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LATE MEDIEVAL WROUGHT IRON FIREARMS FROM THE MUSEUM IN BIECZKA

From the very beginning of existence of firearms, there were two competitive manufacturing techniques – casting and forging. These resulted from the use of two raw materials – copper and its alloys as well as iron. A good example of co-occurrence of weapons manufactured from these two raw materials are the earliest mentions of the use of firearms in the territory of Poland. The first record comes from the Chronicle of Janko of Czarnków and concerns the siege of Puzdry in 1383. While describing this siege, there is a mention of a stone projectile fired from a red brass gun (*lapidem aero de pixide*)². Some years thereafter, in 1391 it was recorded in municipal accounts of Kraków that the town bought 6 cannons upon the request of King Władysław Jagiełło. Among these cannons there were 3 iron (*pixides ferreas*) and 2 copper ones (*pixides cupreas*). At that time 5 iron guns were kept altogether in the municipal armoury³.

Many works have already been written on casting of firearms. These works discussed technical aspects of this issue, as well as technological details, based on metallographic analyses⁴. In this place it must be said that the process of casting of a cannon barrel, with special reference to those of large calibre, was quite complicated and not always successful. An excellent example is offered by a description of such works which were carried out at the foundry in Bratislava in 1440. Manufacturing works of a large cannon started on 8 April with securing clay for preparing the

mould and with processing this clay. This stage lasted until 11 May but already during the casting the mould broke and the metal spilt into the ground. On the next day (12 May), the works were resumed and the process was completed within a month. On 9 June the cannon was ready and it underwent finishing works. Unfortunately, the barrel burst in the course of firing tests on 7 July. Master gunners were not discouraged with this failure and they commenced their works again in Autumn, on 12 September. On 1 October a new mould was filled with alloy. Some complications occurred again, but those were less significant than previously. In all probability, the mould suffered no major damage, as after some days (on 6 October), the process was successfully repeated. There were no obstacles in the further course of works and on 12 October the cannon was ready. On 9 December it successfully underwent firing tests. Obviously, this case is rather extreme, as the same master gunners needed only a month (from 17 October to 24 November) to cast two smaller stone projectile cannons⁵. A similar case occurred in the process of casting of the Teutonic *Grose Bochse* in 1408, when the gunpowder chamber had to be cast again⁶.

Another way was to manufacture barrels in a less complicated but equally labour-consuming process of iron processing using smithing methods. Already in the late Middle Ages, perhaps as early as the late 14th c., first attempts at casting iron guns were undertaken in Western Europe. These, however, were rather isolated cases. The main advantage of cast iron guns was no question their price (one-sixth of the price of a bronze gun). On the other hand, such cannons could be very brittle and thus extremely dangerous for their users⁷. In the case of the heaviest cannons,

¹ This work has been financially supported by the Polish Ministry of Science and Higher Education, project No. NN 109260239, project manager P. Strzyż.

² *Joannis de Czarnkow Chronicon Polonorum*, ed. J. Szlachetkowski, Monumenta Poloniae Historica, Vol. 2, Lwów 1872, p. 751.

³ *Najstarsze księgi i rachunki miasta Krakowa od r. 1300 do 1400*, eds. F. Piekosiński, J. Szujski, Kraków 1878, Part 2, p. 96: „Lubardus recognovit, quod domini consules apud eum quinque ferreas pixides desposuerunt”; J. Szymczak, *Początki broni palnej w Polsce (1383-1533)*, Łódź 2004, p. 80.

⁴ E.g., J. Piaskowski, *Technologia odlewania luf armatnich w XVI-XVIII wieku*, „Przegląd Odlewnictwa”, Vol. 32, 1982, pp. 32-36; Z. Nemcová, *Počiatky puškárskeho remesla v Bratislave*, „Vojenská história”, fasc. 2, 1998, p. 88; J. Szymczak, *Początki...*, pp. 88-91; M. Dąbrowska, *Proces odlewania dział w leżni malborskiej w XV wieku*, „Archaeologia Historica Polona”, Vol. 18, 2009, pp. 21-45.

⁵ J. Durdík, *Pracovní postupy v bratislavské puškarske huti v 1. polovinie 15. století*, „Historie a Vojenství”, 1957, fasc. 3, p. 305.

⁶ G. Żabiński, *The Grose Bochse – A Teutonic Supergun from 1408*, „Fasciculi Archaeologiae Historicae”, Vol. 25, 2012, p. 32.

⁷ O. Johannsen, *Die Anwendung des Gusseisens im Geschützwesen des Mittelalters und der Renaissance*, „Zeitschrift für Historische Waffen- und Kostümkunde” (henceforth as: ZfHWK), Vol. 8, fasc. 1-2, 1918/1920, pp. 12-14, figs. 7-9; this issue has recently been discussed by A. R. Williams, *The Sword and*

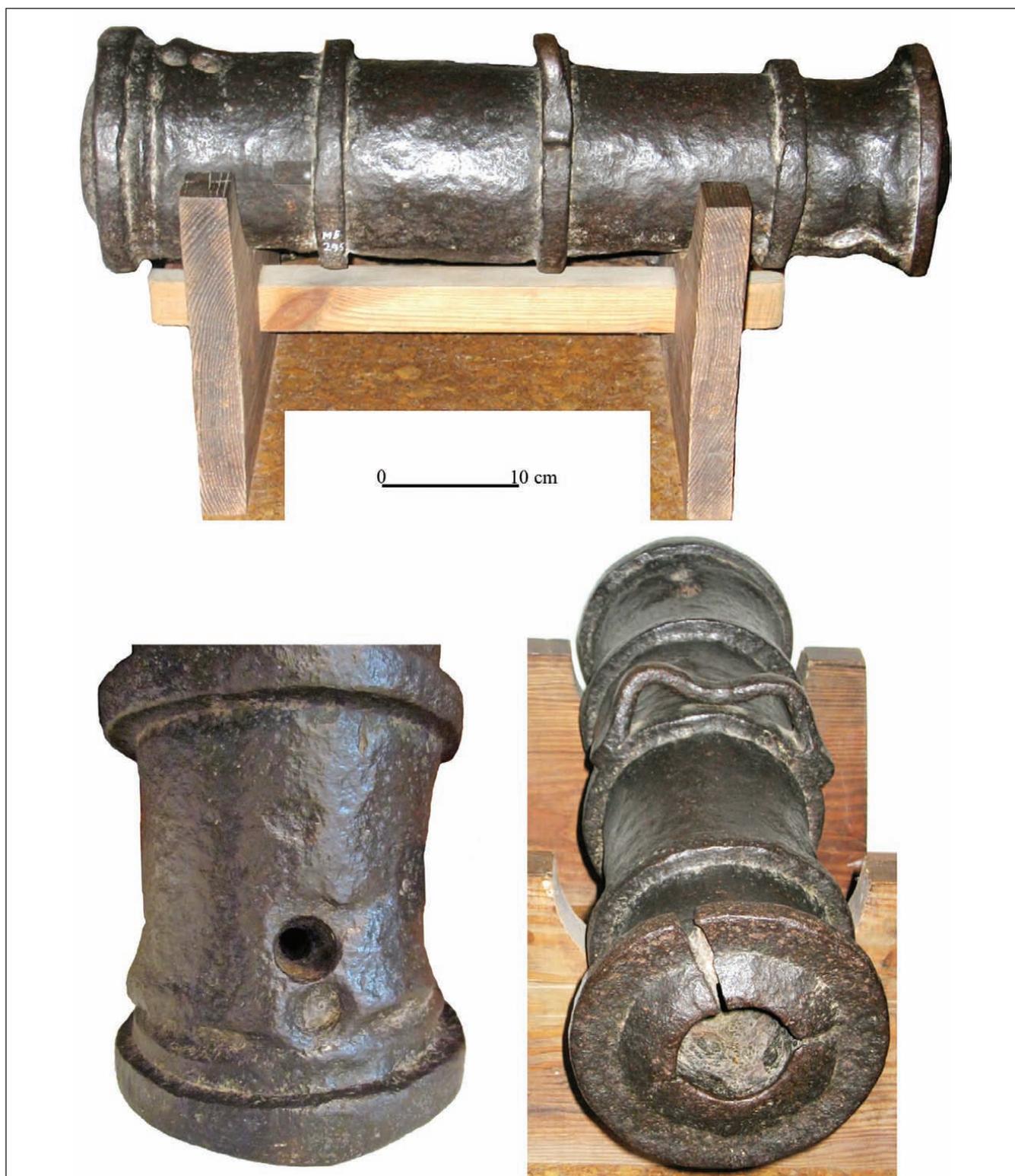


Fig. 1. Veuglaire, Regional Museum in Biecz (inv. No. 295), by P. Strzyż.

their barrels were assembled from bars and rims. There are numerous examples of such cannons in European collections, including guns of considerable weight and size. One of the most significant and the largest items is *Dulle*

Griet from Gent, with the total length of 5.025 m, the muzzle diameter of 64 cm and the weight of as much as 16.4 t.⁸ Not much smaller are other bombards: *Mons Meg* from the

the Crucible. A History of the Metallurgy of European Swords up to the 16th Century, Leiden-Boston 2012, pp. 192-195.

⁸ R. D. Smith, R. R. Brown, *Mons Meg and her sisters*, London 1989, pp. 23, 25, figs. 16, 17, 19, 24; R. D. Smith, K. De Vries, *The Artillery of the Dukes of Burgundy 1363-1477*, Suffolk 2005, pp. 266-267, cat. No. 3.

Castle of Edinburgh in Scotland⁹, from Basel, Boxted, Paris and Berlin, two so-called Michelettes from Mont St. Michel and *Faule Magd* from Dresden¹⁰. The barrels of these cannons consisted of numerous long and narrow bars, placed concentrically along the line of the barrel. For instance, in the case of *Dulle Griet* there were 32 bars 55 mm wide and 30 mm thick, as well as 41 reinforcing rings. The cannon from Basel, being smaller than *Dulle Griet*, was made of 20 bars which were 50 mm wide and 20 mm thick¹¹, and the barrel of *Faule Magd* is composed of 20 iron bars which are 3.5 cm thick and 3-8 cm wide. The entire construction was reinforced with 46 transverse rings¹². Due to the use of such technique of manufacture, the cross-section of the barrel was often not perfectly circular, but had a shape of a polygon with some dozen short sides.

Concerning territories which are closer to Poland, one can mention two bombards from the Museum of Military History in Budapest. The first one, which used to be kept at the Savaria Museum in Szombathely, consists of a narrow gunpowder chamber and a barrel. The chamber is forged as a single part, while the barrel is made of 11 bars, joined at their circumference with 8 iron bands of different width. The interior of the barrel is strongly corroded. However, one can see a thick (3-4 mm) sheet of metal, which was intended to provide the barrel with a more circular cross-section and thus to smoothen any unevenness which originated in the course of assembling of longitudinal bars. At the touch point of both parts of the bombard the bars converge in an oblique manner, and the joint is reinforced with an additional thick ring. The cannon is dated to the late 14th c. A similar construction can be seen in the case of the other cannon. It consists of a gunpowder chamber, forged as a homogeneous part, and a chase part. The chase is made of

numerous bars, over which 10 transverse rings are drawn. This cannon can be dated to the 15th c.¹³

While assembling the barrel from numerous parts, it was possible to either use a higher number of narrow bars with rectangular cross-sections, or to apply a lower number of bars. In the second case, their cross-sections had to be formed into an arched shape. When the barrel or chamber was formed in such a manner, reinforcing rings of different width and external diameter were drawn over it. A gunpowder chamber could be made in a similar way. However, in this case the reinforcing rings had to be much thicker, due to a much higher pressure to which this part of the gun was exposed¹⁴. In the case of guns with smaller calibres, gunpowder chambers could be constructed as homogeneous elements, as with the afore-mentioned Hungarian bombards.

Concerning lighter artillery, such as *houfnice* field cannons, terrace-guns or *veuglaires*, such a complex technique was not necessary and the barrel could be forged from one or a few pieces of iron. In Central European museum collections there are not many original examples of small calibre cannon barrels which are forged from iron. We know only one specimen of a medieval *houfnice* field cannon¹⁵, while there are as many as fourteen terrace-guns¹⁶ and a few *veuglaire* chambers¹⁷.

For this reason, two specimens from the Regional Museum in Biecz deserve special attention. The first one (inv. No. 295, Fig. 1: 1-3) is an iron tube of cylindrical

¹³ J. Kalmár, *Régi magyar fegyverek*, Budapest 1971, p. 158, Figs. 44, 45.

¹⁴ R. D. Smith, *The technology of wrought-iron artillery*, „Royal Armouries Yearbook”, Vol. 5, 2000, pp. 68-72, fig. 1-8.

¹⁵ Z. Drobná, J. Durdík, *Jan Žižka z Trocnova demokratické a bojové tradice našeho lidu. Výstava k 550. výročí smrti Jana Žižky z Trocnova*, Praha 1975, pp. 37, 54, cat. No. 281; J. Prokop, *Klenoty našeho muzea, IV část – husitská houfnice*, „Novobýdžovský zpravodaj”, Vol. 13, fasc. 2, 1986, pp. 11-12; idem, *Nový Bydžov v proměnách století*, Nový Bydžov 2005, p. 35.

¹⁶ J. Durdík, *Husitské vojenství*, Praha 1954, p. 77; idem, *Znojenské puškařství v první třetini 15. století*, „Historie a Vojenství”, fasc. 1, 1955, pp. 85-87, figs. 14, 15; E. Wagner, Z. Drobná, J. Durdík, *Kroje, zbroj a zbraně doby předhusitské a husitské (1350-1450)*, Praha 1956, p. 87; Z. Drobná, J. Durdík, *Jan Žižka z Trocnova...*, pp. 46, 56, cat. Nos. 113, 145; M. Pertl, *Delostřelecké hlavně z počátku 15. století z hradu Český Šternberk*, „Archeologické rozhledy”, Vol. 24, fasc. 3, pp. 312, 313, figs. I: 1-3, II: 1-2; idem, *Nejstarší palné zbrane ze sbírek hradu Českého Šternberka*, „Sborník vlastivědných prací z Podblanicka”, Vol. 25, 1985, p. 130, figs. 1-2; J. Durdík, V. Dolínek, M. Šáda, *Vzácné zbraně a zbroj ze sbírek Vojenského Muzea v Praze*, Praha 1986, p. 205, cat. No. 278; E. Šnajdrová, *Palné zbraně ze sbírky Národního muzea*, Praha 1998, p. 5, 6, cat. Nos. 2-4; T. Durdík, M. Pertl, *Tarasnice z hradu Křivoklátu*, [in:] *Urbes Medii Aevi*, ed. M. Richter, Praha 1984, p. 149, 152, figs. 1-6; K. Malečková, *Palné zbrane. Zbičkové fondy Slovenského národního múzea – Muzea Bojnice*, Bojnice 2005, pp. 8-9.

¹⁷ J. Durdík, *Znojenské puškařství...*, pp. 88-91, fig. 19; J. Kalmár, *op. cit.*, p. 160, fig. 50: a-b.

⁹ R. D. Smith, R. R. Brown, *Mons Meg...*, pp. 1-3, 11, 13, Figs. 3, 5-14; R. D. Smith, K. De Vries, *The Artillery...*, pp. 262-263, cat. No. 1; D. Goetz, *Die Anfänge der Artillerie*, Berlin 1985, p. 48.

¹⁰ R. D. Smith, R. R. Brown, *Mons Meg...*, pp. 46-50, 52-78, figs. 25-60; R. D. Smith, K. De Vries, *The Artillery...*, pp. 264-265, cat. No. 2; D. Goetz, *Die Anfänge...*, p. 26; J. Streubel, *Die Konservierung der „Faulen Magd”. Ein Beispiel für die Pflege nationalen Kulturgutes in der Deutschen Demokratischen Republik*, ZfHWK, 1983, fasc. 1, pp. 54-55, fig. 1; H. Müller, *Alte Geschütze. Kostbare Stücke aus der Sammlung des Museums*, Berlin 1968, pp. 14-15.

¹¹ R. D. Smith, R. R. Brown, *Mons Meg...*, pp. 25, 28, 42-43; R. D. Smith, K. De Vries, *The Artillery...*, pp. 264, 266; M. Beyaert, *Quelques problèmes de développement des armes à feu non portative au moyen âge*, [in:] *Military Studies in Medieval Europe. Papers of the „Medieval Europe Brugge 1997” Conference*, vol. 11, eds. G. de Boe, F. Verharghe, Zellik 1997, pp. 72-73, fig. 2. For the sake of comparison, the barrel of a bombard from Reims from the mid-15th c. was made of 38 iron bars and was reinforced with 33 rings, see P. Contamine, *Wojna w średniowieczu*, Warszawa 1999, p. 154, footnote 82; J. Szymczak, *Początki...*, p. 80.

¹² D. Baarmann, *Die „Faulen Magd”...*, pp. 229-231, figs. 1-2; J. Streubel, *Die Konservierung der „Faulen Magd”...*, p. 54.



Fig. 2. Veuglaire, Regional Museum in Biecz (inv. No. 296), by P. Strzyż.

shape, with the calibre of 6.4 cm and the external diameter at the muzzle of 18.6 cm. Along its entire length (63.2 cm) it is reinforced with five ambient rings. On the top of the central ring there is a holder in the shape of a flattened M. It was originally used for lifting the specimen with ropes. The touch hole is located vertically. Its top diameter is 2.4 cm, while its bottom diameter is 1.4 cm. The specimen now rests in a present-day reconstructed wooden stand.

Of particular interest are hemispherical bulges, which can be seen both in the bottom and the muzzle parts. Another peculiarity is a considerable thickness of the walls, which is nearly 6 cm in the discussed case.

The other specimen is also made of iron (inv. No. 296, Fig 2: 1-4). It has been forged into a cylindrical shape and its calibre is 5.5 cm. Along its entire length (65.7 cm) it is reinforced with six rings. On the third and the fifth ring

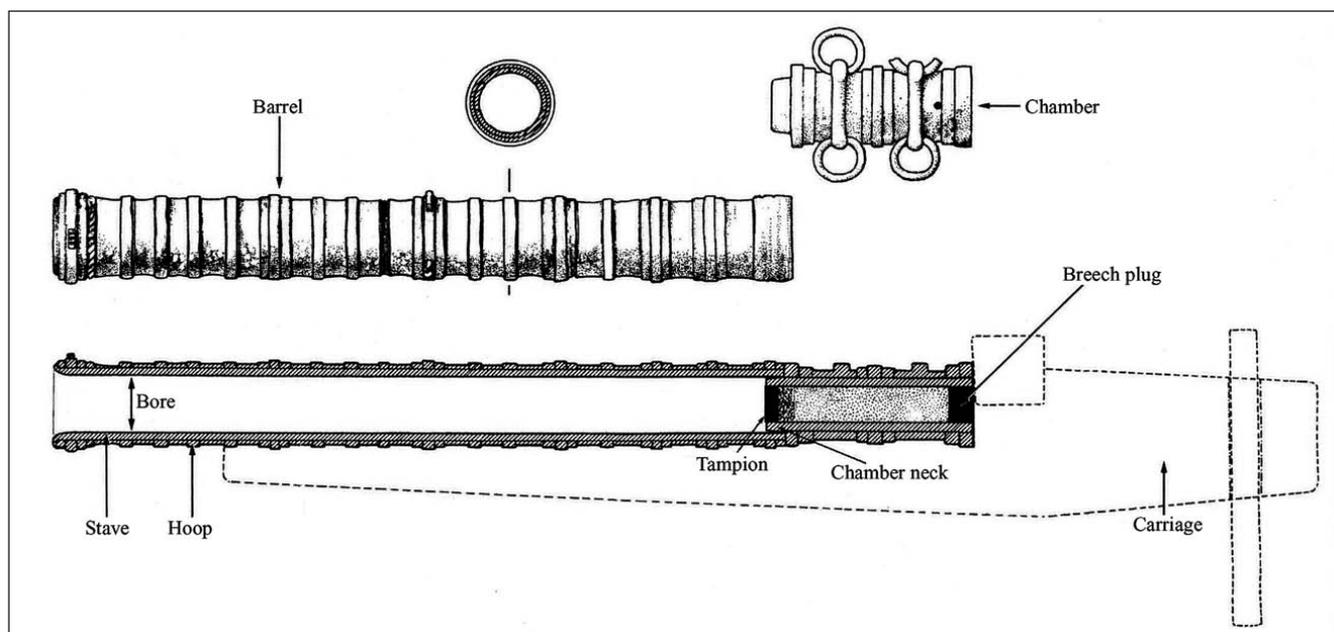


Fig. 3. Construction of a veuglaire, by P. Strzyż.

there are remains of holders. The touch hole is situated vertically and its diameter is 1.5 cm. The specimen rests in a present-day wooden stand, to which it is attached with a broad iron band with three rivets. The construction of the muzzle part is of special interest. It was made as a separate element, with the total length of almost 10 cm. It is attached (with a thread?) to the main part of the barrel. This element is ornamented with an engraved herringbone pattern, enclosed between two ambient lines (Fig. 2: 3). The external muzzle diameter is 19.5 cm, while the muzzle bore diameter is 15.1 cm. Its depth is 5.6 cm. The use of this additional screwed element secured a reasonably tight connection with the barrel. Also in this case a considerable thickness of the walls is significant. It is as much as 7 cm.

It is somehow difficult to propose the chronology and the function of these relics. In museum catalogue cards they are generally dated to the 15th and the 16th c. respectively. As nothing is known on their find places and circumstances of acquisition by the museum, the proposed chronology must be treated with care. Bearing in mind the considerable thickness of the walls of both items and their cylindrical shapes with rings, the lower chronological border may be estimated at c. 1450. This can be supported with examples of similar veuglaire chambers from the Swiss museum in Murten. Their calibres are 14.2 and 7.5 cm and their lengths are 66 and 83.7 cm respectively. They are remarkable for their straight cylindrical shapes, a number of rings, as well as a considerable thickness of their walls. They are dated to about 1450¹⁸.

These analogies from Murten and a careful examination of both discussed items also suggest a possible way of

interpretation of their function. In both cases, especially in the second one, a particular shape of the muzzle implies that these items were supposed to cooperate with other devices. Therefore, it seems that the only possible interpretation is to consider both items as veuglaire chambers. This is additionally supported by their small calibres and the thickness of their walls.

Veuglaire (Fig. 3) were breech-loading artillery. As opposed to other kinds of cannons, they were loaded in their breech parts with a special chamber, which was additionally pressed to the barrel with a metal or wooden wedge¹⁹.

If we interpret the items in question as veuglaire chambers, it is possible to point to a good analogy, offered by the chamber from the Museum in Znojmo (inv. No. 515). It is forged from iron, circular in cross-section and its bore slightly broadens towards the muzzle in a conical manner. The total length of this item is 48.4 cm, while the gunpowder canal is 42.0 cm long. The muzzle calibre is 6.5 cm. There is a ring which connected the chamber with the barrel. Its external diameter is 12.5 cm and its walls are 4.8 cm thick. Based on this information and on a general scheme of construction of a veuglaire (Fig. 3), we can say that the external diameter of the tightening ring roughly corresponds to the barrel calibre. In this case, it would be about 13 cm. The touch hole is on the top. Its diameter is 1.2 cm and it is provided with a priming pan. In the upper

¹⁸ R. D. Smith, K. De Vries, *The Artillery...*, pp. 312-315, cat. Nos. 26, 27.

¹⁹ L. Křížek, Z. J. K. Čech, *Encyklopedie zbraní a zbroje*, Praha 1997, p. 219; M. Gradowski, Z. Żygulski jun., *Słownik uzbrojenia historycznego*, Warszawa 1998, p. 109, fig. 148; J. Szymczak, *Początki...*, pp. 55-56; P. Klučina, *Zbroj a zbraně. Evropa 6.-17. století*, Praha – Litomyšl 2004, p. 458; P. Strzyż, *Średniowieczna broń palna w Polsce. Studium archeologiczne*, Łódź 2011, p. 30.

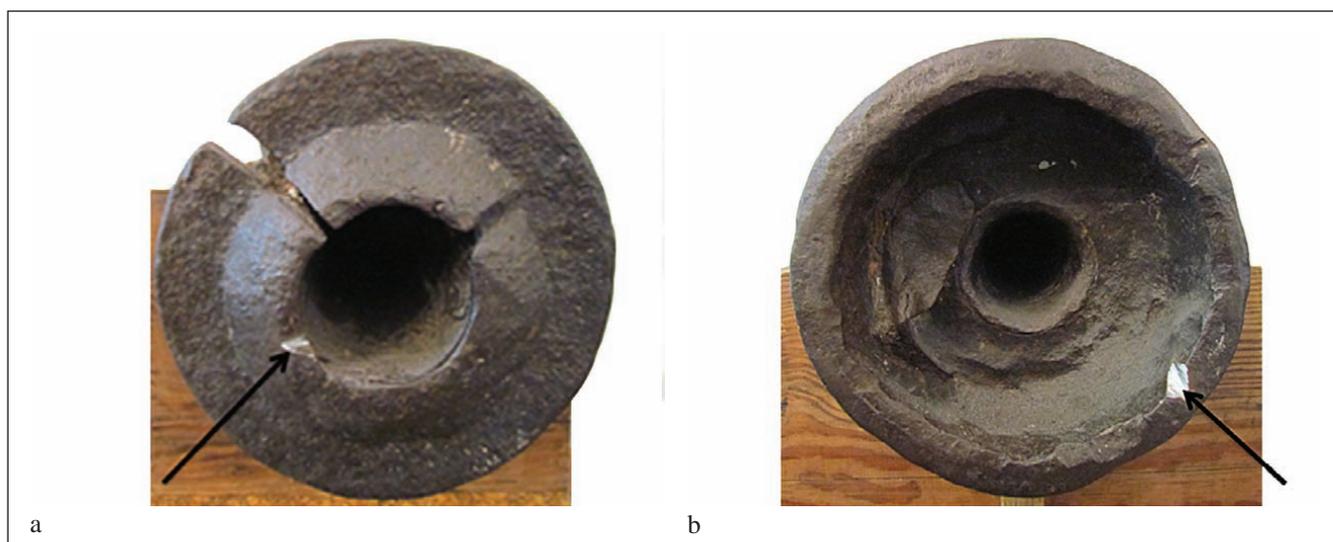


Fig. 4. View of the examined items, sampling spots are marked: a – Sample 1 (inv. No. 295); b- Sample 2 (inv. No. 296), by L. Klimek, P. Strzyż.

part, near the muzzle, there is a holder with a ring, which was used to lift the chamber. There are remains of another holder in the bottom part. In a later period (probably as early as the 16th c.), the chamber was mounted on a wooden stock with the use of three iron bands. Traces of white and blue painted strips can be still seen on it. This item was dated to the first quarter of the 15th c.²⁰ However, it seems that the relic is rather to be broadly dated to the first half of the 15th c. An interesting feature of this item is that in the later period it was mounted on a wooden stock in order to be used as a cannon. Theoretically, it could be said that such a provisory solution could be quite functional. The length of the bore is about 42 cm, which is similar to 15th c. *houfnice* field cannons. On the other hand, the conical shape of the bore negatively influenced the range and accuracy of fire. Concerning the metrical data of the veuglaire from Znojmo, it must have certainly been a cannon of considerable size, as its original calibre may have been 13 cm. It is therefore not excluded that the items from Biecz could also be successfully used as cannons, due to their considerable length and appropriate calibres.

Technological Analyses

In order to clarify the afore-mentioned doubts concerning the function, provenance and chronology of the items in question, it was decided to carry out metallographic examinations. Apart from identifying the structure of the material, it was also intended to determine whether these relics are originals or poorly made later copies²¹. In both cases samples were taken from the muzzle parts (Fig. 4).

²⁰ J. Durdík, *Znojenské puškařství...*, p. 88-91; K. Chamoniola ed., *Od Gotiky k Renesanci. Výtvarná kultura Moravy a Slezska 1400-1550*, Brno 1999, p. 579, cat. No. 301.

²¹ These doubts were still present when these items were published for the first time. This was due to the fact that no

Both samples were placed in special mounts and then sunk in Plyfast resin made by Struers, in order to make later observations in a scanning microscope possible. Then, the samples were ground with sandpapers (gradations from 180 to 1500 grits) and polished with diamond pastes (ending with 1 μm gradation). The polished samples were etched with 4% nital, in order to reveal their microstructures. Microstructure observations were carried out with a Nikon A100 light microscope. Carbon content was assessed approximately, based on microscopic observations. For the purpose of quality analysis of slag inclusions a Hitachi S-3000N scanning microscope with an EDS X-ray microanalyser was used. Hardness tests were done with the Vickers method with a 1N (100G) load, using a Clemex hardness tester. Obtained results are depicted in Figs. 4-16, Tables 1 and 2 and are discussed in the further part of this paper.

Sample 1

Hardness tests

The average hardness of metal in Sample 1 was 141 HV01.

In the entire examined cross-section of Sample 1 one can see fine-grained ferritic-pearlitic microstructure and the size of ferrite grains is between 20 and 50 μm . The presence of a small amount of pearlite in the microstructure (Figs. 5b and 6b) points to a small carbon content in the sample. Based on the area occupied by pearlite, the carbon content in Sample 1 can be estimated at 0.1-0.2% C, which corresponds to soft steel.

There are local concentrations of slag inclusions in the surface of Sample 1 (Fig. 7a, b). The analysis of their

circumstances of their acquisition were known. It was therefore decided to tentatively classify them to a separate group of finds of uncertain chronology, see P. Strzyż, *Średniowieczna...*, pp. 45-47, 126-127, cat. Nos. 4A, 5A, Plates XV, XVI.

Sample 1

Results of metallographic examinations

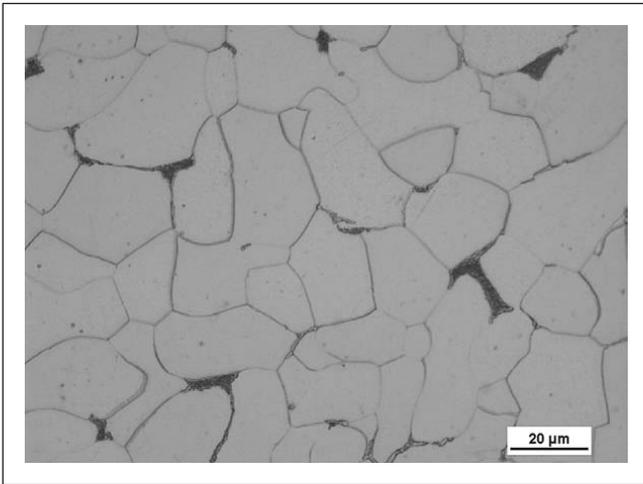


Fig. 5. Sample 1, microstructure images examined by optical microscopy: ferritic-pearlitic microstructure (bright matrix – ferrite; dark constituent at grain boundaries – pearlite), by L. Klimek.

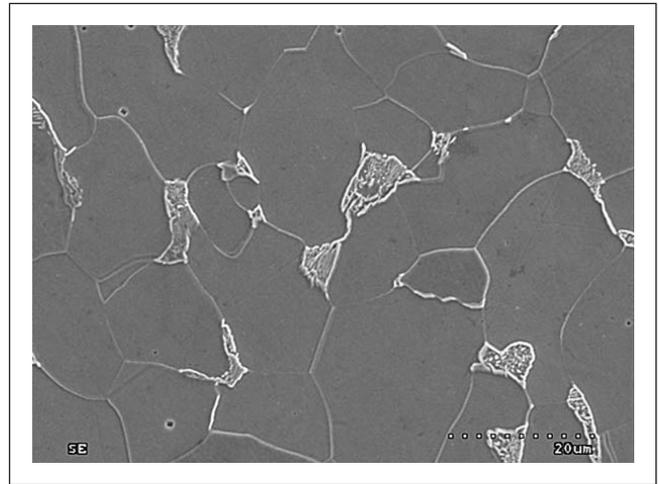


Fig. 6. Sample 1, scanning electron microscope (SEM) micrograph: ferritic-pearlitic microstructure (bright matrix – ferrite; dark constituent at grain boundaries – pearlite), by L. Klimek.

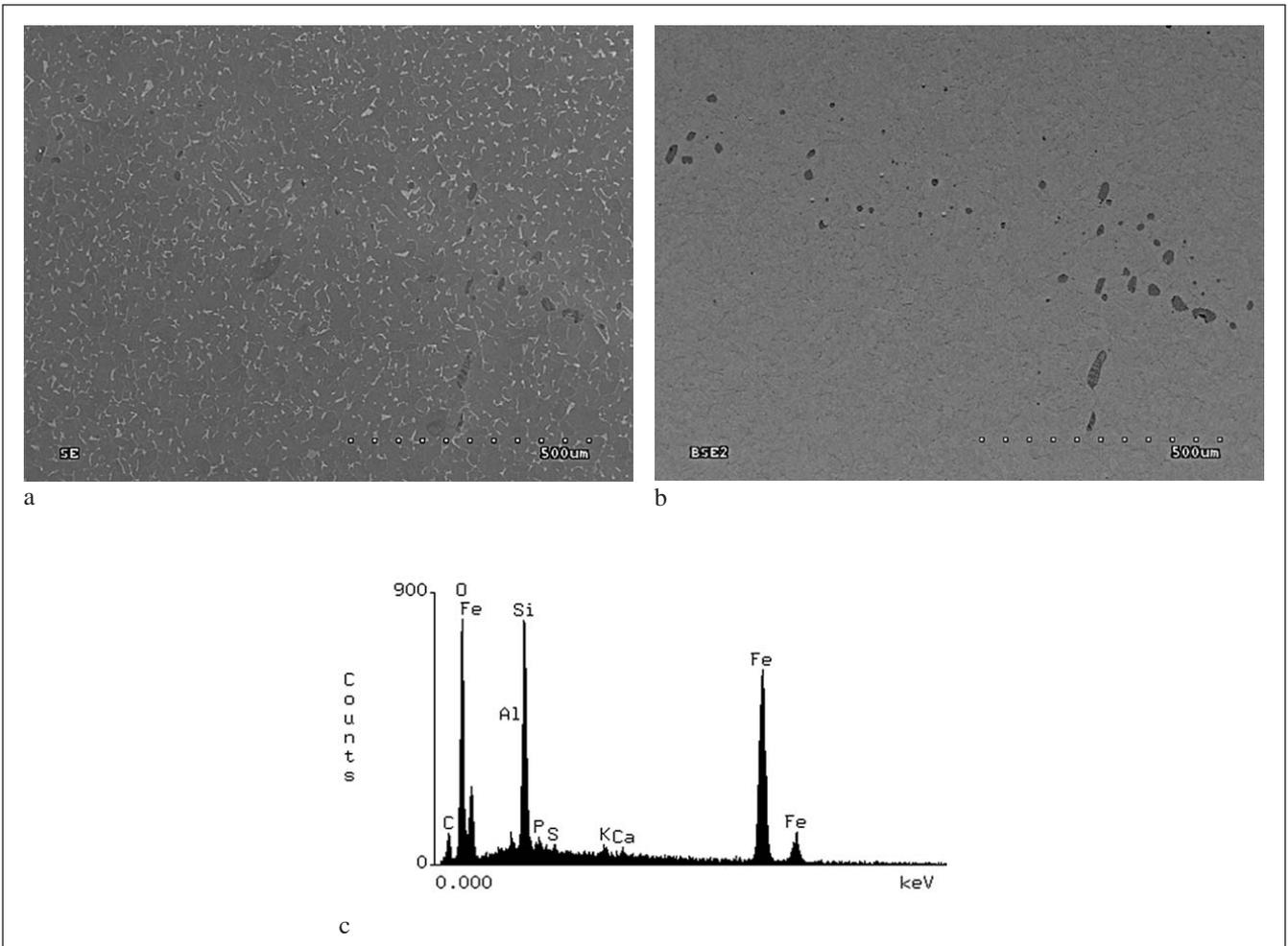


Fig. 7. Sample 1. Analysed concentration of slag inclusions SEM/EDS: a – image of slag inclusions in secondary electrons; b – image of slag inclusions in backscattered electrons (material contrast); c – EDS spectrum from the analysed slag inclusions in Fig. 4b; peaks from O, Si, Fe, Al, P, K, Ca and S can be seen, by L. Klimek.

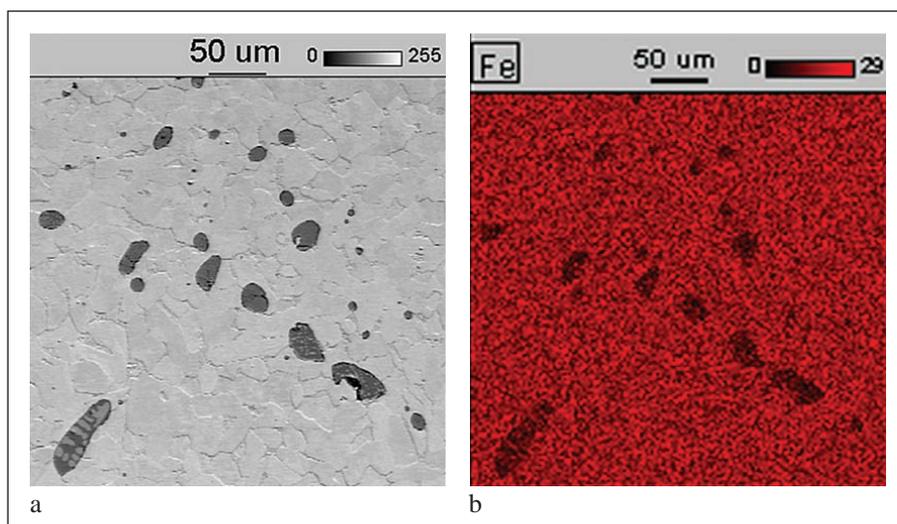


Fig. 8. Surface distribution of elements (X-ray maps) in the analysed concentration of slag inclusions in Sample 1 from Fig. 7b: a – morphology of slag inclusions in the concentration; b – X-ray map of Fe, by L. Klimek.

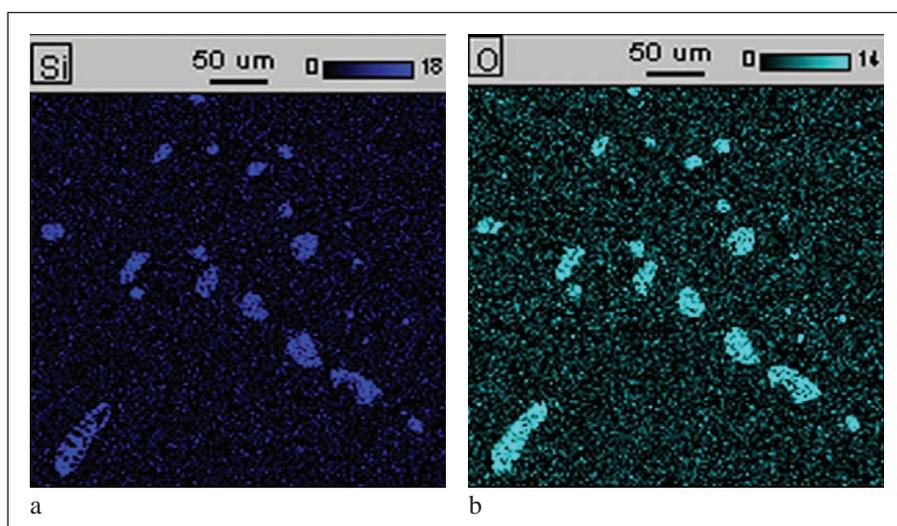


Fig. 9. Surface distribution of elements in the analysed concentration of slag inclusions in Sample 1 from Fig. 8b: a – X-ray map of Si; b – X-ray map of O, by L. Klimek.

chemical composition with the EDS method revealed the presence of the following elements: O, Si, Fe, Al, P, K, Ca and traces of S (Fig. 7c). Maps of surface distribution of the elements in the analysed area of concentration (Fig. 8a) prove that the main components in these slag inclusions are Si, Fe and O (Figs. 8 and 9). These are therefore fayalite type impurities ($2\text{FeO}\cdot\text{SiO}_2$) and their presence is related to production of iron in a smelting furnace.

Based on the metallographic examinations it can be said that Item 1 was made from soft bloomery steel with increased phosphorus content, which is also suggested by hardness tests (141 HV01). Furthermore, the microstructure of the sample and the morphology of slag inclusions suggest that Item 1 was made by means of forging.

Sample 2

Hardness tests

The average hardness of metal in Sample 2 was 172 HV01.

In the entire cross-section of Sample 2 there is ferritic microstructure (Fig. 10) with a small amount of tertiary cementite, distributed at the boundaries of ferrite grains

(Fig. 10: a, b). In some ferrite grains one can see deformation twins (Figs. 10: b), which demonstrate increased phosphorus content in the metal of Item 2. The size of ferrite grains is significantly larger than in Sample 1 and it can be estimated at between some dozen and about 100 μm . Slag inclusions in Sample 2 (Fig. 10: a) also form local concentrations (Fig. 11: a). Maps of surface distribution of elements in the analysed concentration of slag inclusions in Fig. 12 demonstrated the presence of such elements as O, Fe, Mg, Si, Al, Mn, Ca and K (Figs. 13, 14, 15 and 16). The presence of these elements in slag is related both to the kind of ore and to the production of iron in a smelting furnace. The analysed elements are not distributed evenly in the examined slag inclusions, which additionally points to their multiphase structure.

Based on the metallographic examinations it can be said that Item 2 was made from bloomery iron with increased phosphorus content, and locally carburised up to the content of about 0.022% C. The hardness of ferrite (158-181 HV01) and the local presence of deformation twins testify to the presence of phosphorus in the metal. Based on the microstructure of the barrel and the morphology and

Sample 2

Results of metallographic examinations

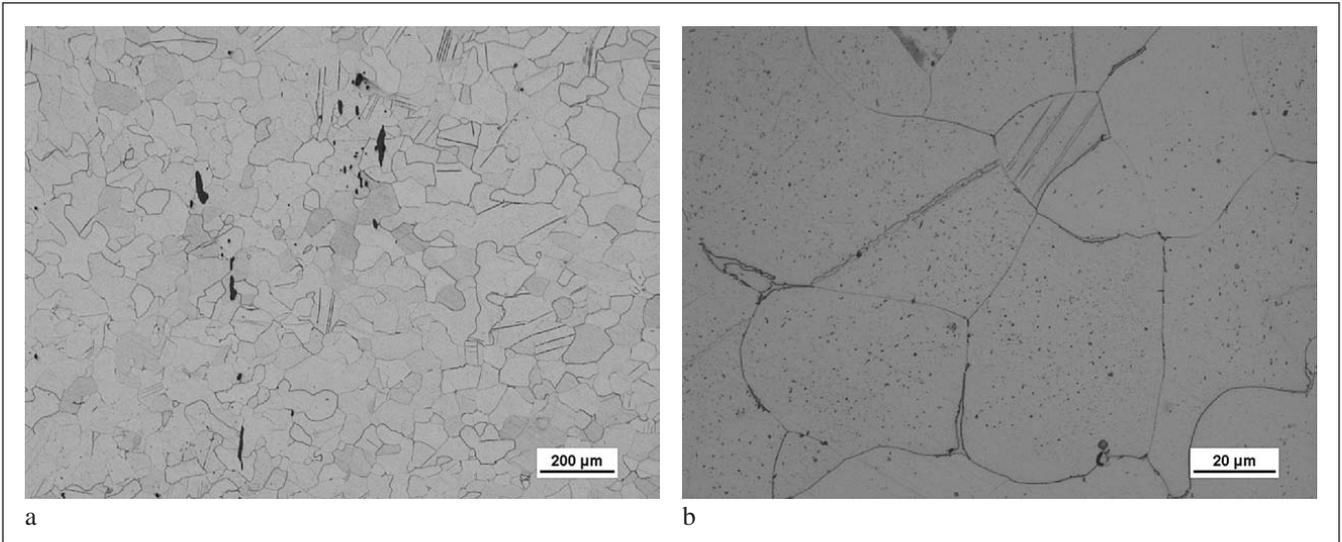


Fig. 10. Sample 2, microstructure images examined by optical microscopy: a – ferritic microstructure (bright) with sparse separations of tertiary cementite in grain boundaries, and elongated slag inclusions (dark); b – ferrite with some tertiary cementite precipitated at the grain boundaries and deformation twins (so-called Neumann bands), by L. Klimek.

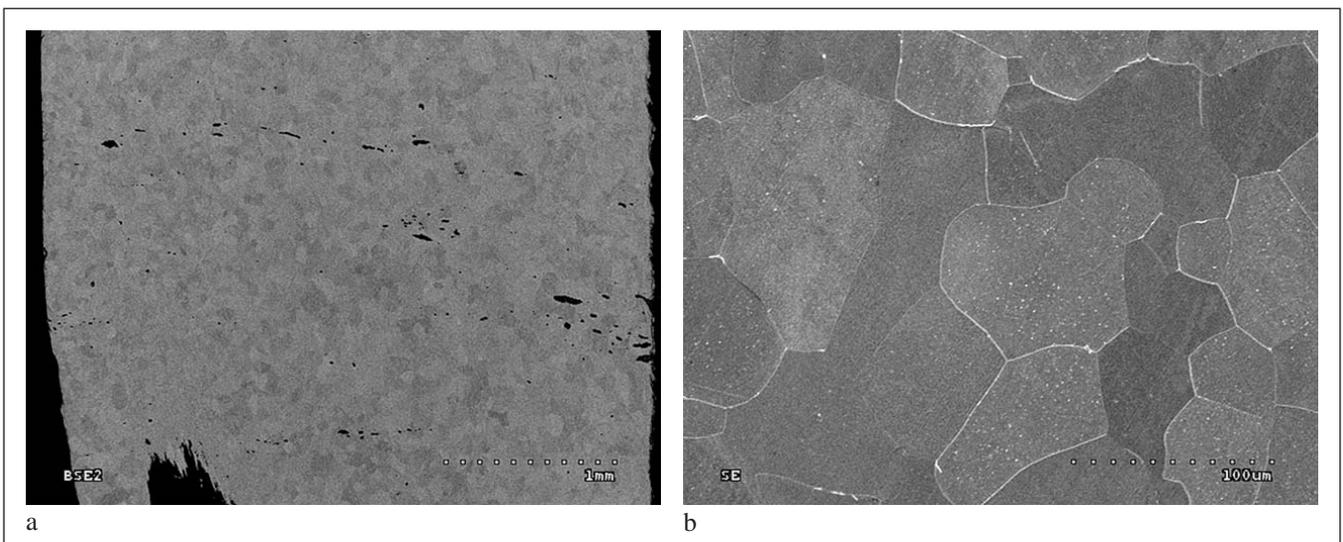


Fig. 11. Sample 2, scanning electron microscope (SEM) micrographs magnifications: a – ferritic microstructure and concentrations of slag inclusions; b – polygonal grains of ferrite, by L. Klimek.

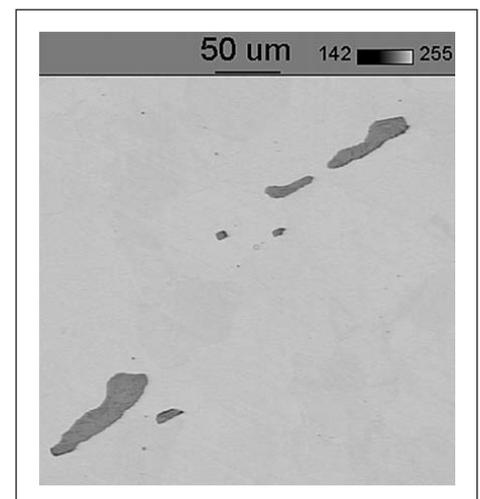


Fig. 12. Morphology of the analysed slag inclusions in Sample 2, by L. Klimek.

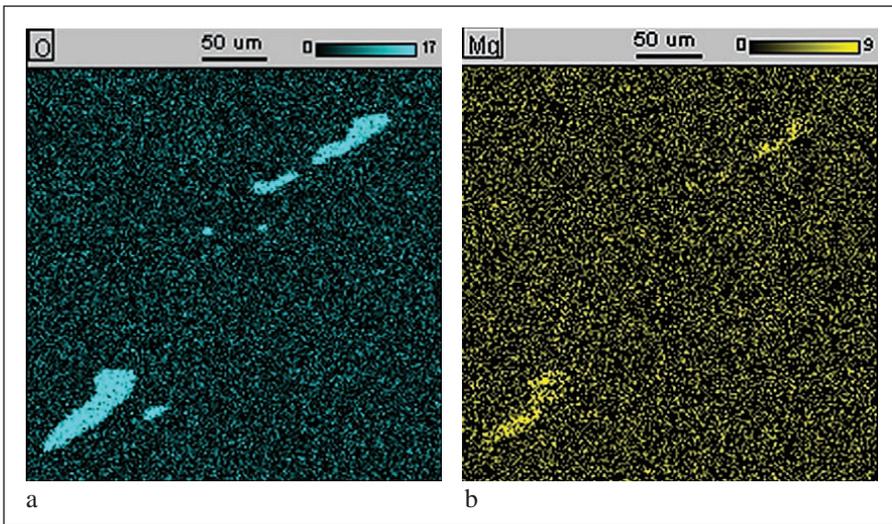


Fig. 13. Surface distributions of elements (X-ray maps) in Sample 2 in the area depicted in Fig. 12, a – X-ray map of O; b – X-ray map of Mg, by L. Klimek.

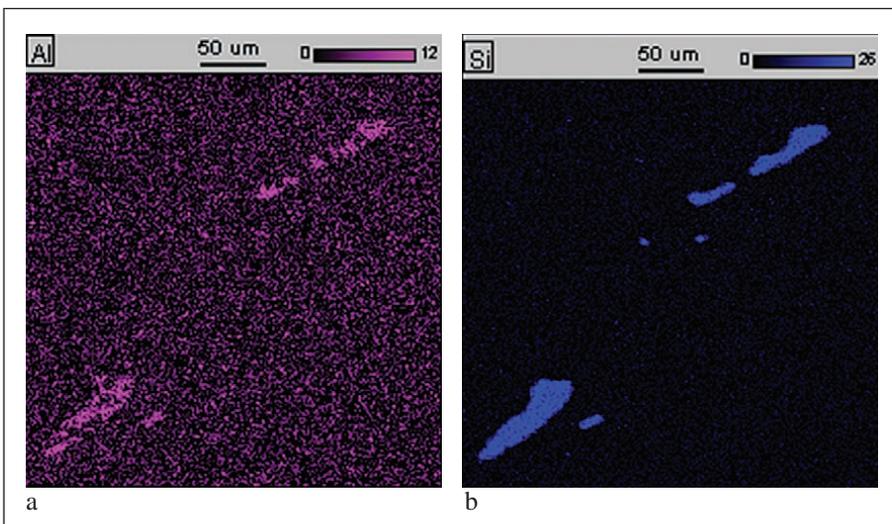


Fig. 14. Surface distributions of elements (X-ray maps) in Sample 2 in the area depicted in Fig. 12, a – X-ray map of Al; b – X-ray map of Si, by L. Klimek.

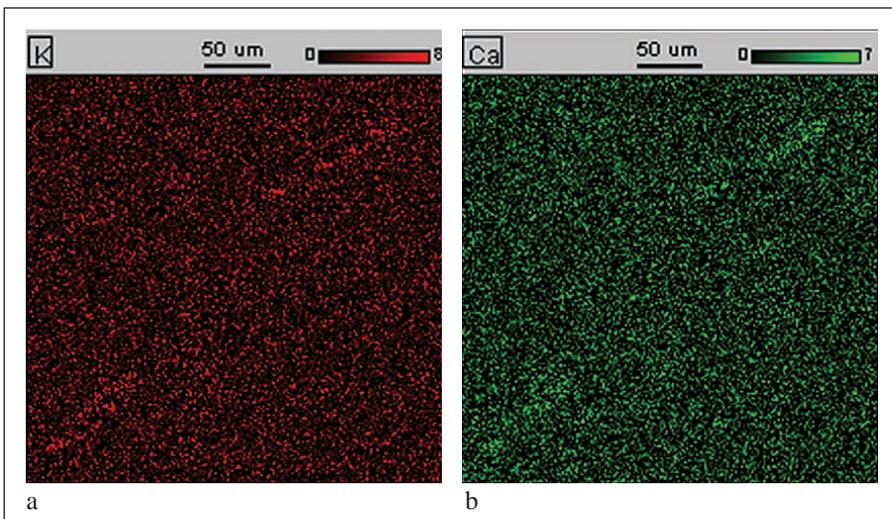


Fig. 15. Surface distributions of elements (X-ray maps) in Sample 2 in the area depicted in Fig. 12, a – X-ray map of K; b – X-ray map of Ca, by L. Klimek.

analysis of slag inclusions, it can be said that Item 2 was also made by forging.

Other analogies

In this place, particular attention could be paid to data from the territory of the Teutonic Order's state in Prussia

and Livonia. There are numerous pieces of information on iron guns in sources from this territory²². On the other

²² The most important sources include: *Das grosse Ämterbuch des Deutschen Ordens*, ed. W. Ziesemer, Danzig 1921; *Das Marienburger Tresslerbuch der Jahre 1399-1409*, ed. E. Joachim,

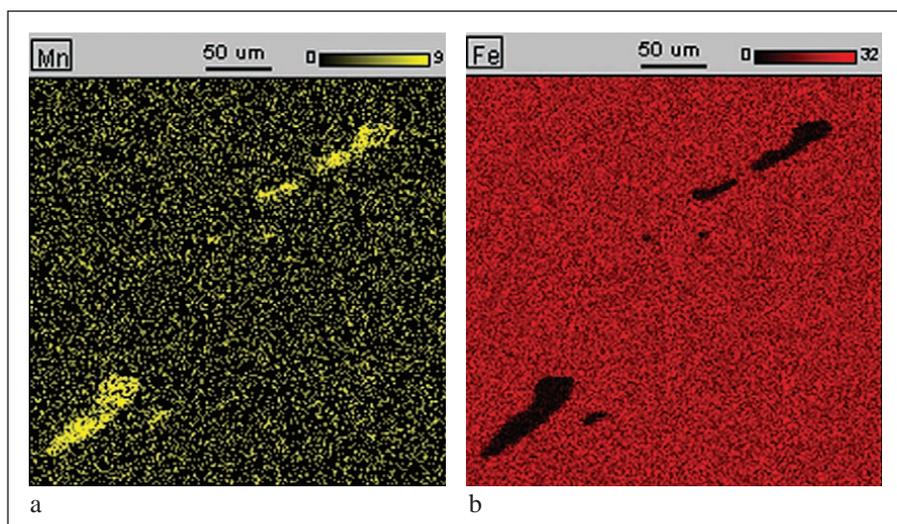


Fig. 16. Surface distributions of elements (X-ray maps) in Sample 2 in the area depicted in Fig. 12, a – X-ray map of Mn; b – X-ray map of Fe, by L. Klimek.

hand, mentions of weapons which could serve as analogies for the discussed items from Biecz are much less frequent. In 1404, the smithing master at Malbork (Marienburg) requested 9 Marks to be paid for the manufacture of 1 gun with 3 gunpowder chambers (*eyne buchse von vier stucken*). It can therefore be assumed that it was an iron veuglaire²³. In 1451, 5 iron veuglaire (*eyserne fogeler*)

Königsberg 1896; *Das Marienburger Ämterbuch (1375-1442)*, ed. W. Ziesemer, Danzig 1916; *Das Marienburger Konventsbuch der Jahre 1399-1412*, ed. W. Ziesemer, Danzig 1913; *Nowa księga rachunkowa Starego Miasta Elbląga, Cz. I (1404-1410)*, ed. M. Pelech, Warszawa 1987; *Nowa księga rachunkowa Starego Miasta Elbląga, Cz. II (1411-1414)*, ed. M. Pelech, Warszawa 1989; *Księga kamlarii miasta Torunia z lat 1453-1495*, eds. K. Kopiński, K. Mikulski, J. Tandecki, Toruń 2007; *Visitationen im Deutschen Orden im Mittelalter*. Bd. 1: 1236-1449, eds. M. Biskup, I. Janosz-Biskupowa, *Quellen und Studien zur Geschichte des Deutschen Ordens*, Vol. 50, Marburg 2002; *Visitationen im Deutschen Orden im Mittelalter*. Bd. 2: 1450-1519, eds. M. Biskup, I. Janosz-Biskupowa, *Quellen und Studien zur Geschichte des Deutschen Ordens*, Vol. 52, Marburg 2004; for the most relevant scholarship see, e.g., J. Szymczak, *Początki...*; V. Schmidtchen, *Die Feuerwaffen des Deutschen Ritterordens bis zur Schlacht bei Tannenberg 1410: Bestände, Funktion und Kosten, dargestellt anhand der Wirtschaftsbücher des Ordens von 1374 bis 1410*, Lüneburg 1977; A. Nowakowski, *Arms and Armour in the Medieval Teutonic Order's State in Prussia*, Łódź 1994; idem, *Arsenaly zamków krzyżackich w Prusach w latach 1364-1431*, [in:] *Medievalia Archaeologica, Acta Archaeologica Lodziensia*, Vol. 31, 1986, pp. 49-100; W. Świętosławski, *Koszty broni palnej i jej użycia w państwie krzyżackim w Prusach na początku XV wieku*, „*Studia i Materiały do Historii Wojskowości*”, Vol. 35, 1993, pp. 19-31; B. Rathgen, *Die Pulverwaffe im Deutschordensstaate von 1362 bis 1450*, „*Elbinger Jahrbuch*”, Vol. 2, 1922, pp. 1-116; A. R. Chodyński, *Bombarda krzyżacka z Kurzętnika, pocz. XV w.* [in:] *Fundacje artystyczne na terenie państwa krzyżackiego w Prusach. Katalog wystawy w Muzeum Zamkowym w Malborku 25 czerwca-12 września 2010 roku*. Vol. 1, ed. B. Pospieszna, Malbork 2010, pp. 126-127, P. Strzyż, *Średniowieczna...*; M. Dąbrowska, *Proces...*

²³ *Das Marienburger Tresslerbuch...*, p. 309; V. Schmidtchen, *Die Feuerwaffen...*, p. 63; W. Świętosławski, *Koszty...*, p. 22; A. Nowakowski, *Arms and Armour...*, p. 335; J. Szymczak, *Początki...*, pp. 107, 286.

were found during a visitation of the commandery in Reval (Tallin)²⁴. In 1461, in the course of the Thirteen Years War, the municipal authorities of Toruń (Thorn) bought 6 iron veuglaire (*eysern camerbuchssen*) from a woman called Pfeilschestynne from Elbląg (Elbing)²⁵. In 1508 and 1509, 2 veuglaire, described as iron naval guns with gunpowder chambers (*eisern schifbuchssen mit camern*) were recorded at the Order's castle in Szeszno (Sehesten)²⁶.

With regard to raw materials, a very interesting mention comes from 1411, when 3 barrels (*vas*) of osmund iron were bought by a Peter Korner from Johann of Toruń (Thorn) upon the request of the Grand Master. This iron was to be used by Johann, the smithing master to forge (*smeden*) guns²⁷. Osemund was cast iron, produced in Sweden in early blast furnaces (this process may have been introduced around 1200) in the form of balls or irregular lumps.²⁸ Apart from the use of high quality imported raw material, the Order's specialists probably also mastered the technology of casting iron in their own workshops. In 1412, 3 Marks were paid for the smithing master at Malbork (Marienburg) for 2 *Schiffpfund* (about 292 kg) for casting large cannonballs for terrace guns (*grosen gelote czu gissen czu den tarrasbochsen*)²⁹.

The role of blacksmiths and other specialists dealing with manufacture of iron firearms is poorly documented in sources as compared with bronze and copper casting. It seems that the significance of iron firearms increased from c. 1450. At that time we can notice an increase in the manufacture of iron barrels at the expense of bronze artefacts. This can be seen in Bratislava, which belonged to

²⁴ *Visitationen...*, Bd. 2, p. 31.

²⁵ *Księga kamlarii...*, No. 15.

²⁶ *Das grosse Ämterbuch...*, pp. 189-190.

²⁷ *Das Marienburger Konventsbuch...*, p. 252.

²⁸ A. R. Williams, *The Sword...*, pp. 189-190.

²⁹ *Das Marienburger Konventsbuch...*, p. 282; on the use of cast iron by the Order see also A. R. Williams, *The Sword...*, pp. 190-191.

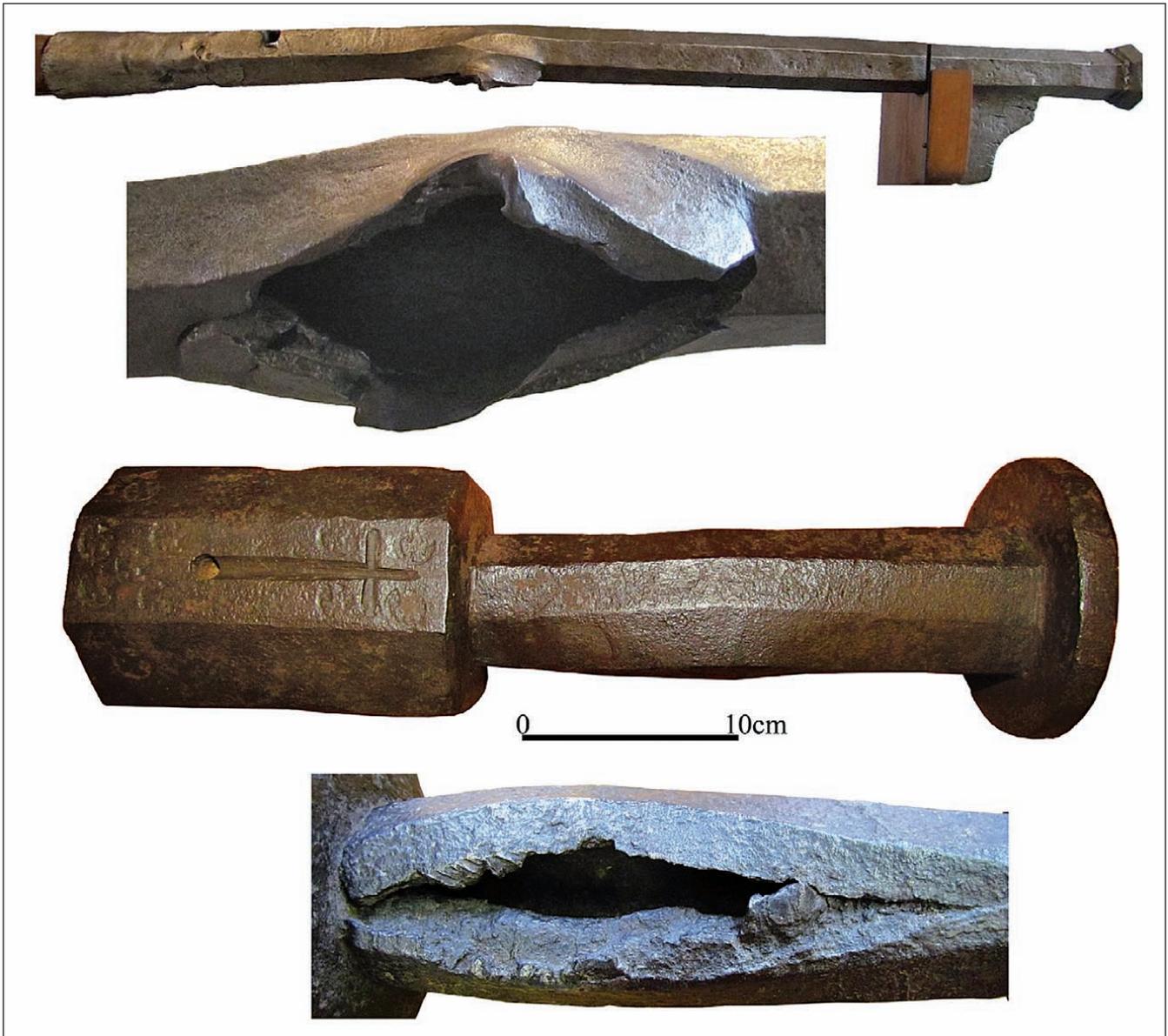


Fig. 17. 1-2 hackbut, castle of Horšovský Týn; 3-4 *piszczel* gun from Moravska Třebova. Photo P. Strzyż.

the Kingdom of Hungary in this period. A plan of casting bronze hand-held gun barrels at the local foundry was given up, and the work was commissioned to two town blacksmiths. In 1458 they manufactured 59 handgonnes which were ordered by the municipal authorities³⁰. The example of blacksmiths from Pszczyna in Silesia testifies to the fact that the manufacture of iron barrels was possible even in small centres. As early as the second half of the 15th c. they were able to make “rury bombardytas” and light *piszczel* guns, referred to in sources as “pixides”³¹.

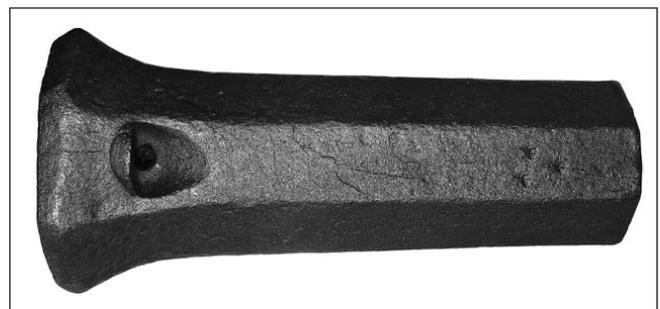


Fig. 18. *Piszczel* gun, Ostrožská Nova Vés.
Photo Museum Ostrožská Nova Vés

³⁰ J. Durdík, *Pracovní postupy...*, pp. 302, 323. As late as 1453 a can founder Hanuš manufactured 60 handgonnes and 9 hackbuts for the town, using 4 Zenteners and 70 pounds of metal, see *ibid.*, p. 322.

³¹ J. Kruczek, *Produkcja broni i oporządzenia jeździeckiego na ziemi pszczyńskiej od XVII do poł. XIX w.*, Pszczyna 1983, p. 47.

Manufacture of small calibre artillery and hand-held firearms was a relatively simple task and it was limited to making a barrel which was circular or polygonal in cross-section. It was made from one or several pieces of iron, which was forged on an iron core. The manufacture of the

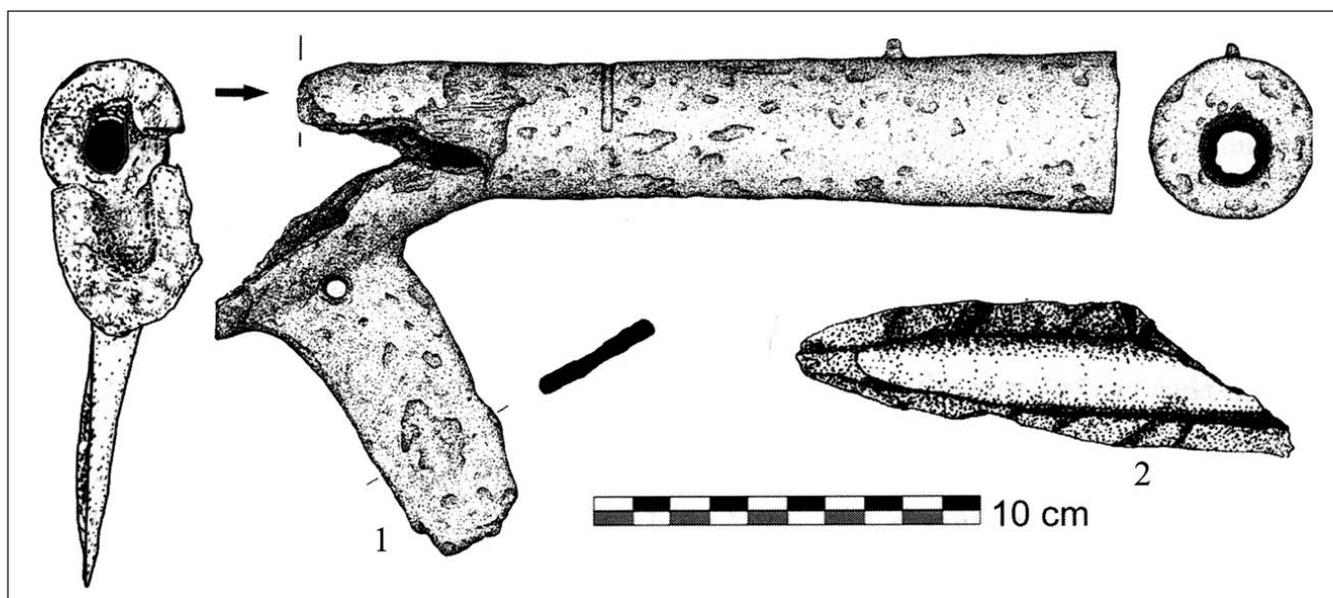


Fig. 19. 1- hackbut, castle of Helfštýn; 2- barrel fragment, castle of Křídlo; 1-2 by Fligel', Hložek, Hošek, Schenk, Žakovský 2010, Fig. 3.

simplest artefacts of this kind was possible even in small smithing workshops. In order to properly manufacture an iron forged barrel, it was necessary to make several elements, depending on the kind of the weapon, and then to assemble them together. The main element was obviously the barrel, which was formed by labour-consuming hot forging on an iron shaft. Then, the bore of the barrel was stopped in its bottom part with a cylindrical tenon. Depending on needs, a socket was formed from a sheet of iron. It was then forge-welded and attached to the barrel. Possible additional parts, such as a hook or a ring which reinforced the muzzle, were forged as separate elements. Then, they were all forge-welded together. If the weapon was to be provided with aiming devices, oblong rectangular slots were made in the barrel. Then, a foresight and a rearsight were made as separate elements and they were secured in the slots. Loops used to join the barrel with the stock in the case of more modern weapons were secured in a similar way. Traces of all these processes can be seen on many surviving examples.

In spite of a relative simplicity of the manufacturing process, damages of iron barrels often occurred. There were numerous reasons for it. Based on inspection of surviving specimens, it seems that a crucial issue was a careful forge-welding of pieces of iron in the barrel. If a touch point of both edges was not processed properly, the barrel could burst. As examples of this kind of damage, one can point to a *piszczel* gun from Moravska Třebova (Fig. 17: 3-4) or a hackbut from the castle of Horšovský Týn (Fig. 17: 1-2).

Another possible reason for damage was unskilled preparation of the raw material for the barrel. This was also due to the use of iron from low quality bog ores, which was widespread as late as the 14th and 15th c. Such iron contained a lot of impurities (e.g., phosphorus or potassium), as it could be seen in the case of the specimens from Biecz.

These impurities could potentially cause micro-cracks and fissures. The results of examinations of the items from Biecz can be compared with results of examinations of iron firearms from the Czech Republic. These are a barrel from the locality of Ostrožská Nova Vés and barrel fragments from the castles of Helfštýn and Křídlo.

The find from the locality of Ostrožská Nova Vés (south-eastern Moravia) has survived in its complete form. Its is 25.7 cm long, its calibre is 3.36 cm and its weight is 9.65 kg (Fig. 18). A sample was taken from its bottom part. The examinations demonstrated a high level of purity of iron (99.92% Fe), and small amounts of Mn (0.05%), P (0.08%) and C (0.05%). There is no sulphur. In microscopic magnification one can only see non-malleable particles of oxides of manganese, silicon, calcium and potassium. The technological analysis demonstrated that the item was forged at the temperature of about 720° C, which caused less deformation during in the course of later cooling and a relative softness of the barrel. To sum up, the raw material was made from the ore which was selected in such a manner so that it did not contain sulphur and with the low content of phosphorus. This gun may be of local manufacture and its quality speaks well about the skills of the smith who made it. This was not an easy task, bearing in mind the massiveness of the gun, especially its bottom part. At the same time, its massiveness rendered the gun resistant to cracks of even 9.5-12.5 mm³².

The barrel fragment from the castle of Křídlo (Fig. 19: 2) is octagonal in cross-section and its calibre is about 2.4-2.5 cm.

³² V. Ustohal, K. Stránský, V. Hanák, *Hákovnice ze Slovácké Půdy*, „Slovacko“, Vol. 33, 1991-1992, pp. 159-164, fig. 4-7, see also D. Fligel', M. Hložek, J. Hošek, Z. Schenk, P. Žakovský, *Interdisciplinární analýza roztržené železné hákovnice z hradu Helfštýn*, „Castellologica Bohemica“, Vol. 12, 2010, p. 457.

The examinations demonstrated that it was made from ferritic iron of a high degree of purity. The metal was carefully forged for many times, which enabled the smith to remove numerous impurities or shift them under the surface of the barrel. At room temperature, the barrel could even withstand structure cracks at the length of 4.3-6.4 mm. In spite of this, the weapon burst. According to the authors of research, it may have been caused by low temperature at which the weapon was used. Such a temperature dramatically decreased the gun's quality and even structure cracks of about 1 mm could prove fatal. In the light of the research and reconstruction of pressure produced by historical gunpowder, it turned out that using the weapon at the low temperature (below zero – in Winter) was the most probable reason. Under such circumstances, even the first shot could make the barrel burst. The use of a too strong gunpowder charge may have been another reason. The research demonstrates that as early as the 15th c. basic shortcomings of firearms were known. It was attempted at eliminating them by means of careful smithing processes³³.

It seems that the part of a hackbut from the castle of Helfštýn in Moravia is later and it can be dated to the late 15th-mid 16th c. (Fig. 19: 1). The preserved fragment is about 24 cm long and its calibre is 1.5 cm. The examinations demonstrated that the barrel was forged from iron with a very high content of phosphorus. Two zones with slightly different structures were observed in the examined surface. The first one was the homogeneous ferritic zone with the

high phosphorus content of c. 0.5-0.6%. The other one is ferritic-pearlitic and the carbon content is about 0.2-0.3%. In the entire surface one can see densely distributed small inclusions of non-malleable admixtures (oxides). Within the other zone, a 4.2 mm long crack was noticed. As it is known, the high content of phosphorus in iron is detrimental for its quality, as it makes it brittle and prone to breaking. The maximum content of phosphorus which does not negatively influence the quality of a given artefact should not be higher than 0.1%. Furthermore, the content of phosphorus in iron can also increase due to the use of hardwood (e.g., oak) charcoal for iron smelting. The barrel from Helfštýn was forged in the temperature over 950° C, which also negatively influenced the quality of the artefact. At this temperature, it came to a diffusion of phosphorus between austenitic and ferritic structures. This resulted in microcracks when the artefact was cooled. Further use of the gun led to enlargement of these cracks and finally caused the weapon to burst. In this particular case, the crack occurred in the internal part of the barrel.³⁴

Based on these analyses it can be said that the quality of these artefacts was not very high. In each case the presence of non-metallic inclusions was noticed, which reduced the toughness of the barrels. This is even seen in the case of the barrel from Helfštýn, which is the latest of all the examined items. It can be therefore said that the only efficient method of preventing guns from breaking was to forge barrels with sufficiently thick walls.

Streszczenie

Późnośredniowieczna broń palna z żelaza kutego z Muzeum w Bieczu

Technika wykuwania w średniowieczu luf broni palnej z żelaza była szeroko rozpowszechniona. W przypadku najcięższych dział (bombard), na przygotowany z szeregu sztab przewod lufy czy też komory prochowej nakładano obręcz – poprzeczne pierścienie wzmacniające. W odniesieniu do artylerii lekkiej: hufnic, taraśnic czy foglerzy, tak złożona technika nie była konieczna i lufę można było wykonać jako odkuwkę z jednego lub najwyżej kilku kęsów żelaza. Dotychczas w Polsce nie prowadzono badań specjalistycznych tego rodzaju broni.

Przedmiotem zainteresowani były dwa średniowieczne żelazne działa przechowywane obecnie w Muzeum Regionalnym w Bieczu (nr inw. 295 i 296), a interpretowane jako komory foglerzy. Próbkę do analiz pobrano z ich części wylotowych, a miały one na celu rozpoznanie struktury materiału i techniki produkcji. Na całym badanym

przekroju wycinka z działa nr 1 (nr inw. 295) występuje drobnoziarnista mikrostruktura ferrytyczno-perlityczna. Mała zawartość perlitu wskazuje na niewielką zawartość węgla w próbce (około 0,1-0,2% C), co odpowiada zawartości tego pierwiastka charakterystycznej dla stali miękkiej. Widoczne w powiększeniu wtrącenia żuźla tworzą miejscami skupiska, a analiza ich składu chemicznego wykazała obecność takich pierwiastków jak: O, Si, Fe, Al, P, K, Ca, oraz ślady S. Wykonane mapy rozkładu powierzchniowego pierwiastków w tym analizowanym obszarze dowodzą, że głównymi składnikami w tych wtrąceniach żuźla są krzem, żelazo oraz tlen. Są to więc zanieczyszczenia związane z dymarskim sposobem otrzymywania żelaza. Na podstawie przeprowadzonych badań metalograficznych można stwierdzić, że lufa działa nr 1 wykonana została z miękkiej stali dymarskiej o podwyższonej zawartości fosforu, na co wskazuje też pomiar twardości metalu – 141 HV01.

Druga z próbek pochodzi z lufy o nr inw. 296. Na całym badanym przekroju obserwujemy mikrostrukturę

³³ K. Stránský, V. Ustohal, *Rozbor fragmentu středověké hákovnice*, „Hutnické listy”, Vol. 48/12, 1988, pp. 907-910, figs. 2-6; see also D. Fligel', M. Hložek, J. Hošek, Z. Schenk, P. Žakovský, *Interdisciplinární analýza...*, p. 457.

³⁴ D. Fligel', M. Hložek, J. Hošek, Z. Schenk, P. Žakovský, *Interdisciplinární analýza...*, pp. 453-455, 457, figs. 10, 11.

ferrytyczną z niewielką ilością cementytu trzeciorzędowego rozmieszczonego na granicach ziaren ferrytu. W niektórych ziarnach ferrytu dobrze widoczne są bliźniaki deformacji, świadczące o podwyższonej zawartości fosforu w metalu tej lufy. W tym przypadku wielkość ziaren ferrytu jest wyraźnie większa niż w lufie nr 1. Występujące w próbce 2 wtrącenia żużla tworzą również miejscami skupiska, a analiza map rozkładu powierzchniowego wykazała obecność takich pierwiastków jak: O, Fe, Mg, Si, Al, Mn, Ca oraz K. W przewadze są to zanieczyszczenia pochodzące z procesu hutniczego, a ich występowanie związane jest zarówno z rodzajem rudy użytej w procesie wytopu jak i z dymarskim sposobem otrzymywania żelaza. Na podstawie przeprowadzonych badań metalograficznych można stwierdzić, że lufa działa nr 2 wykonana została z żelaza

dymarskiego o podwyższonej zawartości fosforu, miejscami śladowo nawęglonego do zawartości ok. 0,022% C. Wyższa twardość ferrytu (średnia twardość 172 HV10) oraz występujące miejscami bliźniaki deformacji świadczą o obecności fosforu w metalu lufy działa nr 2.

Na podstawie przeprowadzonych badań można stwierdzić, że lufy dział wykonane zostały z prawie czystego żelaza, z zastosowaniem obróbki plastycznej – kucia. Jednocześnie jest bardzo prawdopodobne, że obie lufy (komory) mogły być wykonane w lokalnym warsztacie kowalskim, zaopatrzonym w odpowiednie narzędzia. Przeprowadzone analizy potwierdzają nie najwyższą jakość przebadanych wyrobów. Właściwe w każdym z przypadków w przekrojach zanotowano obecność szkodliwych dodatków niemetalicznych osłabiających wytrzymałość luf.

