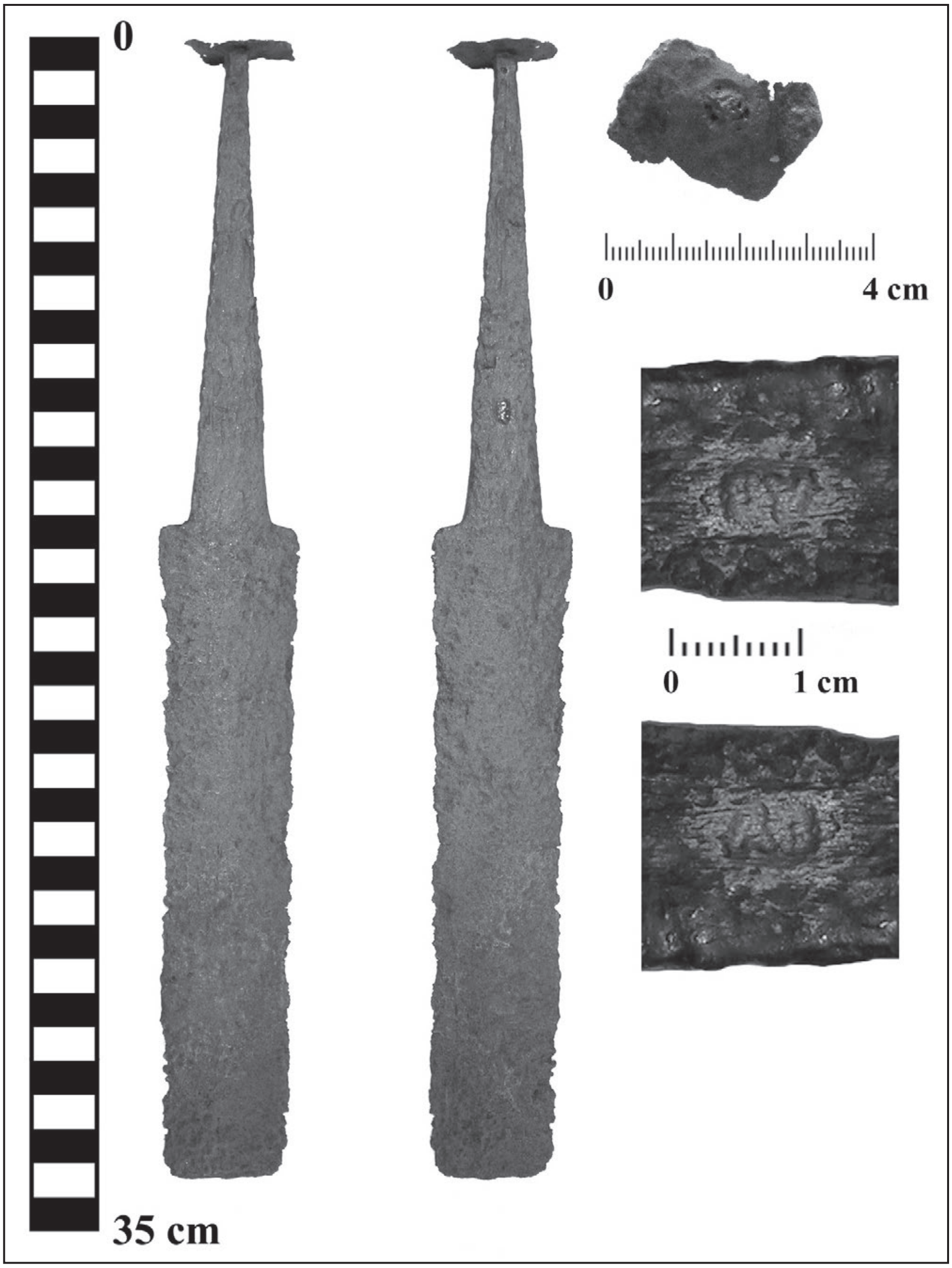

Figura 2. Sword fragment from Grzybowo (Grzybowen), the Ryn District. Photo G. Żabiński.

Metrical data (before conservation)

— total length (preserved): 335 mm
— total weight (preserved): 311 g
— blade length (preserved): 194 mm
— blade width at the hilt: 42 mm
— blade thickness at the hilt: 7 mm
— hilt length: 141 mm
— tang width at the crosspiece: 25.5 mm
— tang thickness at the crosspiece: 7 mm
— tang width at the pommel: 7.5 mm
— tang thickness at the pommel: 5 mm
— pommel head width: 29 mm
— pommel head thickness: 19.5 mm
— pommel head height: 6 mm

Typochronology of the sword

As the sword is lacking an evident archaeological context (its relation to the Roman Period cemetery is possible, but cannot be proved beyond doubt), a later chronology of the find had also to be considered, also including mass-made Industrial Age weapons. Regrettably, due to corrosion, no external traces of Industrial Period manufacturing techniques could be found on the weapon (for such traces see, e.g., Żabiński and Stępiński, 2014). Furthermore, a search in available publications in order to identify analogous artefacts from later periods was carried out and specialists from the Polish Army Museum in Warszawa were consulted. No conclusive results were achieved.

Concerning Roman Period swords, the first type to consider is Type Vimose-Illerup (rapier-shaped swords). Such blades are long or of medium length (66-78 cm), usually narrow or of medium width. Their edges may run in parallel to each other or may be convergent. The total length of such swords is 80-97 cm. Blade cross-sections are usually flat octagonal. Tangs may be short (12-14.5 cm) or long (15.5-21 cm). Tang shoulders are usually right-angled, less often obtuse-angled or arch-shaped. Fully preserved tangs usually end with bronze knobs, mushroom-shaped terminals or washers (Biborski and Ilkjær, 2006: 217-218).

Six subtypes of Type Vimose-Illerup were isolated, differing with blade lengths (66.5-78 cm), blade widths (3.6-5 cm), tang lengths (11.5-over 20 cm) and blade cross-sections (octagonal, rhomboid, or lenticular). Their chronology encompasses Phases C1b (c. AD 210/230-260) and C2 (c. AD 260-310) (Biborski and Ilkjær, 2006: 221-232, Tables 24-29, Figs. 141-146). About 87% of finds of Type Vimose-Illerup swords come from the North European *Barbaricum*, including the territory of the Przeworsk Culture. In the Empire, there are finds from *Germania Superior* and *Inferior* and *Pannonia Superior* (Biborski and Ilkjær, 2006: 235-236)

The sword could also match characteristics of Type Vøien-Hedelisker. Such blades are mostly c. 76-85 cm long, 3.5-5 cm wide and they taper into long points. Tangs are usually short (10.5-14 cm). Tang shoulders are right-angled, obtuse-angled or arch-shaped. Tang ends are hammered flat and they end with pommel heads of Groups 5-7, including rhombic or cross-shaped iron plates, or cast pieces with a motif of an animal head. The total length of such swords is about 89-95 cm. Blade cross-sections are flat, octagonal or rhombic (Biborski and Ilkjær, 2006: 252).

Two subtypes were identified. Subtype 2 (into which the discussed sword could be classified) is remarkable for the rhombic cross-section of the blade. Blades are very long (76-85 cm), narrow or of medium width (3.6-4.6 cm) and they taper strongly. Tangs are short (10.5-13 cm) and their shoulders are right-angled, obtuse-angled or arch-shaped. The chronology of this subtype encompasses phases C2-D (c. AD 260-450) (Biborski and Ilkjær, 2006: 254-257, Tab. 38). The territorial distribution of these swords is chiefly limited to Northern Europe. A few finds are known from the territory of *Germania Superior*. There is one isolated find from Isep in Lesser Poland (Biborski and Ilkjær, 2006: 257).

In the classification system by Ch. Miks, Type Vimose-Illerup corresponds to Type Nydam-Straubing, while Type Vøien-Hedelisker to Tendency/Variant Ejsbøl of Type Nydam-Straubing. Type Nydam-Straubing swords have narrow blades which may taper towards short ogival points. Cross-sections may be of many shapes. This type has five tendencies/variants (Miks, 2007: Vol. 1, 80; Vol. 2, Fore-Plate C. 20-25). A special attention is drawn to Tendency/Variant Newstead and Tendency/Variant Straubing, perhaps in favour of the former.

Tendency/Variant Newstead is remarkable for horizontal or slightly sloping tang shoulders. Blade edges run in parallel to each other or taper immediately under the hilt. Cross-sections are usually rhomboid. Blades are 559-739 mm long and 35-42 mm wide. The tang length may be 110-183 mm, usually 125-160 mm. The chronology encompasses Phases B1b-C1b (c. AD 80-260) (Miks, 2007: Vol. 1, 81-82, Table 16; Vol. 2, Fore-Plate C. 20-21).

Tendency/Variant Straubing includes swords with horizontal tang shoulders. Blades taper gently towards short ogival points. Cross-sections are octagonal, less often rhomboid or lenticular. Blades are 560-815 mm long, usually 630-750 mm. The maximum blade width is between 39 and 49 mm. The tang length is 110-200 mm, usually 120-180 mm. The chronology encompasses Phases B2-D1 (c. AD 80-400) (Miks, 2007: Vol. 1, 83-85, Table 18; Vol. 2, Fore-Plate C. 23).

The find from Grzybowo could also match examples of Type I/6 or I/5 after M. Biborski, dated to Phase B2 (c. AD 80-160) (Biborski, 1978: 60, Fig. 2:d, 3:a) or Group II of Roman swords (Biborski, 1994: 94-95, Fig. 4). P. Kaczanowski described them as Roman imports of Type Newstead, i.e., Early Roman *spathae*. Such blades taper in their forte parts. Such swords appear in the Roman context generally in the 1st-2nd c. AD, and in the *Barbaricum* (mainly in the Przeworsk Culture) - during Phases B1 and B2 (Kaczanowski, 1992: 22-23, 121, Fig. 1:2-3). Their total length is 63-69 cm, the length of the hilt from 12 to 17 cm, and the width of the blade 3.6-4.5 cm. Blade cross-sections are mostly rhomboid or lenticular (Biborski, 1999: 99-100, Fig. 15). Another proposal by M. Biborski identifies such finds as Type II of Early Roman swords. The total length of such blades is 63-68 cm, the width is 3.6-4.8 cm, and the length of the hilt is 12.5-15 cm. Their chronology is as above (Biborski, 1994: 94-95, Fig. 4).

Known swords from the West Balt cultural circle are listed in Appendix 2.[4] In the Bogaczewo Culture finds of swords from the Early Roman Period prevail. Generally, the number of weapons in grave furnishings decreases in the Younger Roman Period. Starting from Phase C2 there are almost no weapons, which is mainly due to changes in burial rites (Kontny, 2008).

Recently, some ritually destroyed sword blade fragments have been discovered at a putative bog offering site in Lake Nidajno (Czaszkowo Site I), the Mrągowo District, in the Prussian

[4] We do not mention here swords dated to the Late Migration Period, i.e., seaxes typical of the Sambian-Natangian area, Lithuania (the West Lithuanian Group and Lower Neman Group) and the Elbląg Group (see, e.g., Kontny, 2013a), spathae from Taurapilis, Utena d., Barrow No. 5 (Tautavičius, 1981: 20ff., Fig. 2-4; Bliujienė and Steponaitis, 2009, 188-192, Figs. 7-8) and Krikštonys, Lazdijaj d., Grave 1 (Kulikauskas, 1959: 73ff., Fig. 3-5; for both spathae see also Kazakevičius, 1988: 94-95, Fig. 37.1-2, 97-98, Fig. 39), seax scabbards or double-edged swords from the Olsztyn Group (Kontny, forthcoming), as they hardly offer any typological analogies to the discussed sword.

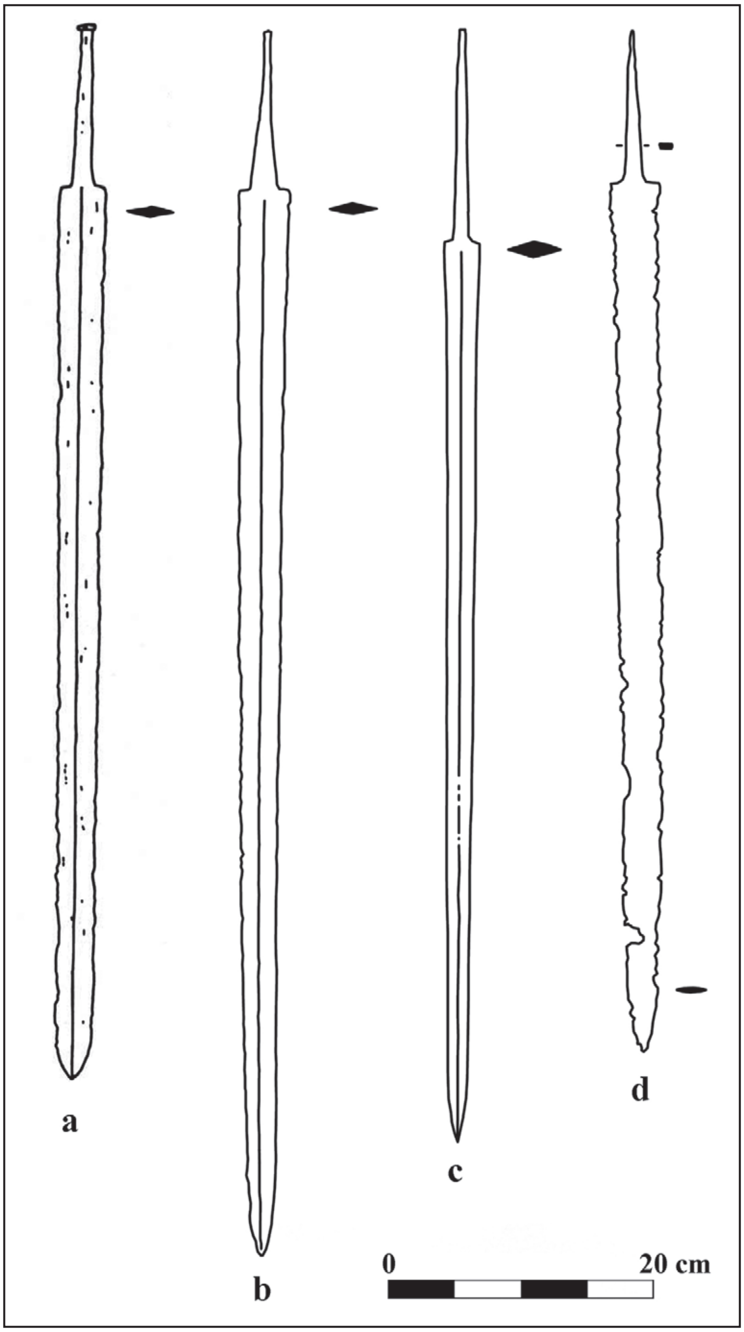

Figura 3. Selected possible typological analogies to the sword from Grzybowo (Grzybowen).

a. Type I/6, Kamieńczyk, Wyszków Comm., Poland, Grave 170, Phase B2 (c. 80-160 AD) (after Biborski, 1978: 59, Fig. 3a; see also Dąbrowska, 1997: 47, Fig. XC:7)
b. Type Vøien-Hedelisker, Subtype 2, Hedelisker, Århus Comm., Denmark, Phase C2 (c. 260-310) (after Biborski and Ilkjær, 2006: 256, Fig. 155.2)
c. Type Newstead, Le Doubs à Pontoux, Saône-et-Loire Dept., France, late 2nd-early 3rd c. AD (after Kaczanowski, 1992: 121, Fig. 1.2)
d. Type Nydam-Straubing, Tendency/Variant Newstead, Rottweil, Rottweil Distr., Germany, after c. 72 AD (?) (after Miks, 2007: Vol. 2, Pl.57.A617)

tribal territory of Galindia (Nowakiewicz and Rzeszotarska-Nowakiewicz, 2012: 59-61, Figs. 34-36; 74-78, Figs. 51-53, 115-119, Figs. 82, 84; Nowakiewicz and Rzeszotarska-Nowakiewicz, 2011). Some of about 250 finds of weaponry and related artefacts may have originated in the territory of the Eastern Roman Empire. A preliminary chronology of the site falls between the 2nd half of the 3rd c. and the early 4th c. AD. This deposit may have been related to Balt-Germanic contacts and/or to migrations of groups of Galindians to southern Europe and back (Nowakiewicz and Rzeszotarska-Nowakiewicz, 2012: 127-137).

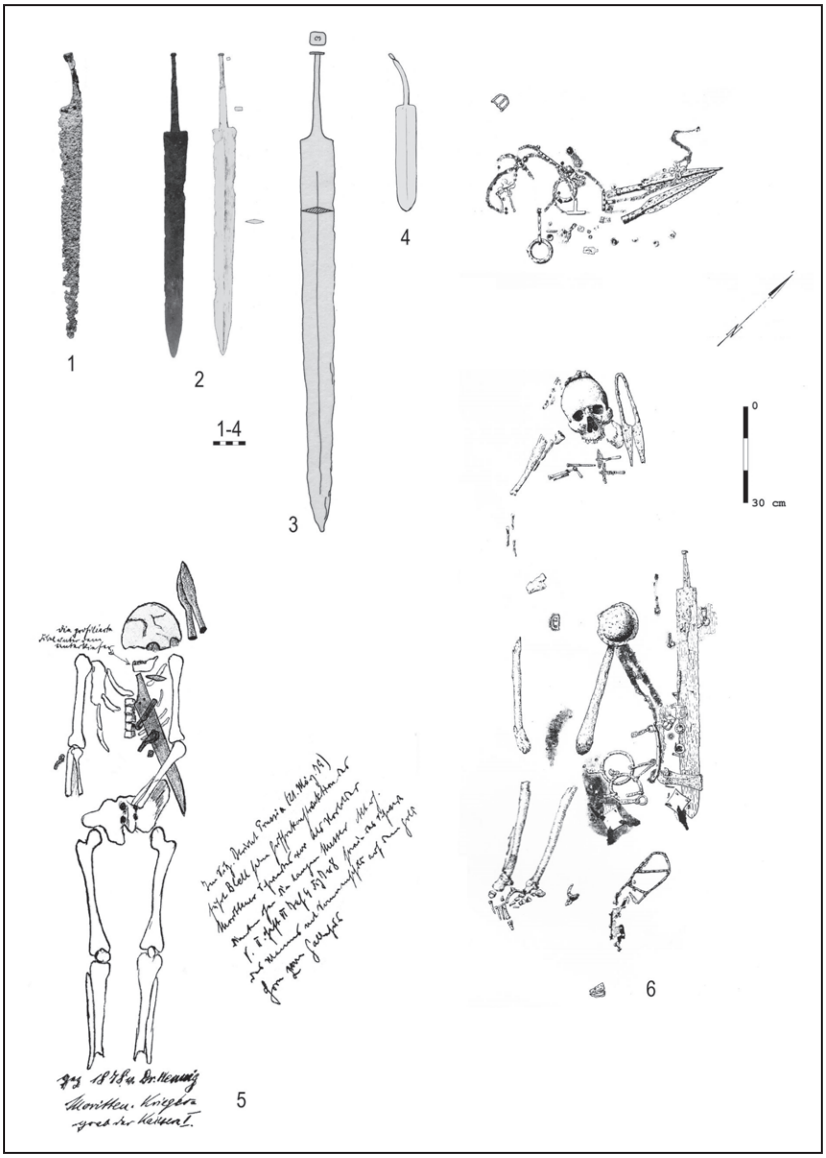

Figura 4. Swords from the West Balt circle. 1 - Sibirskoe, inhumation grave; 2 - Skomack, Grave 23; 3 - Parussnoe; 4 - Fedotovo; 5 - plan of the inhumation grave from Sibirskoe; 6 - plan of Grave 1 from Szwajcaria, Barrow 2. 1-4 - after W. Nowakowski, 2007a; 5 - after Jahn's heritage (courtesy of the Institute of Archaeology, University of Warsaw); 6 - after Antoniewicz, Kaczyński and Okulicz 1958.

THE STAMP ON THE TANG

The putative stamp is located c. 3 cm from the line of the shoulders (Fig. 2). It measures merely 7 x 4 mm. It can tentatively be read as PV or IV and interpreted as the beginning of the Roman name Publius, Iunius, Iulius, Iustulus or the like. If one holds the sword with the blade directed to the left, the stamp can be read as AB.

The forms and function of marks, inscriptions and stamps on Roman swords are very diverse. They could be located both on blades and tangs of these weapons. Apart from symbolic

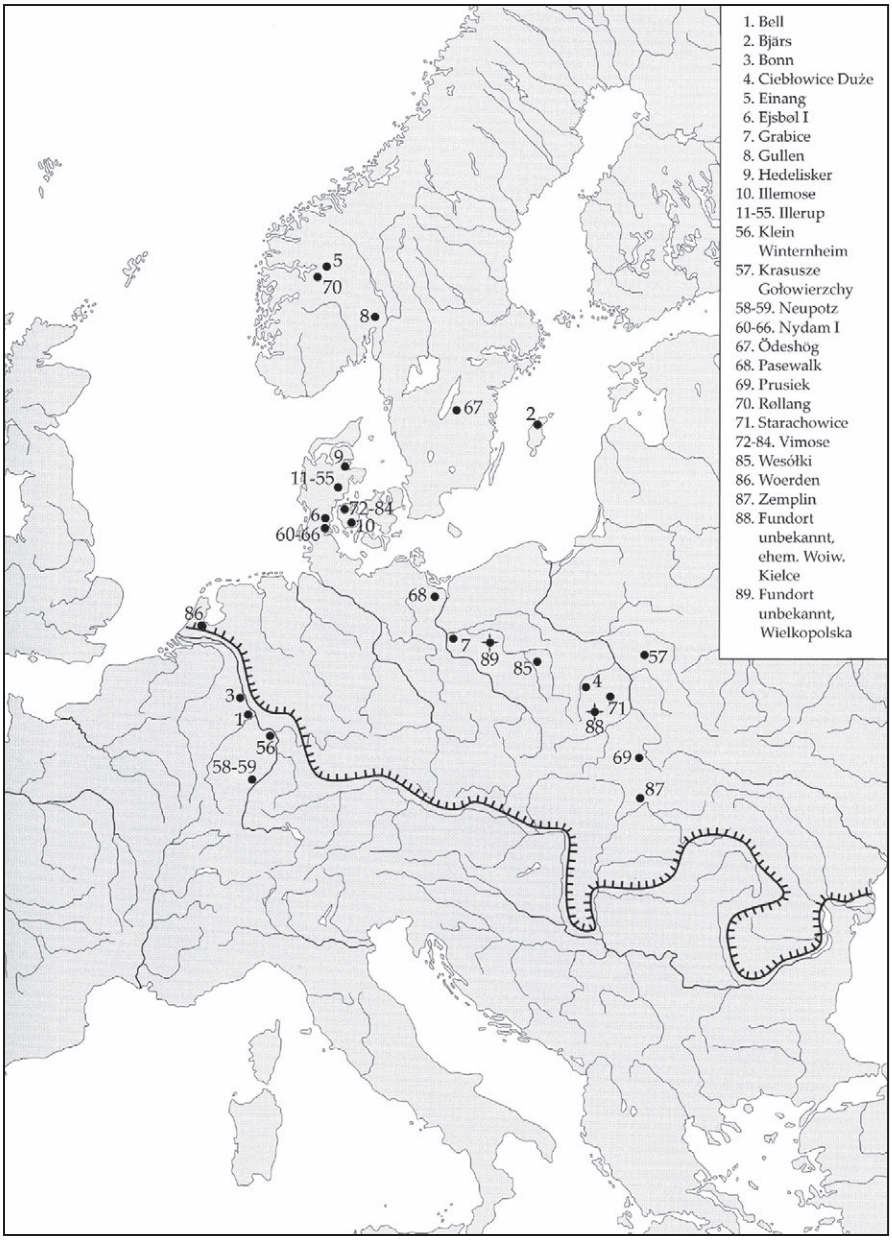

Figura 5. Distribution of Roman Period swords with letter stamps. After Biborski and Kolendo, 2008: 23, Fig. 3.

or devotional meaning, they may have been related to internal organisation of manufacture. The earliest stamps are known from the 1st c. BC. The decline of the use of stamps is usually related to the replacement of private workshops by large state-owned *fabricae* in the 2nd half of the 3rd and the early 4th c. AD (Biborski and Kolendo, 2008: 17-18, 22, 28-29; Biborski and Ilkjær, 2006: 296-322, Fig. 167, Tab. 59, Fig. 168, Tabs. 60, 61, 62; Miks, 2007: Vol. 1, 135-148, Figs. 14-16; Kaczanowski, 1992: 14; Letki, 2009: 49-64). Some researchers assume that workshop stamps are most frequently found on swords with the most complex technology of manufacture (Biborski and Kolendo, 2008: 17, with further reading; Biborski and Ilkjær, 2006: 319-320, Tab. 61; Kaczanowski, 1992: 19-20). It is also worth mentioning observations made by I. M. Stead concerning stamps on Iron Age British swords. This author says that some such stamps on shorts swords were interpreted as astral symbols with religious or magical significance. On the other hand, stamps on longer blades were most probably manufacturers' personal marks. Furthermore, Stead rejects an assumption that stamps were quality marks (Stead, 2006: 48-49).

M. Biborski and J. Kolendo identified 89 swords with 125 letter stamps (Biborski and Kolendo, 2008: 17). Only 6 were found in the territory of the Empire. This corresponds to the proportion of swords known from the Empire and the *Barbaricum*. This is related to a small scale of possession of weapons by the civil population of the Empire, or a much smaller significance of deposition of weapons in graves, waters and bogs (Biborski and Kolendo, 2008: 22-27, Fig. 3, Table 1). Furthermore, Bishop and Coulston say that the Roman army often recycled metal, which also applied to weaponry (Bishop and Coulston, 2006: 27-28).

Stamps on Roman swords usually contain names (Roman, Celtic, Germanic and other) - abbreviations of the *tria nomina*, or individual names only with letters M or F (standing for *manu* and *fecit*) (Biborski and Kolendo, 2008: 29-33). Although no exact counterpart was found, one can suggest possible analogies, taking into account such traits as the rectangular shape of the stamp, the text on it (IV- or A-) or its location on the tang. These are:

- Bjärs, the Hejnum Parish, Gotland, Sweden. A Type Woerden-Bjärs (late 2nd-early 3rd c. AD sword from a Phase C1b grave. A rectangular stamp on the tang can be read as VISIM, i.e., [-]*visi m*(*anu*) (Biborski and Kolendo, 2008: 36, cat. No. 2, 37, Fig. 4.2)
- Illerup, the Skanderup Parish, Denmark. A Type Vimose-Illerup sword (late 2nd-early 3rd c. AD). On one side of the blade there is a rectangular stamp of ACIRONI, i.e., *Acironi*(*us*), *Acironi*(*o*) or A(*ulus*) *Ciron*(*ius*)/*A*(*ulus*) *Cironi*(*o*). On the other side there is a rectangular stamp of A[---] (Biborski and Kolendo, 2008: 38, cat. No. 12, 37, Fig. 4.12)
- Illerup, the Skanderup Parish, Denmark. A Type Vimose-Illerup sword (late 2nd-first half of the 3rd c. AD) from the bog deposit (Phase C1b). On the blade there is a rectangular stamp of IVSTVLVS (Biborski and Kolendo, 2008: 41, cat. No. 25)
- Klein Winterheim, the Mainz District, Germany. A Type Pompeii sword (2nd half of the 1st c. AD) from the temple of Mars Leucetius. On the blade there is a rectangular stamp of IV[--], read as *Iu*[*lius*], *Iu*[*nius*] or the like (Biborski and Kolendo, 2008: 44, cat. No. 56)
- unknown find place, possibly the former Kieleckie Voivodeship (in its borders before 1939). A stray find of a Type Buch-Podlodów sword (c. 250-after 300 AD). There are inlaid figures on both flats (Mars and Victoria), and a rectangular stamp of IVN (for *Iun*[*ius*]) (Biborski and Kolendo, 2008: 50, cat. No. 88, 37, Fig. 4.88).

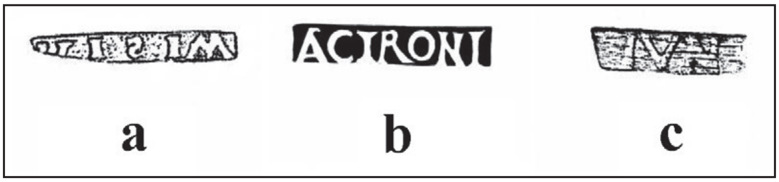

Figura 6. Examples of similar stamps on Roman swords

a. Bjärs, the Hejnum Parish, Gotland, Sweden (after Biborski and Kolendo, 2008: 37, Fig. 4.2)
b. Illerup, the Skanderup Parish, Denmark (after Biborski and Kolendo, 2008: 37, Fig. 4.12)
c. unknown find place, possibly the former Kieleckie Voivodeship (in its borders before 1939), Poland (after Biborski and Kolendo, 2008: 37, Fig. 4.88).

TECHNOLOGICAL EXAMINATIONS

Macro and microstructure

Metallographic examinations of the blade were carried out by Dr Eng Sc Janusz Stępiński at the Academy of Mining and Metallurgy in Kraków. A wedge-shaped sample encompassing a half of the blade's cross-section, was taken c. 5 cm from the broken end (Fig. 7a). The sample was fixed in epoxy raisin, ground using sandpaper (gradations of 200 to 1200 grits) and polished using diamond pastes (9, 3 and 1μ) and aluminium oxide. The surface of the sample's cross-section was then etched with 4% nital reagent in order to reveal its microstructure. Microscopic observations were made with a Leica DMLM light microscope. Hardness tests were made using the Vickers method with a 10 kG load (98N). Scanning electron microscope observations were made using a HITACHI S3500N scanning microscope with an EDS X-ray spectrometer. SEM images were taken from secondary electrons (SE).

A macroscopic image of the blade's cross-section with spots of microscopic observations (1-3) and a schematic distribution of structure components and hardness tests (HV10) can be seen in Fig. 7b-c. The examined cross-section is remarkable for a rather even darkening of its microstructure.

The microstructure near the cutting edge in Spot 1 consists of tempered martensite, troostite and small amount of ferrite (Fig. 7d-g). Farther off from the edge, in Spots 2 and 3 the microstructure is similar, but the share of tempered martensite is lower in favour of pearlite. (Fig. 8). The microstructure also demonstrates that the bladesmith intended to treat thermally (by means of quenching and tempering, or slack-quenching, also known as autoquenching) mainly the cutting edges of the blade. The carbon content is c. 0.7%, which corresponds to the microstructure of hard pearlitic-ferritic steel.

Slag inclusions are hard to discern in the microstructure on the etched surface (Fig. 8b, e). Hardly any traces of plastic deformation can be seen. Scanning electron microscope observations allowed for an isolation of individual slag inclusions (Fig. 9a-b), and local clusters (Fig. 9d). A microanalysis with the use of an EDS X-ray spectrometer demonstrated that individual slag inclusions contained Fe, Si, Ti and traces of Al (Fig. 9c). Inclusions in clusters contain Fe only, that is, these are iron oxides (Fig. 9f). The hardness of the metal in the cutting edge is 469 HV10, in the areas of the flats in the centre of the blade (Spot 3) it is 393-400 HV, while in the centre of the cross-sections its value is 335-337 HV10.

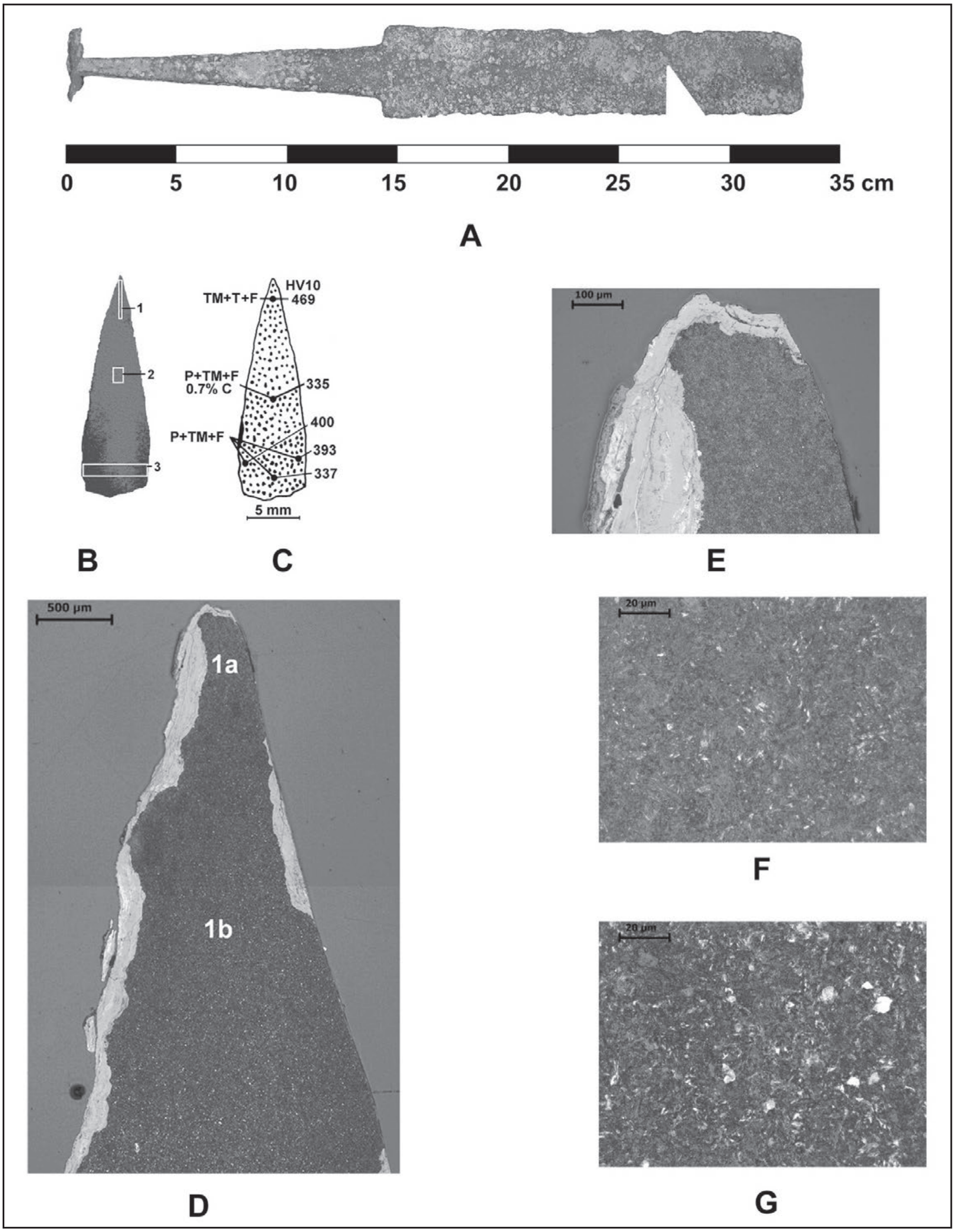

Figura 7. Sword from Grzybowo (Grzybowen): a - spot of sampling; b - macrostructure with spots of microscopic observations (1-3); c - schematic distribution of structure components and hardness tests HV10 (TM - tempered martensite, T - troostite, F - ferrite, P - pearlite; dots mark the presence of carbon); d - corroded edge, Spot 1; e - corroded edge, Zone 1a in Spot 1; f - tempered martensite, troostite and traces of ferrite, Zone 1a in Spot 1; g - tempered martensite, troostite and traces of ferrite, Zone 1b in Spot 1.

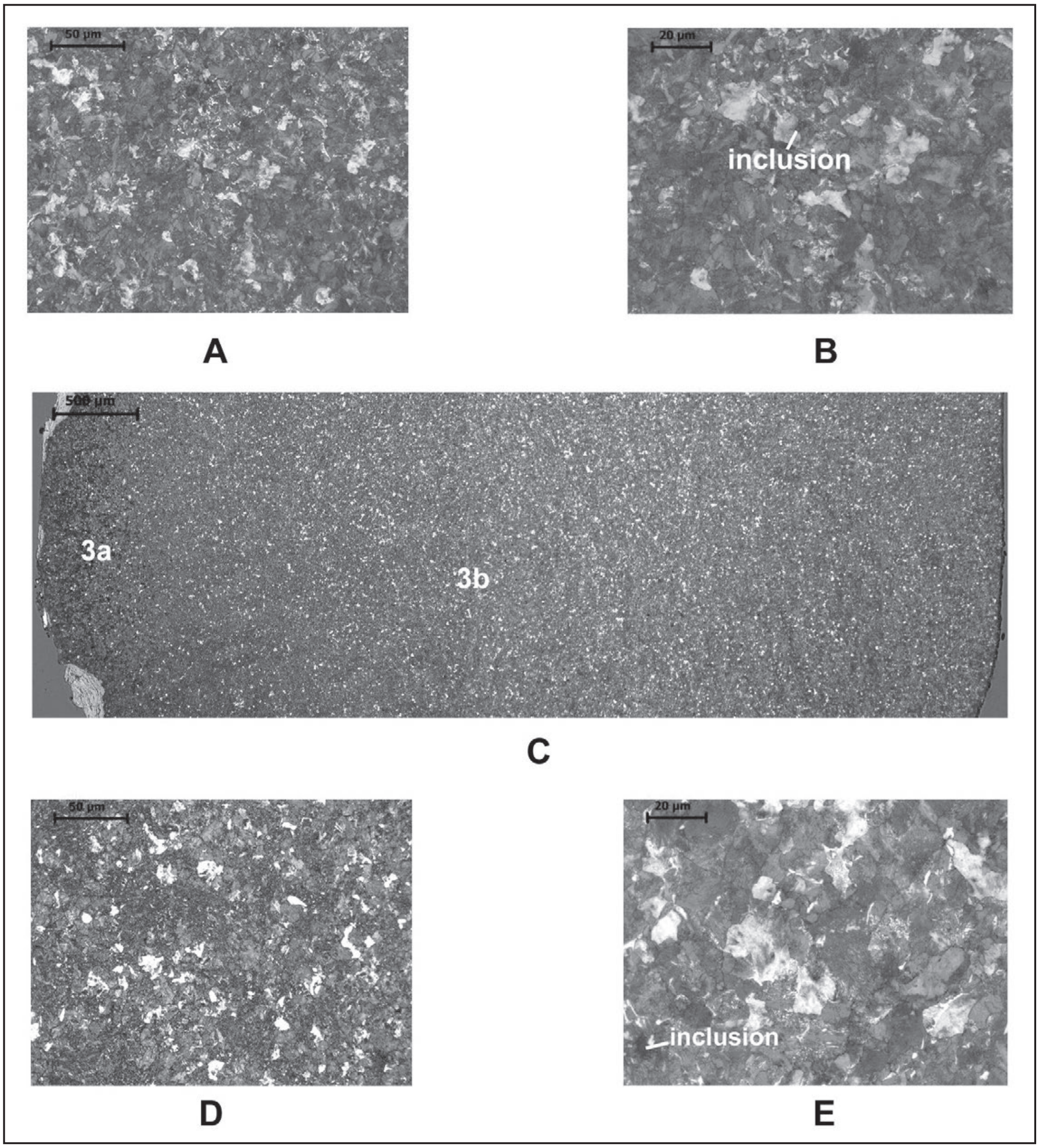

Figura 8. Sword from Grzybowo (Grzybowen): a, b - pearlite and traces of tempered martensite and ferrite in Spot 2; c - microstructure in the cross-section in Spot 3; d - pearlite, tempered martensite and traces of ferrite, Zone 3a in Spot 3; e - pearlite, ferrite and traces of tempered martensite, Zone 3b in Spot 3.

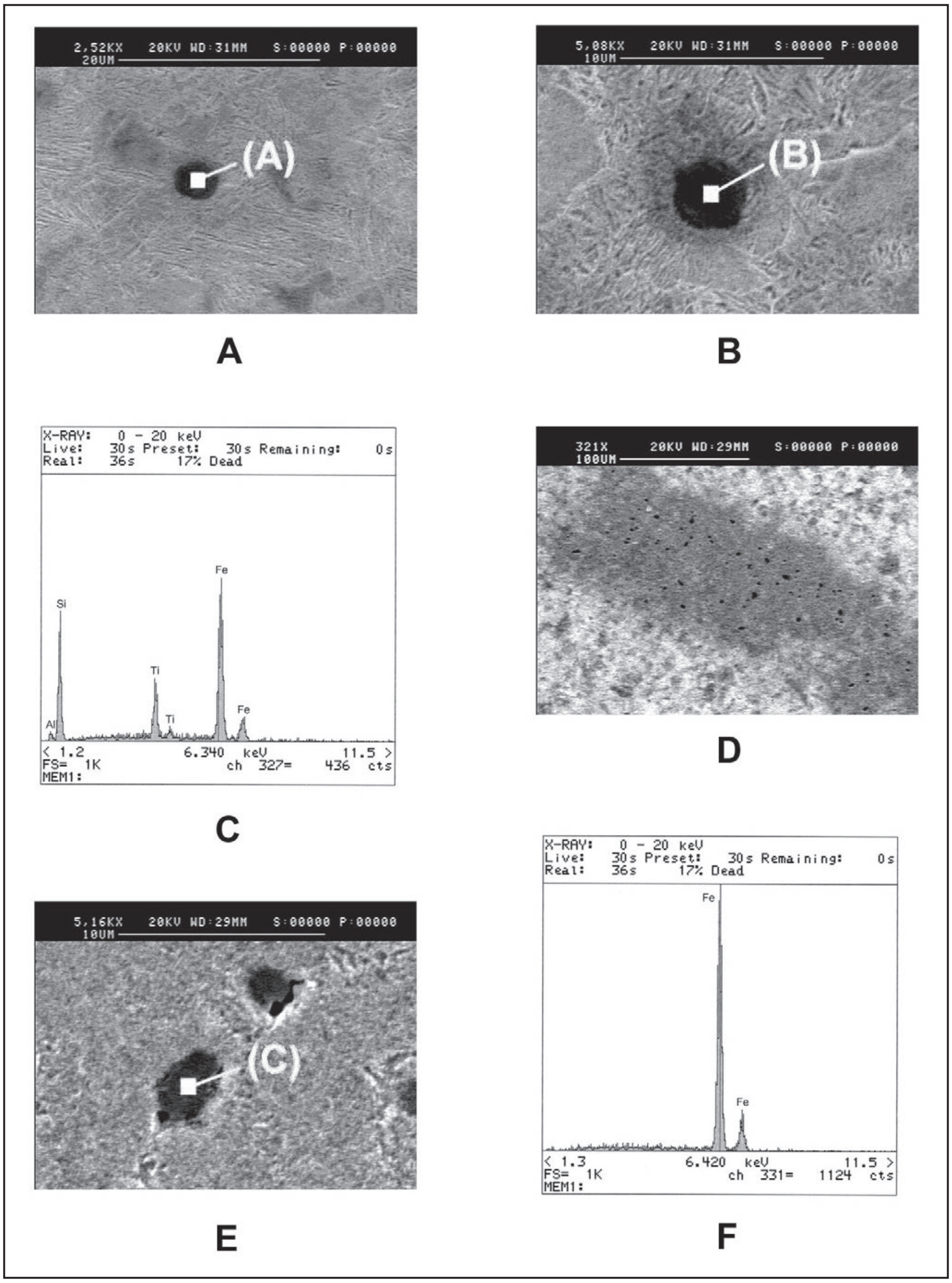

Figura 9. Sword from Grzybowo (Grzybowen). Morphology of slag inclusions, EDS analysis: a, b - individual slag inclusions with spots of analysis (A) and (B); c - EDS spectrum from Spots (A) and (B), peaks from: Fe, Ti, Si and Al; d - sporadic concentrations of slag inclusions; e - analysed slag inclusion from the concentration in Fig. 3d in Spot (C); f - EDS spectrum from Spot (C), peaks from Fe.

In order to better assess the nature of slag inclusions, these were also analysed on the unetched surface of the sample.

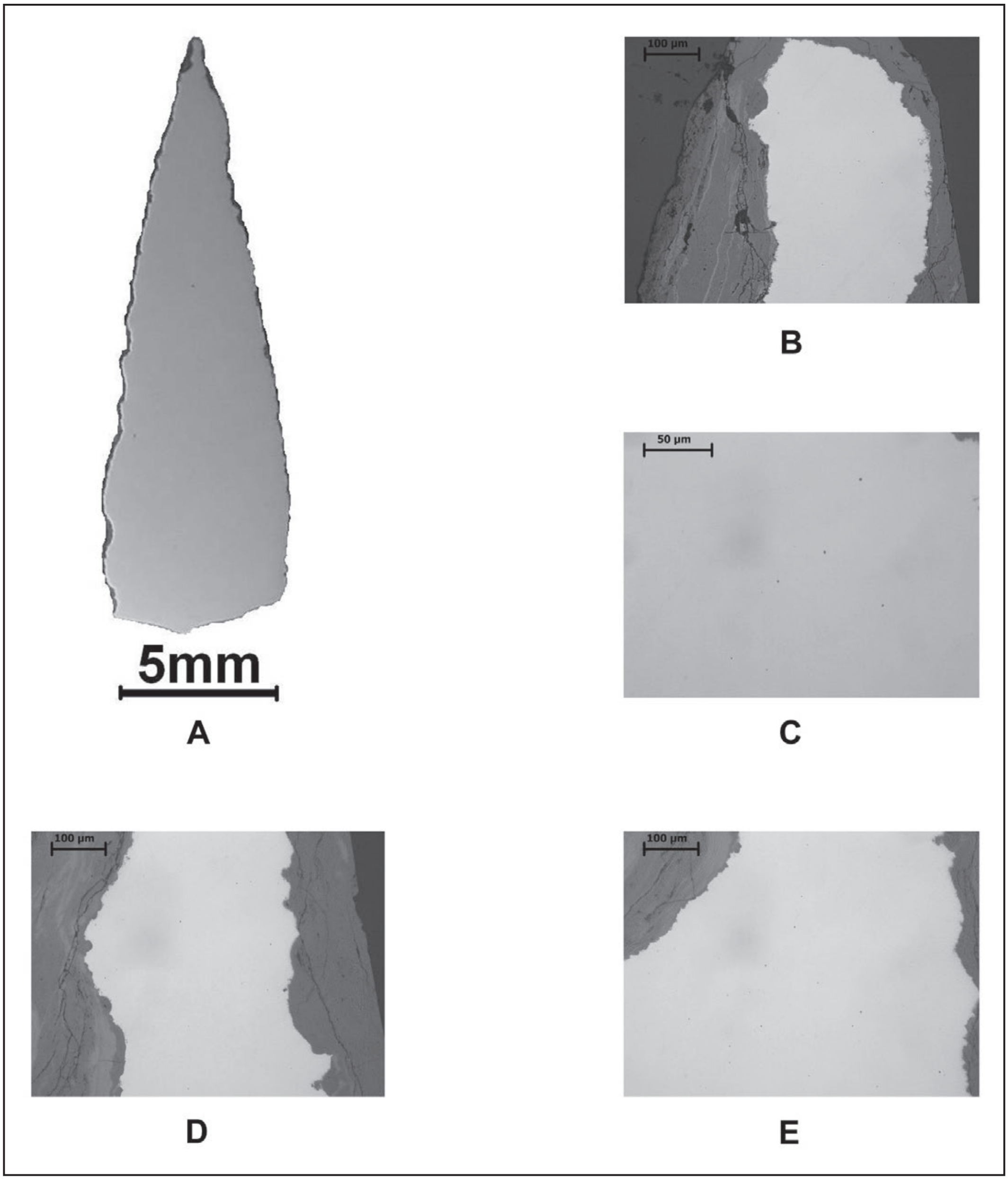

Figura 10. Sword from Grzybowo (Grzybowen): a - unetched cross-section of the sample, slag inclusions are difficult to see with the naked eye; b-e - very tiny slag inclusions near the cutting edge of the blade.

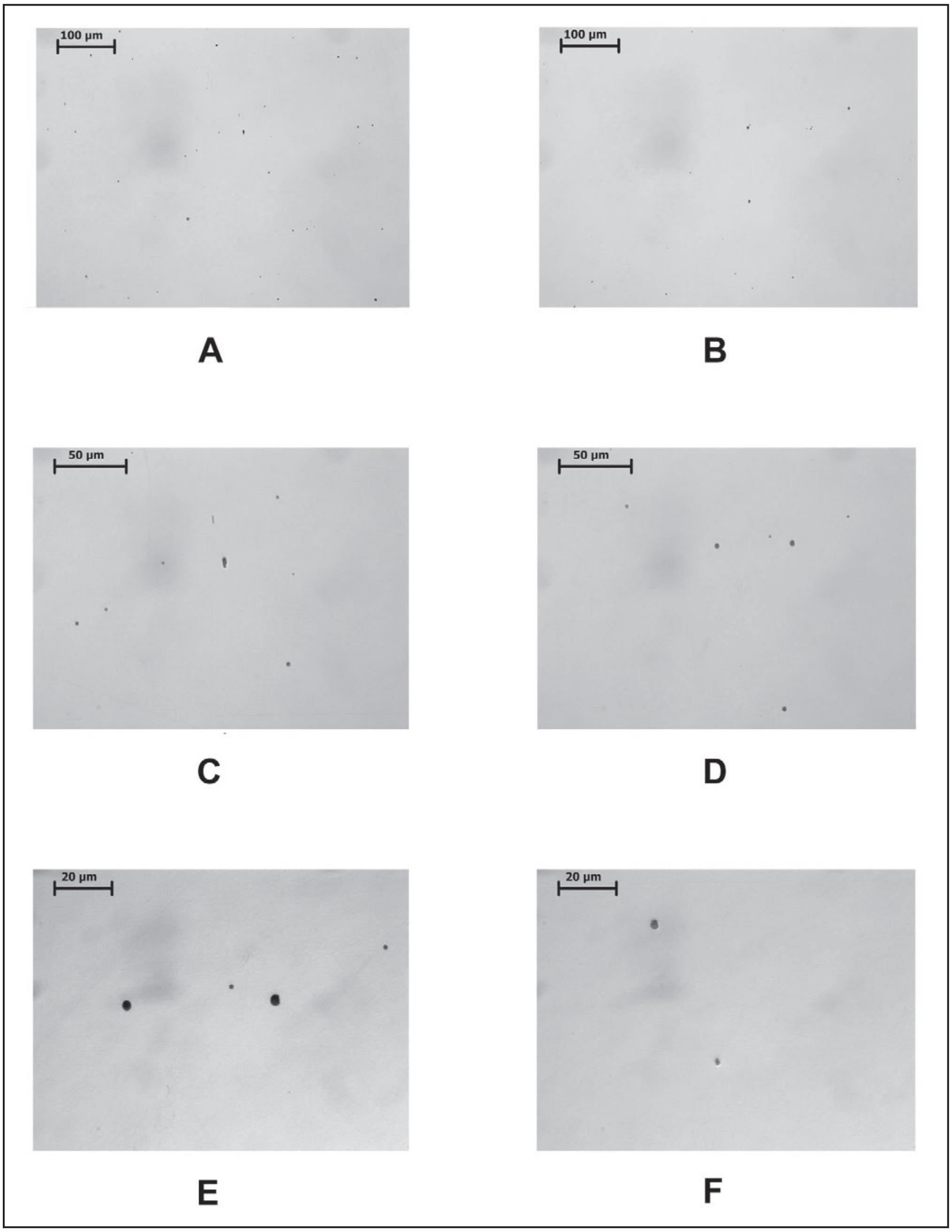

Figura 11. Sword from Grzybowo (Grzybowen): a-f - slag inclusions in the unetched cross-section of the sample, at various magnifications.

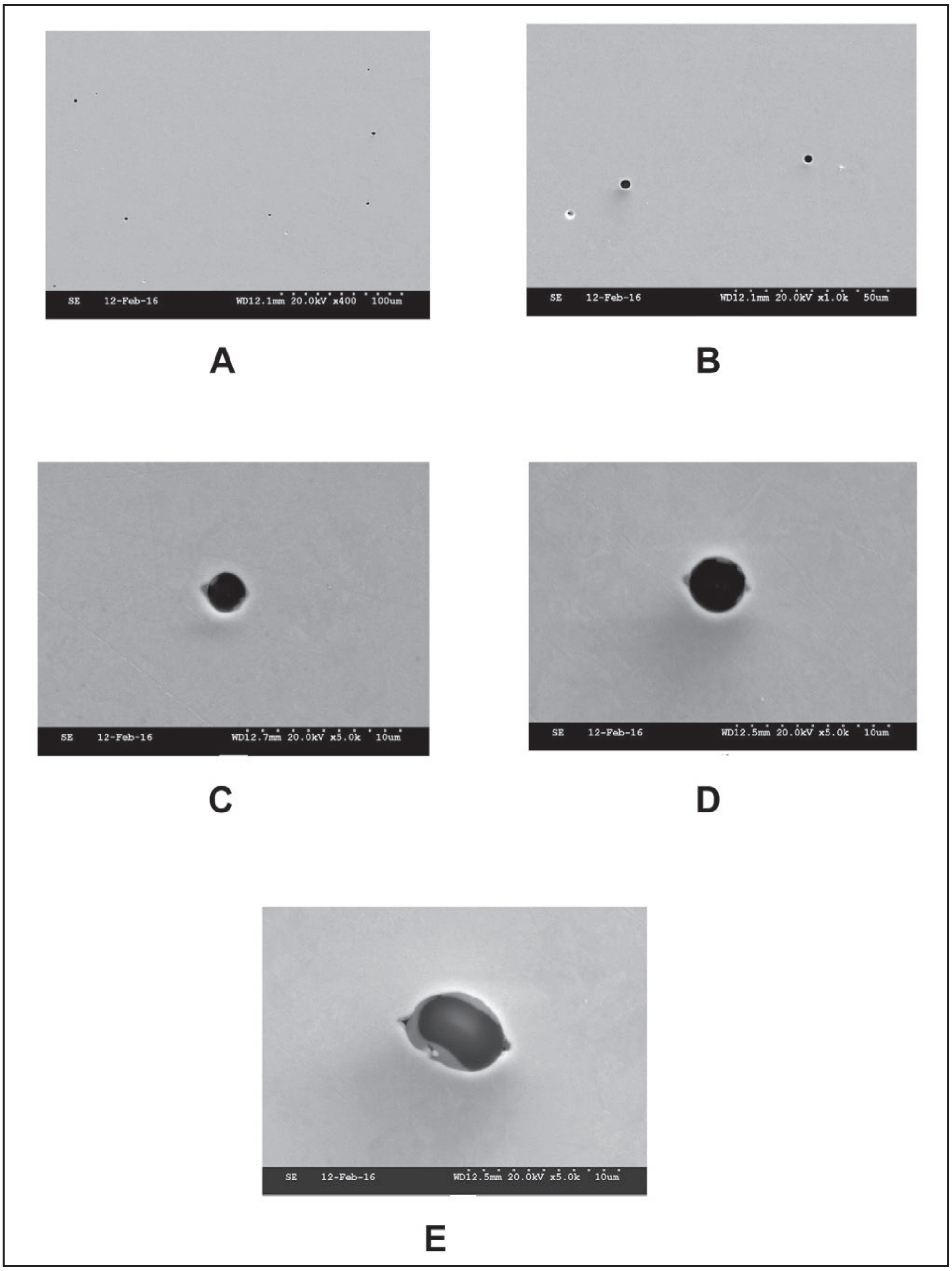

Figura 12. Sword from Grzybowo (Grzybowen): a-e - slag inclusions in the unetched cross-section of the sample, SEM images.

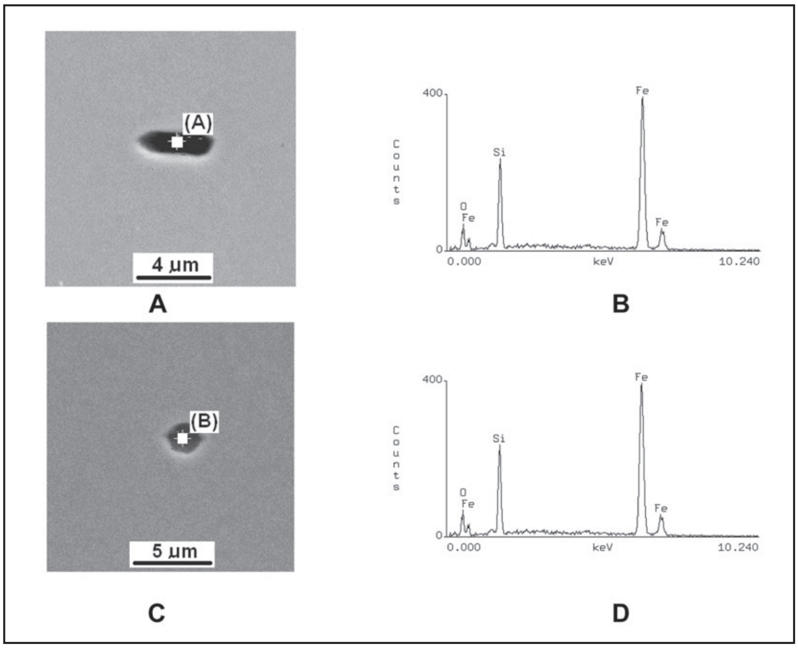

Figura 13. Sword from Grzybowo (Grzybowen). EDS analyses of slag inclusions: a - slag inclusion with the spot of analysis (A); b - EDS spectrum from Spot A, peaks from Fe, Si and O can be seen; c - slag inclusion with the spot of analysis (B); d - EDS spectrum from Spot B, peaks from Fe, Si and O can be seen. These inclusions are iron silicate.

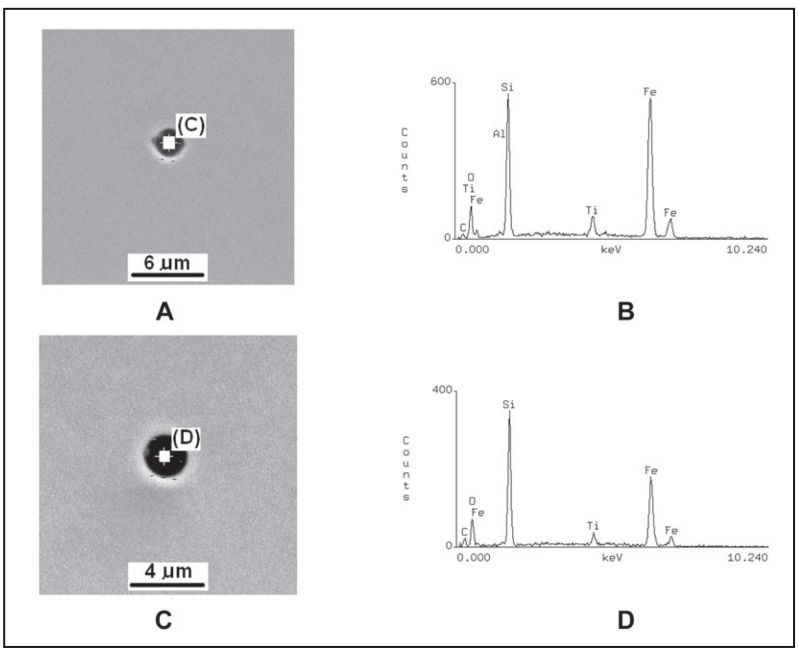

Figura 14. Sword from Grzybowo (Grzybowen). EDS analyses of slag inclusions: a - slag inclusion with the spot of analysis (C); b - EDS spectrum from Spot A, peaks from Fe, Si, Ti, Al and O can be seen; c - slag inclusion with the spot of analysis (D); d - EDS spectrum from Spot B, peaks from Fe, Si, Ti and O can be seen. These inclusions are iron silicate, also containing Ti and Al.

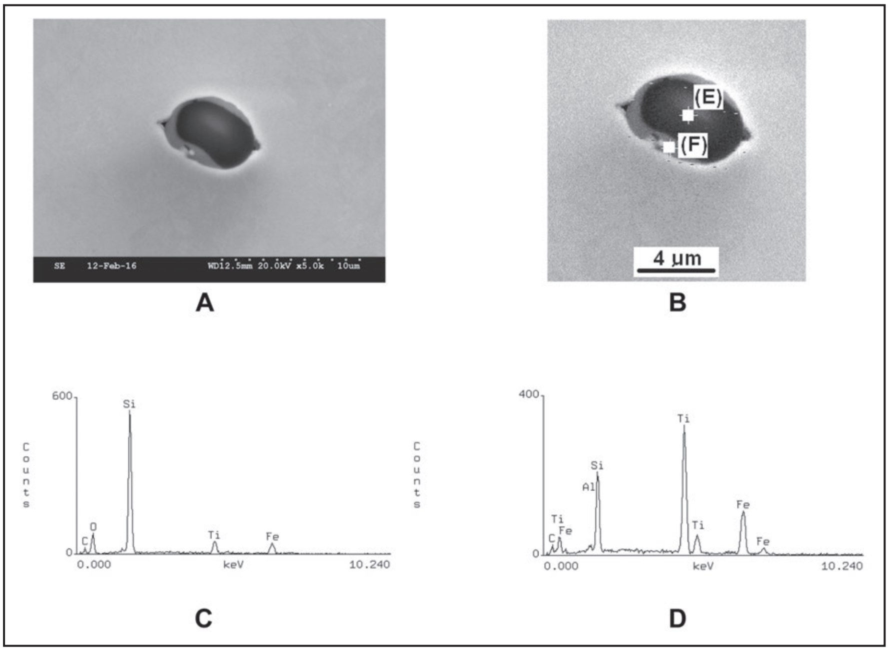

Figura 15. Sword from Grzybowo (Grzybowen). EDS analyses of slag inclusions: a - morphology of a two-phase slag inclusion; b; the analysed inclusion with spots of analyses (E and F); c - EDS spectrum from Spot E, peaks from Fe, Si, Ti, and O can be seen; d - EDS spectrum from Spot F, peaks from Ti, Si, Fe and Al can be seen. Such inclusions are sporadic in the cross-section.

An assessment of the amount of slag was carried out by G. Żabiński by measuring the surface occupied by slag inclusions on a small part of the sample's cross-section (Fig. 10b, d, e). It turned out that the inclusions' share in the total examined surface was slightly above 0.05%. A measurement in Fig. 11a produced a result of c. 0.10%, while that in Fig. 11b - c. 0.057%.

Technology of manufacture

Dr Eng Sc Janusz Stępiński states that the blade was forged from one piece of evenly carburised hard steel. After forging, it underwent thermal treatment. In result, a high quality weapon was produced, with hard edges and a softer core. Both its homogeneous microstructure and the amount and nature of non-metallic inclusions demonstrate that the metal had gone through the liquid phase before it was forged to make the blade. Dr Stępiński says that the presence of Ti may be related to the fact that this element is sometimes used as a deoxidiser in steelmaking. Eventually, Dr Stępiński came to the conclusion that the metal was a product of Industrial Age mass steelmaking processes.[5]

Concerning a technological classification of the construction of the blade (for the scheme see Żabiński, Stępiński and Biborski, 2014; http://www.gladificium.org/construction.html), it can be classified as Type A.II.2 (one piece of steel, thermal treatment possible). This techno-

[5] In order to verify the results, all the afore-mentioned examinations were repeated on another sample, taken from the very end of the blade. As the results were extremely similar, they are not discussed here.

logy is already known in the Roman Period (a Type Vøien-Hedelisker, Subtype 1.1 sword from Isep in Lesser Poland, c. AD 300-450, Biborski and Kaczanowski, 2004: 27-31, Fig. 1a; Biborski and Ilkjær, 2006: 254, Tab. 37, No. 4). However, it became the most widespread in the Middle Ages and in the Modern Period (Tylecote and Gilmour, 1986: 151, Fig. 63 S7, 157, Tab. N, S7, 219-221, Fig. 92; Williams, 2012: 234-235, Figs. 3-7, 236).

Chemical composition of the blade

An analysis of the chemical composition of the blade was also carried out (Dr Eng Sc Paweł Owczarek, the Częstochowa University of Technology, a Spectro K2 spark spectrometer). It was done on the cleaned surface of the flat near the end of the blade. The surface was ground with sandpaper (gradation of 120 grits) and the diameter of the analysed area slightly exceeded 15 mm.

Table 1. Chemical composition of the sword blade from Grzybowo (Grzybowen) (% weight, each result is the average of 3 tests).

C	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**Ni**	**Al**	**Co**	**Cu**	**Nb**
0.608	0.128	0.0283	0.0331	.00423	0.0291	0.0100	0.0145	.00100	.00898	0.0152	.00100
Ti	**V**	**W**	**Pb**	**Sn**	**As**	**Ca**	**B**	**N**	**Fe**	**Ce**	**Zn**
0.0100	0.0164	0.0100	.00100	0.0100	.00311	.00039	.00053	0.0456	99.06	-	-

On the basis of the content of Si (0.128 % weight), an important conclusion can be drawn. As non-metallic inclusions were mostly iron silicate (Fe_2SiO_4), their maximum content in the metal can be calculated at c. 0.9% weight.

A comparative research concerning the chemical composition of the metal was carried out with data for over 300 iron and steel artefacts from the period between the 11th c. BC to the present day, including 66 artefacts of post-c. 1850 date (see Appendix 3).[6] Before dealing with its results, it seems reasonable to briefly discuss how methods of obtaining iron and steel may influence the chemical composition and the presence and amount of slag.

Bloomery (direct) smelting

In this process, the iron basically does not pass through the liquid phase, due to insufficient temperature (below 1500ºC). Bloomery metal usually contains numerous slag inclusions (for an overview of bloomery smelting see, e.g., Buchwald, 2005: 63-70; 90-100, 134-157, 181-186, 225-229, 248-253; Pleiner, 2000: 131-194, 230-250; Tylecote, 1976: 40-42; Calissendorf, 1979: 63-66; Hošek, 2003: 17-22, 221-222; Pleiner, 2006: 240-243; La Salvia, 2007: 7-8; Williams, 2009a: 121).

A minute portion of molten iron (with more than 2% C, non-malleable and usable for casting only) may appear in a bloomery furnace. Finds of pieces of cast iron along with bloomery slag are known from Europe. However, it is often assumed that blacksmiths were long una-

[6] The authors are aware that this data is based on research done with various equipment and with different techniques. Therefore, the results must be treated with care.

ware of the necessary steps to make it usable (Tylecote, 1976: 41-42, 44, Tab. 30, 55, 57, Tab. 38; Kędzierski and Stępiński, 2006: 175-193; Buchwald, 2008: 127, Fig. 110, 190, 302; Pleiner, 2000: 248-249; Williams, 2009b: 68-76; Hošek and Košta, 2013: 24-28; cf. Crew *et alii,* 2011; Pleiner, 2000: 247-250; Biborski and Stępiński, 2014: 265-268, Figs. 2-3)

With regard to the amount of slag, an assessment of the metal's purity was undertaken on the basis of surface percentage taken by inclusions and pores on samples from 1st c. AD bloomery iron bars (with both ferritic areas and steely zones) from Roman shipwrecks near Saintes-Maries-de-la-Mer in France. The surface percentages taken by inclusions and pores varied between 1 and 4%. The authors say that these percentages vary according to bar types. In some types these were generally less than 1.5%, or even as low as 0.5%, while in others - up to 3.5%. Nevertheless, they state that these values are quite low for this type of product (Pagès *et alii*, 2011: 1241, Fig. 7, Column 1, 1242-1243, Tab. 4; see also Williams, 2003: 879).

An analogous slag surface assessment was done on sections of iron and steel pieces of Roman armour from Northern Britain. The obtained results varied between 0.2 and 5% (Fulford *et alii*, 2005: 244, Tab. 1). The lowest value of 0.2% was demonstrated for a 2nd c. AD armguard from Carlisle in England, made of steel with c. 0.6-0.7% C (Fulford *et alii*, 2005: 242-244, Tab. 1, No. 1, 246, Fig. 3.1-2; Fulford, Sim and Doig, 2004: 199-200, 203, Tab.1, No. 13, 233, Fig. 14.3-4). Most interestingly, the authors say that the metal of this armguard may have gone through the liquid phase. They also mention evidence from Late Roman/Early Medieval Italy for intentional process of decarburisation of bloomery cast iron into high carbon steel (Fulford *et alii*, 2005: 246).

Similar data were obtained by Fulford, Sim and Doig for sections of finds of other parts of Roman weaponry (the surface of slag was between less than 0.2 and 5.5%). (Fulford, Sim and Doig, 2004: 201, Figs. 4-5, 202-206, Tab 1.) The lowest value of less than 0.2% was found in a ferritic iron plate of a late 1st-2nd c. AD *lorica* from Vindolanda in England (Fulford, Sim and Doig, 2004: 200, 205, Tab. 1, No. 33, 217, Fig. 14.1-2).

Blast furnace

In Europe, the blast furnace (indirect) process came into existence probably in the 12th c. During refining, about 20-25% of iron forms slag, while the remaining iron loses almost all its carbon, silicon and manganese (Pleiner, 2000: 84-85; Buchwald, 2008: 228-230, 304-304; Tylecote, 1976: 65-66, 81-89; Williams, 2012: 187-201).

At the blast furnace site at Lapphyttan in Sweden (c. 1150-1225-c. 1400), the refined metal could be iron osmund (less than 0.3% C) and steel osmund (more than 0.3% C) (Buchwald, 2008: 240-247, Tab. 7.4 and 7.5, 248-249, Tabs. 7.7-7.8, Fig. 217). In the microstructure of a soft ferritic osmund bar L3658 from Lapphyttan there are numerous slag inclusions (Buchwald, 2008: 248, Fig. 215). The chemical composition of hypereutectoid steel osmunds (c. 1450-1500) from Hulk W-5 discovered near Gdańsk in the Baltic Sea was the following: c. 1.0-1.2% C, <0.05% P, <0.05% Si, <0.05% Mn (Buchwald, 2008: 253).

A sample from an early blast furnace site at Jubach (Siegerland, Germany) demonstrates changes in the chemical composition from grey pig iron to refined wrought iron: C: from 3.4% to 0.13%; Si: from 0.78% to 0.04%; Mn: from 0.36% to 0.02%; P: from 0.67% to 0.14%; Ni: from 0.21% to 0.19% (Buchwald, 2008: 204-206, 209, Tab. 6.8; Pleiner, 2000: 82-85; for similar data concerning pig iron refined in the so-called Walloon process see Buchwald, 2008: 277-301, Figs. 250, 253; Tylecote, 1976: 87-88; for the so-called German forge method see Buchwald, 2008: 356-359, 365, Fig. 301, 366-367, Fig. 303, 388-389, Figs. 334 and 335, Tab. 11.4, 417-418, Fig. 351, Tab. 11.10).

In 1784, Henry Cort invented the puddling process. The bath of molten pig iron was agitated with iron bars and the carbon was burned out by oxidising gases. Puddled iron balls manufactured in such a manner still contained some slag. These were hammered in order to squeeze the slag out (which was not entirely possible) and to shape them for rolling (Buchwald, 2008: 502-507; for microstructures with numerous slag inclusions see ibid., 512, Fig. 426, 513, Figs. 427, 428; 514-519, Tab. 13.20, Figs. 429, Figs. 431-432; Tylecote, 1976: 111-112). The carbon content was c. 0.23- 0.016% C, and the manganese content between 0.33 and 0.014% Mn (Buchwald, 2008: 509-510, Tab. 13.10).

Concerning the amount of slag in refined wrought iron, the share of about 3% weight is usually stated, although it may vary between about 1 and more than 5% (Tylecote, 1976: 109, Tab. 60; Aston and Story, 1942: 3, 20-26; Walker, 2002: 444-445, 447; Navasaitis *et alii*, 2003: 10-12).

Typical present day blast furnace pig iron contains c. 94% Fe, 4.5-4.7% C, 0.3-0.8% Si, 0.02-0.06% S, 0.06-0.08% P, 0.3-0.8% Mn. Soft steel made from such iron will contain about 0.05% C, 0.1% Si, 0.015% S, 0.015% P and 0.15% Mn (Blicharski, 2004: 19, Tab. 1.1, 23, 34, Tab. 1.2; Verhoeven, 2005: 152, Tab. 14.1 - modern tool steels with 0.35-1.55% C and 0.25-1.6% Mn).

There were numerous steelmaking processes before 1856, i.e., the beginning of Henry Bessemer's experiments (Buchwald, 2008: 447, Tab. 12.1; Tylecote, 1976: 68, 86-88, 90-91; Pleiner, 2000: 137; Williams, 2012: 210-212). The most important methods included:

Steel from manganese-rich and phosphorus-poor ores

Blooms can contain areas of steel and these can be easily recognised by the blacksmith (Pleiner, 2000: 136-137, 245; Buchwald, 2008: 447). In the microstructures of the afore-mentioned 1st c. AD bloomery iron bars from Roman shipwrecks near Saintes-Maries-de-la-Mer there were both ferritic areas and steely zones (with between 0.2 and 0.8 % C) (Pagès *et alii*, 2011: 1237-1238, Fig. 3, 1239, Fig. 4, 1240, Fig. 6, 1242-1243, Figs. 9-11, 1245, Tab. 4; Biborski and Stępiński, 2014: 267-271, Figs. 4-6). Furthermore, certain ores give good steels (so-called "natural steels") in the bloomery. Slag inclusions are usually few and small and the manganese content in the metal is below 0.05% (Buchwald, 2008: 449-456, Tab. 12.3). Forging and drawing removes much slag and annealing homogenises the steel with regard to carbon content (Buchwald, 2008: 457; cf. Hoyland, Gilmour in Kindi, 2006: 22-23, 56). Bloomery iron from phosphorus-poor ores can also partially pass through the liquid phase and it can become evenly and highly carburised (Wrona, 2013; Wagner, 1990).

Steelmaking in the blast furnace process by imperfect fining

Small lumps of good quality steel were obtained from pig iron in a fining hearth (Buchwald, 2008: 461). During the process, the carbon content decreased from c. 3.5% to below 0.9%, and the manganese and silicon contents to below 0.1% (Buchwald, 2008: 458). Based on the example of pig iron from an 18th c. *Flossofen* (high blast furnace) site in Schmalkalden in Thuringia, the pig iron charge initially contained about 3.5% C, which decreased to c. 0.5-0.6% C. The metal also lost almost all silicon (to c. 0.02% Si) and manganese (to c. 0.04% Mn). Numerous small slag inclusions can be seen in a sample of such steel (Buchwald, 2008: 216-220, Figs. 196-198).

Puddled steel

In 1850, H. Fehland from Haspe in the Ruhr Basin smelted pig iron in a reverberatory furnace under a reducing flame. A certain amount of *Spiegeleisen* (4-5% carbon, c. 4% manganese) was added to the bath. Eventually, steel with c. 0.5-1.2% C was obtained. This process was soon abandoned due to the invention of the Bessemer process. Welsh pig iron from the Ebb Vale iron works contained 2.68% C, 2.21% Si, 1.23% Mn, 0.43% P, and 0.125% S. After the puddling process, the received steel contained 0.50% C, 0.11% Si, 0.14% Mn, 0.10% P, and 0.002% S (Buchwald, 2008: 519, Tab. 13.14; Tylecote, 1976: 127-128).

Steelmaking by superficial carburising

Carburising often occurs unintentionally in the forging hearth. For intentional carburising, the artefact should be covered with carboniferous paste and heated to c. 800-850° C. In 19th c. Sweden packs of iron bars in a skin filled with sawdust and horn and covered with clay were gently heated until the organic components charred. The packs were then covered with clay and heated in the hearth. Finally, short bars were hammer-welded and drawn out to form faggoted steel (Buchwald, 2008: 462-465).

Case carburising

In this process, the artefact is placed in a sealed container for up to 60 hours in the temperature of 900-980 °C. The depth of case-carburising may be even 5.5 mm. A 17th c. description recommends the use of carbon-free iron, because steel may become too hard and brittle (Buchwald, 2008: 465-468, Tab. 12.6).

Cementation steel

This process consisted in heating of iron bars to high temperatures for up to 10 days in sealed containers filled with charcoal. It was first applied in the early 17th c. Such steel was used in late 17th c. Sweden for mass manufacture of cold steel weapons (Buchwald, 2008: 468-470). A drawback of cementation steel was a certain amount of fining slag (Buchwald, 2008: 477). Bars of such steel contained from c. 0.5% to c. 1.5% C (Buchwald, 2008: 471-474; Tylecote, 1976: 91, 126-127).

Bar iron dipped in molten iron

This process, also known as the Brescian process, was probably invented in Italy after c. 1300. Forged iron blooms were dipped into a bath of molten cast iron for 4-6 hours. Then, the blooms were drawn out under the forge hammer and quenched. The carbon content in the surface of the bloom increased to c. 1.5%, while in the core it was below 0.1%. By cutting the bloom into smaller pieces and repeating the bath it may have been possible to obtain excellent steel with the average of 0.6-0.8% C (Buchwald, 2008: 185-187, 190-191, 474-475; Tylecote, 1976: 90).

Wootz and Damascene steel (crucible steel)

The process was probably invented at the turn of the eras. Such steel was made in Central Asia, India, and Sri Lanka. Swords from such steel were made in India, Persia, Turkey and the territory of southern Russia. Many were traded via Damascus, hence the name Damascene swords. According to N. Belaiew's examinations in 1918, most sword blades had the carbon content of 1.2-1.8% C, but there were a few blades with 0.7-0.8% C (Buchwald, 2008: 475-476; Kindi, 2006: 14-23, 51-54, 144-147, 153-155, 163-166; Feuerbach, 2006: 12-13; Feuerbach, 2002: 182-184, 190-197, 204-215; Piaskowski, 1974: 157-238). Furthermore, B. Zschokke mentioned an Oriental sabre made from crucible steel with merely 0.596% C (Zschokke 1924, 654, 656, Tab. A, No. 8). A. Feuerbach mentions six methods of making crucible steel: 1. direct reduction from the ore; 2. melting and casting steel into a mould; 3. decarburisation by oxidising liquid cast iron; 4. decarburisation of cast iron with iron oxide; 5. reacting iron and carbon (carburisation); 6. co-fusion of cast iron and bloomery/wrought iron (Feuerbach, 2002: 112). Small crucibles were sealed with clay, and then were placed in a charcoal-fired furnace. They were heated for 4-6 hours at c. 1200 °C. The steel accumulated at the bottom of the crucible in the form of a disc or an egg (c. 8 x 2 cm). It contained only trivial amounts of slag. The key was to mix wrought iron and carbon donor in such proportions so that the carbon content in the metal would be c. 1.1-1.8% C (Buchwald, 2008: 475-477; Feuerbach, 2002: 32-74, 107-128, 131-152, 155, 159-177; Williams, 2012: 24-34, 36-37; Tylecote, 1976: 47-48; see also Lang, Craddock and Simpson, 1998: 7, 12-13).

Feuerbach proposed criteria for the identification of crucible steel - if more than one were met, the presence of crucible steel could be suggested:

- no or very little slag
- mottled appearance of the etched surface
- homogeneous carbon content
- spheroidal cementite
- evidence of slow cooling and often a divorced eutectic transformation matrix (Feuerbach, 2006: 12-16; Feuerbach, 2005: 28; Feuerbach, 2002: 171, Tab. 29, 221-225, 248-250; on the other hand, Lang, Craddock and Simpson say that the only certain way to identify crucible steel is by means of finding traces of a dendritic macrostructure, see Lang, Craddock and Simpson, 1998: 9-10, Figs. 3-5).

With regard to the chemical composition of metal, Feuerbach gives an example of an ingot with c. 1.2-1.4% C, 95% Fe, 0.2% Cu, 0.06% Mn and 0.03% P (Feuerbach, 2002: 104, 117). Based on examinations of a few Oriental blades, Zschokke says that the content of manganese was usually between 0.005% and 0.159% Mn (Zschokke, 1924: 656, Tab. A, Nos. 3, 5, 7, 8, 9, 10).

A. R. Williams assumed that some Early Medieval VLFBERHT swords had been made from Asian hypereutectoid crucible steel. He interpreted finds of lumps of hypereutectoid steel from the emporium of Hamwic as possible imports (Edge and Williams, 2003: 203-208; Williams, 2007: 233-243; Williams, 2009a: 121-184; Williams, 2012: 117-183; Selucká, Richtrová and Hložek, 2002: 28-29). However, it has also been proposed that such lumps may be of European origin (Pleiner, 2006: 23-52; Feuerbach, 2002: 232). Hypereutectoid microstructures were also found in other Early Medieval European swords (9th c. swords with composite blades from Mikulčice and Stará Kouřim in Bohemia). Although J. Hošek and J. Košta assume that Central Asian steel may have been used in these blades, they say that it is sometimes possible to find eutectoid or hypereutectoid microstructures in European bloomery steel. Furthermore, they propose that European specialists may have been able to carburise iron in crucibles and thus receive steel of potentially hypereutectoid level (Hošek and Košta, 2013: 7, 16-28).

A very interesting find is an Early Roman Period iron lump from Risan (Greek *Rhizon* or Latin *Risinium*) in Montenegro. It is shaped as a flat irregular cuboid. In its microstructure there is a network of secondary cementite and ledeburite against the background of pearlite. Slag inclusions are numerous. The average carbon content exceeds 2% C. The presence of ledeburite and the homogeneous microstructure demonstrate that the metal passed through the liquid phase. The lump may have been forged to its present shape from an ingot of crucible steel. Biborski and Stępiński say that the ingot may have been originally discoid (a few cm thick and a dozen or so cm in its diameter) and it may have been imported from Asia, possibly from India (Biborski and Stępiński, 2014: 272-275, Figs. 7-9). Apart from the shape of the lump, the process of forging is suggested by numerous slag inclusions, some of which are elongated.

P. Kucypera and J. Hošek propose that some finds of cast iron may have been by-products of obtaining high carbon steel in the bloomery process. They also discuss the so-called "Aristotle's furnace," i.e., a method of obtaining hypereutectoid steel by means of heating wrought iron with charcoal fuel in a small shaft furnace with strong artificial blast, although they are aware that there is no direct evidence for using this method in Early Medieval Europe (Kucypera and Hošek, 2014).

Crucible steel - the Huntsman process

This process (invented by Benjamin Huntsman in the 1740s) consisted in heating charges of cementation steel and coke in clay crucibles (holding between c. 4 and c. 50 kg) for 6-12 hours. Such steel was considered better than any other steel available at that time and it was almost slag-free (Buchwald, 2008: 477-481, Figs. 406-407; Tylecote, 1976: 127).

The Bessemer and the Thomas processes

These processes are based on an idea of blowing air through molten pig iron. The combustion of impurities and part of the iron itself produces enough heat to raise the temperature to c. 1530 °C. Therefore, the formed steel remains molten and can be cast into moulds. In the 1860s the Bessemer converter became a major steel producer (it was possible to produce 10 tons of steel in ten minutes). If the pig iron charge contains c. 4.2% C, c. 1.7% Si and c. 0.8% Mn, after 14 minutes all these elements will be almost completely burned out and the content of Mn will be less than c. 0.1%. The steel was homogeneous and almost slag-free. From c. 1900 the Bessemer process started to be replaced by the open hearth process (Buchwald, 2008: 524-528, Fig. 443; Tylecote, 1976: 144-147; see also Blicharski, 2004: 27, Fig. 1.5). In 1876, in order to cope with the problem of British phosphorus-rich pig iron, Sidney G. Thomas and Percy C. Gilchrist provided the converter with a dolomite lining and added burned lime to the bath. The Thomas process became far more important than the Bessemer process, as 90% of world's iron ores are phosphorus-rich. It disappeared in the third quarter of the 20th c. (Buchwald, 2008: 528-532, Fig. 444; Tylecote, 1976: 144-147).

The Siemens-Martin (open hearth) process

In 1856, Friedrich and Karl Wilhelm Siemens patented a way of heating of furnaces using the regenerative principle. In the 1860s Karl Wilhelm and a French iron master Pierre Martin built a furnace with a shallow bowl-shaped hearth and regenerative chambers. The first successful melting took place in 1882 in St Petersburg in Russia and by 1940, 75% of steel was made in the open hearth process. This process made it possible to produce very homogeneous steel with extremely tiny slag inclusions. From 1975, the Siemens-Martin steel was gradually superseded by oxygen-blown and electric-melted steel (Buchwald, 2008: 532-537; Tylecote, 1976: 144-147).

An assessment of the surface of slag inclusions has recently been carried out by A. Thiele and J. Hošek on a cross-section of present-day low carbon steel (S235JRG2, 0.17% C). The obtained result was 0.3% of the sample surface (Thiele and Hošek, 2015: 37). Similar results were received by J. Krawczyk and B. Pawłowski for 35B2+Cr steel (0.37-0.38% C, 0.07-0.08% Si, 0.68-0.75% Mn, 0.008-0.010% P, 0.005-0.012% S). The total fraction of non-metallic inclusions on the surfaces of examined samples was between 0.210±0.012 and 0.299±0.032% (Krawczyk and Pawłowski, 2008: 116, Tab. 1, 118, Tab. 3; Krawczyk and Pawłowski, 2012: 723, Tab. 1, 724, Tab. 2). An example of even cleaner steels is given by M. Opiela and A. Grajcar for newly-developed microalloyed steels with 0.28-0.31% C, 1.41-1.45% Mn, 0.29-0.30% Si, 0.006-0.008% P and 0.004% S. The surface fraction of non-metallic inclusions was 0.075% on average (Opiela and Grajcar, 2012: 130, Tab. 2, 131-133, Tab. 3).

It can now be discussed how the metal in the sword in question matches particular technological patterns. A very homogeneous carbon distribution and a very low slag content can naturally suggest the Bessemer, Thomas or Siemens-Martin processes. However, very good bloomery steel should also be taken into consideration (Dr Ann Feuerbach, personal communication on 1 July 2014). This seems especially relevant in view of the fact that based on slag surface assessments the amount of slag in mass-made steel and very clean bloomery metal may sometimes be similar. The afore-mentioned examples of Roman armour from Carlisle and Vindolanda seem to be especially instructive, with special reference to the metal in the find from Carlisle, which may have gone through the liquid phase. Furthermore, hypoeutectoid crucible steel could be considered. Blast furnace smelting and fining or puddling are rather to be excluded, as the content of non-metallic inclusions in the discussed sword is much too low. Furthermore, the carbon content is much too homogeneous for steel obtained by superficial carburising. Case-carburising or cementation could be possible, but not with the use of blast furnace refined iron.

Some traits of the chemical composition of the metal in the sword are much more similar to artefacts preceding the blast furnace age (see Appendix 3). As mentioned, the content of Mn in the discussed sword is 0.0238%. A query was carried out with the criterion of the manganese content less than 0.1% Mn. 203 artefacts from all periods and made in various processes met this criterion. 167 of them were made from non-blast furnace metal (including crucible steel). The remaining ones were blast furnace metal (cast iron, refined iron which was in some cases later carburised, iron or steel osmunds, puddled iron), which can be disregarded due to a much higher content of slag. Only 5 artefacts were made in the Bessemer process (Appendix 3, Nos. 260, 261, 280, 281, 282). Interestingly, their carbon content was much lower (0.10% C) than in the discussed sword. Similar data was provided by analyses of pre-c. 1910 liquid steels (*Flussstahl*), done at the German Federal Institute for Materials Research and Testing (*Bundesanstalt für Materialforschung und -prüfung*). For steels with C contents of 0.025-0.2%, the Mn contents were 0.036-0.052% (Helmerich, 2005: 31, Tab. 5, 42, Tab. 7). Furthermore, there were 3 replica swords of 19th c. or later date (Appendix 3, Nos. 247, 248, 249), where nothing certain can be said about their technology of manufacture.[7]

[7] In order to compare these observations with properties of present-day steels, a query was carried out in a freely available on-line Matweb Material Property Data database (http://www.matweb.com/search/CompositionSearch.aspx; query in All Metals, access on 20 February 2016). The query was carried out using the following criteria: Fe min. 97.0%,

With regard to the presence of titanium in the discussed sword (0.0100%), the same content of this element was found in an early 20th c. German bayonet (Appendix 3, No. 296). On the other hand, a similar content of Ti was identified in Medieval or Modern Period artefacts made from bloomery metal (Appendix 3, Nos. 190, 197, 208, 210). No. 190, the famous St Peter's sword from Poznań Cathedral (perhaps c. 1250-1350), is especially instructive here, as the presence of Ti was also detected by EDS examinations of smelting slag (Nosek and Stępiński, 2011: 85, 87, Fig. 7c; Stępiński, Żabiński and Nosek, 2015: 34, 42, Fig. 25c).

CONCLUSIONS

It can, therefore, be very tentatively suggested that the sword might be a genuine Roman Period weapon made from very clean bloomery steel (or hypoeutectoid crucible steel?). Although the microstructure of the metal can also suggest an Industrial Age origin, the authors of the paper were unable to identity any artefact from that period with a morphology similar to the discussed sword. If one carefully assumes a Roman Period provenance of the discussed sword,[8] the find of such a weapon in the vicinity of Lake Dejguny can be explained by the participation of the local population in interregional exchange of goods, also including artefacts from the Empire. On the other hand, it is much more difficult to propose the provenance of raw material it was made from. It may have been either of European or of Central Asia origin. All in all, it seems that a final recognition of the discussed sword as a Roman Period weapon could only come from discoveries of other swords made from similar metal in undoubted Roman Period contexts.

ARCHIVAL SOURCES

Foto-Archiv - part of the Photo Archive of the Prussia-Museum, the Museum für Vor- und Frühgeschichte in Berlin

Grenz's archive - Rudolf Grenz's files, the Archäologisches Landesmuseum Schloβ Gottorf in Schleswig

Jahn's archive - Martin Jahn's files, the Institute of Archaeology of the University of Warsaw

Jakobson's archive - Felix Jakobson's files, the Latvijas Nacionalais vēstures muzejs (National History Museum) in Riga (Archeologiczne dziedzictwo, 2011)

Jankuhn's archive - Herbert Jankuhn's files, the Archäologisches Landesmuseum Schloβ Gottorf in Schleswig

Kossina's archive - Gustaff Kossina's files, the Library of the Humboldt-Universität in Berlin

Kostrzewski's archive - Józef Kostrzewski's files, the C. K. Norwid Voivodeship and City Library in Zielona Góra

Mn 0.00-0.1%, Si 0.00-0.2%. It produced 8 results, which were various types of steel, but all of them had at least 0.1% of Mn. Another query was done in a Total Materia commercial database (http://search.totalmateria.com/AdvancedSearch/AdvancedSearch; query in All Materials, access on 23 February 2016). 3 results were obtained, all being iron powders. A bit different image emerges from German DIN norms for steels from the first half of the 20th c. For some types of structural steels, the DIN 1611 norm only stated that the content of S and P should not exceed 0.06% each and that the total content of both these elements should not exceed 0.1%. The content of C in such steels could be even 0.6% (Werkstoffnormen 1927, 31; Werkstoffnormen, 1938: 30). For other types of construction steels, the DIN 1661 norm stated that the content of S and P should not exceed 0.04% and the total content of both these elements should not exceed 0.07%. For steels with the content of C between 0.25 and 0.6%, the maximum content of Si was 0.35% and that of Mn – 0.8%. (Werkstoffnormen, 1927: 40; Werkstoffnormen, 1938: 66). The discussed sword would match those characteristics.

[8] Bartosz Kontny notified his separate opinion. He judges that the identification of the find as a Roman sword is pre-mature as there are no Roman swords of cast steel known from the Empire or Barbaricum and the analyses of blades made so far are at odds with the technology of the discussed sword.

Prussia-Archiv - part of the archive of the Prussia-Museum, the Museum für Vor- und Frühgeschichte in Berlin

Prussia-Sammlung - part of the Prussia-Museum collection, the Museum für Vor- und Frühgeschichte in Berlin

Schmiedehelm's archive - Martha Schmiedehelm's files, the Tallinna Ülikooli Ajaloo Instituut, Arheoloogia Arhiiv (Institute of History of the University of Tallin, Archive of Archaeology)[9]

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APPENDIX 1

The cultural-settlement context and the chronology of the cemetery

The sword was found close to a Bogaczewo Culture cemetery in Grzybowo (Grzybowen) (cf. Nowakowski, 2001a: 56-57; 2013: 70-71; Juga-Szymańska, 2014: 265-266). It was situated somewhere on a slope of a hill on the western bank of Lake Dejguny. Regrettably, a precise location of the cemetery is unknown[10] (Fig. 1: B-C).

In the late 19th c. G. Bujack and other antiquaries were believed to carry out examinations at the cemetery (Peiser, 1919: 313; Bezzenberger, 1897: 32; Hollack, 1908: 54). In 1907, examinations were undertaken by F. E. Peiser. Finds were deposited at the Prussia-Museum in Königsberg (Kaliningrad) (R. Grenz/C. Engel's archive; Archeologiczne Dziedzictwo, 2011: Grzybowen 001). They probably did not survive the last war.

F. E. Peiser says that the site was already partially excavated (Fig. 16: A). Therefore, relations between individual burials were not certain (Peiser, 1919: 313, Plate XXX). Later changes in the landscape rendered it impossible now to localise the cemetery in a more precise manner (Fig. 16: B).

Peiser examined only part of the site. He discovered 24 cremation graves, including 19 urn graves and 3 clusters of bones. Out of two pit features with remains of the funeral pyre, one was probably a burial with no urn. The other was part of an urn grave (Peiser, 1919: 318).

For finds from Grzybowo (Grzybowen) a chronological system worked out for the Bogaczewo Culture in the Roman Period by W. Nowakowski was used (Nowakowski, 1982; 2007b). In this system, Phases A3-B1 correspond to the second half of the 1st c. BC and the first half of the 1st c. AD (Horizon 1); Phase B2a - the second half of the 1st c. AD (Horizon 2); Phase B2b - the first half of the 2nd c. AD (Horizon 3); Phases B2/C1 and C1 - the second half of the 2nd c. and the 1st half of the 3rd c. AD (Horizon 4); Phase C2 - the second half of the 3rd c. to the third quarter of the 4th c. AD.

In Feature 19 a bronze fibula was found. Its bow was ornamented with two lines of dots (Peiser 1919, 317). Based on surviving drawings (Jahn's archive; Kossina's archive; Schmiedehelm's archive 7_13c_165; Archeologiczne dziedzictwo, 2011: Grzybowen 001; Fig. 17), it can be classified as Type O according to J. Kostrzewski (1919), or more precisely as Type A.2/O, Variant A.2aII (Völling, 1994; Demetz, 1999). Drawings by Felix Jakobson (Archeologiczne dziedzictwo, 2011: Grzybowen 001; Fig. 17: A), G. Kossina (Fig. 17: C) and M. Jahn (Fig. 17: B) show that the fibula is provided with a lower cord. Remains of a fibula which "very probably" belonged to the same type were also found in Feature 22 (Peiser, 1919: 317; cf. Nowakowski, 2001a: 57).

Feature 19 also yielded 2 shield boss nails and a rectangular quartzite striker (Archeologiczne dziedzictwo, 2011: Grzybowen 001; Fig. 17: A). Similar strikers in the Bogaczewo Culture are dated to the late Phase B1 and the early Phase B2 (Iwanicki and Juga-Szymańska, 2007: 57).

Previous scholarship has proposed to date the assemblage from Feature 19 to Phase A3 (Kontny, 2007: 96-97, Pl. 1) or the late Phase A3-early Phase B1 (Iwanicki and Juga-Szymańska, 2007: 57). A "shift" in the dating of Grave 19 to Phase B1 must be considered. Such a chronology of Type A.2aII fibulae is confirmed by co-occurrence of finds of this type with A.67 fibulae in cemeteries of the Przeworsk Culture in Masovia (form A.67b according to S. Demetz, 1999; Dąbrowska, 2008: 21, Pl. 1, 32-33, 124).[11]

Finds from Feature 1 included i.a. 3 bronze fragments, possibly remains of an eye fibula (Peiser 1919, 313). Its spring was probably made from wire which was rectangular in cross-section. This is a remarkable trait of eye fibulae of Group III of the Prussian series (Almgren, 1923: Pl. III: 57-61). This find can be generally dated to Phase B2 (Nowakowski, 2007b; Iwanicki and Juga-Szymańska, 2007: 56-57; Juga-Szymańska, 2014: 40).

From Feature 4 comes a bronze pin with a head ornamented with rows of dots (Peiser, 1919: 314; Jahn's archive; Schmiedehelm's archive 7.13-22; Juga-Szymańska, 2014: 265). A partially melted orna-

[10] From a formal point of view, a mutual relation between the sword and the cemetery is merely a hipothesis, although a very likely one. We could tentatively assume that the sword was secondarily deposited in result of works carried out in recreation plots. It is perhaps in this area that the cemetery "in Grzybowen" was located.

[11] The authors are indebted to Dr Andrzej Maciałowicz (Institute of Archaeology of the University of Warsaw) for consultation.

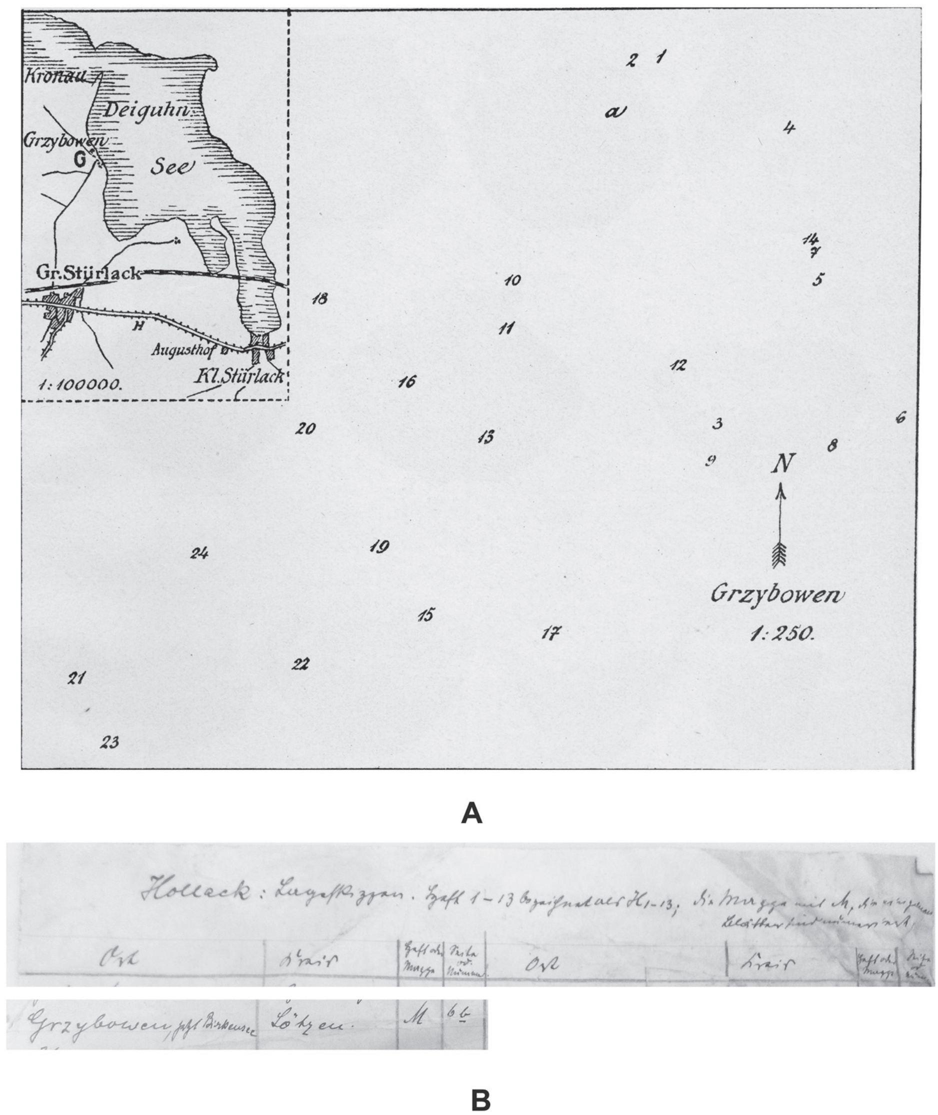

Figura 16. A - location and the plan of cemetery in Grzybowo (Grzybowen) from the examinations in 1907 (Peiser 1919, Pl. XXX). B - fragments of a list by E. Hollack concerning sketches of locations of local cemeteries with information on the site in Grzybowo (Grzybowen) (E. Hollack Nachlass, PM-IXf9, b-3).

mented bronze pin was also found in Feature 10, together with a rod bracelet (Peiser, 1919: 315-316; Schmiedehelm's archive 7.13-22, 7.20d-30; Juga-Szymańska, 2014: 266). Both pins correspond to Type A according to B. Beckmann, Variant 1 according to A. Juga-Szymańska (2014: 56-57, Pl. II: 14,01/04, with further reading; cf. Beckmann, 1969: 108, 117).

An iron pin from Feature 8 belongs to Type A Variant 5 according to A. Juga-Szymańska (Peiser, 1919: 315; Schmiedehelm's archive 7.13-22; Beckmann, 1969: 108, 117; Juga-Szymańska, 2014: 57-58). Pins of Type A Variant 1 are generally dated to Phases A3-B1 and B2. A co-occurrence of the pin with a bracelet with mushroom-shaped ends can narrow down the chronology of Feature 10 to Phases B1-B2a (Iwanicki and Juga-Szymańska, 2007: 59; Juga-Szymańska, 2014: 57, 265-266).

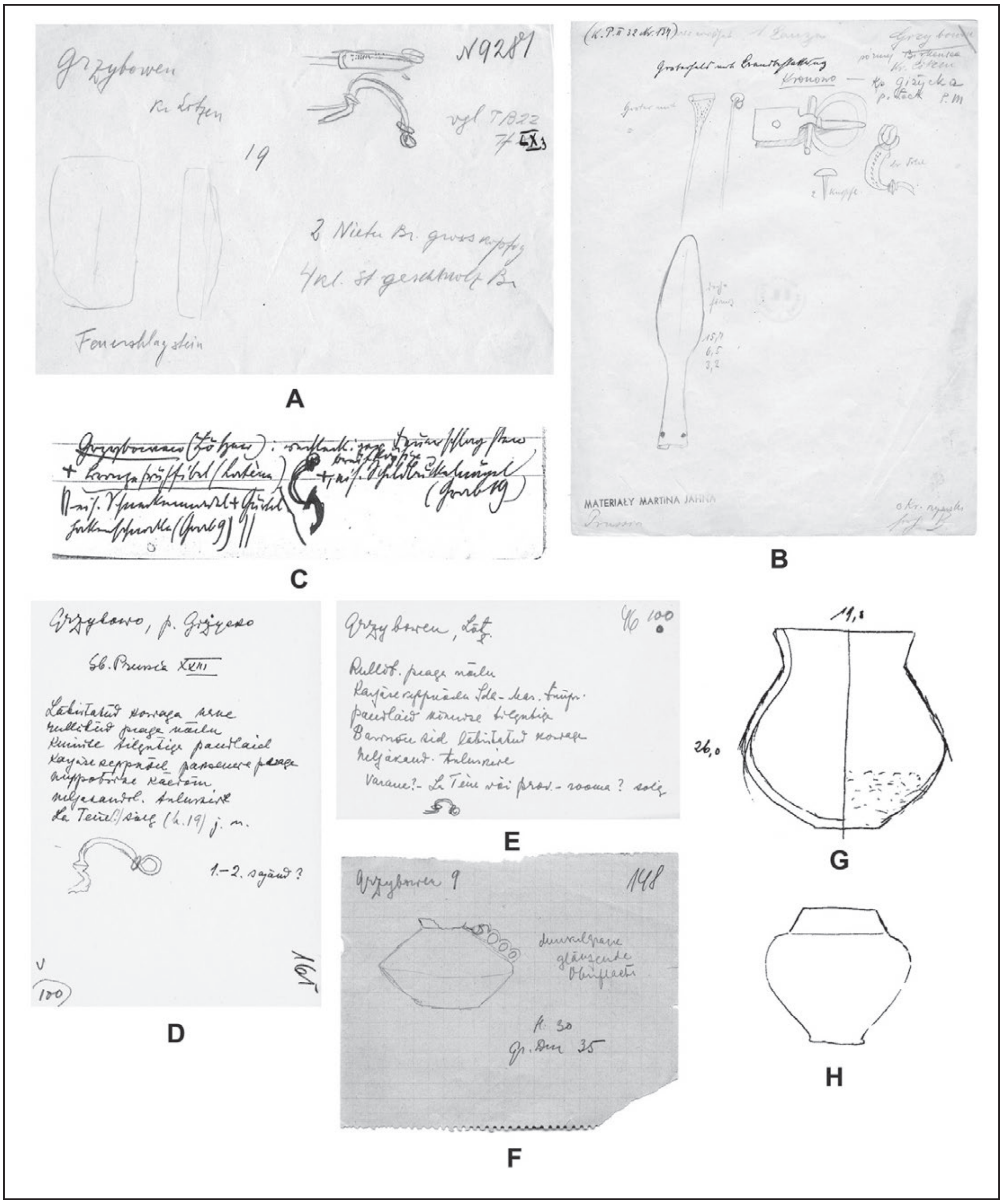

Figura 17. A - furnishings of Grave 19 after F. Jakobson's archive (Archeologiczne Dziedzictwo 2011, Grzybowen 001). B - card with sketches of finds by M. Jahn (Jahn's Archive). C - fragment of a note by G. Kossina on furnishings of Graves 19 and 9 (7_13c_165; 7_13b_46; 7_20d_148) D, E, F - notes of M. Schmiedehelm on furnishings of Graves 19 and 9. G, H - urns from Graves 8 and 19 after H. Jankuhn (Nowakowski 2013, Pl. 121: 1, 2).

In Feature 9, in the urn with the four-opening handle of Type ID according to P. Szymański (Szymański, 2000: 154, 175) there was an iron pin (Peiser, 1919: 315). It corresponds to Type B I (Beckmann, 1969: 117; Juga-Szymańska, 2014: 266, Pl. IX: 14.03; Jahn's archive; Schmiedehelm's archive 7.13-22, 78; 7.20d-148).

Pins of Type B I appear in the Masurian Lake District at the end of Phase B1 and remain in use in Phase B2a. The find from Feature 9 belongs to the earliest ones, dated to Phase B1 (Juga-Szymańska, 2014: 62-64, 266).

An iron buckle from Feature 9 can be classified as Type AC.4 (Madyda-Legutko, 1986: 16-18), Type IVa of the Prussian series. This find, together with the afore-mentioned pin of Type B I allows to date the assemblage to Phase B1-early B2 (Iwanicki and Juga-Szymańska, 2007: 51-52, Pl. III: 9-11; Jahn's archive). A similar iron buckle was found in Feature 23. It resembled a find from Warnicker Forst, Feature IVa (Peiser, 1919: 317; cf. Kemke, 1909: 389). The chape of the latter clearly resembles a buckle from Rominten (Radužnoe), Grave VI, which was found i.a. with a Type B I pin (Kemke, 1909: 389; Jankuhn's archive, Forst Warnicken, Stelle IVa; Nowakowski, 2013: 58-59, Pl. 82: 2). The find from Feature 23 can thus be classified as Type IIb and dated to the early Phase B2 (Iwanicki and Juga-Szymańska, 2007: 48-49, Pl. III: 4). The chronology of both buckles and thus Features 9 and 23 can therefore fall within the late Phase B1-early Phase B2.

F. E. Peiser mentions an iron spearhead in Feature 20 and points to a possibly similar spearhead from Rondsen (Grudziądz-Rząd) (Peiser, 1919: 317; Anger, 1890: Pl. IV: 8; Kostrzewski, 1919: 112, Fig. 106; Kontny, 2007: 103-104). Ceramic vessels found at the cemetery mainly fulfilled the role of urns (Fig. 17: F-H). They can be dated to Phases A3-B1-late Phase B2 (Szymański, 2000: 153-154, 175).

The chronology of finds from the examined part of the cemetery falls within Phases A3/B1 to B2. It encompasses Horizons 1 and 2 of the Bogaczewo Culture, that is, the Early Roman Period. Regrettably, it is impossible to say whether the cemetery was not used in the later period.

APPENDIX 2

Finds of Roman and Early Migration Period swords and scabbards in the West Balt circle: a - cultural attribution, b - sword or scabbard elements, c - other grave furnishings, d - chronology, e - bibliography, f - remarks.

Chrustal'noe, Ray. Zelenogradsk, Kaliningrad Obl., Russia (ex-Wiekau, Kr. Fischhausen), Grave 34

a. The Dollkeim-Kovrovo Culture
b. Double-edged sword with a wooden grip, length 52.5 cm (preserved), width 5 cm; probably Type Lauriacum-Hromówka or Woerden-Bjärs after M. Biborski and J. Ilkjær (2006, 200-217); wood and leather scabbard
c. Two heads of shafted weapons; axe; shield boss, Type 7a after M. Jahn (1916); two bronze spurs, Subgroup E3 after J. Ginalski (1991); bridle-bit and other parts of headgear; knife; silvered bronze brooches, Type 129 and 130 after O. Almgren (1923); enameled plate; belt buckle, Group G after R. Madyda-Legutko (1986); strap end (?), Type 9 after R. Madyda-Legutko (2011)
d. B2/C1-C1a
e. Heydeck, 1909: 218-219, Pl. XXXVIIIa-g; Gaerte, 1929: Figs. 152, 159e; La Baume, 1944: 8, Fig. 10; Nowakowski, 1994: 384; 1996, Pl. 50-51; 2007b, 85, 91

Fedotovo, Ray. Pravdinsk, Kaliningrad Obl., Russia (ex-Plauen, Kr.Wehlau), stray find

a. The Dollkeim-Kovrovo Culture
b. Double-edged sword, probably made from a broken blade, blade length 26 cm
c. -
d. Roman Period (B)?
e. Bezzenberger, 1900: 124; Nowakowski, 2007b: 91, Figs. 1.1, 2.5; Jankuhn's archive

Grunajki, Banie Mazurskie Comm., Poland (ex-Gruneyken, Kr. Darkehmen), stray find

a. The Bogaczewo Culture; erroneously attributed to the Sudovian Culture (Engel, Iwanicki and Rzeszotarska-Nowakiewicz, 2006)
b. Double-edged sword, a circular plate at the end of the tang, Type II after M. Biborski (1978) or Type Mainz, Variant Haltern-Camulodunum after Ch. Miks (2007), length 51.5 cm, width 3.5 cm

c. -
d. B1-B2(a)
e. Stadie, 1919: 415, Fig. 187; Jahn, 1916: 128; Gaerte, 1929: Fig. 197b; Nowakowski, 1994: 384, Fig. 2.5; 2007b, 85; Engel, Iwanicki and Rzeszotarska-Nowakiewicz, 2006: Pl. III.7; Miks, 2007: Vol. 1, Table 1, Vol. 2, 599; Nowakowski, 2013: 53, 213, Pl. 72.3; Jankuhn's archive; Jahn's archive

Koczek II, Świętajno Comm., Poland (ex-Koczek, Kr. Sensburg), Grave 122
a. The Bogaczewo Culture
b. Single-edged sword, Type D/2 after M. Biborski (1978), length 57 cm, width 4.5 cm,
c. Head of a shafted weapon, Type XIII after P. Kaczanowski (1995); knife; belt buckle Type G36 after R. Madyda-Legutko (1986); bronze fibula, Type 133 after O. Almgren (1923); rivet; whetstone; clay pot
d. B2c-B2/C1
e. Nowakowski, 2001b: 160-162, Fig. 1; Juga, Ots and Szymański, 2003: 216, Fig. 2623.1, 4; Nowakowski, 2007b: 87-88, Fig. 3; 2013, 66, 191-192, 208-209, 212, Pl. 108.2-5, 109.1-4; Jahn's archive; Jankuhn's archive; Schmiedehelm's archive 7.12.63a-64, 7.13e.174, 7.13e.187-188
Łaźne, Świętajno Comm., Poland (ex-Haasznen, Kr. Oletzko), Grave 59
a. The Bogaczewo Culture
b. Dagger, made probably from a double-edged sword of Type II after M. Biborski (1978), length 25 cm, width 3.5 cm; 2 C-shaped scabbard clasps
c. Belt buckle, probably Type D1 after R. Madyda-Legutko (1986); strike-a-light; flint fragment; 2 clay pots
d. B2(a)
e. Gaerte, 1929: Fig. 197a; Nowakowski, 1994: 384; 2007b, 91; Schmiedehelm's archive 7.12.32, 7.13.21, 7.13e.43, 7.13e.119

Mojtyny, Piecki Comm., Poland (ex-Moythienen, Kr. Sensburg), Grave 27
a. The Bogaczewo Culture
b. Single-edged sword, Type C/1 after M. Biborski (1978), length 53 cm, width 4.5 cm
c. 2 spurs, Subgroup E2/3 after J. Ginalski (1991); bronze fibula, Type 80 after O. Almgren (1923); clay pot
d. B2a-B2b
e. Hollack and Peiser, 1904: 47-48, Pl. V.27a-c; Gaerte, 1929: Fig. 150; Nowakowski, 1994: 383, Fig. 2.2; 2007b, 85; Prussia-Museum Foto-Archiv PM-F 2572
5. -

Onufryjewo, Ruciane-Nida Comm., Poland (ex-Onufrigowen, Kr. Sensburg), Grave 220
a. The Bogaczewo Culture
b. Single-edged sword, Type C or D (?) after M. Biborski (1978)
c. Head of a shafted weapon, close to Type Kaczanowski XVII (?); shield grip; pin, Type C after B. Beckmann (1969); three amber beads; pendant
d. C1a
e. Schmiedehelm's archive 7.12.103a, 7.13.24, 7.13b.331; 7.13e.205; Prussia-Archiv PM-A 1162/1.147; Prussia-Museum inv. No. PM VII.77.9291

Parussnoe, Ray. Zelenogradsk, Kaliningrad Obl., Russia (ex-Gaffken, Kr. Fischausen), stray find (?)
a. The Dollkeim-Kovrovo Culture
b. Double-edged sword, Type V (?) after M. Biborski (1978), length 75-80 cm, width below 5 cm
c. -
d. B2b-C1a
e. Gaerte, 1929: Fig. 129c; Nowakowski, 1994: Fig. 2.8; 2007b, 89, Figs. 1.7, 2.4; Grenz's archive; Schmiedehelm's archive VM 9.21.40; Prussia-Museum inv. No. III.311.2176

Sibirskoe, Ray. Pollesk, Kaliningrad Obl., Russia (ex-Moritten, Kr. Labiau), inhumation grave
a. The Dollkeim-Kovrovo Culture

b. Single-edged sword, Type C/1 (erroneously classified as Type B/1, Nowakowski, 2007b: 87) after M. Biborski (1978), preserved length 45.5 cm, width 5 cm; lenticular fitting, handle part?
c. Two heads of shafted weapons; strike-a-light, Type IA2a after M. Jonakowski (1996); two brooches - of Type 60 and 77 after O. Almgren 60 (1923); belt fitting
d. B2a
e. Bezzenberger, 1897: 7, Fig. 11; Nowakowski, 1994: 382, Fig. 2.1; 1996, Pl. 90:1-6; 2007b: 87, Fig. 2:1; Grenz's archive; Jahn's archive; Jankuhn's archive; Schmiedehelm's archive 7.25

Skomack Wielki, Stare Juchy Comm., Poland (ex-Skomatzko, Kr. Lyck), Grave 23
a. The Bogaczewo Culture
b. Double-edged sword, a circular copper-covered plate at the end of the tang, close to Type II/2 after M. Biborski (1978), Group VI after M. Biborski (1994) or Type Pompeii after P. Kaczanowski (1992) of 'classical' Variant after Ch. Miks (2007: Vol. 1, 112-113), length 47 cm, width 3.7 cm
c. 2 spurs, Subgroup C1 after J. Ginalski (1991); 2 bridle bits, one of which belongs to Type 1B3, 2B after M. Ørsnes (1993); knife; scissors; 2 belt buckles; 2 silver beads; clay pot
d. B1-B2a
e. Kotzan, 1936: 90, 97-98; La Baume, 1941: 54, Fig: 6.c-d; Nowakowski, 1994: 384-385, Fig. 2.4; 2001a, 97-98, Fig. 10; 2007b, 88, Fig. 2.2-3; Grenz's archive; Prussia-Museum Archiv PM-A 802/1-115, 802/3-049; Prussia-Sammlung inv. No. VIII.84.521

Szurpiły, Jeleniewo Comm., Poland, Site 4 ('Targowisko'), stray find
a. The Bogaczewo Culture?/the Sudovian Culture?
b. Single-edged sword, Type D/2 after M. Biborski (1978), preserved length 13 cm, width 6 cm
c. -
d. B2
e. Sawicka, 2007: 171, Fig. 2; Nowakowski, 2007b: 91

Szwajcaria, Suwałki Comm., Poland, Barrow 2, Grave 1
a. The Sudovian Culture
b. Double-edged sword, bone pommel, Type Folkeslunda-Zaspy, Subtype 1 after M. Biborski and J. Ilkjær (2006) or Type Lauriacum-Hromówka, Variant Hromówka after Ch. Miks (2007); scabbard with an iron slide close to Type Kaczanowski VII (1992)
c. 2 strap connectors; balteus fittings; 3 circular bronze plates fitted with silver and gilded foil; silvered bronze shield grip; bronze silvered rectangular, with a washer; silvered bronze crescent; silver balteus buckle, Type D17 after R. Madyda-Legutko (1986); small axe; ornamented head of a shafted weapon, Type 15/Vennolum after J. Ilkjær (1990); ornamented head of a shafted weapon, Type XV after P. Kaczanowski (1995); shield boss, Type 8 after M. Jahn (1916) or Type D after N. Zieling (1989); 2 spurs, Type Szwajcaria after U. Giesler (1978); bridle bit, Type 1C1, 2B after M. Ørsnes (1988); headgear; bridle bit, Type 1C1, 2C after M. Ørsnes (1988); parts of headgear; knife's fragment; silver belt buckle, close to Type E after R. Madyda-Legutko (1986); belt buckle, close to Type E14 after R. Madyda-Legutko (1986); belt buckle, close to Type D30 after R. Madyda-Legutko (1986); 3 bronze-silvered strap ends, close to Type 6.1 after R. Madyda-Legutko (2011); bronze strap end, close to Type 2.6 after R. Madyda-Legutko (2011); 2 bronze brooches with notched silver wire, Type 167 after O. Almgren (1923); 2 bronze tweezers; antler comb Type II after S. Thomas (1960)
d. C1b
e. Antoniewicz, Kaczyński and Okulicz 1958, 23-31, Pl. I-IX; Nowakowski 1994, 385, Fig. 2:10; 2007b, 86; Biborski and Ilkjær, 2006: 388; Miks, 2007: Vol. 2, 739, Pl. 113: A717; Kontny, 2013b; Jaskanis, 2013: 76-80, Pl. CXVII-CXXV; inv. No. PMA/IV/4498

Szwajcaria, Suwałki Comm., Poland, Barrow 25, Grave 2
a. The Dollkeim-Kovrovo Culture
b. Double-edged sword, pattern-welded, Type Ejsbøl-Sarry, Subtype 3 after M. Biborski and J. Ilkjær (2006), or Type Illerup-Wyhl after Ch. Miks (2007) with fragments of scabbard, length 94.5 cm, width 5.7 cm; balteus fitting close to Type II after M. Biborski (1997), diameter 2 cm
c. Scissors; silver *Bügelknopffibel* brooch, close to Type Leipferdingen, Variant Lichtenberg after A. Rau (2010, 190); two amber beads; fragments of clay pots

d. C3-D1
e. Antoniewicz, 1961: 8-10, Fig. 7-8, Pl. V; Antoniewicz, 1962: 186-193, Figs. 1, 3; Madyda-Legutko, 1992: 110, Pl. XII.5; Nowakowski, 1982: 83, Fig. 8; 1994, 385, Fig. 2.9; 1998, 109-110, Fig. 12, Pl. IV.4; 2007b, 86; Biborski and Ilkjær, 2006: 388-389; Miks, 2007: Vol. 2, 739, Pl. 129.A718; Bitner-Wróblewska and Stawiarska, 2009: 312-313, 341, Figs. 10, 12g-h; Jaskanis, 2013: 93-94, Pl. CLXII; State Archaeological Museum in Warszawa, inv. No PMA/IV/4998

Wólka, Kętrzyn Comm., Poland (ex-Wolka-See bei Wolka, Kr. Rastenburg), bog site, Stray Find 1
a. The Bogaczewo Culture
b. Double-edged sword, Type Lauriacum-Hromówka (?) after Ch. Miks (2007), or Type Lauriacum-Hromówka after M. Biborski-J. Ilkjær. Preserved length 62.4 cm, width 5.2 cm, pattern-welded, another fragment of the blade survived separately
c. -
d. C1-C2
e. Antiquarium, 1848: 411; Katalog, 1880: 444; Raddatz, 1993: 131, No. 2, 6, Fig. 1.4; Nowakowski, 2001a: 116, Pl. IX.2; Nowakowski, 1994: 386; Miks, 2007: Vol. 2, 763, Pl. 116; Nowakowski, 2013: 96, 213-214, Pl. 175.3; Kontny 2015: 318, Fig. 1.1; Jahn's archive; Jankuhn's archive.
f. W. Nowakowski (2001a: 116) attributed the sword to Type Ejsbøl (?) after P. Kaczanowski (1992) or Type Snipstad after M. Biborski-J. Ilkjær (Nowakowski, 2013: 96).

Wólka, Kętrzyn Comm., Poland (ex-Wolka-See bei Wolka, Kr. Rastenburg), bog site, Stray Find 2
a. The Bogaczewo Culture
b. Double-edged sword, Type Straubing-Nydam after Ch. Miks (2007), or Type Lachmirowice-Apa (?) after M. Biborski and J. Ilkjær (2006), preserved length 48 cm, width 4 cm, pattern-welded
c. -
d. B2b-C1b
e. Antiquarium, 1848: 411; Katalog, 1880: 444; Raddatz, 1993: 131, No. 5, Fig. 1.2; Nowakowski, 1994: 386; Nowakowski, 2001a: 116, Pl. IX.1; Miks, 2007: Vol. 2, 763, Pl. 87; Nowakowski, 2013: 95, 213-214, Pl. 175.2; Kontny 2015: 318-319, Fig. 1.2; Jahn's archive; Jankuhn's archive.
f. W. Nowakowski (2013: 95) classified the sword as Type Ejsbøl-Sarry after M. Biborski and J. Ilkjær (2006), or Type Augst (?) according to P. Kaczanowski (2001a: 116).

Wólka, Kętrzyn Comm., Poland (ex-Wolka-See bei Wolka, Kr. Rastenburg), bog site, Stray Find 3
a. The Bogaczewo Culture
b. Double-edged sword, Type Straubing-Nydam after Ch. Miks (2007), or Type Lachmirowice-Apa (?) after M. Biborski and J. Ilkjær (2006), surviving length 40.8 cm, width 4.5 cm
c. -
d. B2b-C1b
e. Antiquarium, 1848: 411; Raddatz, 1993: 131, Fig. 1.1; Nowakowski, 2001a: 116; Miks, 2007: Vol. 2, 763, Pl. 87; Nowakowski, 2013: 95, 213-214, Pl. 175.1; Kontny 2015: 319, Fig. 1.3; Jahn's archive; Jankuhn's archive
f. W. Nowakowski (2013, 95) attributed the sword to Type Lachmirowice-Apa (?) after M. Biborski-J. Ilkjær.

Wólka, Kętrzyn Comm., Poland (ex-Wolka-See bei Wolka, Kr. Rastenburg), bog site, Stray Find 4
a. The Bogaczewo Culture
b. Double-edged sword, Type Lauriacum-Hromówka (?) after Ch. Miks (2007), and Type Lauriacum-Hromówka after M. Biborski-J. Ilkjær (2006). Surviving length 26 cm, width 5.5 cm
c. -
d. C1-C2
e. Antiquarium, 1848: 411; Raddatz, 1993: 131, Fig. 1.3; Nowakowski, 2001a: 116; Miks, 2007: Vol. 2, 763, Pl. 116; Nowakowski, 2013: 96, 213-214, Pl. 174.3; Kontny 2015: 319, Fig. 1.4; Jahn's archive; Jankuhn's archive;
f. W. Nowakowski (2013: 95) classified the sword as Type Folkeslunda-Zaspy after M. Biborski and J. Ilkjær.

Wólka, Kętrzyn Comm., Poland (ex- Wolka-See bei Wolka, Kr. Rastenburg), bog site, Stray Find 5

a. ?
b. Sword fragment
c. -
d. ?
e. Antiquarium, 1848: 411, No. 133; Raddatz, 1993: 131, No. 1; Nowakowski, 2001a: 116

Appendix 3
Chemical composition of iron and steel artefacts.

Este apéndice es un anexo incluido solo en la versión electróníca del artículo:

A possible Roman period sword from Grzybowo (Grzybowen), Masuria, NE Poland. The archaeological and technological context; por Grzegorz Żabiński, Aleksandra Rzeszotarska-Nowakiewicz, Tomasz Nowakiewicz, Bartosz Kontny y Paweł Kucypera.

Gladius XXXVI (2016).

APPENDIX 3. Chemical composition of iron and steel artefacts (% weight)

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
1	Philistine sword, c. 1100 BC (Tylecote, 1976: 44, Tab. 29)	0-0.8	0.01	0.01	0.01				0.10			0.01					0.052			
2	Luristan sword, Iran, 11th c. BC (Tylecote, 1976: 44, Tab. 29)	0.067	0.23	<0.01	0.04	0.002														
3	Luristan sword, c. 9th c. BC (?) (Maryon *et alii*, 1961: 181-183)	0.067	0.23	<0.01	0.04	0.002														
4	Knife, Radzovce, Slovakia, Kyjatice Culture, 8th c. BC (Pleiner, 2006: 198; high Cu content)	0.8-1.0		0.027	0.015				0.018			0.494								
5	Sword, Hallstatt, Grave 2029, c. 700-600 BC (Buchwald, 2005: 116, Tab. 5.1.B)	0.2-0.3			0.4															
6	Luristan sword, Iran, 7th c. BC (Tylecote, 1976: 44, Tab. 29)	0.3		<0.17			<0.015		0.024			0.04				0.015				
7	Knife, Lovosice, Bohemia, Princely Grave III, proto-Celtic Bylany Culture, HC, 6th c. BC (Pleiner, 2006: 201; high Cu content)	0.35-0.6			tr.							0.72								
8	Spearhead, Deve Hüyük, Syria, 6th c. BC (Tylecote, 1976: 44, Tab. 29)	0-0.6							0.21											
9	Sword, Głowin (Glofenau), the Strzelin District, Silesia, Gr. 4/1927 (cremation), La Tène LT B1 (c. 400-330/320) (Piaskowski, 1959: 152-153, Fig. 91; id., 1961b, 93, Tab. I, No. 8, 94, Tab. II, No. 8, 95, Figs. 1h and 2h, 96-98, Fig. 6a-c, 99; Pleiner, 1993: 113-114, No. 114, 139, Tab. 9, No. 53; Bochnak, 2007: 26-27)	0.4-0.8	0.051		0.028	0.018														
10	Celtic sword, Holubice, Moravia, No. 606, c. 350 BC (Buchwald, 2005: 116-117, Tab. 5.1.B; Pleiner, 1993: 95; id. 2006, 203)	0.3-0.8		0.016	0.018				0.090			tr.								
11	Celtic sword, Holubice, Moravia, No. 597, c. 350-100 BC (Buchwald, 2005: 116, Tab. 5.1.B, 121; Pleiner, 1993: 91)	0.1-0.2		tr.	0.01				0.040			tr.								
12	Celtic sword, Holubice, Moravia, No. 600, c. 350-100 BC (Buchwald, 2005: 116, Tab. 5.1.B, 121-122; Pleiner, 1993: 92)	0.1-0.2		tr.	0.15				0.065			0.07								
13	Celtic sword, Tuchomyšl, Bohemia, No. 613, c. 350-100 BC (Buchwald, 2005: 116, Tab. 5.1.B, 122; Pleiner, 1993: 83)	0.3-0.6		0.012	0.28				0.018			0.13								
14	Celtic sword, Tuchomyšl, Bohemia, No. 614, c. 350-100 BC (Buchwald, 2005: 116, Tab. 5.1.B, 122; Pleiner, 1993: 84)	0-0.2		tr.	0.11				tr.			0.73								

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
15	Celtic sword, Zemplín, Slovakia, No. 510, c. 100 BC (Buchwald, 2005: 116, Tab. 5.1.B, 120; Pleiner, 1993: 97)	0.3-0.4		0.055	0.04				0.012			0.06								
16	Celtic sword, Makotřasy, Bohemia, No. 588, c. 350 BC (Buchwald, 2005: 116-117, Tab. 5.1.B; Pleiner, 1993: 86)	0.2-0.6		tr.	0.15				0.032			0.0								
17	Celtic sword, Holubice, Moravia, No. 604, c. 350 BC (Buchwald, 2005: 116-117, Tab. 5.1.B; Pleiner, 1993: 95)	<0.1		0.031	0.09				0.048			0.05								
18	Celtic sword, Holubice, Moravia, No. 602, c. 350 BC (Buchwald, 2005: 116-117, Tab. 5.1.B; Pleiner, 1993: 93)	0.1-0.3		0.008	0.11				0.024			0.04								
19	Celtic sword, Holubice, Moravia, No. 601, c. 350 BC (Buchwald, 2005: 116-117, Tab. 5.1.B; Pleiner, 1993: 93)	0.1-0.3		0.016	0.06				0.051			tr.								
20	Celtic sword, Holubice, Moravia, No. 599, c. 350 BC (Buchwald, 2005: 116-117, Tab. 5.1.B; Pleiner, 1993: 92)	0-0.2		0.019	0.34				0.011			tr.								
21	Celtic sword, Jenišův Újezd, Bohemia, No. 586, c. 350 BC (Buchwald, 2005: 116-117, Tab. 5.1.B; Pleiner, 1993: 82; id. 2006, 204)	<0.1		0.014	0.76				0.051			0								
22	Celtic sword, Tuchomyšl, Bohemia, No. 615, c. 350-100 BC (Buchwald, 2005: 116, Tab. 5.1.B, 122; Pleiner, 1993: 85)	0.2-0.5		tr.	0.24				0.032			0.35								
23	Celtic sword, Makotřasy, Bohemia, No. 596, c. 350 BC (Buchwald, 2005: 116-118, Tab. 5.1.B; Pleiner, 1993: 90)	0.1-0.3		0.017	0.07				0.034			0.05								
24	Celtic sword, Křenovice, Moravia, No. 595, c. 300 BC (Buchwald, 2005: 116, Tab. 5.1.B, 118; Pleiner, 1993: 89)	0.4-0.7		0.030	0.03				0.065			tr.								
25	Hammerhead, Tonglüshan, Daye County, Hubei, China, white-mottled cast iron, 300 BC (Buchwald, 2008: 315, Tab. 9.4, No. 2)	4.3	0.19	0.05	0.15	0.019														
26	Celtic sword, Holubice, Moravia, No. 603, c. 300 BC (Buchwald, 2005: 116, Tab. 5.1.B, 118; Pleiner, 1993: 94)	0.5-0.6		0.017	0.11				0.078			0.03								
27	Celtic sword, Holubice, Moravia, No. 605, c. 300 BC (Buchwald, 2005: 116, Tab. 5.1.B, 118; Pleiner, 1993: 95)	0.5-0.7		0.023	0.04				0.191			0.11								
28	Celtic sword, La Tène, Zihl deposit, Switzerland, No. 199, c. 250 BC (Buchwald, 2005: 116, Tab. 5.1.B, 119; Pleiner, 1993: 108)	0-0.3		tr.	0.21				0.055			0.0								
29	Celtic sword, Holubice, Moravia, No. 598, c. 250 BC (Buchwald, 2005: 116, Tab. 5.1.B, 118-119; Pleiner, 1993: 91)	0.1-0.3		0.013	0.04				0.097			0.08								
30	Sword, Warszawa-Żerań, Masovia, Przeworsk Culture, c. 220/200-60 BC (A1-A2), Type 1 Bochnak (Piaskowski, 1959: 156; id. 1960, 276, Tab. 3, No. 8, Pl. LXXI, No. 8, Pl. LXXIV.6, 277, Tab. 4, No. 8, 278-279; Pleiner, 1993: 133, No. 118, 149, Tab. 10, No. 62; Bochnak, 2005: 55, 209, 245, cat. No. 232)	0.1			0.005	0.041														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
31	Sword, Sobocisko (Zottwitz), the Oława District, Silesia, Przeworsk Culture, inhumation cemetery, La Tène Period, c. 200-100 BC (Peschek, 1939: 356-357, Fig. 186; Piaskowski, 1959: 152-153, Fig. 90, 157; id. 1961, 93, Tab. I, No. 4, 94, Tab. II, No. 4, 95, Figs. 1d and 2d, 96-97, Figs. 3d, 4h, 5a, 98; Pleiner, 1993: 131 No. 112, 139, Tab. 9, No. 24; Bochnak, 2005: 243, cat. No. 201)	0.75	0.03		0.05	0.032														
32	Celtic sword, Maloměřice, Moravia, No. 593, c. 200 BC (Buchwald, 2005: 116, Tab. 5.1.B, 119-120; Pleiner, 1993: 88)	<0.05		0.017	0.45				0.015			tr.								
33	Celtic sword, Maloměřice, Moravia, No. 592, c. 200 BC (Buchwald, 2005: 116, Tab. 5.1.B, 119; Pleiner, 1993: 88)	0.1-0.4		0.016	0.09				0.171			0.07								
34	Celtic sword, Makotřasy, Bohemia, No. 587, c. 200 BC (Buchwald, 2005: 116, Tab. 5.1.B, 119; Pleiner, 1993: 86)	<0.1		tr.	0.16				0.031			0.0								
35	Sword, Niecieplin, the Garwolin District, Masovia, Przeworsk Culture, cremation grave, Type II Kostrzewski, La Tène Period, c. 130/115 BC-AD 1 (LT D) (Piaskowski, 1963: 26-27, Tab. II, No. 12; id. 1962: 151-153, Fig. 18.26, Tab. 4a, No. 26, Tab. 4b, No. 26, 154, Fig. 20d-e; Kozłowska, 1958: 358, Pl. CXI.17, 362; Niewęgłowski, 1972: 254-255; Dąbrowska, 1988: 252)	0.2	0.05		0.016	0.002														
36	Wedge, India, 125 BC (Tylecote, 1976: 60, Tab. 39).	0.70		0.02	0.02	0.008														
37	Sword, Dobrzankowo, the Przasnysz District, Masovia, Grave 32, Przeworsk Culture, c. 120-60 BC, Type A Bochnak (single-edged) (Piaskowski, 1971: 172, Tab. 1, No. 10, 173-175, Tab. 2, No. 10, Fig. 1.10, 176, Fig. 2.10, 178, Fig. 9, 183; Bochnak, 2005: 214, 228, 266, Pl. XVI.4.2)	0.8		0.02	0.1	0.027														
38	Sword, Dobrzankowo, the Przasnysz District, Masovia, Grave 34, Przeworsk Culture, c. 120-60 BC (A2), Type 5.1 Bochnak (Piaskowski, 1971: 172, Tab. 1, No. 14, 173-175, Tab. 2, No. 14, Fig. 1.14, 176, Fig. 2.14, 179, Fig. 11; Bochnak, 2005: 209, 227-228, 234, cat. No. 40, 255, Pl. V.1)	0.1-0.4			0.2	0.003			0.35			0.07								
39	Sickle-shaped knife, Dobrzankowo, the Przasnysz District, Masovia, Grave 11, Przeworsk Culture, 1st c. BC (Piaskowski, 1971: 172, Tab. 1, No. 5, 173)	0.1		0.02	0.053				0.00											
40	Knife 1, Dobrzankowo, the Przasnysz District, Masovia, Grave 6, Przeworsk Culture, 1st c. BC (Piaskowski, 1971: 172, Tab. 1, No. 2, 173)	0.1		0.045	0.016	0.013			0.04			0.04								

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
41	Knife 2, Jadowniki Mokre, the Tarnów District, Lesser Poland, Site 1 (destroyed cremation grave) Przeworsk Culture, c. 1st c. BC (Piaskowski, 1956: 49-50, Tab. IV, No. 3)	0.62	0.00	0.05	0.11				0.00											
42	Spearhead 1, Dobrzankowo, the Przasnysz District, Masovia, Grave 12, Przeworsk Culture, 1st c. BC (Piaskowski, 1971: 172, Tab. 1, No. 5, 173)	0.1			0.040				0.08											
43	Ringgriffmesser-type knife, Hostýn, Moravia, Celtic oppidum, 1st c. BC (Pleiner, 2006: 201)	0.01-0.7		0.046	0.051				0.146											
44	Knife 1, Jadowniki Mokre, the Tarnów District, Lesser Poland, Site 1 (destroyed cremation grave) Przeworsk Culture, c. 1st c. BC (Piaskowski, 1956: 49-50, Tab. IV, No. 2)	0.20	0.00	0.05	0.06															
45	Celtic sword, Maloměřice, Moravia, No. 594, c. 200 BC (Buchwald, 2005: 116, Tab. 5.1.B, 120; Pleiner, 1993: 89)	<0.05		tr.	0.10				0.028			tr.								
46	Knife 2, Dobrzankowo, the Przasnysz District, Masovia, Grave 23, Przeworsk Culture, 1st c. BC (Piaskowski, 1971: 172, Tab. 1, No. 8, 173, 176)	<0.01		0.00	0.32				0.00			0.00								
47	Scissors (?), Jadowniki Mokre, the Tarnów District, Lesser Poland, Site 2a (destroyed cremation grave) Przeworsk Culture, c. 1st c. BC (Piaskowski, 1956: 49-50, Tab. IV, No. 6)		0.05	0.01	0.03				0.00											
48	Spearhead 3, Jadowniki Mokre, the Tarnów District, Lesser Poland, Site 3 (destroyed cremation grave) Przeworsk Culture, c. 1st c. BC (Piaskowski, 1956: 49-50, Tab. IV, No. 6)	0.82	0.00	0.17	0.03															
49	Knife 3, Wymysłowo, the Gostyń District, Greater Poland, Grave 125 (cremation), Przeworsk Culture, 1st c. BC (Piaskowski, 1961a: 173, 186-187, Tab. IV-V, No. 27)	<0.01	0.06	0.00	0.202	0.004			0.00			0.00								
50	Sword, Oblin, the Garwolin District, Masovia, Grave 291 (cremation), Przeworsk Culture, c. 60 BC-AD 1 (A3), Type I Kostrzewski (Biborski *et alii*, 2007: 131, Fig. 1d, 137-138, Fig. 5; Biborski *et alii*, 2003: 98, Fig. 1d (No. 4), 100; Biborski *et alii*, 2002: 81-82, Fig. 1d, 89-90, Figs. 20-25; Czarnecka, 2007: 65-66)	0.2-0.7		0.024	0.059															
51	Sword, Oblin, the Garwolin District, Masovia, Grave 45a (cremation), Przeworsk Culture, c. 60 BC-AD 1 (A3), Type IV Kostrzewski (Biborski *et alii*, 2007: 131, Fig. 1, 133, 135, Fig. 3; Biborski *et alii*, 2003: 98, Fig. 1b (No. 2), 99; Biborski *et alii*, 2002: 81-82, Fig. 1b, 85-86, Figs. 8-12; Czarnecka, 2007: 21-22)	0.6-0.7		0.012	0.067															

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
52	Sword, Oblin, the Garwolin District, Masovia, Grave 292 (cremation), Przeworsk Culture, c. 60 BC-AD 1 (A3), Type III Kostrzewski (Biborski *et alii*, 2007: 131, Fig. 1a, 133-134, Fig. 2; Biborski *et alii*, 2003: 98, Fig. 1a (No. 1), 99, 104, Fig. 2; Biborski *et alii*, 2002: 81-82, Fig. 1a, 83-84, Figs. 2-7; Czarnecka, 2007: 66)	0.5-0.65		0.058	0.057															
53	Sword, Oblin, the Garwolin District, Masovia, Grave 297 (cremation), Przeworsk Culture, c. 60 BC-AD 1 (A3), Type I Kostrzewski (Biborski *et alii*, 2007: 131, Fig. 1c, 133-134, 136-137, Fig. 4; Biborski *et alii*, 2003: 98, Fig. 1c (No. 3), 99-100; Biborski *et alii*, 2002: 81-82, Fig. 1c, 87-88, Figs. 14-19; Czarnecka, 2007: Fig. 67-68)	0.1-0.4		0.036	0.055															
54	Spearhead 2, Dobrzankowo, the Przasnysz District, Masovia, Grave 30, Przeworsk Culture, c. 50 BC - AD 50 (Piaskowski, 1971: 172, Tab. 1, No. 9, 173, 176)	0.1			0.29				0.00			0.00								
55	Sickle-shaped knife 2, Stupsk, the Mława District, Masovia, stray, Przeworsk Culture, 1st c. AD (Piaskowski, 1971: 172, Tab. 1, No. 27, 173, 181)	<0.01		0.00	0.050				0.00											
56	Knife 3, Dobrzankowo, the Przasnysz District, Masovia, Grave 32, Przeworsk Culture, 1st c. AD (Piaskowski, 1971: 172, Tab. 1, No. 12, 173, 176)	0.2-0.6		0.03	0.09	0.004			0.00			0.18								
57	Gladius, the legionary camp in Vindonissa, Switzerland, Type Pompeii, Vindonissa-Museum Brugg, inv. No. 1938, 1st C. AD (Biborski *et alii*, 1986: 45-46, 50, Tab. II, 57-58, Fig. 8)	0.0-0.5	0.15	0.04	0.08				0.06			0.03								
58	Knife 4, Dobrzankowo, the Przasnysz District, Masovia, Grave 34, Przeworsk Culture, 1st c. AD (Piaskowski, 1971: 172, Tab. 1, No. 13, 173, 176)	0.1-0.8		0.00	0.063				0.00			0.00								
59	Sword, Domaradzice, the Rawicz District, Greater Poland, Grave 1 (cremation), Przeworsk Culture, c. AD 1-80 (B1), Type I.2 Biborski (Piaskowski, 1959: 150, Tab. 1, No. 5, 160, Fig. 99, 174, Fig. 122.2; id. 1963, 26-27, Tab. II, No. 1; id. 1961a, 170-172, 184-185, Tab. II-III, No. 1. 192, Fig. 1.1, 193, Fig. 2.1; Biborski, 1978: 58-59, Fig. 2a, 111, Tab. 2, 148, cat. No. 30; Kostrzewski, 1954: 157, Fig. 4.6)	0.1-0.15	0.02	0.02	0.138	0.004														
60	Spearhead 3, Dobrzankowo, the Przasnysz District, Masovia, Grave 34, Przeworsk Culture, 1st c. AD (Piaskowski, 1971: 172, Tab. 1, No. 15, 173, 176)	0.1			0.022	0.009			0.00											

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
61	Spearhead, Domaradzice, the Rawicz District, Greater Poland, Grave 1 (cremation), Przeworsk Culture, c. AD 1-80 (B1) (Piaskowski, 1961a: 171, 184-185, Tab. II-III, No. 2)	0.1-0.4	tr.	0.08	0.057				tr.											
62	Knife 2, Domaradzice, the Rawicz District, Greater Poland, Grave 1 (cremation), Przeworsk Culture, c. AD 1-80 (B1), (Piaskowski, 1961a: 171, 184-185, Tab. II-III, No. 6)	0.6	0.06	0.00	0.160				tr.			0.00								
63	Knife 4, Domaradzice, the Rawicz District, Greater Poland, Grave 107 (cremation), Przeworsk Culture, 1st c. AD (Piaskowski, 1961a: 171, 184-185, Tab. II-III, No. 17)	0.5	0.15	0.00	0.218				tr.											
64	Sickle-shaped knife 1, Stupsk, the Mława District, Masovia, stray, Przeworsk Culture, 1st c. AD (Piaskowski, 1971: 172, Tab. 1, No. 26, 173, 181)	0.1		0.03	0.063				0.02											
65	Pillar, Dhar, India, no date (cca. BC/AD) (Tylecote, 1976: 60, Tab. 39)	0.02			0.28															
66	Knife, Stupsk, the Mława District, Masovia, stray, Przeworsk Culture, 1st c. AD (Piaskowski, 1971: 172, Tab. 1, No. 25, 173, 181)	0.1-0.5		0.00	0.075	0.003			0.13			0.02								
67	Spearhead 4, Dobrzankowo, the Przasnysz District, Masovia, stray, Przeworsk Culture, 1st c. AD (?) (Piaskowski, 1971: 172, Tab. 1, No. 18, 173, 176)	0.1			0.034	0.004			0.00											
68	Spur 2, Domaradzice, the Rawicz District, Greater Poland, Grave 14 (cremation), Przeworsk Culture, 1st c. AD (Piaskowski, 1961a: 171, 184-185, Tab. II-III, No. 14)	0.2-0.3	0.03	0.00	0.04	0.005			tr.											
69	Anchor D, one of Lake Nemi ships, before 50 AD (Buchwald, 2005: 109, Tab. 4.10)	0.07	(0.162)	0.039	0.061	0.001						0.15								
70	Nail B, one of Lake Nemi ships, before 50 AD (Buchwald, 2005: 109, Tab. 4.10)	0.21	0.004	tr.	0.04	0.006			-			0.016								
71	Nail A, one of Lake Nemi ships, before 50 AD (Buchwald, 2005: 109, Tab. 4.10)	0.019	0.01	0.002	0.09	0.011			0.040			0.063								
72	Nail C, one of Lake Nemi ships, before 50 AD (Buchwald, 2005: 109, Tab. 4.10)	0.04	0.009	0.003	0.063	0.011						0.33								
73	Sword, Oblin, the Garwolin District, Masovia, Grave 1 (cremation), Przeworsk Culture, c. AD 80-160 (B2) (Biborski *et alii*, 2007: 131, Fig. 1h, 143-144, Fig. 9; Biborski et alii, 2003: 98, Fig. 1h (No. 8), 101-102; Czarnecka, 2007: 12)	0.2		0.001	0.112															

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
74	Sword, Krupice, the Siemiatycze District, Podlachia, Grave 337 (cremation), Przeworsk Culture, c. AD 80-210/230 (B2-C1a), Type IV Biborski (Biborski *et alii*, 1997: 227-232, Tab. I, 236, Fig. 1c, 240-241, Figs. 22-26; Biborski and Ilkjær, 2006: 172, Tab. 5, No. 5, 173, Fig. 122.3; Jaskanis, 2005: 75)	0.1-0.65		0.05	0.11				0.04			0.03								
75	Sword, Oblin, the Garwolin District, Masovia, Grave 76 (cremation), Przeworsk Culture, c. AD 80-160 (B2) (Biborski *et alii*, 2007: 131, Fig. 1i, 143, 145-146, Fig. 10; Biborski *et alii*, 2003: 98, Fig. 1i (No. 9), 102, 107, Fig. 5; Czarnecka, 2007: 29)			0.004	0.184															
76	Sword, Oblin, the Garwolin District, Masovia, Grave 62 (cremation), Przeworsk Culture, c. AD 80-160 (B2), Type Canterbury-Kopki 2 Biborski Ilkjær (Biborski *et alii*, 2007: 131, Fig. 1g, 141-143, Fig. 8; Biborski *et alii*, 2003: 98, Fig. 1g (No. 7), 101, 105, Fig. 4; Biborski and Ilkjær, 2006: 172, Tab. 5, No. 8; Czarnecka, 2007: 25-26)	0.2-0.5		0.020	0.105															
77	Sword, Oblin, the Garwolin District, Masovia, Grave 45b (cremation), Przeworsk Culture, c. AD 80-160 (B2), Type Lachmirowice-Apa 1.1 Biborski, Ilkjær (Biborski *et alii*, 2007: 131, Fig. 1e, 137, 139, Fig. 6; Biborski *et alii*, 2003: 98, Fig. 1e (No. 5), 100, 105, Fig. 3; Biborski and Ilkjær, 2006: 187, Tab. 11, No. 14, 188, Fig. 128.4; Czarnecka, 2007: 22)	0.1-0.6		0.011	0.098															
78	Sword, Krupice, the Siemiatycze District, Podlachia, Grave 134 (cremation), Przeworsk Culture, c. AD 80-160 (B2), Type I Biborski (Biborski *et alii*, 1997: 227-229, 232, Tab. I, 236, Fig. 1b, 237-238, Figs. 2-10, 231; Jaskanis, 2005: 38-39)	0.1-0.6		0.03	0.07				0.02			0.04								
79	Nail (Group A II), Inchtuthil, Scotland, Great Britain, before AD 87 (Tylecote, 1976: 54, Tab. 35)	0.22-0.8	0.08	0.03	0.043	0.017														
80	Nail (Group A I), Inchtuthil, Scotland, Great Britain, before AD 87 (Tylecote, 1976: 54, Tab. 35)	0.2-0.9	0.15	0.17	0.008	0.009														
81	Nail (Group B), Inchtuthil, Scotland, Great Britain, before AD 87 (Tylecote, 1976: 54, Tab. 35)	0.05-0.7	0.10	0.03	0.09	0.007														
82	Nail (Group D), Inchtuthil, Scotland, Great Britain, before AD 87 (Tylecote, 1976: 54, Tab. 35).	0.05	0.08	0.03	0.035	0.01														
83	Nail (Group E), Inchtuthil, Scotland, Great Britain, before AD 87 (Tylecote, 1976: 54, Tab. 35).	0.06-0.35	0.05	nil	0.16	0.003														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
84	Nail (Group C), Inchtuthil, Scotland, Great Britain, before AD 87 (Tylecote, 1976: 54, Tab. 35).	0.10-0.55	0.04	nil	0.053	0.006														
85	Sickle blade, Mianchi County, Hehan, China, malleable white cast iron (annealed) AD 100 (Buchwald, 2008: 315, Tab. 9.4, No. 6)	0.57	0.2	0.14	0.34	0.060														
86	Shield-boss rivet, Niecieplin, the Garwolin District, Masovia (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 152-153, Tab. 4a, No. 28, 155)	<0.01		0.015	0.106															
87	Spearhead, Dratów, the Łęczna District (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 156-157, Tab. 5a, No. 30)	0.01	0.075	0.00	0.032	0.006														
88	Spearhead, Dratów, the Łęczna District (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 156-157, Tab. 5a, No. 32)	0.25	0.102	0.07	0.125				0.00											
89	Knife, Dratów, the Łęczna District (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 156-157, Tab. 5a, No. 32, 158)	0.01-0.2		0.035	0.022				0.00			0.00								
90	Spur, Wymysłowo, the Gostyń District, Greater Poland, Grave 84 (cremation), Przeworsk Culture, 2nd c. AD (Piaskowski, 1961a: 173, 186-187, Tab. IV-V, No. 26)	0.25	0.03	0.07	0.18															
91	Knife 7, Młodzikowo, the Środa Wielkopolska District, Greater Poland, (cremation), Przeworsk Culture, 2nd-3rd c. AD (Piaskowski, 1961a: 175, 186, Tab. VI, No. 41)	0.1-0.8	0.01	0.13	0.04															
92	Strike-a-fire, Abrahám, Grave 93 (cremation), Slovakia, 2nd c. AD (Pleiner, 2006: 199)	1.7		0.07	0.018				0.035			0.089								
93	Spade-head, Tieshenggou, Gongxian County, Henan, China, white cast iron, AD 100 (Buchwald, 2008: 315, Tab. 9.4, No. 3)	3.82	0.09	0.12	0.40	0.022														
94	Ploughshare-cap, Mianchi County, Henan, China, grey cast iron, AD 100 (Buchwald, 2008: 315, Tab. 9.4, No. 5)	4.47	0.06	0.04	0.24	0.028														
95	Sword pendant, Niecieplin, the Garwolin District, Masovia (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 152-153, Tab. 4a, No. 28, 155)	<0.01		0.059	0.063				0.00			0.00								
96	Sword fragment, Augst, Switzerland, Type Straubing-Nydam, Römermusem Augst, inv. No. 1961.1568, Roman Period (Biborski *et alii*, 1986: 45-46, 50, Tab. II, 62-63, Fig. 12)	0.1	0.09	0.02	0.30				0.09			0.02								

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
97	Fitting, Łajski, the Legionowo District, Masovia (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 144-145, Tab. 3a, No. 23, 147)	<0.01		0.023	0.52				0.00			0.00								
98	Mattock-head, Guxingzhen, Zhengzhou, Henan, China, white cast iron, AD 100 (Buchwald, 2008: 315, Tab. 9.4, No. 4)	3.30	0.16	0.19	0.21	0.060														
99	Spearhead, Niecieplin, the Garwolin District, Masovia (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 152-153, Tab. 4a, No. 25)	0.4-0.8	0.103	0.00	0.013	0.010			0.00											
100	Spearhead, Łajski, the Legionowo District, Masovia (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 143-145, Tab. 3a, No. 15)	0.01		0.035	0.460	0.003			0.00											
101	Knife 2, Łajski, the Legionowo District, Masovia (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 143-145, Tab. 3a, No. 17, 146)	0.2	0.01	0.110	0.083	0.002			0.00											
102	Scissors, Łajski, the Legionowo District, Masovia (cremation grave), Przeworsk Culture, Roman Period (Piaskowski, 1962: 130, 144-145, Tab. 3a, No. 21, 147)	<0.01	0.105	0.025	0.019	0.008			0.00			0.00								
103	Spatha sword, Augst, Switzerland, Type Straubing-Nydam, Römermusem Augst, inv. No. 1961.4401, c. AD 150-275 (C1) (Biborski *et alii*, 1986: 45-48, 50, Tab. II, 51-52, Fig. 3)	0.1-0.77	0.20	0.06	0.13				0.15			0.21								
104	Sword, Wąchock, the Starachowice District, Lesser Poland (cremation grave), Przeworsk Culture, c. AD 160-230, Type Lachmirowice-Apa 2 Biborski Ilkjær (Piaskowski, 1963: 24, Tab. I, No. 2, 58; id. 1962, 137-139, Figs. 6.11, 7.11, 8d, 140-141, Tab. 2a, No. 11, 142, Fig. 9, 160, 163-164, 169-170; Biborski and Ilkjær, 2006: 189, Tab. 12, No. 7, 190, Fig. 129.2)	0.7		0.01	0.15															
105	Sword, Stare Gardzienice, the Lipsko District, Lesser Poland (cremation grave), Przeworsk Culture, c. AD 200-300 (Piaskowski, 1963: 24, Tab. I, No. 6, 28, Tab. III, No. 6; id. 1962, 158, 160-161, Tab. 6a, No. 35, Tab. 6b, No. 35, 163, 164-165, Figs. 27.35, 28a-c)	0.7	0.06		0.04	0.006														
106	Knife 1, Wymysłowo, the Gostyń District, Greater Poland, Grave 37 (cremation), Przeworsk Culture, 3rd c. AD (Piaskowski, 1961a: 173, 186-187, Tab. IV-V, No. 20)	0.6-0.7	0.09	0.00	0.17															
107	Spearhead 4, Grave Mound 8, Szwajcaria, the Suwałki District, Prussia, 3rd-4th c. AD (Piaskowski, 1958: 58, 61, Tab. 1, No. 7, 65-66)	<0.01	0.09	0.00	0.08				0.02											

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
108	Roman Period sword, Nydam, Denmark, 3rd c. AD (Williams, 2012: 67)	0.62	0.15	0.363	0.054	0.073														
109	Roman Period sword, Nydam, Denmark, 3rd c. AD (Williams, 2012: 67)	0.52	0.107	0.016	0.146	0.011														
110	Spearhead 3, Perevodiv, the Sokal District, Ukraine, 3rd c. AD (Piaskowski, 1967: 197, 209, 211, Tab. 1, No. 17)	0.01		0.03	0.345	0.006			0.00			0.00								
111	Axehead 2, Grave Mound 8, Szwajcaria, the Suwałki District, Prussia, 3rd-4th c. AD (Piaskowski, 1958: 58, 61, Tab. 1, No. 8, 66)	0.1-0.7	0.01	0.00	0.10				0.06											
112	Scissors, Grave Mound 2, Szwajcaria, the Suwałki District, Prussia, 3rd-4th c. AD (Piaskowski, 1958: 58, 61, Tab. 1, No. 5, 64-65)	0.1	0.06	0.00	0.07				0.06											
113	Sword, Hromovka, the Starokonstantyniv District, Ukraine, c. AD 210/230-260 (C1b) Type Lauriacum-Hromówka 2 Biborski Ilkjær (Piaskowski, 1967: 197-199, Fig. 1.19, 200, Fig. 2.19, 207, Figs. 34-37, 208, Fig. 38, 210, 211, Tab. 1, No. 19, 211, 213, Tab. 2, No. 19; Biborski and Ilkjær, 2006: 203, 205, Fig. 136.1; Dąbrowska and Godłowski, 1970: 78, Pl. I, II.1-3)	0.5-0.7		0.03	0.04															
114	Crucible steel Central Asian sword blade (uncertain chronology) (Buchwald, 2008: 476, Tab. 12.9).	1.42	0.11	0.13	0.035	0.038														
115	Crucible steel Central Asian sword blade (uncertain chronology) (Buchwald, 2008: 476, Tab. 12.9).	1.62	0.027	tr.	0.09	0.007														
116	Crucible steel Central Asian sword blade (uncertain chronology) (Buchwald, 2008: 476, Tab. 12.9).	0.60	0.12	0.16	0.25	0.032														
117	Crucible steel Central Asian sword blade (uncertain chronology) (Buchwald, 2008: 476, Tab. 12.9).	1.49	0.005	0.08	0.10	0.05														
118	Sword, Borowo, the Kościan District, Greater Poland, Przeworsk Culture, c. AD 375-450, Type XI.2 Biborski (Piaskowski, 1959: 150, Tab. 1, No. 7, 160, Figs. 100-101, 174, Fig. 122.4; id. 1963, 26-27, Tab. II, No. 8, 64, Fig. 53; id. 1961a, 178, 180, Tab. X, No. 59, 212, Figs. 80.59, 81.59, 214, Figs. 88-89; Biborski, 1978: 92-93, Fig. 54c, 111, Table 2, 146-147, cat. No. 9)	0.3-0.75	0.02		0.045	0.06														
119	Chisel, Ceylon, 5th c. AD (Tylecote, 1976: 60, Tab. 39)	tr.		nil	0.28	0.033														
120	Nail, Ceylon, 5th c. AD (Tylecote, 1976: 60, Tab. 39)	tr.		nil	0.32	nil														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
121	Delhi Iron Pillar, wrought iron, c. 400 AD (Buchwald, 2005: 261)	0.08-0.28			0.11-0.48	0.0008			<0.05			<0.05								
122	Sword, Grzybowo c. 300 AD (?)	0.608	0.128	0.0283	0.0331	.00423	0.0291	0.0100	0.0145	.00100	.00898	0.0152	0.0100	0.0164	.00100	0.0100	.00311	.00039	0.0456	99.06
123	Sword, 6th-7th c., crucible steel (Williams, 2007: 240)	1.37	0.046	0.068	0.042	0.013													0.01	
124	Sword, Kałdus, Land of Chełmno, Grave 364, Type E, H or V (Petersen), c. 750-950, blade (Kaźmierczak and Rybka, 2010: 175-179, Tab. 1)		0.60		0.12	0.19				0.19					0.32					98.58
125	Sword, Kałdus, Land of Chełmno, Grave 364, Type E, H or V (Petersen), c. 750-950, forte (Kaźmierczak and Rybka, 2010: 175-179, Tab. 1)			0.06																99.06
126	Sword, Kałdus, Land of Chełmno, Grave 364, Type E, H or V (Petersen), c. 750-950, hilt (Kaźmierczak and Rybka, 2010: 175-179, Tab. 1)		0.57		0.13	0.06				0.38					0.07		0.09			98.71
127	Sword, Kałdus, Land of Chełmno, Grave 364, Type E, H or V (Petersen), c. 750-950, crosspiece (Kaźmierczak and Rybka, 2010: 175-179, Tab. 1)		0.09	0.35			0.16			0.12		0.13								99.14
128	Sword, Wijk bij Duurstede, Netherlands, Special Type 2 (Petersen), pattern-welded, c. 775-850, Sample 2 (Ypey, 1980: 190, 202)	0.21	0.09	0.04	0.22	0.04			tr.											
129	Sword, Wijk bij Duurstede, Netherlands, Special Type 2 (Petersen), pattern-welded, c. 775-850, Sample 3 (Ypey, 1980: 190, 202)	0.72	0.09	0.05	0.32	0.04			tr.											
130	Sword, Wijk bij Duurstede, Netherlands, Special Type 2 (Petersen), pattern-welded, c. 775-850, Sample 4 (Ypey, 1980: 190, 202)	0.86	0.15	0.04	0.30	0.05			tr.											
131	Sword, Wijk bij Duurstede, Netherlands, Special Type 2 (Petersen), pattern-welded, c. 775-850, Sample 1 (Ypey, 1980: 190, 202)	0.84	0.10	0.04	0.42	0.03			tr.											
132	Sword, Glanshammar, Sweden, National Museum of Antiquities in Stockholm, No. 13202:5, Viking Age, cutting edge (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.028				<0.002	0.012		0.052	0.006								
133	Spear, Broa, Sweden, National Museum of Antiquities in Stockholm, No. 19734:36, Viking Age, cutting edge (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.007				0.007	0.019		0.045	0.008								
134	Spear, Broa, Sweden, National Museum of Antiquities in Stockholm, No. 19734:36, Viking Age, side (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.018				0.039	0.009		0.014	0.005								

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
135	Spear, Broa, Sweden, National Museum of Antiquities in Stockholm, No. 19734:36, Viking Age, centre (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.002				0.025	0.005		0.008	0.005								
136	Sword, Glanshammar, Sweden, National Museum of Antiquities in Stockholm, No. 13202:5, Viking Age, centre (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.003				0.006	0.023		0.010	0.005								
137	Spear, Östveda, Sweden, National Museum of Antiquities in Stockholm, No. 8974, Viking Age, cutting edge (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.005				0.008	0.003		0.021	0.002								
138	Sword, Sanda, Sweden, National Museum of Antiquities in Stockholm, No. 7480:40, Viking Age, side (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.007				0.006	0.080		0.051	0.013								
139	Viking Age sword, Donnybrook, County Dublin, Ireland, c. 800-900 AD, edge (Williams, 2012: 170-171; Williams, 2009: 140)	0.3-0.4		0.1	tr.	tr.			0.2-0.3											
140	Sword, Sanda, Sweden, National Museum of Antiquities in Stockholm, No. 7480:40, Viking Age, cutting edge (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.004				0.007	0.030		0.021	0.011								
141	Sword, Hedesunda, Sweden, National Museum of Antiquities in Stockholm, No. 8974, Viking Age (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.022				<0.002	0.010		0.075	0.008								
142	Spear, Östveda, Sweden, National Museum of Antiquities in Stockholm, No. 8974, Viking Age, centre (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.011				0.040	0.020		0.045	0.009								
143	Spear, Kolbäck, Sweden, National Museum of Antiquities in Stockholm, No. 17343:1779, Viking Age, centre (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.007				0.006	0.1		0.011	0.010								
144	Spear, Ölbo, Sweden, National Museum of Antiquities in Stockholm, No. 12016A, Viking Age, centre (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.010				0.013	0.005		0.031	0.006								
145	Spear, Kolbäck, Sweden, National Museum of Antiquities in Stockholm, No. 17343:1779, Viking Age, side A (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.011				0.007	0.09		0.013	0.018								
146	Spear, Kolbäck, Sweden, National Museum of Antiquities in Stockholm, No. 17343:1779, Viking Age, side B (Bergman and Arrhenius, 2005: 69, Tab. 21)			0.005				0.004	0.08		0.007	0.026								
147	Viking Age sword, Donnybrook, County Dublin, Ireland, c. 800-900 AD, centre (Williams, 2012: 170-171; id. 2009, 140)	0.2		0.1-1.0	0.02	0.01				<0.01										

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
148	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 28 small prill, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.05	0.0							0.2								94
149	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 28 double prill, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.05	0.0							0.2								94
150	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 5, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.06	0.1							0.3								96
151	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. A.3.7 prill 2, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.05	0.03							0.1								92
152	Ingot, a crucible steel workshop at Merv, Turkmenistan, ID No. Merv ingot, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12, 117)	1.2-1.4		0.06	0.03							0.2								95
153	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 12, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.1	0.02							0.2								95
154	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 7, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.1	0.1							0.3								94
155	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 8, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.0	0.03							0.3								97
156	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 11, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.1	0.00							0.3								95
157	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 13, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.3	0.1							0.3								94
158	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 16, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.1	0.06							0.3								94
159	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 34, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.0	0.1							0.1								94
160	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 19, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.2	0.0							0.1								94

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
161	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. A.3.7, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.04	0.4							0.1								91
162	Prills, a crucible steel workshop at Merv, Turkmenistan, ID No. 10, crucible steel, late 9th-early 10th c. (Feuerbach, 2002: 101, Tab. 12)			0.1	0.03							0.2								96
163	Sword, Elbląg-Pole Nowomiejskie (Elbing-Neustädterfeld), Prussia (cremation grave), c. 900-1000, Type H Petersen (Mazur and Nosek, 1973: 4, Tab. 1, Fig. 1, 6-7, Figs. 6-8, 9, Fig. 14, 10-11, Figs. 17-20, 12-13, Tab. 2, 14, Figs. 21-22, 15, Fig. 23, 16, Figs. 24-29, 17, Figs. 30 and 35, 18; Kirpičnikov and Jagodziński, 2006)	0.8			0.034-0.022				0.04-0.03			0.03								
164	Billhook, Ceylon, Middle Ages (Tylecote, 1976: 60, Tab. 39)	tr.		tr.	0.34	0.02														
165	Crucible steel ingot, Spot 4, Termez, Uzbekistan, 12th-13th c. (Feuerbach, 2002: 146, Tab. 24)			0.03	0.0							0.01								91
166	Socket of a lancehead, Bohemia, Middle Ages, 44/96 (Hošek, 2003: 120, Tab. 16)	0.03	0.030	0.006	0.220	0.007			0.050	0.007	0.020	0.010			0.004					
167	Crucible steel ingot, Spot 1, Termez, Uzbekistan, 12th-13th c. (Feuerbach, 2002: 146, Tab. 24)			0.03	0.0							0.0								88
168	Crucible steel ingot, Spot 3, Termez, Uzbekistan, 12th-13th c. (Feuerbach, 2002: 146, Tab. 24)			0.01	0.0							0.0								88
169	Sword, private collection, Italy, 12th c. (Williams, 2012: 282-283)	0.04-0.54	0.08	0.015	0.10	0.01													0.01	
170	Crucible steel ingot, Spot 2, Termez, Uzbekistan, 12th-13th c. (Feuerbach, 2002: 146, Tab. 24)			0.03	0.02							0.02								90
171	Pig iron No. 132, hypereutectic white. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	4.34	0.84	1.95	0.021	0.021														
172	Pig iron No. 163, hypereutectic grey. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	4.14	1.18	1.40	0.040	0.011														
173	Pig iron No. 5004, hypoeutectic grey. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	2.79	1.40	0.44	0.025	0.024														
174	Pig iron No. 4367, hypereutectic white. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	4.57	0.17	2.52	0.038	0.012														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
175	Pig iron No. 2884, hypoeutectic white. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	3.06	0.79	0.32	0.018	0.050														
176	Pig iron No. 127, eutectic grey. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	4.00	1.02	1.05	0.030	0.030														
177	Osmund No. 2421, steel knife. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 246, Tab. 7.5)	0.97	0.03	<0.01	0.009	0.007														
178	Pig iron No. 180, hypereutectic white. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	4.10	1.10	1.35	0.028	0.028														
179	Osmund No. 2734, steel scrap. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 246, Tab. 7.5)	0.51	0.10	0.06	0.011	0.019														
180	Osmund No. 3734, iron scrap. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 246, Tab. 7.5)	0.34	0.10	0.08	0.012	0.024														
181	Osmund No. 834, steel. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 246, Tab. 7.5)	0.58	0.04	0.03	0.024	0.005														
182	Osmund No. 1410, soft iron. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 246, Tab. 7.5)	0.16	0.07	0.03	0.017	0.005														
183	Pig iron No. 4295, hypereutectic white. Blast furnace centre, Lapphyttan, Sweden, c. 1150-1225 (Buchwald, 2008: 245, Tab. 7.4)	4.46	0.21	1.80	0.026	0.039														
184	2 Beams, Konarak, Orissa, India, 13th c. AD (Tylecote, 1976: 60, Tab. 39)	0.11		tr.	0.02	0.02														
185	Sword, the British Museum, 1881-08-02-127, Solingen (?), 13th c. (Williams, 2012: 256-257)	0.01-0.6		0.055	0.04				0.04		0.03									
186	Falchion, Poznań Cathedral, Greater Poland, St Peter's Sword, c. 1250-1350, Type II Seitz (Nosek and Stępiński, 2011, 77-82, Figs. 1-3, 85-102, Figs. 6-10, Tab. 1; Stępiński et alii, 2015: 34-46, Tab. 1, Figs. 19-28)	0.2-0.77	0.14	0.11	0.19	0.02	0.024			0.008	0.007		0.006					0.09		
187	Sword, Kraków Cathedral, Lesser Poland, Szczerbiec, c. 1250, Type XII, I, 6 Oakeshott (Biborski, Stępiński and Żabiński, 2011: 101-105, Figs. 8-17, 137-140)	0.1-0.7	0.153	0.023	0.092	0.015			0.044	0.029		0.002								

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
188	Sword, Kraków II, Lesser Poland, c. 1300-1450, Type XVIa/XIIIa, -, 1 Oakeshott (Cabalska and Mazur, 1982: 9, No. 2, 11-14, Tab. 2-3, Figs. 1.2, 2.2, 4)			0.1	0.042				0.06			0.08								
189	Sword, Chełm, the Bochnia District, Lesser Poland, c. 1300-1450, Type XIIIa (?), I, - Oakeshott (Cabalska and Mazur, 1982: 9, No. 3, 11-14, Tab. 2-3, Figs. 1.2, 2.2, 4)			0.1	0.021				0.05			0.05								
190	Sword, Stary Sącz I, the Nowy Sącz District, Lesser Poland, c. 1300-1450, Type XIIIa, H/J, 2 Oakeshott (Cabalska and Mazur, 1982: 9, No. 4, 11-14, Tab. 2-3, Figs. 1.4, 2.3, 5-6)			0.07	0.014				0.04			0.01								
191	Undefined artefact, Příšovice, Bohemia, c. 1350-1450, P 20 271 (Hošek, 2003: 62, 64-65, Tab. 4)	0.09	0.120	0.004	0.320	0.008		0.001	0.030	0.001		0.020	0.007							
192	Undefined artefact, Příšovice, Bohemia, c. 1350-1450, P 19 208 (Hošek, 2003: 62, 64-65, Tab. 4)	0.15	0.430	0.060	0.330	0.037		0.003	0.260	0.001		0.180		0.001	0.015	0.609	0.112			
193	Axe, Příšovice, Bohemia, c. 1350-1450, P 19 204 (Hošek, 2003: 56, 64-65, Tab. 4)	0.040	0.130	0.002	0.285	0.015	0.004	0.005	0.003	0.009		0.044			0.015	0.877	0.087			
194	Sword, Stary Sącz III, the Nowy Sącz District, Lesser Poland, c. 1350-1450, Type XVII, H1, 12 Oakeshott (Cabalska and Mazur, 1982: 9-10, No. 6, 11-14, Tab. 2-3, Figs. 1.3, 2.6, 12-13)			0.1	0.041				0.06			0.07								
195	Sword, Stary Sącz II, the Nowy Sącz District, Lesser Poland, c. 1350-after 1400, Type XVII, -, 1 Oakeshott (Cabalska and Mazur, 1982: 9, No. 5, 11-14, Tab. 2-3, Figs. 1.1, 2.4, 7-10)			0.07	0.014				0.05			0.05								
196	Axe, Příšovice, Bohemia, c. 1350-1450, P 19 203 (Hošek, 2003: 56, 64-65, Tab. 4)	0.02	0.470	0.030	0.141	0.011	0.012	0.040	0.120	0.020		0.170		0.008	0.216	0.256	0.230			
197	Crossbow bolt, Turnovsko, Bohemia, c. 1400-1450 (Hošek, 2003: 158)	0.08	0.01	0.006	0.72	0.005			0.05			0.02			0.003					
198	Osmund pieces (2), hypereutectoid steel,, Hulk W-5 discovered near Gdańsk (Danzig) in the Baltic Sea, c. 1450-1500 (Buchwald, 2008: 253)	1.0-1.2	0.05<	0.05<	0.05<															
199	Grey cast iron fire-back, Walloon origin, 16th c. (Buchwald, 2008: 306, Tab. 9.2)	3.59	1.07	0.89	0.72	0.030														
200	Grey cast iron fire-back, Sussex, 16th c. (Buchwald, 2008: 306, Tab. 9.2)	3.55	0.65	0.63	0.62	0.070														
201	Grey cast iron fire-back, Sussex, 16th c. (Buchwald, 2008: 306, Tab. 9.2)	3.64	0.52	0.42	0.56	0.086														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
202	Grey cast iron fire-back, Sussex, 16th c. (Buchwald, 2008: 306, Tab. 9.2)	3.69	0.64	0.94	0.57	0.098														
203	Grey-mottled cast iron fire-back, Sussex, 16th c. (Buchwald, 2008: 306, Tab. 9.2)	3.27	0.78	0.76	0.66	0.058														
204	Grey cast iron fire-back, Walloon origin, 16th c. (Buchwald, 2008: 306, Tab. 9.2)	3.75	1.14	1.58	0.62	0.030														
205	Munition armour, Graz, Styria, Austria (possible import from Nürnberg), 1550-1575 (Williams 2003, 654-655)	0.03	0.05	<0.07	0.07		<0.05	0.02	0.03			0.03	<0.01	<0.02		<0.01				
206	White pig iron found at the blast furnace site in Kölebacks near Foglaslätt, Vester Götland, Sweden, 17th c. (Buchwald, 2008: 349)	2.8		0.01	0.53	0.15														
207	Landsknecht munition armour, Graz, Styria, Austria, 1615-1631 (Williams, 2012: 208-209)	0.45	0.19	<0.07	0.010	0.008	0.05	0.02	0.07	0.035		0.21	<0.01	0.05		<0.01				
208	Steel part of a water wheel, Siegerland, Germany, 1630. Fined blast furnace metal (Buchwald, 2008: 208, Tab. 6.7)	0.89	0.015	(0.08)	0.06	0.02														
209	Bar iron No. 45 (pig iron refined with the “German forge” method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.25	0.06	0.002	0.08	0.002			0.010		0.001	0.006								
210	Bar iron No. 47 (pig iron refined with the “German forge” method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.03	0.01	0.005	0.39	0.009			0.011		0.018	0.10								
211	Bar iron No. 48 (pig iron refined with the “German forge” method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.02	0.03	0.007	0.31	0.006			0.010		0.018	0.09								
212	Bar iron No. 119 (pig iron refined with the “German forge” method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.03	0.05	0.006	0.33	0.008			0.010		0.016	0.07								
213	Bar iron No. 86 (pig iron refined with the “German forge” method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.03	0.01	0.001	0.04	0.002			0.001		0.001	0.007								
214	Bar iron No. 112 (pig iron refined with the “German forge” method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.33	0.09	0.003	0.08	0.003			0.001		0.001	0.005								
215	Bar iron No. 209 (pig iron refined with the “German forge” method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.71	0.09	0.004	0.02	0.003			0.002		0.001	0.005								

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
216	Bar iron No. A (pig iron refined with the "German forge" method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.35	0.02	0.003	0.03	0.003			0.001		0.001	0.006								
217	Bar iron No. A (pig iron refined with the "German forge" method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.38	0.007	0.003	0.05	0.002			0.001		0.001	0.006								
218	Grey pearlitic pig iron, a Swedish cannon from the Laesø Island Swedish shipwreck 1650 (Buchwald, 2008: 306, Tab. 9.2)	4.15	0.40	0.62	0.10	0.07														
219	Bar iron No. 117 (pig iron refined with the "German forge" method), the Laesø Island Swedish shipwreck, Denmark, 1650 (Buchwald, 2008: 364, Tab. 10.15)	0.02	0.03	0.005	0.40	0.007			0.012		0.021	0.10								
220	Anchor, Emmerich, on the Rhine, 50 km NW of Duisburg, Germany, 1661. Fined blast furnace metal (Buchwald, 2008: 208, Tab. 6.7)	0.21	0.03	0.02	0.03	0.01						0.04								
221	Cast iron fireback "The Arms of Meugens," Orval furnace, Belgium, 1661 (Buchwald, 2008: 276, Tab. 8.6)	3.52	1.07	0.23	1.38	0.02														
222	Cast iron double cauldron, Liège furnace, Belgium, 1682 (Buchwald, 2008: 276, Tab. 8.6)	3.70	0.56	0.43	1.47	0.02														
223	Cast iron fireback "The Escape to Egypt," Pays de Liège furnace, Belgium, 18th c. (Buchwald, 2008: 276, Tab. 8.6)	3.93	1.37	0.79	0.65	0.03														
224	Cast iron fireback "Rahier et Oyenbrugge," Bra sur Lienne furnace, Belgium, 1700 (Buchwald, 2008: 276, Tab. 8.6)	3.64	0.89	0.66	0.57	0.02														
225	Hirschfänger (steel cutlass), Germany, c. 1700. Fined blast furnace metal (Buchwald, 2008: 208, Tab. 6.7). High % of Cu typical for many Siegerland ores	0.58	(0.12)	(0.07)	0.08	0.02						0.36								
226	Cast iron brazier, Franchimont furnace, Belgium, 18th c. (Buchwald, 2008: 276, Tab. 8.6)	3.66	1.12	1.07	1.08	0.03														
227	Cast iron cauldron, Pays de Liège furnace, Belgium, 18th c. (Buchwald, 2008: 276, Tab. 8.6)	3.82	1.40	0.55	1.26	0.14														
228	Damascene (crucible steel) Oriental sabre, Modern Period (Zschokke, 1924: 656, Tab. A, No. 10; Buchwald, 2008: 476, Tab. 12.9)	1.726	0.062	0.028	0.172	0.020														
229	Damascene (crucible steel) Oriental dagger, Modern Period (Zschokke, 1924: 656, Tab. A, No. 3)	1.677	0.015	0.056	0.086	0.007														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
230	Damascene (crucible steel) Oriental sabre, Modern Period (Zschokke, 1924: 656, Tab. A, No. 9; Buchwald, 2008: 476, Tab. 12.9)	1.342	0.062	0.019	0.108	0.008														
231	Damascene (crucible steel) Oriental sabre, Modern Period (Zschokke, 1924: 656, Tab. A, No. 8; Buchwald, 2008: 476, Tab. 12.9)	0.596	0.119	0.159	0.252	0.032														
232	Damascene (crucible steel) Oriental sabre, Modern Period (Zschokke, 1924: 656, Tab. A, No. 7; Buchwald, 2008: 476, Tab. 12.9)	1.874	0.049	0.005	0.127	0.013														
233	Damascene (crucible steel) Oriental dagger, Modern Period (Zschokke, 1924: 656, Tab. A, No. 5)	1.575	0.011	0.030	0.104	0.018														
234	Gun barrel found at Christiansbro, Copenhagen's harbour, Denmark, pearlitic grey cast iron with graphite, 18th c. (Buchwald, 2008: 331)	3.5	1	0.1	0.1															
235	Cross on a graveyard, Unkel am Rhein, 15 km S of Bonn, Germany, 1714. Fined blast furnace metal (Buchwald, 2008: 208, Tab. 6.7). High % of Cu typical for many Siegerland ores.	0.05	0.01	0.02	0.10	0.01						0.80								
236	Iron bar, spire from the top of the gate-house at Frederiksborg Castle, Hillerød, Denmark, before 1733 (Buchwald, 2008: 437)	0.11	0.01	0.02	0.021	0.006														
237	Cast iron fireback "The Arms of Baillet," Habay-la-Vieille furnace, Belgium, 1733 (Buchwald, 2008: 276, Tab. 8.6)	3.45	0.58	0.21	1.36	0.04														
238	Steel part of a water wheel, Alzental, Siegerland, Germany, before 1750. Fined blast furnace metal (Buchwald, 2008: 208, Tab. 6.7). High % of Cu typical for many Siegerland ores	0.61	0.06	0.10	0.07	0.03						0.32								
239	Chisel, Odenwald, Germany, before 1750 (average of two analyses). Fined blast furnace metal (Buchwald, 2008: 208, Tab. 6.7)	0.16	(0.2)	(0.25)	0.23	0.006						0.04								
240	Iron wedge, Schwarzwald, Baden, Germany, before 1750. Fined blast furnace metal (Buchwald, 2008: 208, Tab. 6.7)	0.31	0.02	0.0	0.12	0.008						0.01								
241	Cast iron fireback "Silhouette of a Grenadier," Theux furnace, Franchimont, Belgium, 1770 (Buchwald, 2008: 276, Tab. 8.6)	3.46	0.95	0.96	1.05															
242	Cast iron fireback "Silhouette of the Sun," Theux furnace, Franchimont, Belgium, 1770 (Buchwald, 2008: 276, Tab. 8.6)	3.65	1.08	n.d.	0.76	0.02														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
243	Cast iron cauldron, Pays de Liège furnace, Belgium, 1786 (Buchwald, 2008: 276, Tab. 8.6)	4.08	1.01	0.68	0.77															
244	Grey pearlitic pig iron for the casting of Swedish cannons. About 1840 (Buchwald, 2008: 306, Tab. 9.2)	2.56-3.35	0.95-1.00	0.15-0.25	0.032-0.040	0.035-0.040														
245	Grey pearlitic pig iron for the casting of Swedish cannons, another variety. About 1840 (Buchwald, 2008: 306, Tab. 9.2)	3.35-3.40	0.61-0.72	0.20-0.37	0.036-0.039	0.040-0.050														
246	Unalloyed crucible steel (Huntsmann crucible process, almost slag-free), Krupp, Germany, 1850s (Buchwald, 2008: 480, Tab. 12.11)	1.00-1.18	0.06-0.33	0-0.08	0.02	0-0.015						0-0.30								
247	Post c. 1850 replica of a medieval sword, Golub-Dobrzyń, edge (Rybka, 2011: 114-115, Fig. 4, 121-122, Tab. 1)						0.01	0.02	0.21			0.17								96.63
248	Post c. 1850 replica of a medieval sword, Golub-Dobrzyń, crosspiece (Rybka, 2011: 114-115, Fig. 4, 121-122, Tab. 1)			0.09				0.02				0.19								97.69
249	Post c. 1850 replica of a medieval sword, Golub-Dobrzyń, pommel (Rybka, 2011: 114-115, Fig. 4, 121-122, Tab. 1)			0.03				0.03				0.05								97.72
250	Post c. 1850 replica of a medieval sword, Szczecin (Stettin) 1, Pomerania, edge (Rybka, 2011: 116-118, Fig. 5, 121-122, Tab. 1)			0.62			0.93	0.03	0.12			0.22		0.00						96.82
251	Post c. 1850 replica of a medieval sword, Szczecin (Stettin) 1, Pomerania, crosspiece (Rybka, 2011: 116-118, Fig. 5, 121-122, Tab. 1)			0.54			0.26	0.02	0.04			0.28		0.00						97.18
252	Post c. 1850 replica of a medieval sword, Szczecin (Stettin) 4, Pomerania, edge (Rybka, 2011: 116-118, Fig. 5, 121-122, Tab. 1)			0.55			1.04	0.03	0.08			0.51								96.13
253	Post c. 1850 replica of a medieval sword, Szczecin (Stettin) 4, Pomerania, crosspiece (Rybka, 2011: 116-118, Fig. 5, 121-122, Tab. 1)			0.56			0.10	0.03	0.07			0.5		0.02						97.16
254	Post c. 1850 replica of a medieval sword, Szczecin (Stettin) 4, Pomerania, pommel (Rybka, 2011: 116-118, Fig. 5, 121-122, Tab. 1)			0.43			0.07	0.02				0.11								98.95
255	Post c. 1850 replica of a medieval sword, Sanok, edge (Rybka, 2011: 118-120, Fig. 6, 121-122, Tab. 1)			0.43			0.02	0.01				0.25		0.02						95.02
256	Unalloyed crucible steel (Huntsmann crucible process, almost slag-free), Neuberg, Germany, 1850s (Buchwald, 2008: 480, Tab. 12.11)	0.63	0.36	0.33	0.049	0.023						tr.								
257	Post c. 1850 replica of a medieval sword, Sanok, fuller (Rybka, 2011: 118-120, Fig. 6, 121-122, Tab. 1)			0.54			0.04	0.02				0.29								94.92

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
258	Unalloyed crucible steel (Huntsmann crucible process, almost slag-free), Inneberg, Germany, 1850s (Buchwald, 2008: 480, Tab. 12.11)	0.75	0.39	0.39	0.041	0.039						0.01								
259	Unalloyed crucible steel (Huntsmann crucible process, almost slag-free), Krupp gun, Germany, 1850s (Buchwald, 2008: 480, Tab. 12.11)	1.18	0.33	tr.	0.02	0.0			0.12			0.30?								
260	Bessemer iron, experimental smelt, Great Britain, 1856 (Buchwald, 2008: 524, Tab. 14.1)	0.08	tr.	tr.	0.43	0.16														
261	Bessemer iron, experimental smelt, Dowlais Iron Works, Great Britain, 1857 (Buchwald, 2008: 524, Tab. 14.1)	0.06	0.01	0.0	1.93	0.28														
262	Armour plate, puddled iron (not slag-free), Low Moor Company, West Yorkshire, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.0016	0.12	0.28	0.11	0.10			n.d			n.d.								99.37
263	Bar for cable-bolts, puddled iron (not slag-free), Dowlais Ironworks, Glamorgan, South Wales, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	n.d.	0.13	0.014	0.42	0.06			0.008			0.001								98.54
264	Iron sheet, puddled iron (not slag-free), common quality, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.03	0.22	n.d.	0.39	n.d.			n.d			n.d.								
265	Iron sheet, puddled iron (not slag-free), best quality, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.04	0.17	n.d.	0.18	n.d.			n.d			n.d.								
266	Armour plate, puddled iron (not slag-free), “too steely,” Weardale Iron Company, Durham, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.17	0.11	0.33	0.09	0.06			n.d			n.d.								
267	Armour plate, puddled iron (not slag-free), Beale and Company, Newbold, Derbyshire, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.04	0.17	0.25	0.23	0.12			n.d			n.d.								
268	Armour plate, puddled iron (not slag-free), “too steely,” Shortridge & Howell, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.23	0.02	0.11	0.02	0.19			n.d			n.d.								
269	Armour plate, puddled iron (not slag-free), Thames Iron Company, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.03	0.16	0.03	0.17	0.12			n.d			n.d.								
270	Armour plate, puddled iron (not slag-free), for the French frigate “La Gloire,” Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.14	n.d.	n.d.	0.03	0.06			n.d			n.d.								
271	Boiler plate, puddled iron (not slag-free), Russel’s Hall, Dudley, Worcestershire, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	0.19	0.14	n.d.	0.14	0.17			tr.			n.d.								99.36
272	Bar for rails, puddled iron (not slag-free), Dowlais Ironworks, Glamorgan, South Wales, Great Britain, 1860s (Buchwald, 2008: 509, Tab. 13.10)	n.d.	0.26	0.025	0.70	0.21			tr.			0.001								97.92

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
273	Langelinie Bridge, Copenhagen, Thomas process iron, Rothe Erde ironworks, Dortmund, Germany, 1892-1894 (Buchwald, 2008: 537, Tab. 14.10)	0.040	0.026	0.47	0.08	0.055	0.012		0.037			0.016							0.014	
274	Langelinie Bridge, Copenhagen, Thomas process iron, Rothe Erde ironworks, Dortmund, Germany. 1892-1894 (Buchwald, 2008: 537, Tab. 14.10)	0.049	0.024	0.55	0.13	0.070	0.021		0.037			0.015							0.014	
275	Langelinie Bridge, Copenhagen, Siemens-Martin iron, girder, Thyssen steelworks, Mühlheim a.d. Ruhr, Germany. Before 1895 (Buchwald, 2008: 537, Tab. 14.10)	0.032	0.025	0.36	0.021	0.068	0.001		0.026			0.136							0.007	
276	Langelinie Bridge, Copenhagen, Siemens-Martin iron, rivet, Thyssen steelworks, Mühlheim a.d. Ruhr, Germany. Before 1895 (Buchwald, 2008: 537, Tab. 14.10)	0.120	0.028	0.47	0.014	0.093	0.001		0.022			0.101							0.005	
277	Bessemer steel, Hofors, Sweden, about 1900. For axles and gun barrels (Buchwald, 2008: 524, Tab. 14.1)	0.30	0.018	0.22	0.026	<0.005														
278	Bessemer steel, Hofors, Sweden, about 1900. For saw blades and drills (Buchwald, 2008: 524, Tab. 14.1)	1.10	0.044	0.36	0.020	<0.005														
279	White pig iron for a Walloon forge in Uppland, Sweden. Dannemora ore. Before 1900 (Buchwald, 2008: 306, Tab. 9.2)	3.80-3.95	0.10-0.16	0.50-0.75	0.012-0.015	0.020-0.025														
280	Bessemer iron, Långshyttan, Klosters AB, Hedemora, Dalarna, Sweden, about 1900. Bar iron, bands, hoops, strips, wire rods (Buchwald, 2008: 528, Tab. 14.2)	0.05	0.01	0.06	<0.05															
281	Bessemer iron, Nykroppa, Filipstad, Värmland, Sweden, about 1900. Tubes and plates (Buchwald, 2008: 528, Tab. 14.2)	0.08	0.04	0.08	<0.05															
282	Bessemer iron, Bångbro, Kopparberg, Vestmanland, Sweden, about 1900. Tubes, plates and bar iron (Buchwald, 2008: 528, Tab. 14.2)	0.10	0.03	0.09	<0.05															
283	Bessemer iron, Västanfors, Fagersta, Vestmanland, Sweden, about 1900. Spring steel, tool steel (Buchwald, 2008: 528, Tab. 14.2)	0.55	0.07	0.43	<0.05															
284	Bessemer steel, Hofors, Sweden, about 1900. For rails, tyres and hammers (Buchwald, 2008: 524, Tab. 14.1)	0.50	0.024	0.26	0.025	<0.005														
285	Bessemer steel, Hofors, Sweden, about 1900. For files and springs (Buchwald, 2008: 524, Tab. 14.1)	0.90	0.036	0.32	0.021	<0.005														
286	White-mottled pig iron for a Lancashire forge. Mixed ores plus calcite flux. Before 1900 (Buchwald, 2008: 306, Tab. 9.2)	4.00-4.25	0.10-0.30	0.20-0.30	0.050-0.080	<0.010														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
287	Bar iron (pig iron refined with the “Walloon forge” method) produced from Dannemora ores in Uppland, Sweden. About 1900 (Buchwald, 2008: 385, Tab. 10.20)	0.09-1.33	0.05-0.08	0.14-0.15	0.009-0.013	0.007-0.009						0.010								
288	Bar iron (pig iron refined with the “Walloon forge” method) produced from Dannemora ores in Uppland, Sweden. About 1900 (Buchwald, 2008: 385, Tab. 10.20)	0.02-1.20	0.04-0.07	0.10-0.14	0.010-0.011	0.004-0.007						n.d.								
289	Bar iron (pig iron refined with the “Walloon forge” method) produced from Dannemora ores in Uppland, Sweden. About 1900 (Buchwald, 2008: 385, Tab. 10.20)	0.09-0.75	0.04	0.12-0.17	0.010-0.012	0.003-0.009						0.009								
290	Grey ferritic-pearlitic pig iron from brown hematite. Forest of Dean, Gloucestershire, England. Before 1900 (Buchwald, 2008: 306, Tab. 9.2)	3.26	2.34	0.23	0.14	0.04														
291	Bessemer steel, Hofors, Sweden, about 1900. For files, springs and chisels (Buchwald, 2008: 524, Tab. 14.1)	0.70	0.030	0.29	0.023	<0.005														
292	Grey pearlitic pig iron from decomposed spathic carbonate. Weardale, Durham, England. Before 1900 (Buchwald, 2008: 306, Tab. 9.2)	3.24	1.80	1.45	0.19	0.04														
293	Bessemer steel, Hofors, Sweden, about 1900. For plates and wires (Buchwald, 2008: 524, Tab. 14.1)	0.15	0.012	0.18	0.027	tr.														
294	Grey pearlitic pig iron from argillaceous ore. Black Bed Mine, Low Moor, Yorkshire, England. Before 1900 (Buchwald, 2008: 306, Tab. 9.2)	2.90	2.57	1.12	0.64	0.05														
295	White pig iron for conversion to malleable iron. Manganese- and sulphur-poor ores. Before 1900 (Buchwald, 2008: 306, Tab. 9.2).	3.80-4.10	0.10-0.30	0.10-0.15	0.028-0.080	0.005-0.010														
296	German bayonet Mk 98/05	0.436	0.743	1.1300	0.0587	0.0261	0.0176	0.0100	0.0376	.00100	0.0271	0.2000	0.0100	0.0131	.00100	0.0100	0.0477	.00472	0.1340	97.10
297	Crucible cast steel for Solingen sword blades, before 1924 (Zschokke, 1924: 656, Tab. A, No. 12)	0.499	0.518	0.413	0.045	0.038														
298	Pattern-welded Solingen steel, before 1924 (Zschokke, 1924: 656, Tab. A, No. 11)	0.606	0.059	0.069	0.024	0.007														
299	Bessemer iron, Germany, about 1935. For rails (Buchwald, 2008: 524, Tab. 14.1)	0.24-0.30	0.13-0.35	0.65-0.75	0.015-0.016	0.14-0.15														
300	Bessemer iron, Germany, about 1935. For plates and wire (Buchwald, 2008: 524, Tab. 14.1)	0.09-0.15	0.08-0.14	0.12-0.15	0.004-0.06	0.03-0.04														
301	Bessemer iron, Germany, about 1935. For gear-wheels (Buchwald, 2008: 524, Tab. 14.1)	0.50-0.60	0.33-0.38	0.80-0.90	<0.02	<0.02														

ID	Find	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Ti	V	Pb	Sn	As	Ca	N	Fe
302	Thomas process iron. Before 1944. Railroad rails (Buchwald, 2008: 531, Tab. 14.5)	0.45-0.55	0.10-0.30	0.55-0.90	0.04-0.08	0.04-0.07														
303	Thomas process iron. Before 1944. Wire (Buchwald, 2008: 531, Tab. 14.5)	0.05-0.08	tr.	0.20-0.40	0.04-0.08	0.04-0.07														
304	Thomas process iron. Before 1944. Plate and sheet, hard variety (Buchwald, 2008: 531, Tab. 14.5)	0.15-0.25	tr.	0.40-0.60	0.05-0.08	0.04-0.07														
305	Thomas process iron. Before 1944. Bar iron, constructional steel (Buchwald, 2008: 531, Tab. 14.5)	0.05-0.10	tr.	0.30-0.50	0.05-0.08	0.04-0.07														
306	Thomas process iron. Before 1944. Plate and sheet, soft variety (Buchwald, 2008: 531, Tab. 14.5)	0.05-0.09	tr.	0.20-0.40	0.04-0.08	0.04-0.07														
307	White-mottled pig iron, a "waisted dwarf blast furnace," ironsand ore, China, the Great Leap Forward Period, 1958 (Buchwald, 2008: 315, Tab. 9.4, No. 1)	4.2	0.20	0.26	0.35	0.027														
308	Siemens-Martin steel, DIN 17140, Class 3, D8-2, early 1980s (Buchwald, 2005: 298)	0.05	0	0.35	0.02	0.02													0.005	
309	Grey pearlitic pig iron, anvil, recommended composition. Sweden. Modern (Buchwald, 2008: 306, Tab. 9.2)	3.4-3.6	1.2-1.5	0.7-1.0	0.3-0.5	max 0.10														
310	White cast pig iron for conversion to white heart malleable iron. European practice. Modern (Buchwald, 2008: 306, Tab. 9.2).	2.8-3.5	0.4-0.9	0.2-0.4	0.08-0.15	max 0.4														
311	Rail, steel, basic open hearth process, Great Britain, modern (Buchwald, 2008: 509, Tab. 13.10)	0.70	0.17	0.70	<0.04	<0.04			n.d			n.d.								