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ELEMENTS OF EARLY MODERN HAND-HELD FIREARMS FROM THE SITE OF THE CIOŁEKS' CASTLE IN ŻELECHÓW, GARWOLIN COUNTY

ABSTRACT

Bis W. and Strzyż P. 2025. Elements of early modern hand-held firearms from the site of the Ciołeks' castle in Żelechów, Garwolin County. *Sprawozdania Archeologiczne* 77/2, 557-576.

In 2022, fragments of hand-held firearms were discovered at the site of the castle of the Ciołek family in Żelechów, Garwolin County, Masovian Voivodeship. Based on the craftsmanship, analogies known from the literature, and museum artefacts, it can be assumed that these were elements of a 16th-century hackbut. They most likely originated from a single barrel, which was damaged during use. Metallurgical analyses have shown that the barrel was forged from iron. A formal analysis allowed for a graphical reconstruction of its original form.

Keywords: Żelechów castle, Ciołek family, fortalicium, Middle Ages, hackbut
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INTRODUCTION

The fortalice of the Ciołek family of Żelechów is one of the few knightly residences located on the borderland between Masovia and Lesser Poland, in the north-eastern part of the Sandomierz Voivodeship (referred to as the Stężyca Land from the late 16^{th} century) (Pałucki 1993, 48). Due to the limited number of preserved written records and only a few

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identified archaeological sites from the medieval and early modern periods, this area has rarely been the focus of historians and archaeologists. Most archival records concerning the region, particularly the castle and land court books stored in the Central Archives of Historical Records in Warsaw, were destroyed during the Second World War in 1944 (Stobiecki 1957, 27; Wolff 1957, 205, 217-219). This has significantly hindered the study of estates in the area, including magnate and noble residences. Nevertheless, previous research has identified several private residential and defensive complexes, with relics preserved in four locations: Górzno (Górzno Commune), Kaleń (Sobolew Commune) (Górska *et al.* eds 1976, 49-50, 66; Wróblewski 2006, 38, 61, 66, 112), Wilczyska (Miastków Kościelny Commune) (Bis 2021), and Żelechów (Żelechów Commune) (Bis *et al.* 2018; 2019; 2021). Additionally, written sources mention two now-lost structures: the castle of the 'starost' (a royal administrative and judicial official (a reeve) for a district/county ('powiat'), a sheriff) in Stężyca (Wróblewski 2006, 112) and the residence of the Maciejowski family in Maciejowice (Dunin-Wąsowicz 1993, 86; Libicki and Libicki 2013, 313) (Fig. 1).

The seat of the Ciołek family was located in the north-western part of the present-day town of Żelechów, in the middle of a wide, marshy valley along a watercourse known as

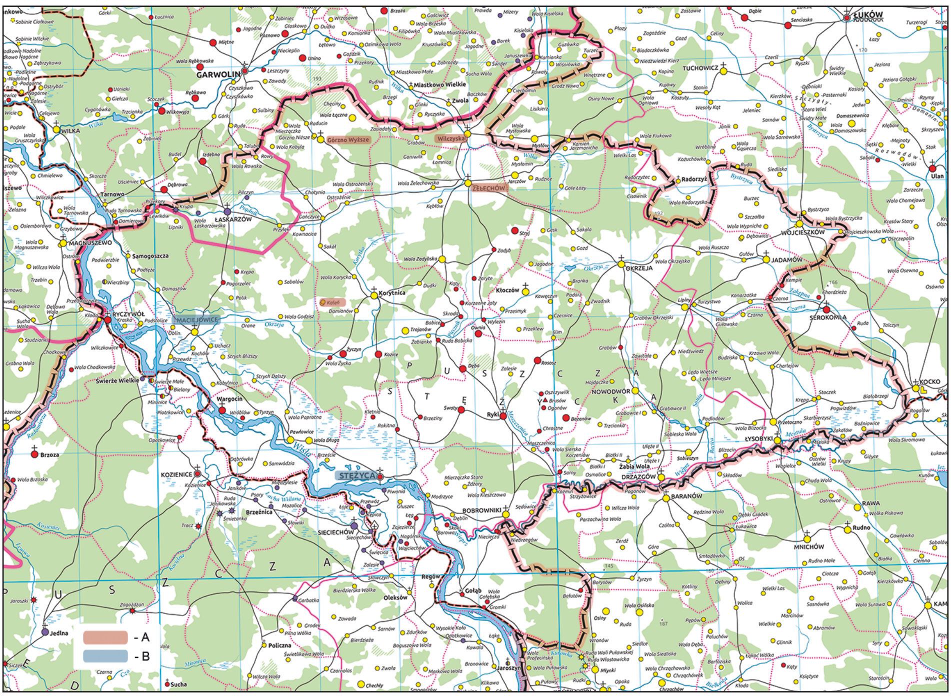


Fig. 1. Location of residential-defensive seats in the Stężyca Land. A – sites preserved in the landscape; B – sites known from written sources. Fragment of the map 'Ziemie polskie Korony w drugiej połowie XVI w.' (source: www.atlasfontium.pl). Compiled by W. Bis

Żelechówka, which currently flows in a regulated, deepened, and in part artificially shaped channel. The site is now a wasteland situated about 100 metres from the road leading towards Wilczyska, and in the immediate vicinity of contemporary fishponds (Fig. 2). Archaeological surveys conducted between 2016 and 2024 confirmed the location of the castle, allowing for the determination of its construction method, building materials, as well as the phases and duration of its use (Bis *et al.* 2019). The complex was quadrilateral in shape, with maximum dimensions of 85 × 90 metres. It consisted of a centrally located square platform (with a side length of 50 metres), surrounded by a moat (approximately 10 metres wide), beyond which was an earth rampart formed during the excavation of the moat (Fig. 3). The results of fieldwork, finds of movable artefacts (coins, ceramic vessels, and stove tiles), dendrochronological evidence, analyses of stratigraphic layers, and written sources suggest that the structure was built around the mid-15th century and was in use until the end of the 17th century. At least three main phases of its operation were distinguished. In the first phase, dated from the mid-15th to the mid-16th centuries, it served as the family seat of the Ciołeks, with a masonry residential tower and utility buildings in the courtyard. In the second phase, from the mid-16th century to the end of the century, after

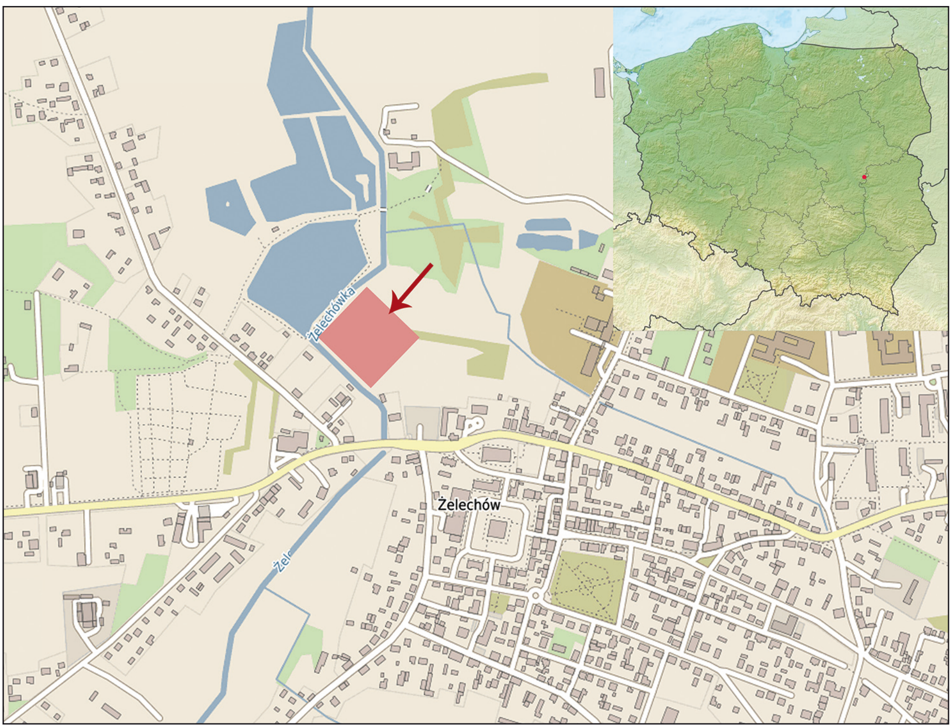


Fig. 2. Location of the Ciołek fortalice within the town of Żelechów.
Compiled by W. Bis, base map from: https://polska.e-mapa.net/

extensive modernisation, the complex was transformed into a late Renaissance noble residence, featuring a wooden manor house in the courtyard. The moat was filled in, and residential and utility buildings were constructed on the ramparts, some of which were paved with stones. Inside the manor, an impressive heating stove made of Renaissance-style tiles was installed. The third phase, beginning at the turn of the 17^{th} century, marked the end of the castle's representative function. The functional change was probably prompted by a large fire that destroyed the wooden buildings, as evidenced by the cultural layers. The structure was not rebuilt in its previous form but was instead transformed into a noble manorial grange ('folwark'), serving as an administrative centre for the surrounding estates. The agricultural and utilitarian function of this complex is further evidenced by a large wood-lined well with a crane for drawing the water, constructed on the site of the burned manor.

The surviving written sources indicate that the estate belonged to the Żelechów line of the Masovian Ciołek family, whose members held prominent state offices. Andrzej Ciołek (d. circa 1448) served as *stolnik* (pantler) of Sandomierz (1420-1421), then as 'podkomorzy' (chamberlain) (1422-1436) and 'starost' of Sandomierz (1425-1429, 1432) (Kurtyka *et al. eds* 1990, 326), and ultimately as the general 'starost' of Greater Poland (1434-1436) (Bielińska *et al.* 1985, 173). His father, also named Andrzej (d. 1396), held the office of standard-bearer of Płock and later became the voivode of Masovia. He was the brother of

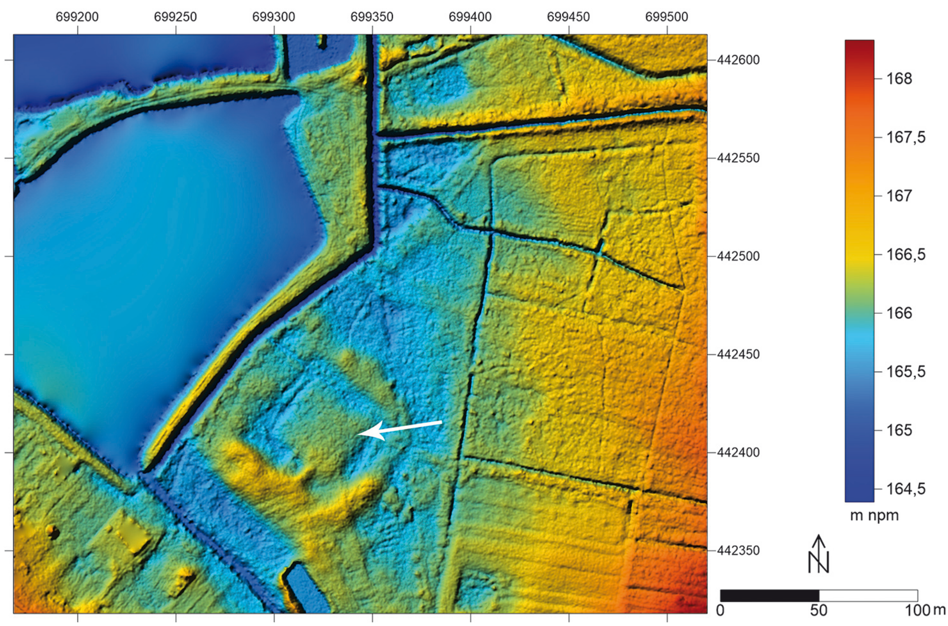


Fig. 3. Digital terrain model of the river valley and the Ciołek castle complex in Żelechów. Compiled by W. Małkowski (Faculty of Archaeology, University of Warsaw)

Stanisław, Bishop of Poznań (b. *circa* 1382 – d. 1437) (Piotrowicz 1938, 77). After the death of Andrzej, the 'starost' of Sandomierz, his son, also named Andrzej, settled in Żelechów, inheriting not only the local estate but also Wola Żelechowska, Kłębów, and Wilczyska (Boniecki 1900, 218). The first recorded mention of the Ciołek residence in Żelechów appears in the *Liber Beneficiorum* by Jan Długosz, which notes that the local knightly manor (*praedium militare*) contributed four 'grzywnas' in tithes to the church and parish priest of Żelechów (Długosz 1864, 560). The town of Żelechów had probably already attained urban law by the early 15th century, as evidenced by the 1418 record of Wojciech Crispus, the Żelechów 'vogt' (advocatus), in the Lublin land court registers. In 1447, King Kazimierz IV Jagiellon granted the town the right to hold an annual fair and weekly markets on Tuesdays (Bis *et al.* 2018, 354). In later records, the Ciołek residence in Żelechów is referred to as a fortalice (*fortalicium*). It was first mentioned in 1515 in connection with the division of the Żelechów estate between Andrzej Ciołek and his half-brother, Feliks of Zielonka. Andrzej transferred half of the local estate, including the town, fortalice, and several villages, to Feliks, while pledging the other half to him for 1,000 'grzywnas'. A second reference to the fortalice appears in a 1523 document concerning a family dispute in which Jan (Andrzej's brother) attempted to recover these properties from Feliks of Zielonka, who was then the 'starost' of Łuków (Bis *et al.* 2018, 355). The conflict escalated, leading to royal intervention. On 11 April 1523, King Zygmunt the Old issued a mandate to Mikołaj of Szydłowiec, castellan of Sandomierz, royal treasurer, and 'starost' of Radom, instructing him to restore Jan *Czolek de Zelechow* to the estates of *Feliks de Zyelyanka*, castellan of Chełm and 'starost' of Łuków, namely the town of *Zelechow cum fortalitio* and the villages of *Vola Zelechowska, Ostrozenye i Lomnycza* 'even by force if necessary' (Wierzbowski 1910, 243, no. 4208; Bis *et al.* 2018, 355). The resolution of the dispute remains unknown, but the Ciołek family likely regained the estate, as in 1527 another member of the family, also named Jan, styled himself as being 'of Żelechów' (AGAD, MK. 1527, fol. 264v; Wierzbowski 1910, 306, 307, no. 5208).

There is no written evidence regarding the later fate of the fortalice. It is possible that it was destroyed during the Second Northern War (1655-1660), perhaps as early as the end of 1655. It is known that on the night of 24-25 December that year, the Swedish army devastated the nearby village of Stężyca (Nagielski *et al.* 2015, 440). Extensive destruction was also recorded in Łuków, where most of the town's buildings, three wooden churches, and a hospital were burned down (Nagielski *et al.* 2015, 453, 454). The Swedes also occupied the castle in nearby Wilczyska, which they probably left in ruins (Chlebowski 1893, 462). The Żelechów complex probably continued to function in the second half of the 17th century, although its form and purpose remain unclear. In 1673, a poll tax register recorded that a tax of 8.5 florins was levied on the Żelechów manor, assessed on seven inhabitants: the estate manager and his wife, along with five servants (AGAD, ASK 1673, k. 486). The continued use of the site during the second half of the 17th century is further corroborated by numerous finds of Polish and Lithuanian copper alloy machine-struck shilling ('szeląg') coins minted between 1659 and 1668 during the reign of King Jan II Kazimierz. Most of these coins were recovered from near-surface cultural layers across almost all archaeological trenches. It is likely that by the late 17th or early 18th century, the residence of the Żelechów owners was relocated to another part of the town. In 1722, the Żelechów estate was acquired by brothers Wacław and Seweryn Rzewuski from its then-owner, Stanisław Linkaus. According to an inventory compiled in 1729, following Wacław's complete acquisition of the estate, the wooden palace and farmstead buildings were situated 'outside the town, on a distinctive height' ('pod miastem, na miejscu osobliwym wzgórzystym') (Justyniarska-Chojak and Pielas 2016, 99), a location that can be identified with that of the 19th-century manor house that still exists today.

DESCRIPTION AND DATING OF THE ARTEFACTS

Fragments of hand-held firearms were discovered during archaeological investigations conducted in 2022. They were found in the north-eastern part of the castle courtyard, within a sub-turf layer near the moat (Figs 4 and 5). The assemblage consists of two unevenly sized barrel fragments, both forged from iron and featuring a polygonal cross-section. The larger of the two fragments (Fig. 4: 1-2; 5: 1) represents the breech section of the barrel. A short segment of this fragment preserves the whole circumference of the barrel, including the breech plug, while further along, approximately half of the circumference survives, comprising four of the original eight polygonal sides. Unfortunately, the attachment point for the rectangular priming pan plate with a touch hole for ignition has not been preserved. As mentioned, the iron tenon, originally used to seal the barrel, has been preserved in the breech. X-rays were taken at the IAE PAN Laboratory in Warsaw. Unfortunately, the obtained images do not allow for the resolution of the question whether the breech plug was screwed in or driven in and welded. It is heavily corroded, externally resembling a pyramid, while its internal form remains cylindrical. The diameter of the tenon corresponds to the internal bore diameter of the barrel, providing an estimate of the firearm's calibre, which was probably 1.9 cm. Following conservation, the dimensions of this fragment are as follows: total length (including tenon), 19.6 cm; length without tenon, 18.2 cm; tenon base, 1.6 × 1.2 cm; breech thickness, 3.95 cm; external width at the breech, 4.85 cm; barrel wall thickness at the breech, 1.35-1.45 cm; barrel wall thickness closer to the muzzle, 1.15 cm; total weight, 915 g.

The second barrel fragment (Fig. 4: 3, 4; 5: 2) represents a non-specific central section, of which only a small portion of the circumference has survived. This includes one complete side and two adjacent, partially preserved sides. As a result, it cannot be conclusively determined whether the barrel originally had an octagonal cross-section. There are also examples of 16th-century hackbuts with variable polygonal-round barrel cross-sections,

Fig. 4. Iron barrel fragments of the hackbut from Żelechów Castle: 1-2 – fragment of the breech section; 3-4 – fragment of the central section. Photo: W. Bis

for example, specimens in the Museum in Znojmo and the National Museum in Prague (Czech Republic) or Copenhagen (Denmark) (see Strzyż 2014, cat. No. 50, pl. 63; Šnajdrová 2014, 67, fig. 5; McLachlan 2010, 58). The preserved length of this fragment is 10.3 cm, with a wall thickness of 1.15 cm and a weight of 140 g. Due to its condition, determining the exact calibre is challenging. However, it appears to be slightly larger than that of the previously described section, measuring approximately 2.0-2.1 cm. It should be noted that this difference is minimal and may be due to barrel expansion caused by an explosion. The rupture of barrels was not an uncommon occurrence, as confirmed by other archaeological finds and, in some cases, written sources (*e.g.*, Fligel' *et al.* 2010, 477-479, fig. 2 and 3; Marek and Konczewski 2010, 111, 112; Chudzińska 2011, 205-211, fig. 2; Boguszewicz 2020, 261, fig. 18: a and c; Sawicki 2024, 199-201, figs 1-3). Among the relatively numerous lead projectiles for smoothbore firearms discovered during the archaeological investigations, a lead ball with a diameter of 1.9 cm was found (Fig. 6). This projectile can hypothetically be associated with the remains of the hackbut described above.

The origins of hackbuts in Europe date back to the second half of the 14th century. They developed through the addition of a recoil-absorbing hook to the barrel of the earliest forms of hand-held firearms, known as *piszczel* guns. During the 15th century, hackbuts underwent rapid evolution, transforming from primitive short-barrelled weapons into highly effective battlefield arms by the end of the century. Several key improvements contributed to their enhanced functionality, including an increase in barrel length, the

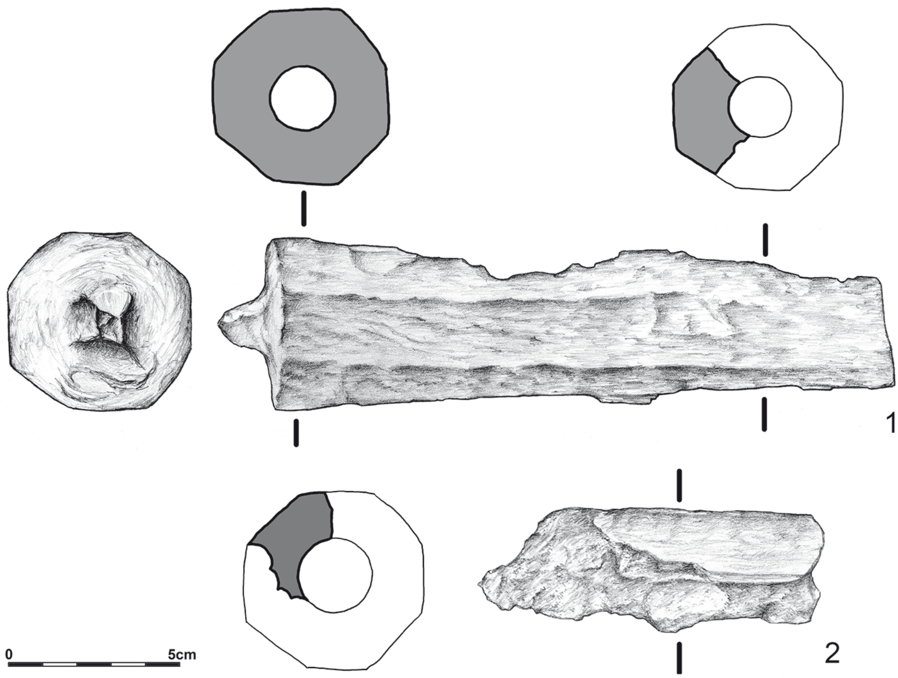


Fig. 5. View and cross-sections of the two barrel fragments from the Żelechów hackbut.
Drawing: E. Gumińska

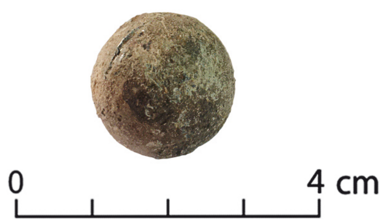


Fig. 6. Lead projectile (calibre: 1.9 cm) from the courtyard of Żelechów Castle.
Photo: W. Bis

relocation of the touch hole to the right side of the barrel, and the introduction of rudimentary firing mechanisms. Additionally, simple sighting devices — a front sight and a rear notch — became more common, and barrels began to be mounted on wooden stocks with a slightly curved, downward-sloping butt (*e.g.*, Müller 1957, 123, fig. 185: b; Durdík 1979, 4; Szymczak 2004, 48, 49; for a broader discussion, see McLachlan 2010, 31-33, 36-37; Strzyż 2014, 56-62, pls 20-29, 34-54). Further developments occurred in the early 16th century, most notably the introduction of the matchlock mechanism, a relatively simple yet highly effective firing system that appeared in multiple variations (*e.g.*, Müller 1957, 123, fig. 184, 185: c; Durdík *et al.* 1977, 34, figs 1 and 2; Durdík 1979, 4; Szymczak 2004, 49, 50, fig. 10; McLachlan 2010, 54; Barbu 2013, 38-42, figs 56-61). Moreover, the breech was now sealed with a tenon featuring a cubic protrusion, which was either hammered or screwed into the barrel's end to reinforce the barrel-stock connection. The touch hole was supplemented with a rectangular priming pan plate containing a shallow depression for the priming powder. This method of ignition remained in use throughout the 16th and 17th centuries (Matuszewski 2000, 17, 18; Strzyż 2014, 62-64, pls 55-57; Strzyż *et al.* 2016, 100, 101).

The parameters and appearance of the partially preserved breech section of the barrel from Żelechów place it within the category of hand-held firearms characteristic of the 16th century. However, in attempting to determine its precise date of manufacture, it is necessary to rely on comparable artefacts, as the discovered fragments were found in a loose context within the humus layer. Unfortunately, the majority of such finds lack precise provenance information and, consequently, clear chronological attribution. Among Renaissance hackbuts preserved in Polish collections, the best analogue is a well-preserved specimen currently housed in the Museum of Jarosław. However, its original provenance remains unknown (Fig. 7). This hackbut has a total length of 90.5 cm (including the tenon), a breech diameter of 4.2 cm, a calibre of 1.9 cm, and a total weight of 4.4 kg.

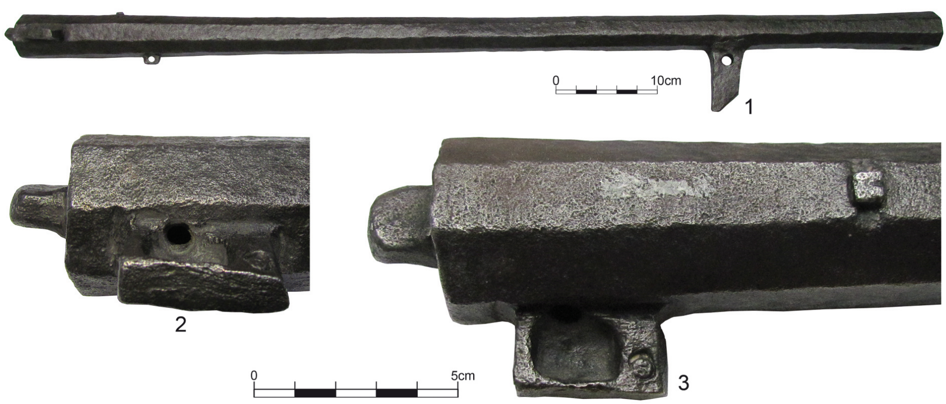


Fig. 7. Hackbut from the Museum in Jarosław, first half of the 16th century: 1 – general view; 2 – breech section with touch hole and tenon; 3 – breech section with priming pan plate, tenon, and rear sight notch. After Strzyż 2019, fig. 1

These measurements suggest that it was a firearm designed for an infantryman fighting in open field engagements rather than one exclusively used from fortified city walls or castle defences. The weapon has been broadly dated to the first half of the 16th century (for a more detailed discussion, see Strzyż 2019, 308, 309, fig. 1: 1-5). This hackbut represents a relatively lightweight construction for its type, and its dimensions — particularly the breech diameter and calibre — are almost identical to those of the breech section of the barrel from Żelechów. Moreover, its excellent state of preservation allows for the reconstruction of the original appearance of the Żelechów firearm.

Among comparable finds from Poland, two iron hackbuts recovered in 2009 during archaeological excavations of the town hall remains in Chełm are also noteworthy. Both artefacts were found within the fill of a structure whose function remains unclear, and whose construction has been broadly dated to the 16th – early 17th centuries. The barrels have survived in varying states of preservation. The most relevant comparison to the Żelechów find is a hackbut (inventory no. CH-Ł/111W/09) with a polygonal barrel cross-section and a breech section ending in a tenon with a prismatic projection. It has a total length of 153.7 cm, a calibre of 2.3 cm, and a weight of approximately 21 kg. The chronology of both specimens has been established at around the mid-16th century (Strzyż *et al.* 2016, 102-105, tab. 1-2, figs 8: 1 and 9).

For Central Europe, there is a notable scarcity of hackbuts from the 16th century with precise archaeological dating. A particularly significant specimen is a hackbut barrel from Eger Castle in northern Hungary, currently housed in the local museum (inventory no. 80.24.1). This artefact is heavily corroded. However, it retains an octagonal cross-section at both the breech and muzzle ends, transitioning to a circular cross-section in the middle section. It was found in fire destruction layers associated with the 1552 siege of Eger by Ottoman forces. The firearm has a length of 85.5 cm, a calibre of 1.6 cm, and a breech diameter of 4.3 cm. It was probably made in the late first half of the 16th century, possibly just before the expected siege (see Strzyż *et al.* 2016, 103, tab. 1, fig. 11; Strzyż 2019, 311, fig. 3). The parameters of this hackbut indicate that, like the example from the Museum in Jarosław, it belonged to a lighter variant, which could be operated freely by a shooter without the need for additional support (Fig. 8). Additionally, historical sources concerning firearms in the Grand Duchy of Lithuania in the 16th century refer to firearms with a calibre below 2 cm as small hackbuts (*cf.*, Volkau 2019, 138, pl. 1).

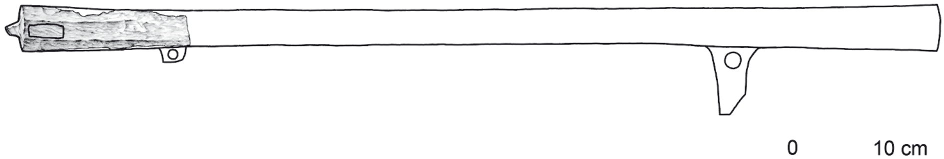


Fig. 8. Reconstruction drawing of the Żelechów hackbut barrel.
Drawing: E. Gumińska

In addition to the aforementioned more significant discoveries, fragmented remains of hand-held firearms are also encountered during archaeological excavations. One such example is a barrel fragment with a calibre of approximately 1.5 cm, discovered during investigations of the manor house in Zduny, Jarocin County. This artefact was found within the remains of the fourth construction phase of the site, dated to the late 16th – mid-17th centuries. The authors identified it as part of a musket barrel; however, given the fragmentary and non-diagnostic nature of the find, its precise classification remains uncertain (Grygiel and Jurek 1999, 144, 153, 154, fig. 118: 1).

Mentions, albeit scarce, of private castle owners possessing firearms can also be found in written sources. For example, in 1504, a court case was brought by Andrzej of Włodzisław against Benedykt (Bieniasz) Pogorski of Brzezie regarding the seizure of twelve '*bombardas alias foglari*' (Nowakowski 2006, 105). Similarly, in 1502, documents related to a dispute over the estate at Rytwiany castle recorded an arsenal including 40 hackbuts and as many as 200 'handgonnes' (Szymczak 2004, 331). Comparable firearm stockpiles were held in royal castles. In 1494, records from the Brześć Kujawski castle list seven hackbuts (Szymczak 2004, 322). In 1509, the Kazimierz Dolny castle had an even larger arsenal, containing 39 hackbuts (including 32 new ones), along with 1,200 lead balls and a barrel of gunpowder (Szymczak 2004, 328). Similarly, in 1516, the inventory of the castle in Bolesławiec on the Prosna included 28 hackbuts and nine 'handgonnes', and two decades later, an additional 10 hackbuts were purchased (Górski 1902, 229; Żemigała and Grabarczyk 1982, 43; Szymczak 2004, 329). Hackbuts were also an essential part of the armament of 16th-century castles in the Grand Duchy of Lithuania. In 1552, amid rising tensions with Muscovy, 605 hackbuts were sent from Vilnius to border castles, with the largest supplies reaching the region's key strongholds: Polotsk, Vitebsk, and Braslaw (Volkau 2023, 29-30). Between 1552 and 1562, Polotsk received 21 cannons and 256 hackbuts, Vitebsk eight cannons and 203 hackbuts, and Braslaw 90 hackbuts between 1556 and 1559 (Volkau 2023, 35, 47). Written sources also document large deliveries of firearms to the castle in Kamieniec Podolski during the reigns of the last two Jagiellonian kings. In 1522, a shipment from Kraków included 20 hackbuts, 12 barrels of gunpowder, and 20 centners of lead for casting bullets. By 1572, an inventory of the castle's armoury recorded 70 hackbuts and 140 demi-hackbuts (Hański 2022, 16, 21).

THE MANUFACTURING TECHNIQUE OF THE ŻELECHÓW BARREL IN A COMPARATIVE CONTEXT

A sample was taken from the chamber section of the barrel for specialist examination (Fig. 4: 1, 2). Metallographic analyses were conducted using a Neophot 21 microscope equipped with a Hanneman microhardness measurement system. In contrast, chemical composition analyses were performed using a Tescan VEGA GMS (S5153) scanning electron microscope, integrated with an EDS Aztec Live Advanced – Ultim Max 40 X-ray microanalysis system. The metallographic specimen was extracted using a Secotom precision cutter, provided by Struers. It was then embedded in PolyFast thermosetting resin and subsequently polished on a Tegramin disc polisher (Hensel *et al.* 2025).

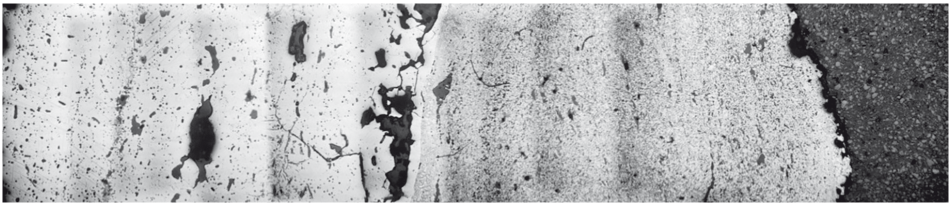


Fig. 9. Cross-section of the Żelechów hackbut barrel. Photo: Z. Hensel

Fig. 10. Structural composition of the Żelechów hackbut: 1 – middle section; 2 – transition zone between the outer casing and the 'core'; 3 – internal section. Photo: Z. Hensel

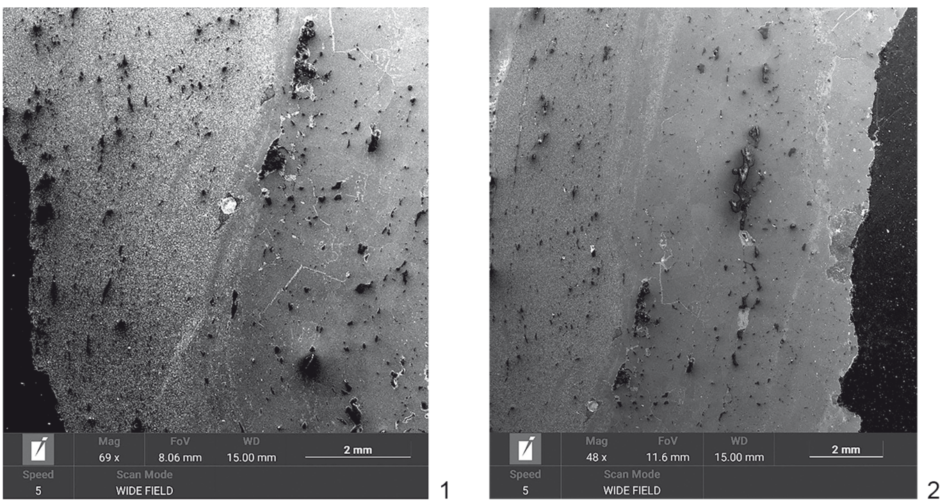


Fig. 11. Structure of the Żelechów hackbut: 1 – external section; 2 – internal section. Photo: Z. Hensel

Metallographic observations revealed that the barrel was forged from an iron-carbon alloy with a variable carbon content, ranging from trace amounts to approximately 0.2%. A higher carbon content, with ferrite-pearlite structures, was observed in the outer part of the barrel. At the same time, the core consisted of ferrite structures with a high phosphorus content (Fig. 9). No weld lines indicating the joining of multiple iron bars were detected. However, scattered non-metallic slag inclusions were observed, probably resulting from the metallurgical process and the inherent brittleness of the high-phosphorus raw material. This type of structural variability was also noted in other sections of the analysed fragment (Figs 10: 1-3).

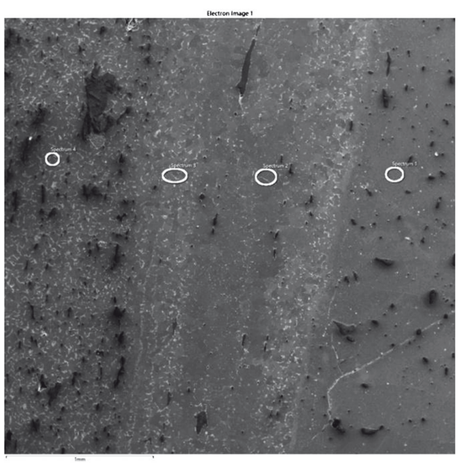
The microhardness tests revealed the highest values in ferritic iron, reaching 274 HV0.1, while areas containing pearlite exhibited a hardness of 164 HV0.1. The high local microhardness of the analysed structures was caused by a significant phosphorus content, with measurements indicating a local increase up to 0.93%, while the minimum recorded content was 0.05% (see Table 1). The heterogeneity of the structural and chemical composition was further confirmed by scanning electron microscope analyses (Fig. 11: 1, 2). The considerable variation in phosphorus content resulted in a high degree of variability in the mechanical properties of the material used (Okamoto 1990; Stewart *et al.* 2000). The observed physicochemical characteristics and the nature of the non-metallic inclusions indicate that the metal was produced using the bloomery smelting technique. It is worth noting that high-phosphorus steel is brittle and lacks impact resistance. This characteristic may have been a direct cause of the characteristic fracture observed in the damaged hackbut, where the fibrous structure of the break is clearly visible.

The production of iron barrels for handheld firearms, as well as smaller-calibre artillery pieces (*e.g.*, terrace guns, light field cannons, and veuglaires), did not present significant technical challenges. The process primarily involved shaping a cylindrical or polygonal barrel from either a single thick iron bar or several thinner iron bars, which were forged around an iron mandrel (Smith 2000, 72-74, fig. 13). Written sources provide evidence of such mandrels used in barrel production, for example, in Görlitz (Zgorzelec), where in 1424, a payment of six groschen was made for an item referred to as a 'kerneysen', probably a mandrel used for shaping gun barrels (Strzyż 2014, 235). The final processing of an iron-forged handheld firearm barrel required the addition of several auxiliary components (*e.g.*, front sight, rear sight, and hook), which were then assembled with the barrel to form a functional unit. The crucial step was sealing the breech section of the barrel with a tenon, which was then securely hammered into place. This tenon is clearly visible in the breech section of the Żelechów barrel. Similar traces of this manufacturing process can also be observed in a hackbut housed in the Hungarian National Museum in Budapest (Strzyż 2014, 235, cat. no. 175, pl. 37: 5).

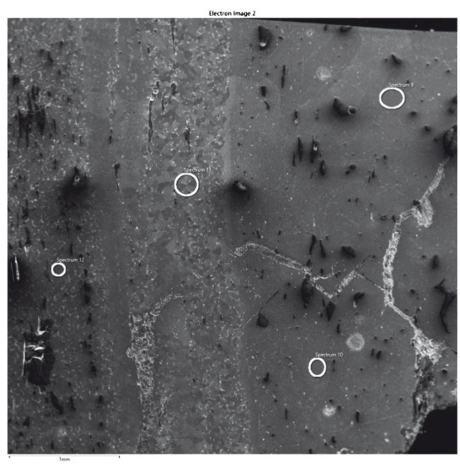
Spectrometric analysis of the Żelechów barrel fragments revealed that the material used for production was almost pure iron (Fe) with minor additions of carbon (C), phosphorus (P), and trace amounts of other elements (see Table 1). This composition is typical

Table 1. Results of the spectrometric analysis of the Żelechów hackbut (wt%). Prepared by P. Gan and Z. Hensel

Spectrum 1	Line Type	Wt%	Wt% Sigma		Spectrum 9	Line Type	Wt%	Wt% Sigma
Al	K series	0	0,01		Al	K series	0,13	0,07
Si	K series	0,04	0,01		Si	K series	0,08	0,06
P	K series	0,8	0,01		P	K series	0,93	0,06
S	K series	0,01	0,01		S	K series	0	0,05
Ti	K series	0	0,01		Ti	K series	0	0,06
Cr	K series	0,01	0,01		Cr	K series	0,03	0,06
Mn	K series	0,02	0,02		Mn	K series	0	0,08
Fe	K series	99,11	0,03		Fe	K series	98,82	0,13
Spectrum 2	Line Type	Wt%	Wt% Sigma		Spectrum 10	Line Type	Wt%	Wt% Sigma
Al	K series	0	0,01		Al	K series	0,03	0,06
Si	K series	0,06	0,01		Si	K series	0,32	0,06
P	K series	0,34	0,01		P	K series	0,88	0,06
S	K series	0,01	0,01		S	K series	0	0,05
Ti	K series	0	0,01		Ti	K series	0	0,05
Cr	K series	0	0,01		Cr	K series	0,01	0,05
Mn	K series	0,01	0,02		Mn	K series	0	0,08
Fe	K series	99,59	0,03		Fe	K series	98,75	0,12
Spectrum 3	Line Type	Wt%	Wt% Sigma		Spectrum 11	Line Type	Wt%	Wt% Sigma
Al	K series	0	0,01		Al	K series	0	0,06
Si	K series	0,04	0,01		Si	K series	0,23	0,06
P	K series	0,14	0,01		P	K series	0,17	0,05
S	K series	0	0,01		S	K series	0,02	0,05
Ti	K series	0	0,01		Ti	K series	0,01	0,06
Cr	K series	0,01	0,01		Cr	K series	0	0,06
Mn	K series	0,01	0,02		Mn	K series	0,04	0,08
Fe	K series	99,8	0,03		Fe	K series	99,53	0,14
Spectrum 4	Line Type	Wt%	Wt% Sigma		Spectrum 12	Line Type	Wt%	Wt% Sigma
Al	K series	0,01	0,01		Al	K series	0	0,07
Si	K series	0,05	0,01		Si	K series	0,15	0,06
P	K series	0,05	0,01		P	K series	0,05	0,05
S	K series	0,01	0,01		S	K series	0,03	0,05
Ti	K series	0	0,01		Ti	K series	0,04	0,05
Cr	K series	0	0,01		Cr	K series	0	0,05
Mn	K series	0,01	0,02		Mn	K series	0	0,08
Fe	K series	99,87	0,03		Fe	K series	99,72	0,1



Structure of the hackbut with marked measurement points for chemical composition analysis (1–4)



Structure of the hackbut with marked measurement points for chemical composition analysis (9–12) of such products, which did not require the complex forging techniques employed in the manufacture of bladed weapons (*e.g.*, welding iron and steel bars, applying hardened overlays, or tempering). In the case of iron barrels, usually forged from soft ferritic iron, a certain degree of elasticity was even desirable. However, the key factor influencing barrel quality was the care taken in preparing the material. These firearms often contained a high concentration of non-metallic impurities (*e.g.*, phosphorus, potassium, and sulphur), which could serve as potential sites for microcracks and fissures. Specialist analyses of comparable finds confirm the presence of such defects. Although such studies are relatively rare, the available results are consistent in their general findings. For instance, the barrel from Ostrožská Nová Ves (Czech Republic), dated to the late 14th century, was forged from high-purity iron (Fe 99.82%) with trace amounts of manganese (Mn 0.05%), phosphorus (P 0.08%), and a low carbon content (C 0.05%). Analysis of the manufacturing technique revealed that the material was forge-welded at approximately 720°C, resulting in minimal deformation during subsequent cooling. The low carbon content resulted in a soft, ferritic structure. Overall, the weapon was produced from ore specifically selected to avoid sulphur contamination and minimise phosphorus content, leading to a high-quality final product (Ustohal *et al.* 1991-1992, 159-164, figs 4-7; Fligel' *et al.* 2010, 483, 485). A chronologically closer example to the Żelechów specimen is a hackbut barrel from Helfštýn Castle (Czech Republic), dated to the late 15th-early 16th centuries. Only the muzzle section with the hook has survived. Analysis of its surface revealed two areas with slightly different structures. The first was characterised by a uniform ferritic structure with a high phosphorus content (P 0.5-0.6%) and a hardness of 161±14 HV0.1, while the second was characterised by a ferrite-pearlite structure (C 0.2-0.3%), where a 4.2 mm-long crack was observed. As is well known, high phosphorus content in iron is highly detrimental, as it increases brittleness and susceptibility to cracking. The maximum acceptable phosphorus content that does not negatively affect material quality should not exceed 0.1%. Elevated phosphorus levels in iron could result from the use of hardwood charcoal in the smelting process and the reliance on bog ores. The Helfštýn barrel was forged at temperatures exceeding 950°C, which influenced its final quality. At such high temperatures, phosphorus diffused into the ferritic structures of the barrel, leading to the formation of microcracks during cooling. Continued use of the firearm would have progressively enlarged these cracks, eventually causing catastrophic failure (Fligel' *et al.* 2010, 481-483, 457, figs 9-11; Strzyż 2014, 237; Žákovský and Schenk 2017, 45, 127, cat. no. 254). Structural analysis was also performed on a hackbut barrel from Esztergom Castle (Hungary), dated to the late 15th-early 16th centuries. The chemical composition of the sample indicated a ferrite-pearlite structure (C 0.2-0.3%), with an average hardness of approximately 167 HV0.1 (Strzyż 2014, 238, cat. no. 146, pl. 33: 4-6). These values are consistent with those observed in other hackbuts and iron artillery barrels from the 15th-16th centuries. Similar results were obtained from the analysis of two iron veuglaire (chambered-gun) barrels housed in the Museum of Biecz. The barrels were made of iron with a ferritic and ferrite-pearlite structure, with a high content of non-metallic impurities. The final hardness of the specimens was measured at 141 HV0.1 and 158-181 HV0.1 (see Klimek *et al*. 2013, 88-92, figs 4-16; Strzyż 2014, 235-236, cat. nos 103 and 104, pls 98 and 99; Smith and Brown 1989, 90-102, figs 73-83; Lazar 2015, 242-269, figs 73-97).

CONCLUSIONS

Despite the highly fragmented nature of the discovered barrel remains from Żelechów, the gathered evidence strongly suggests that it belonged to a firearm of the hackbut type. The form of its breech section allows it to be dated to approximately the first half of the 16th century, although the possibility of prolonged use cannot be excluded. This find represents one of the few examples of such firearms discovered through systematic archaeological excavations in Poland. Based on comparative material, it is estimated that the original barrel measured approximately 100 cm in length and had a calibre of 1.9 cm. This was not a particularly heavy weapon; its weight probably ranged between 4-5 kg, and when fitted with a stock and additional accessories (*e.g.*, a ramrod mounted on the side of the stock),

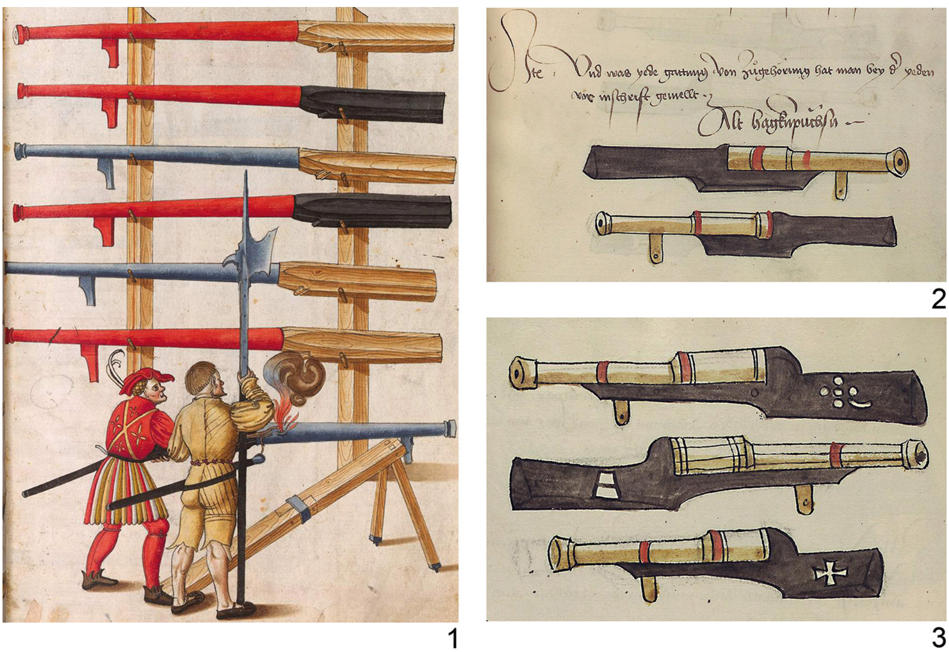


Fig. 12. Examples of hackbuts from the turn of the 16th century. 1. Innsbruck (c. 1502). Source: Zeugbuch Kaiser Maximilian I, Bayerische Staatsbibliothek, Cod. icon. 222, fol. 73. 2 & 3. Landshut (c. 1485). Source: Ulrich Beßnitzer, Zeughausinventar von Landshut, Universitätsbibliothek Heidelberg, Cod. Pal. Germ. 130, fol. 36v and 38r

it may have weighed around a kilogram more (Fig. 8). This made it significantly more mobile than heavier, longer, and more massive wall-mounted firearms, which typically required a support, such as a fortification wall. The specialist analyses revealed that the barrel of this hackbut was poorly manufactured, and the material contained high levels of phosphorus (up to nearly 1%). This highly undesirable characteristic increased brittleness and reduced the barrel's resistance to the high pressures of gunpowder gases. It is possible that these flaws in craftsmanship contributed to an explosion that ultimately destroyed the firearm.

Due to limited written sources, it remains uncertain who used this firearm and during what period. However, one possibility is that it was employed in the first quarter of the 16th century, during the family conflict and armed attempt by Jan Ciołek to reclaim the castle from Feliks of Zielonka, the 'starost' of Łuków. The intervention of the local 'pospolite ruszenie' (noble levy), as recorded in the 1523 entry, suggests a likely timeframe for the use of this firearm by the garrison occupying the fortalice. It is known that this was not the only firearm used at the site. A stone cannonball was found inside a building uncovered in the castle courtyard, dated to the late 15th – first half of the 16th centuries.

The possibility that this hand-held firearm was used at a later date cannot be ruled out either. Layers of burning were identified in most of the archaeological trenches, indicating a fire that destroyed the castle buildings in the second half of the 16th century. Whether this fire resulted from accidental ignition or was a consequence of defensive actions remains unknown at this stage of research.

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