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MODERN FLINT MINING LANDSCAPES AND FLINT KNAPPING EVIDENCE FROM THE KRAKÓW GUNFLINT PRODUCTION CENTRE – WHAT WE KNOW FROM LIDAR AND FIELD SURVEY

ABSTRACT

Szubski M., Niebylski J., Gruzdz W., Jakubczak M. and Budziszewski J. 2022. Modern flint mining landscapes and flint knapping evidence from the Kraków Gunflint Production Centre – What we know from LiDAR and field survey. *Sprawozdania Archeologiczne* 74/1, 247-268.

We know that on the Polish territories that belonged to Austrian and Russian Empires, from the second part of the 18th till the 19th centuries, gunflint workshops were operating. One of the workshop centres were situated in the Kraków region (southern Poland) and others were located in the regions of Ivano-Frankivsk (Ukraine, former Austrian monarchy) and Kremenets (Ukraine, former Russian monarchy). The number of workshops, the quantity of products and their export gave them significance on a European scale. We used several methods to preliminary investigate the area near Kraków using LiDAR and field verification. We analysis three modern flint mines in this region – Zelków, Karniowice and Mników which have preserved anthropogenic relief and well-preserved flint workshops on the surface. Flints obtained during field verification (studies included a sets of cores and technological blanks) were analyzed. Our efforts allowed us to attempt to recreate the chaîne opératoire for Polish gunflint workshops as well to determine differences between particular sites.

Keywords: conflict archaeology, flint mining, gunflints, Lesser Poland, modern period

Received: 07.02.2022; Revised: 25.05.2022; Accepted: 16.10.2022

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INTRODUCTION

When the archaeological scientific community was crystallising in Kraków in the mid-19th century (Chochorowski 2015; Woźny and Dziegielewski 2017 (2018); Woźny 2018), gunflint workshops near the city were still functioning. In the archives of the Archaeological Museum in Kraków, there is a note about them from 1871 by Józef Łepkowski, and the Museum's collection includes a collection of flint products from Żelków, Kraków district (Łepkowski 1871). However, for many decades, they did not attract any more interest from archaeologists. It was only in 1964 that Bolesław Ginter and Stanisław Kowalski published their short study on the production of gunflints and their importance for the cognition of prehistoric flint-knapping (Ginter and Kowalski 1964). That publication did not bring about the revival of interest in the subject and the information on modern flint mines in Żelków remained an open secret exclusively for the Kraków community of Stone Age researchers for the following decades. A similar fate befell the modern flint mine in Mników, Kraków district, which was discovered by Krzysztof Sobczyk during the excavations conducted in Brzoskwinia, yet was not published either. Information on the modern mining of Jurassic flints from the vicinity of Kraków was ignored even in monographic studies devoted to it (Kaczanowska and Kozłowski 1976). The precise location of the site from Żelków was published only thanks to the surface research of Jacek Lech's team conducted in the Prądnik basin and in the neighbouring areas in the years 1976-1980 (Lech *et al.* 1984, 235, 236). However, fieldwalking conducted in the framework of the research project known as the Polish Archaeological Record (Polish name: Archeologiczne Zdjęcie Polski – AZP) conducted a decade later by Jacek Górski and Mirosław Zajac, which was archived on the Archaeological Site Record Sheet (Polish abbreviation: KEZA) and accompanying documentation as Site 1 in Żelków (region number: 100-55, site 94), signalled again problems with the precise determination of the boundaries of the site and the need for carrying out comprehensive research there. Concurrently, publications appearing in foreign literature emphasised the importance of gunflint production from the vicinity of Kraków (Slotta 1981, 351, 352; Cheben and Struhár 1999).

In the Kraków community, only Anna Dagnan-Ginter (Dagnan-Ginter *et al.* 1992) and Bolesław Ginter (2009; 2015) consistently published further materials related to modern flint production. In more recent times, Jerzy Libera from the Maria Curie-Skłodowska University in Lublin has also become interested in gunflints (*e.g.*, 2014; 2015; Mączyński and Libera 2015), which resulted, among other things, in Marek Lalak's master's thesis (2006). In the international environment, the organization of an informal research group devoted to gunflint production by Torben Bjarke Ballin (2013) brought a significant revival of work on this issue. During their visit to Poland in April 2013, Austrian researchers, Gerhard Trnka and Michael Brandl, drew attention to the need for intensifying the research carried out on the gunflint production centre near Kraków (Fig. 1).

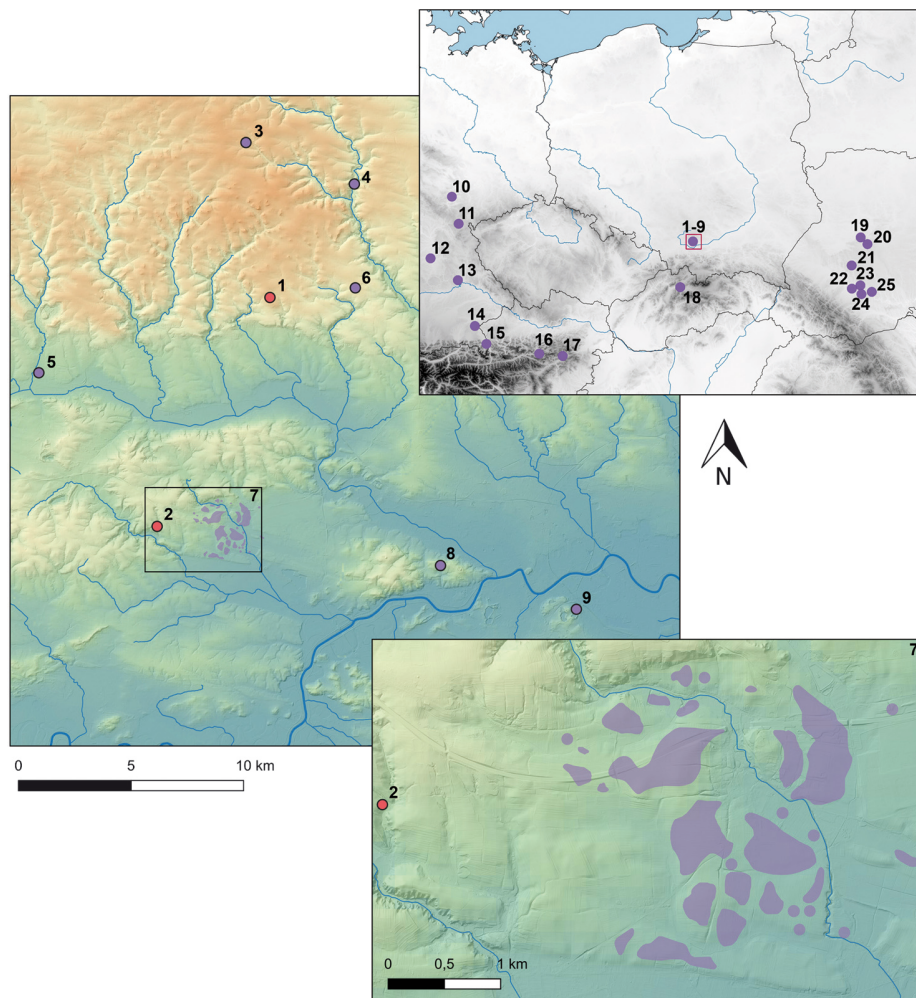


Fig. 1. Upper – location of gunflint production sites in Central Europe; middle – location of gunflint production sites in the area of the Kraków Gunflint Production Centre; lower – the area of sites related to gunflint production, discovered during the AZP research project in the region of Morawica. Key: 1 – Karniowice and Zerków flint mines and the Bolechowice, Karniowice and Zerków workshops (Poland), 2 – Mników flint mine (Poland), 3 – Sąspów workshop (Poland), 4 – Ojców workshop (Poland), 5 – Dębnik and Paczółtowiec (Krzeszowice) workshops and flint mine (Poland), 6 – Duża Cave in Mączne Skąły (Wielka Wieś) workshop (Poland), 7 – Aleksandrowice, Chrosna and Mników workshops and the Morawica workshop and flint mine (Poland), 8 – Kraków-Zwierzyniec workshop (Poland), 9 – Kraków-Podgórze flint mine (Poland), 10 – Wiederau (Rochlitz) agate mine (Germany), 11 – Schneeberg workshop (Germany), 12 – Nuremberg workshop (Germany), 13 – Burglengenfeld workshop and flint mine (Germany), 14 – Halsbach agate mine (Germany), 15 – Glasenbach workshop (Austria), 16 – Seewiesen flint mine (Austria), 17 – Gams bei Hieflau flint mine (Austria), 18 – Bešeňová workshop (Slovakia), 19 – Sapaniv workshop and flint mine (Ukraine), 20 – Kremenets workshop (Ukraine), 21 – Berezhany workshop (Ukraine), 22 – Nyzhniv workshop and flint mine (Ukraine), 23 – Mariyampil flint mine (Ukraine), 24 – Nezvysko workshop (Ukraine), 25 – Dolyna flint mine (Ukraine). Map projected by J. Niebylski, drawn by M. Jakubczak

The Warsaw community had already been working for two years on the use of airborne laser scanning for the identification of sites related to the exploitation of flint (Budziszewski *et al.* 2019). Thus, when the ISOK (IT system for protection against extraordinary hazards) scans of the neighbourhood of Kraków were made available, the area of interest also included the remains of the modern flint mining from that region. The analyses of the digital terrain model were supplemented with fieldwork surveys in the forest between Zerków and Karniowice in March and December 2014, and the outcomes of those works were presented at the international symposia in Barcelona in 2015 (Budziszewski *et al.* 2015) and Spiennes in 2016 (Budziszewski *et al.* 2019). At the same time, work on gunflint in the region near Kraków was started by Jakub Niebylski, who in 2013-2014 was preparing a pro-seminar and then a master's thesis at the Institute of Archaeology of the Jagiellonian University in Kraków (Niebylski 2017b). Therefore, it was decided to join efforts by conducting another series of field surveys in the Karniowice forest and Mników in the spring of 2017. The results of those works were summarized by organizing a session "Gunflints: production, distribution and use" with researchers from Austria and Belgium, as part of the 23rd Annual Meeting of the European Association of Archaeologists, held in Maastricht in 2017 (*e.g.*, Jakubczak *et al.* 2017; Niebylski 2017a), whereas their Polish abstract was presented a few weeks later at the conference "Jurassic Flint in prehistory" in Kraków. Independent research on materials from Zerków from the collection of the Archaeological Museum in Kraków was carried out in 2016 by the team of Dagmara Werra (Werra *et al.* 2019). In 2018-2021, the work was continued by Jakub Niebylski as a research task "Galician gunflint production centres", carried out as part of the scientific plan of the Institute of Archaeology and Ethnology, Polish Academy of Sciences.

GUNFLINTS AND THE HISTORICAL BACKGROUND OF THEIR USAGE

A gunflint is a fragment of flint, or another rock or mineral of appropriate hardness, processed suitably by splitting or grinding. It allows a spark to be struck after hitting or rubbing it against a steel frizzen, which is an element of a firearm lock, and thus ignites the material on its pan (Niebylski 2018a, 61). It was mounted in the flintlock of hand firearms, in order to strike sparks igniting the charge of fine black powder placed on the pan, transferring the flame through the touch hole to the barrel, enabling the combustion of the main propellant charge (coarse black powder) in the barrel, the increased pressure of the combustion products of which expelled a projectile (Fig. 2: C; Niebylski 2018a, 61). They were made of lead, and in the absence of regulatory wraps, fragments of leather, a flattened lead bullet, paper from a cartridge and birch wood were also used as packing (Badzińska 2016, 18; Krajewski 2017, 339; Niebylski 2018a, 61).

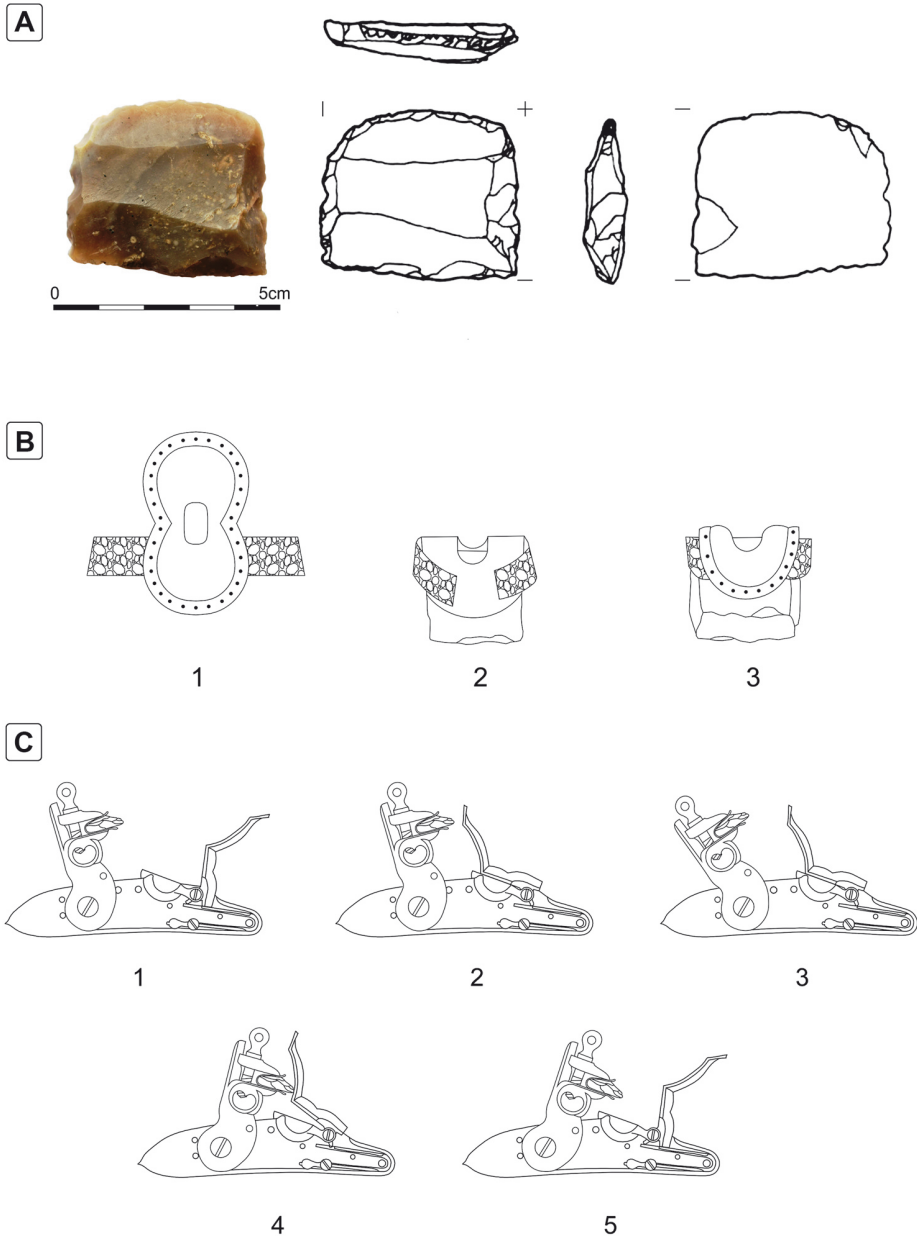


Fig 2. A – Gunflint found during excavation at Rabin Beer Meisels street in Kraków. Photo and drawn by J. Niebylski. B – a lead gunflint wrap and how to properly assemble it. 1. The unfolded wrap, 2. the lower surface of the gunflint with the mounted wrap, 3. the upper surface of the gunflint with the mounted wrap. After Maciejewski 1980, 138. C – The principle of operation (1-5) of the flintlock. Designed by J. Niebylski, drawn by K. Rosińska-Balik

Gunflints were initially made on flakes, and in the course of time, they began to be made on broken blades. The production of gunflints with the use of a newer technique was carried out by the splitting method – in the British and French tradition, and by grinding – in the German tradition (Skertchly 1879, 41-64; Witthoft 1970, 33, 34, 36, 37, 43, 46; Brandl 2013, 139-143; von Kaiser 2013). In Galicia, for the needs of the Austrian Empire's army, gunflints were made in accordance with the French tradition, and in horizontal projection, they were similar to the shape of a horseshoe (Niebylski 2018a, 69). They were different in size in order to optimally match the size of the lock of the weapon – the width of both the pan and frizzen, as well as the distance between their axes and the barrel. Russian gunflints have a cross-section more similar to a trapezoid (Brandl and Niebylski 2019).

The flintlock was used until the end of the first half of the 19th century, when it was replaced with a percussion lock as a result of rearming the armies with a new weapon (Maciejewski 1980, 13; Niebylski 2018a, 57, 71). Gunflints were stored as military reserves for a while, and then that stock was disposed of. The evidence of such activities are the deposits of discarded gunflints discovered at the Neugebäude Castle in Vienna, the Zamość Fortress, the Modlin Fortress, and the Olomouc Fortress (Penz and Trnka 2004; Libera 2014; 2015, 218, 219; Brandl and Niebylski 2019). After rearming the armies of Western and Central European countries, the weapon using the gunflint lock was still used for civilian purposes, mainly hunting and recreation, as well as being exported to other countries, whose armies were armed with inferior firearms (Barandiarán 1974, 196-197; Slotta 1981, 359; de Latour 2009, 76).

After firearms using a flint lock for ignition had become popular in the 17th century, gunflints were produced individually by their users and were not standardized. A metal hammer was utilised to form them (Brandl 2013, 139). In France, such production was certified in 1643 in the Meusnes area (Loir-et-Cher dep.), while in England in 1686, in the Brandon region (Suffolk County), yet it was not carried out continuously (Skertchly 1879, 3; Witthoft 1970, 43; Weiner 2012, 969).

More or less at the onset of the 1740s, the method of producing gunflints formed from broken blades became popular in the Meusnes region (Witthoft 1970, 34, 36; Weiner 2012, 969). The military specimens had one striking edge and a horseshoe shape provided by retouching three tangent edges. At that time, the share of production intended for the civil market and export was significant (Brandl 2013, 139, 143). That method was adopted around the beginning of the 1790s in the Brandon area (Weiner 2012, 969). Those gunflints had one impact edge, and the remaining edges were formed into a rectangular shape at the stage of breaking the semi-finished product. Contrary to the situation in France, English gunflints were produced exclusively for the needs of their own army (Brandl 2013, 142, 143).

Before 1790, Austria ordered 10 million gunflints a year in France, the cost of which was 20,000 florins (Raymond and Roth 1809, 96, 157; von Keess 1824, 621). Due to the need for becoming independent from importing that strategic product, the Archduke of

Austria, Joseph II Habsburg, issued an appeal on September 10, 1787, in which he promised to transfer a prize of 100 ducats to a person who would find suitable flint outcrops in the country and set up a gunflint factory, as well as additional gratification of 200 ducats for maintaining production (Vollständige... 1789, 450; Hacquet 1792, 63). This was realised in 1787 in Nyzhniv (Ivano-Frankivsk Oblast) in today's Ukraine, where traces of mining have been preserved until now (Brandl *et al.* 2019, 38). In 1788, a total of 200,000 gunflints were produced, 40-50,000 of which were sold to the civil market (Hacquet 1792, 58).

Shortly after the establishment of the centre in Nyzhniv, more factories were opened in that area, as well as in the Kraków region. They form two clusters – the Kraków Gunflint Production Centre near Kraków (Kraków district) and the Ivano-Frankivks Gunflint Production Centre (Ivano-Frankivsk and Ternopil Oblasts), where gunflints for the needs of the Habsburg Monarchy were produced (Fig. 1; Niebylski 2017a, 323; 2018b, 48-49; Budziszewski *et al.* 2019, 40). The third source of gunflint production for the needs of Habsburg armies was the region of Verona (Veneto region) in Italy (Brandl 2013, 148-156).

The region of gunflint production near Ivano-Frankivsk includes, among others, such places related to the production of gunflints as: Berezhany, Dolyna, Mariyampil, Nezvysko and Nyzhniv (Niebylski 2018a, 70, 72). Close ties between these localities are noticeable. The production from Berezhany was moved in 1803 to the factory in Nyzhniv due to unfavourable climatic conditions (Hacquet 1806). Until 1817, the workshop in Nyzhniv had been supplied from the raw material extraction site in Mariyampil (von Thielen 1827, 177).

In the Kraków region, the following places are associated with producing gunflints: Aleksandrowice, Bolechowice, Chrosna, Dębnik, Karniowice, Kraków-Podgórze, Kraków-Zwierzyniec, Krzeszowice, the Duża Cave in Mączne Skały, Mników, Morawica, Ojców, Paczółtowie, Sąspów, Wielka Wieś and Zelków (Kolberg 1871, 40; Dryja 2005, 68; Ginter 2009, 346; 2015, 288; Niebylski 2018a, 67, 68). Only some of them are mentioned in written sources, while others are known thanks to archaeological data. Among the ones that were mentioned in the historical sources were some gunflint production in Kraków-Zwierzyniec – “between Kraków and Bielany” (Kołaczkowski 1888, 519; Schnür-Peplowski 1896, 127), Kraków-Podgórze (Hacquet 1792, 40, 41, 61; 1796, 79, 80; 1806, 5, 6, 16; Raymond and Roth 1809, 157; von Keess 1824, 492), Krzeszowice (Bredetzky 1811, 416; von Hoyer 1831, 204, 205; Kolberg 1871, 40) and Morawica (von Oeynhausens 1822, 266-267; Umiński 1879, 7). It is Morawica, indeed, that appears to have been a large centre of gunflint production, well accessible archaeologically. The following villages around it: Aleksandrowice, Chrosna, Mników and also Morawica have produced numerous surface discoveries of gunflint production waste, which, however, should be referred to the centre in Morawica (Fig. 1; Niebylski 2018a, 67-68). In addition, the flint mine in Mników was probably the raw material base for that workshop. On the other hand, the following places: Bolechowice, Karniowice, the Duża Cave in Mączne Skały, Ojców, Sąspów and Wielka Wieś form a distinct cluster near Zelków, where gunflints were produced in home workshops. The villages of Dębnik and Paczółtowie, where home workshops could be found as well, are located

quite close to Krzeszowice; therefore, they should probably be referred to the factory mentioned in the sources, the operation of which in 1811 has been confirmed (Bredetzky 1811, 416; von Hoyer 1831, 204-205; Kolberg 1871, 40).

Among these sites, the places of the extraction of the raw material are the mining fields visible in the terrain and located in Mników, Karniowice and Zelków (Jakubczak *et al.* 2017, 324; Niebylski 2018a, 67, 68; Budziszewski *et al.* 2019, 17). The sources also mention a flint mine located in the mountains in the Morawica region, where there were 2-3 slightly recessed shafts, from which the raw material was extracted for the needs of that workshop (von Oeynhausen 1822, 266, 267). Most likely, this information is related to the mining field in Mników.

In the case of some sites, the names of their managers are known. The workshop in Kraków-Zwierzyniec was established by the mining counsellor Wampe and the postmaster Reichendorfer from Wieliczka (Kołaczkowski 1888, 519). Moreover, in 1811, Wampe owned a workshop in Krzeszowice (Bredetzky 1811, 62). Another owner of the workshop in Kraków-Zwierzyniec is also known. It was Sperling, a German colonist and the owner of a nearby lime kiln, as well as the coal mine in Jaworzno, Jaworzno district (Bredetzky 1811, 62). It is highly likely that the gunflint production in other sites was accompanied by the lime industry that required significant amounts of excavated limestone material, which is a waste material in the process of extracting flint. In the light of reports, fire was used in the workshop in Krzeszowice, which perhaps should be interpreted as a working lime kiln. As stated in the note by Józef Łepkowski drawn up in 1871, the flints processed at that time in Zelków were collected by carters from Morawica (Łepkowski 1871). Perhaps those workshops were to certain extent related to each other.

The production of flint items other than gunflints is also certified in this gunflint production centre. What has been confirmed in some of them is manufacturing flints for fire strikers, a large number of which was found at the site in Aleksandrowice, as well as in the Duża Cave in Mączne Skąły, Mników and Zelków (Ginter and Kowalski 1964, 84; Dagnan-Ginter *et al.* 1992, 15; Ginter 2015, 290, 292-295).

In the factory in Kraków-Zwierzyniec, the employees were four boys aged 8 to 16 (Bredetzky 1811, 241, 242). For comparison purposes, in the workshop in Berezhan, the number of the workers ranged from 50 to 80, while in Nyzhniv there were 33 employees (Schnür-Peplowski 1896, 127; Brandl 2013, 255). Their number was related to a significant amount of gunflint production. Before 1827, two million gunflints were produced annually in Nyzhniv, while production in 1844 was 1.5 million (von Thielen 1827, 358; Brandl 2013, 256). From the Kraków Gunflint Production Centre, not only were surplus products exported to the neighbouring regions (Cheben and Struhár 1999), but also in the case of Morawica to China, Japan and America, whereas gunflints from Krzeszowice were exported to Turkey (Kolberg 1871, 40; Umiński 1879, 7). In Poland, a merchant Jan Franciszek Fiszer (1773-1815), whose shop was located in Kraków at Rynek Główny 44 also traded in gunflints (Wawel Louis 1977, 90).

The end of manufacture in the Kraków Gunflint Production Centre was a kind of slow phasing out. This was related to the lack of demand for gunflints for military purposes, after arming the army with weapon with a percussion lock, which no longer required a gunflint. Gunflint-makers, however, still produced them for the civil market for some time, while in the last period of the workshop's operation, the production of flints for fire strikers was probably significant. The workshop in Zerków was operating the longest, and production there ceased around 1880 (Ginter and Kowalski 1964, 84). The centre in Morawica was functioning before 1822, at least until 1879 (von Oeynhausen 1822, 266-267; Umiński 1879, 7). The workshop in Kraków-Podgórze was still in operation in 1871, when production in Dębnik and Paczółtowice had already been finished, and at that time its traces were waste heaps near gunflint-makers' households that had still not been removed (Kolberg 1871, 40).

DETECTION AND VERIFICATION METHODS

Thanks to the dissemination and the possibility of almost cost-free acquisition of data from airborne laser scanning, extensive prospection of forested areas has become possible, including re-analysis of the already discovered and studied sites (*e.g.* Budziszewski and Wysocki 2012; Budziszewski and Grabowski 2014; Banaszek 2015). The airborne laser scanning data used for this work were obtained as part of the ISOK project. Initially, this program assumed aerial scanning of the valleys of the main Polish rivers, but over time, its area was enlarged and at present, it covers the entire country. The data on the analyzed area were obtained in standard I that provides cloud density at the level of at least 4 points/m² (Kurczyński and Bakuła 2013). Light Detection and Ranging (abbreviation: LiDAR) has already shown its significant usefulness in the search for and the analysis of flint mining sites (Jakubczak 2012; Radziszewska 2015; Szubski 2016; Budziszewski *et al.* 2018; 2019; Sudoł-Procyk *et al.* 2018).

The acquired point cloud was reclassified with the use of the *Axelsson* algorithm in the LAStools software. The proper execution of this operation allows for a significant increase in the number of points classified as lying on the ground. In certain situations, the default classification used in the ISOK program leads to the complete erasure of archaeological features from the Digital Terrain Model (DTM), as, for instance, in the case of the megalithic cemetery in Wietrzychowo, Nidzica district (Kiarszys and Szalast 2014, 281, 282). Hence the need for reclassifying the point cloud, especially when analyzing objects poorly preserved in the terrain, such as the relics of the prehistoric (and modern) flint mining.

The topic of preparing appropriate visualizations has already been discussed in the literature several times. Nevertheless, it is worth mentioning once again that the selection of appropriate filters and settings is crucial in order to obtain as much information as possible, and the LiDAR data can be visualised in many more ways than a shaded terrain

model and its coloured version with the use of hypsometry (*cf.* Kokalj and Hesse 2017; Kiarszys and Banaszek 2017). The mine profile is a specific type of the manifestation of an archaeological site, and thus, it requires a special approach towards its visualisation. Due to the fact that the principles of operation and the capabilities of particular visualisations have frequently been widely described (*e.g.*, Kokalj and Hesse 2017), below we will present only their parameters. In the case of Karniowice, the best outcomes were obtained thanks to applying *Local Dominance* (radius: min. 10, max. 15; observer height: 1.6 m; histogram stretch: 0.85-1.2 m). For the site in Zelków, where the profile has been better preserved, the radius was lowered to 5-10, and the height of the observer was set to the default 1.7 m. The set in Mników is located on a relatively steep slope, therefore, the *Local Dominance* visualisation could not be used in this case. The best results were provided by Sky View Factor (search radius 16) and shading from 16 directions (*multi-hillshading*), the angle of incidence of light is 35 degrees.

The microtopography of the flint mine in Zelków

The mining field covers the area of approx. 1.5 ha and it has an irregular shape (Fig. 3: D). It is now entirely covered with forest. There are no visible signs of agricultural or forestry cultivation. The deep remains of cavities and distinctive waste heaps confirm its good state of preservation. The largest shaft hollows have a diameter of about 10 m, and the difference between the bottom of the hollow in relation to the top of its heap reaches up to 2 m.

Attention should be paid to the correlation of the LiDAR data with the Austrian cadastral map from the end of the 19th century (1896). After overlaying the map on the digital terrain model, it is clearly visible that some of the boundaries of the mining field coincide with the boundaries of the plots (Fig. 4), especially the eastern and south-western borders (the border of plots 226 and 228). This relationship with the cadastral boundaries clearly shows that the mining field was exploited in modern times. Referring to the French traditions, which were probably modelled on the exploitation of flint in the 18th century, those plots were leased by the owners of gunflint factories (Emy 1978, 55-57; Jamnik 1993, 31; Brandl 2013, 138). The very good preservation of the remains of the mine is further evidence of the modern origins of its profile.

The microtopography of the flint mines in Karniowice

The complex in Karniowice consists of at least three mining fields with a varied mine relief (Fig. 3). The northernmost zone (A) has an area of approx. 0.4 ha, and is covered with earthworks of a poorly visible profile (type 1 – marked in green on the map), some shaft hollows are noticeable, yet it is not feasible to analyse them in more detail. In this area, there are slight traces of forest ploughing, which certainly contributed to the destruction of the earthworks.

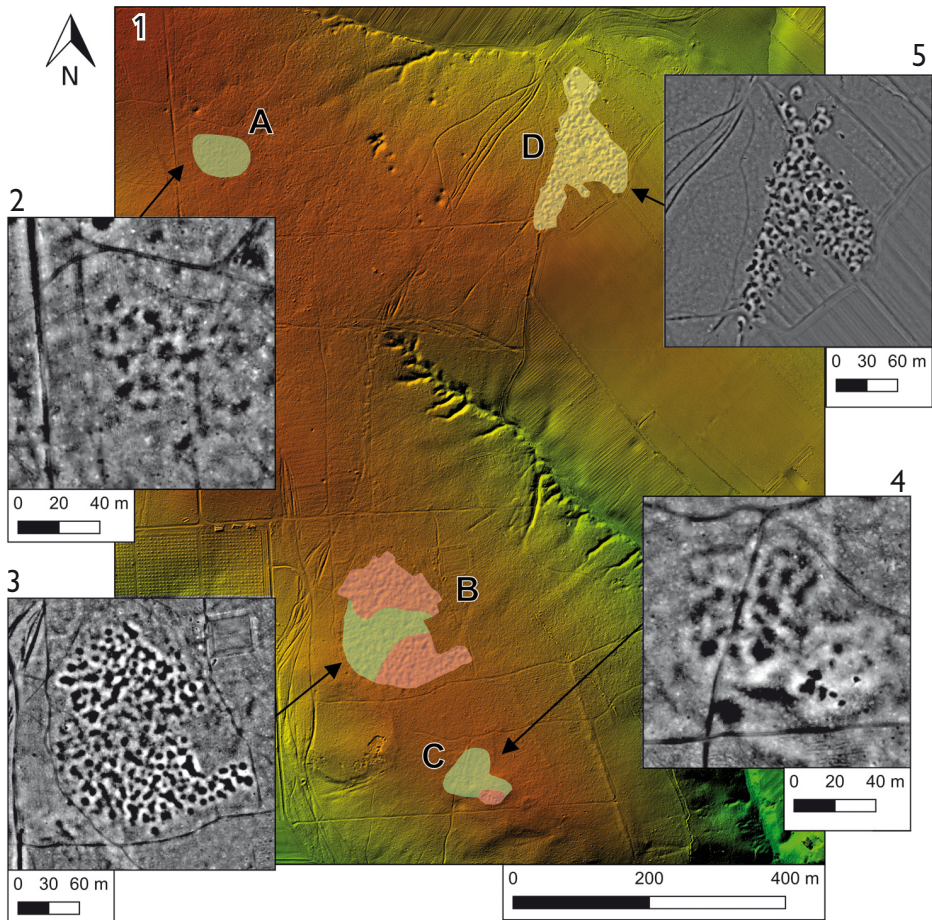


Fig. 3. Mining fields in Karniowice (A, B, C) and Zerków (D).
 Visualisations: Hillshading (1) and Local Dominance (2, 3, 4, 5). Drawn by M. Jakubczak

The central mining field (B) has an area of 2.4 ha, approximately 0.5 ha of which is covered in the central part with a more delicate relief similar to that in field A. The remaining part of the mining field is covered with a much more distinct relief (type 2 – marked in red on the map) and it consists of large (max. 8-9 m) and distinct hollows surrounded by waste heaps. The difference in the topography may result from discrepancies in the type of flint exploitation related to the use of the site in various periods, but also from the state of preservation. Although there are no visible traces of forest or agricultural ploughing, it cannot be excluded that that part of the field was partially destroyed in one way or another. In addition, it ought to be mentioned that some of the shafts, particularly in the southern part, seem to be arranged in lines, which suggests an organized exploitation.

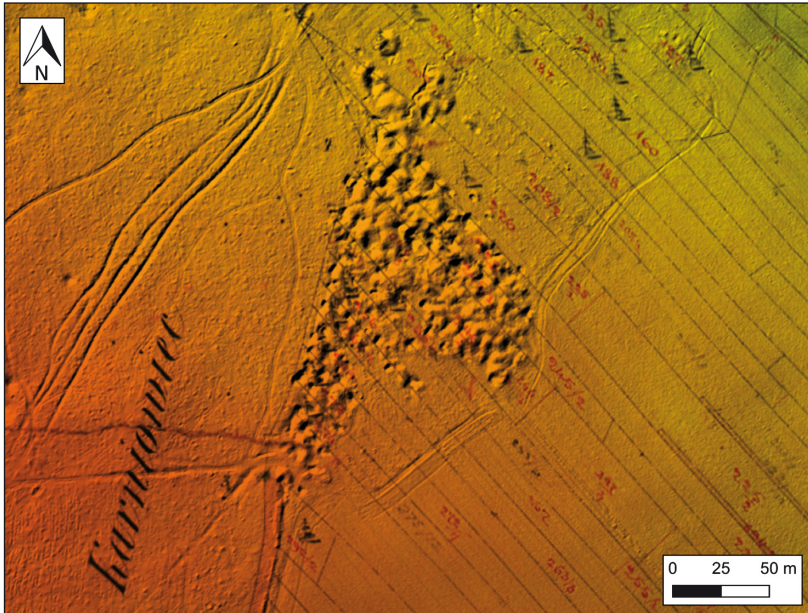


Fig. 4. Hillshaded DTM of the Żelków mining field, with overlapped 19th century cadastral map from 1896. Drawn by M. Jakubczak

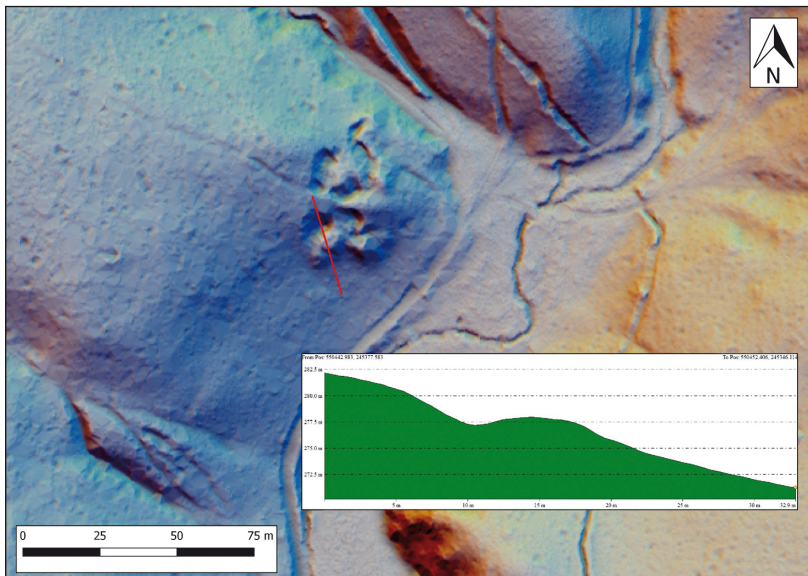


Fig. 5. Multi-hillshading of the Mników mine with a cross section of one of the shafts. Drawn by M. Jakubczak

The southern mining field (C) with an area of about 0.5 ha has mainly a type 1 profile, similar to field A, with the exception of a few shafts in its southern part. The largest of the shafts has a diameter of about 7 m. What is visible are the waste heaps. Also here, as in the case of field B, these discrepancies may result from both a divergent type of exploitation and the state of preservation.

The microtopography of the flint mine in Mników

The mining field in Mników is located on the western slope, about 15 meters above the bottom of the Pólrzeczka Gorge (Fig. 5). It consists of seven clearly visible hollows. Each of them has a heap on the side of the valley. Exploitation was carried out with the use of the quarry method, digging into the side of the slope, while the excavated material was thrown towards the slope. The small size of the site proves that the raw material was used for a short time at that point.

FIELD VERIFICATION

In the case of the airborne laser scanning method, due to possible errors in the DTM point cloud classification, the verification of all features documented by remote sensing is absolutely necessary (Holata and Plzák 2018, 33, 34). Verification is particularly vital in the case of flint mining research, as a similar profile may arise due to divergent anthropogenic or natural activities (Budziszewski *et al.* 2018, 217, 218). For this reason, the revealed features were subjected to field verification, during which the sites were measured with a handheld GPS (Global Positioning System) receiver, whereas a small sample of flint material was collected from the surface – the collected material mainly consisted of distinctive core forms and chip residues. So far, no regular surface tests aimed at obtaining a statistically significant sample of flint products have been carried out on these sites.

FLINT MATERIAL

Due to the numerous sources of the periods when they were produced, the technology of producing gunflints is well understood from the point of view of individual links in the *chain of operations*. The evidence comes from both written sources and the tradition that has survived in some parts of Europe practically to the present day. In order to represent the materials from the sites in Mników, Zelków and Karniowice, a sample of flints from the surface was collected, mainly cores and occasionally non-characteristic waste, such as flakes and blades. The technological analysis was focused on two aspects of gunflint making. First, the features of the technique were presented. Then, an attempt was made to describe

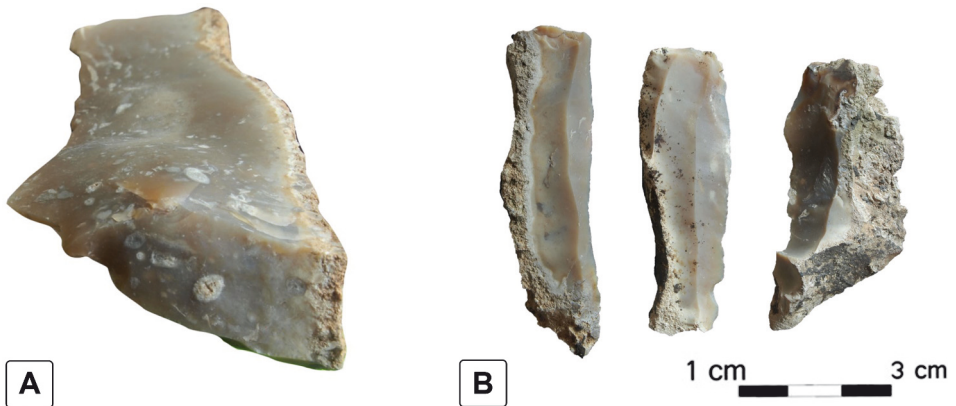


Fig 6. Blades from Zelków mining site. A – The specimen shows a large, massive butt and a well-distinct hertz cone on the bulb characteristic for hard hammer percussion. B – Specimens with cortical side. Photo by M. Szubski

knapping methods at individual sites analysed in the study – in the context of the way in which the cores were prepared and exploited.

In accordance with the state of our scientific knowledge, the gunflint making industries are the only technologies in Poland utilising steel tooling in flint production. These tools, specialized hammers, due to their hardness, left characteristic technological traces on the fragments of flint that were split off with them. The individual features listed below may appear on products and waste from other archaeological contexts, but the coexistence of most of them in the collection is a solid indication that we are dealing with modern gunflint manufacturing. Additionally, it should be emphasised that it is better to interpret the majority of technological traces from flakes and blades rather than from core forms that are frequently worn out and do not represent the middle stages of production. Gunflint production in the analysed collections is characterised by the following features: a flaking angle for obtaining blades usually around 60-80°, pronounced bulb with “ring crack” marking the point of percussion or even “errailure scar”, mostly plain butts that are wide and thick, when we compare them to the rest of the blade (Fig. 6: A) and the distal parts of the blades are usually curved. Some blades obtained from the site are characterized by the presence of the cortical surface along one of the sides (Fig. 6: B). All of them fulfil the presented morphological criteria proving the use of a steel hammer.

Flint-making methods used for the production of gunflints in the researched assemblages can be broadly divided into two groups. The first one is related to the exploitation of blades and flake material registered at the sites in Zelków and Mników. The blades were obtained from single-platform cores, prepared with one blow and most probably not rejuvenated if not needed in later stages of production. The flakes of forms in this group do not show any traces of preparation, so it should be assumed that the block was “opened” with

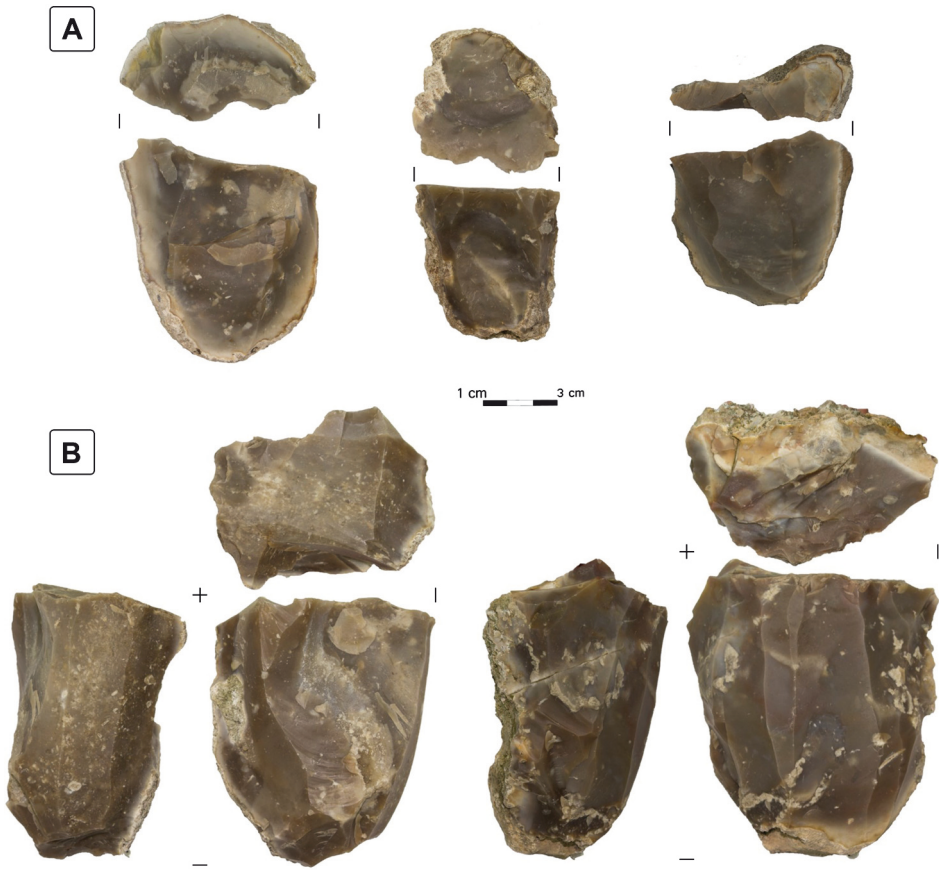


Fig. 7. Methods of obtaining blades.

A – Zelków mining site. Flint cores from described method I of obtaining blades. B – Karniowice mining site. Blade cores from described method II of obtaining blades. Photo by M. Szubski

a series of cortex blades and flakes. The coring angle on the analysed cores is sharp. The negatives on a flake are rather irregular, often with a flake morphology rather than a blade, which was arguably a desirable aim of gunflint production (Fig. 7: A).

The second core category was recorded in Karniowice (Fig. 7: B). The obtained cores are characterised by a sub-conical shape, with rejuvenated platforms and traces of negatives with a much more regular course, which makes them similar to Neolithic blade technologies (Dzieduszycka-Machnikowa and Lech 1976). On the basis of the morphology of the negatives, it can be assumed that the cores were made with the use of two techniques: hard hammer – possibly including rock hammers, and tools made of softer raw materials that could not be precisely specified. On the basis of these conclusions, several hypotheses can be formulated. The first one concerns a specific kind of palimpsest – the 19th century gunflint

makers picked up from the outcrop area and processed Neolithic cores. The second assumes connections with the *chain of operations* of Neolithic manufacturers who, in the last stages of production, processed blade cores with the use of hard hammers. That could be related to the learning process – the cores were provided to younger adepts who, for instance, learned to process them. Moreover, it could be linked with other cultural processes within those communities.

CONCLUSIONS

The preliminary research carried out allows us to conclude that the mines in Mników and Zelków are associated only with modern gunflint production. On the other hand, the complex of sites in Karniowice probably documents modern mining activity on sites used for the same purpose in prehistoric times. One of the key conclusions from the research to date on modern traces of flint mining is the uniqueness of the degree of their preservation, which should be properly conserved. Until recently, those sites had only roughly-prepared KEZAL sheets and the awareness of their location and chronology among Polish archaeologists was low.

In order to start comprehensive research on modern flint mining in the area of the Kraków Gunflint Production Centre, the following activities should be taken into consideration:

1. It is necessary to continue the research on the surface relief at the sites in Zelków and Karniowice to be able to separate the remains of the prehistoric and modern mining activities. We know from the experience of the research on the prehistoric mining field in Borownia (Radziszewska 2015; Budziszewski *et al.* 2019) that more precise scans than those performed within the ISOK project are required for this. The analysis of the profile should be supplemented with geophysical surveys, the most appropriate of which today seems to be Ground Penetrating Radar (GPR);

2. The detailed surface surveys on the mines are necessary after obtaining a precise DTM of the terrain, as well as field surveys in the vicinity of the sites in Zelków and Karniowice in accordance with the suggestions included in the AZP study. Such research will allow the identification and dating of individual workshops scattered near the mining fields;

3. It is necessary to collect and process the flint materials obtained so far from the sites of gunflint provenance, as well as conduct further technological analyzes that may shed light on the problem of the diversity of mine relief type observed by us (whether it results from chronological, technical, or another differentiation). Therefore, it is crucial to better understand the flint techniques used by historic knappers. At first sight, the question of distinguishing the prehistoric and modern techniques of flint processing with blade technology seems to be obvious. The analyzes of the material obtained from the area of the

mine, where we can find them in parallel (*e.g.*, Karniowice) demonstrate, however, that this is not such a trivial issue;

4. The identification of three regions related to the Kraków Gunflint Production Centre gives rise to the need for building a canon of physicochemical analyzes that would allow for the differentiation of products from particular regions. Such research has already been initiated (Brandl and Niebylski 2019; Werra *et al.* 2019), and with the increasing number of flint assemblages, including ready-made gunflints, it should be standardized and continued;

5. It is necessary to initiate the historical research on the problem of gunflint production at the end of the Kingdom of Poland and its evolution in the following centuries. In particular, the issues of the ownership of individual mines and plots, as well as potential locations of home workshops reached by the half-products, probably obtained from the mine.

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