Milanówek/Falęcin – a settlement of iron-smelters from the Late Antiquity

Milanówek-Falęcin – sídliště hutníků železa z doby římské

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The settlement at Milanówek/Falęcin is a part of large centre of iron production of the Przeworsk Culture, dating from the Late Pre-Roman and Roman Periods, and located in the western Masovia (central Poland). The site was discovered in the 1960s during surface surveys, and its area is estimated to 9–12 hectares. Over time, various non destructive archaeological methods have been employed at the site (e.g. aerial photography, geomagnetic surveys, advanced surface prospection), and excavations were carried out over an area of ca 1500 m². There have been found remains of nearly 1000 slag pit furnaces, 4 lime kilns, 1 'horse-shoe-shaped' kiln, 2 buildings and several pits. The excavation yielded also a large set of artefacts, of which some were subjected to expert analysis (e.g. chemical composition of slags, mineralogical composition of clay of relic of shafts). On the basis of geomagnetic surveys and excavations it is presumed that the settlement at Milanówek Falęcin may contain remains of about fifteen thousand slag-pit furnaces.

Przeworsk culture – iron metallurgy – Roman Period

Osídlení v Milanówek-Falęcinu bylo součástí rozsáhlého centra výroby železa převorské kultury, nacházející se v západním Mazovsku (střední Polsko) a pocházející z pozdního předřímského a římského období. Lokalita byla objevena v šedesátých letech 20. století pomocí povrchových průzkumů a její plocha se odhaduje na 9–12 hektarů. V průběhu času byla lokalita zkoumána různými nedestruktivními archeologickými metodami (např. letecké snímkování, geomagnetické průzkumy, povrchová prospekce), výkopové práce byly provedeny na ploše ca 1500 m². Odkryty byly relikty téměř tisícovky pecí se zahloubenou nístějí, čtyři vápenické pece, pec ve tvaru podkovy, stopy dvou nadzemních staveb a několik jam. Výkopy přinesly také velký soubor artefaktů, z nichž některé byly podrobeny odborné analýze (např. stanovení chemického složení strusek a mineralogického složení hlíny reliktů šachet pecí). Na základě geomagnetických průzkumů a výkopů se předpokládá, že osídlení v lokalitě Milanówek-Falęcin může obsahovat pozůstatky zhruba patnácti tisíc pecí se zahloubenou nístějí.

převorská kultura – metalurgie železa – doba římská

In the late 1960s and early 1970s, a cluster of settlements of the Przeworsk Culture dating to the Late Pre-Roman Period and the Roman Period (2nd century BC – 4/5th century AD) was discovered in the western Mazovia (central Poland). It was a result of a comprehensive field survey programme known as Archeologiczne Zdjęcie Mazowsza i Podlasia (Archaeological Map of Mazovia and Podlachia). A dense concentration of around 240 archaeological sites, spread across the area of approx. 300 km², where traces of an extensive iron production were uncovered, was registered in the eastern part of the cluster (*fig. 1*). This concentration is called the Mazovian Centre of Metallurgy.

Surface surveys allowed to determine territorial borders and structure of this phenomenon as well as to distinguish from within hundreds of newly discovered sites those of key importance for identifying the characteristic features of local settlement. A selected number

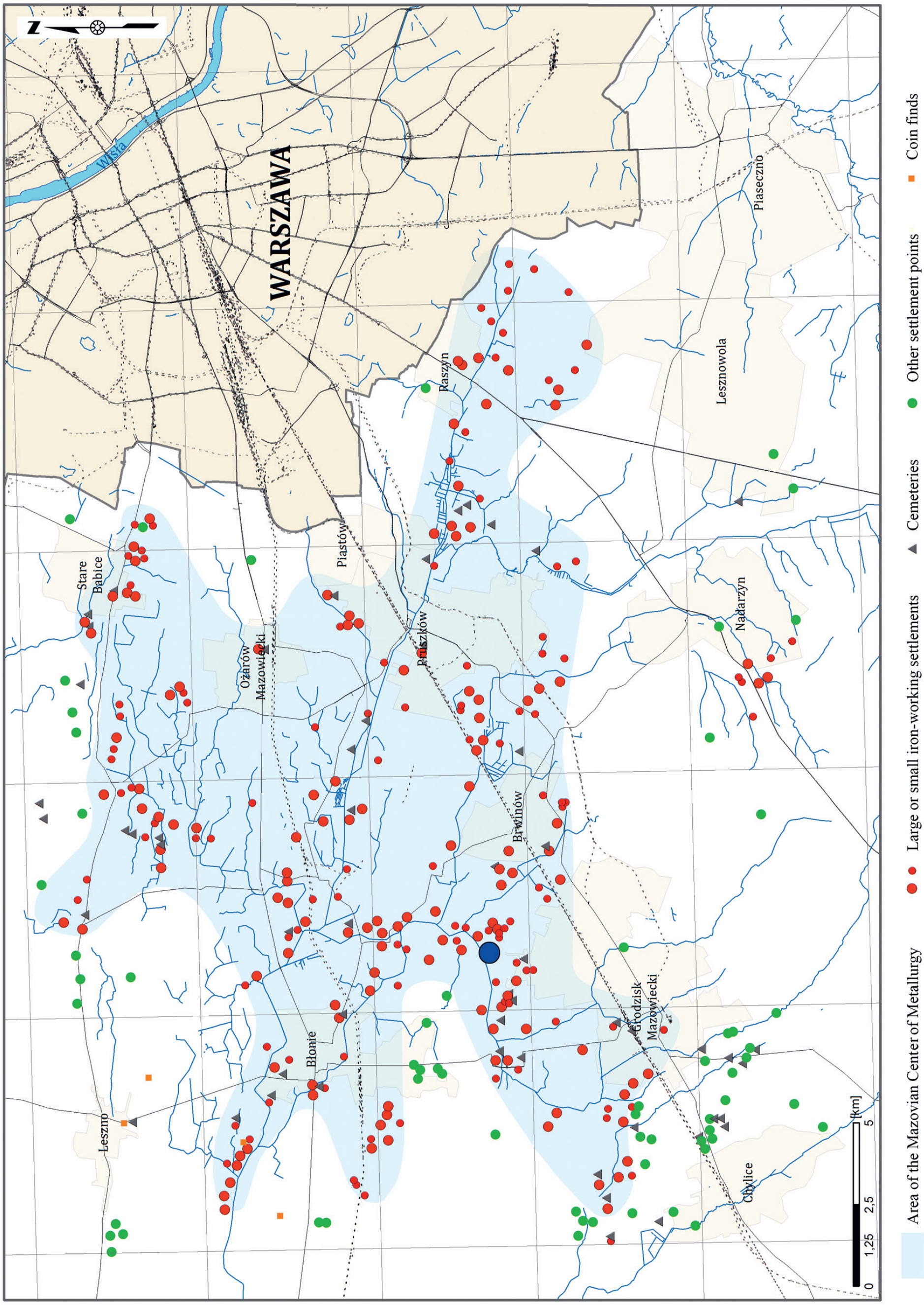

Fig. 1. A site in Milanówek/Falęcin (blue dot) on the background local settlement cluster of the Przeworsk Culture from the Late Pre-Roman and Roman Periods (acc. *Woyda 2002*, with modifications).
Obr. 1. Lokalita Milanówek-Falęcin (modrá tečka) na pozadí uskupení místních sídlišť převorské kultury z pozdně předřímského a římského období (podle *Woyda 2002*, upraveno).

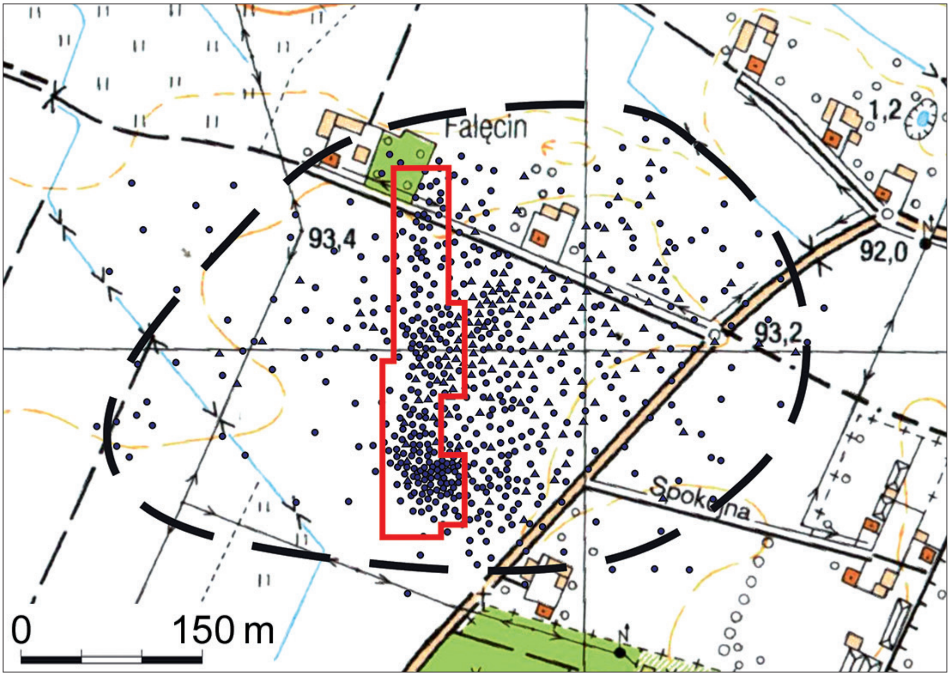

Fig. 2. Location of the settlement in Milanówek/Falęcin (black dotted line – presumed range of a site; dark blue dots and triangulars – fragments of slag and pottery shards on surface of ground; red outline – area of geomagnetic research).
Obr. 2. Poloha sídliště v Milanówku-Falęcinu (černá tečkovaná čára – předpokládaný rozsah sídliště; tmavě modré tečky a trojúhelníky – úlomky strusky a keramických střepů na zemském povrchu; červený obrys – geomagneticky prozkoumaná plocha).

of most promising sites was the object of a pioneer programme of non-destructive archaeological prospection[1], and the results were later verified during excavations. A vast settlement discovered at the border of Milanówek, Grodzisk Mazowiecki County, and Falęcin, Pruszków County, approx. 25 km south-west of Warsaw, was one of such sites. It is situated on a sandy hill bordered to the north and east by the wetland of the valleys of the river Rokitinica and its unnamed tributary and to the south by a gentle slope from where another small watercourse flows to the west. At the moment of discovery, the site was identified by numerous pottery sherds, pieces of daub and especially lumps of slag present on the surface of the ground. Based on the spread of the material, the size of the site was estimated at 9–12 hectares (*fig. 2* and *5: A*). The material was spread unevenly. Pottery dominated in the central part of the hill. Slag was predominant in the central-western and southern parts of the site. This particular spread of artefacts led to the idea of a dual – production/habitation – character of the settlement, with the production zone clearly separated.

[1] E.g., aerial photography, electrical resistance, geomagnetic, thermal radiation, geological and geomorphological surveys, etc.

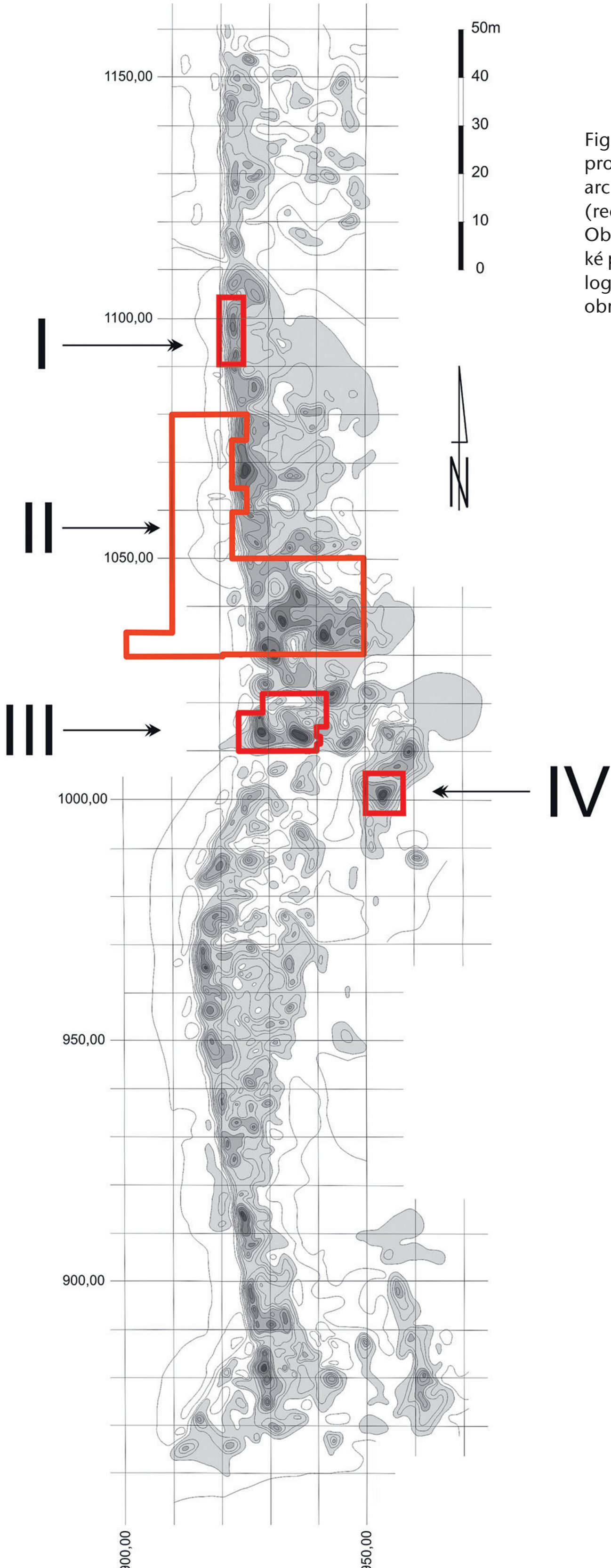

Fig. 3. Results of geomagnetic prospecting and location of archaeological trenches I–IV (red outline).
Obr. 3. Výsledky geomagnetické prospekce a poloha archeologických sond I–IV (červený obrys).

A large part of the settlement (3 ha constituting 20–30 % of the site) where the archaeological material was most dense on the surface was subjected to a geomagnetic survey (*fig. 2*). The goal of the survey was to detect possible anomalies which – as was assumed[2] – would be the indication of the presence of the remnants of bloomeries at the site. As a result of the survey, a magnetic anomaly about 300 meters long and 10–30 meters wide with clearly defined borders (particularly on its western side) was detected in the area (*fig. 3*).

The results of the prospection were then verified during the excavations conducted by S. Woyda in the years 1974–1975 and 1987–1988. The excavations took place in the central part of the site, slightly to the west of the hill peak, where the strongest anomalies were registered by the measurement equipment. It covered around 1550 m^2 of the surface (*fig. 3*). The biggest trench measuring 1240 m^2 was positioned across the length of the magnetic anomalies and alongside its western border. The rest of the excavation units, much smaller in size, were also situated within the range of the anomalies – in the centre or near its western edge. Excavations confirmed the results of the geomagnetic survey. In all of the units which were at least partially positioned within the field of the bigger magnetic anomalies, remnants of bloomeries – in form of pits containing lumps or blocks of slag – were found. In the areas were the equipment did not indicate significant anomalies, little to no remains of iron smelting furnaces were discovered. However, there were other features detected there, e.g., lime kilns.

The last excavation at the site took place in 2009. It was a rescue excavation preceding a construction of a water pipe meant to supply modern homesteads located within the borders of the site. The trench was almost 340 meters long and 0.8 meters wide – it dissected the NE part of the site (including the top of the hill) along the NW–SE axis (next to northern edge of road leading to houses lying in the area of site). In its NE part, several tens of pits divided into two groups by a small strip of empty land were discovered. A lime kiln was unearthed in the middle of the empty space. These features can be connected with the furnaces field registered during the geomagnetic survey. A 'new' furnace cluster consisting of more than 30 furnaces (registered over a 50-meter-long distance) was discovered in the SE part of the trench (to the SE of the hill peak), outside the area covered by the geomagnetic survey. Both clusters were divided by a 150-meter-long strip of land with no traces of iron smelting production. The furnace cluster newly discovered in 2009 is probably a part of a separate iron smelting workshop. Its shape and size, and, consequently, an estimation of a number of remnants of bloomeries to be found there, require a wide range of verification in the field. During all the excavation seasons, about 1000 traces of iron smelts were registered altogether.

All iron smelting furnaces discovered in Milanówek/Falęcin so far were one-time use units of the pit type. The majority of the features found within the range of the magnetic anomalies formed a vast slag-pit furnace cluster characteristic of the Mazovian Centre of Metallurgy: station of the so called 'disorganized' type, with an elongated and quite narrow shape. It was situated along the north-south axis. Its particular feature was a straight western border several hundred meters long (*fig. 4: II* and *5: B*). The highest density of

[2] Based on the results of earlier surveys of bloomery sites discovered in the Holy-Cross Mountains (cf. *Bielenin 1992*, 44–48).

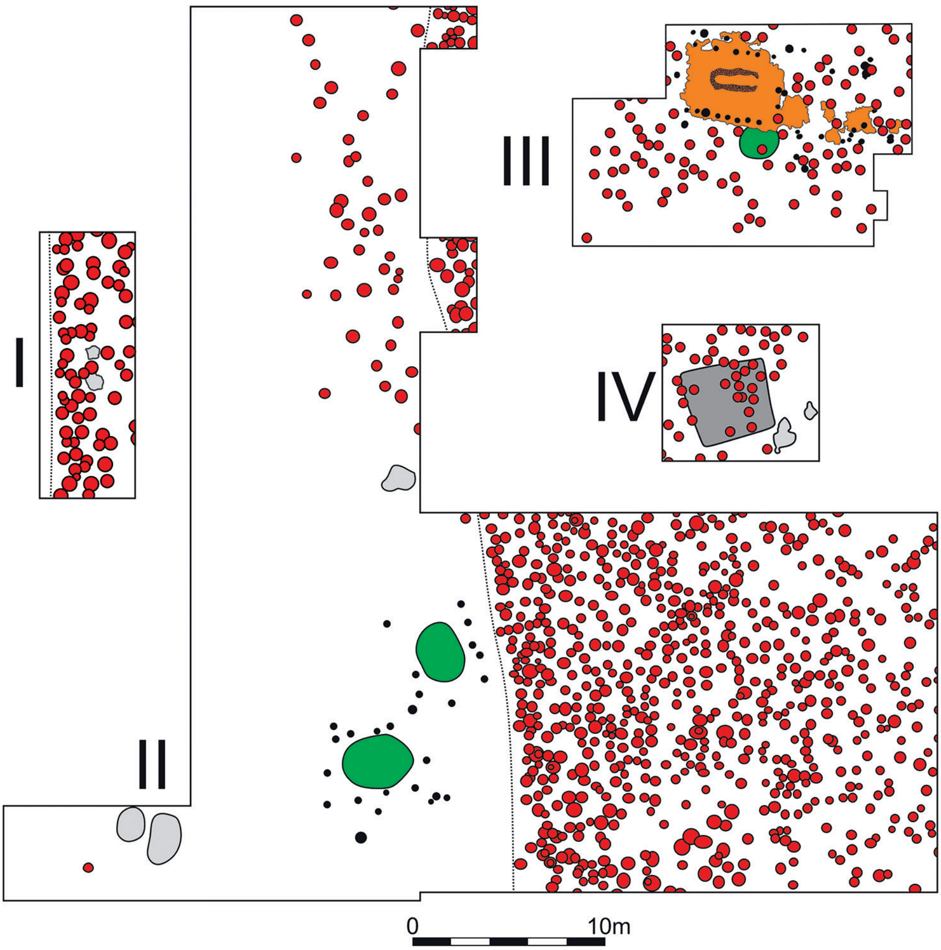

Fig. 4. Plans of archaeological trenches I–IV (red – slag-pit furnaces; green – lime kilns; black – postholes; orange – relics of house with 'horseshoe-shaped' furnace; dark grey – house; light grey – other pits; dotted line – western border of 'huge' cluster of slag-pit furnaces).
Obr. 4. Plány archeologických sond I–IV (červeně – pece se zahloubenou nístějí; zeleně – vápenické pece; černě – kůlové jamky; oranžově – pozůstatky domu s podkovovitě tvarovanou pecí, tmavošedě – další jámy; tečkovaná čára – západní hranice rozsáhlého shluku pecí se zahloubenou nístějí).

slag-pits, in places exceeding 180 items per 100 m², was registered along this border. The presence of such a distinct line with furnaces positioned alongside it is difficult to explain[3]. The most often used explanation points to the beliefs of the local population which might have been manifested in such a particular separation of the production zone from the rest of the settlement (*Woyda 2005*, 141–142; *Orzechowski 2013*, 219–220). Moving

[3] Similar arrangement can be seen at other, better researched, iron smelting sites from Mazovia (*Woyda 2005*, 135, 137).

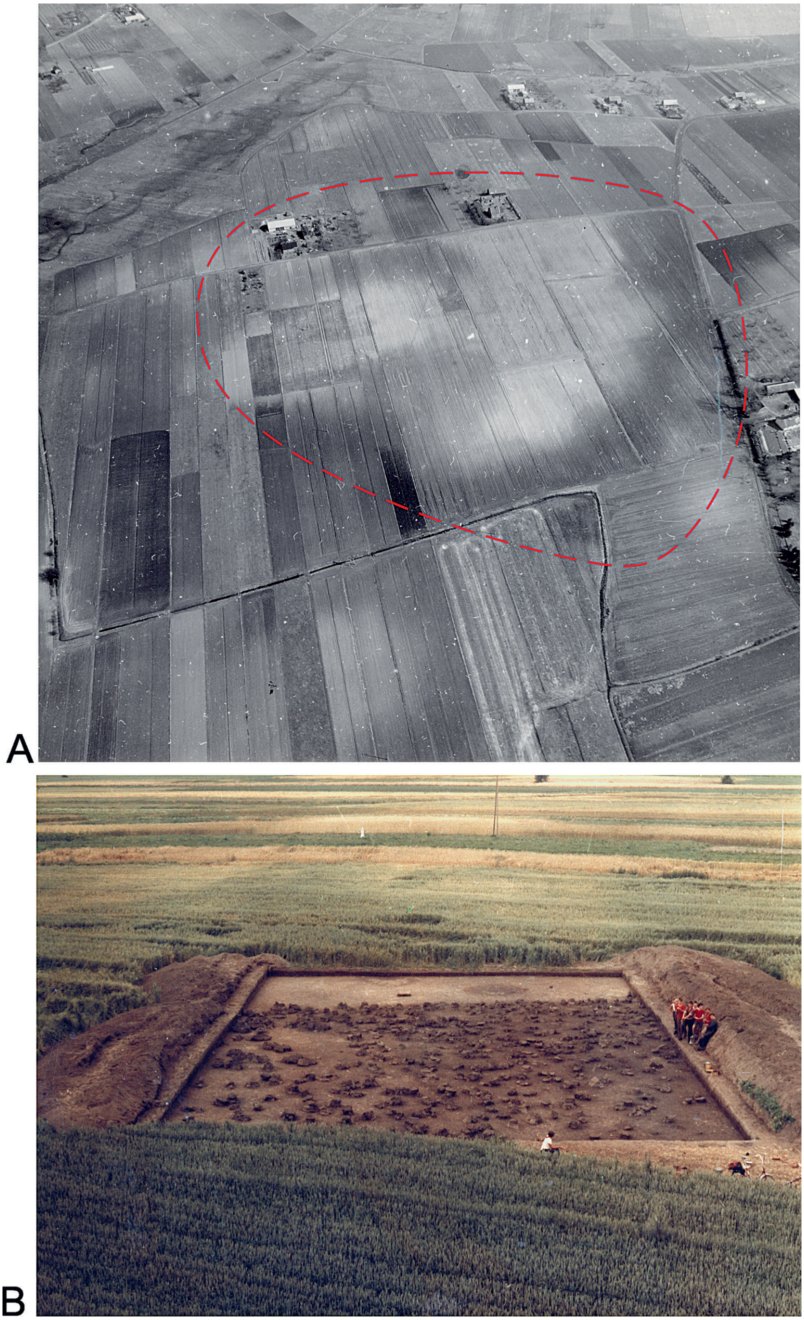

Fig. 5. Milanówek/Falęcin. A – an aerial view on site from the east, 1981 (photo Woyda); B – view on S–E part of trench II with well visible western border of 'huge' slag-pit furnace cluster (photo Woyda).
Obr. 5. Milanówek-Falęcin. A – letecký pohled na lokalitu od východu, 1981; B – pohled na jihových. část sondy II s dobře viditelným západním okrajem rozsáhlého shluku pecí se zahloubenou nístějí.

several meters to the east of the western border, the concentration of furnaces becomes noticeably less dense (fewer than 100 items per are). Unfortunately, the eastern border of the cluster was not registered during the excavations. Based on the excavations and geophysical prospection, it appears that several thousands of bloomeries could have been in use in the area of the 'huge' slag-pit furnace cluster.[4]

Another concentration of furnaces, much smaller and less dispersed, was situated next to the western border of the great slag-pit furnace cluster. The functioning of this station is difficult to interpret. Its location didn't follow the pattern according to which several thousand neighbouring furnaces were built. The main issue hindering any attempt at an explanation of this phenomenon (and not just this one, see below) is the inability to precisely indicate the time at which each furnace was constructed. This applies to both the furnaces lying within the great slag-pit furnace cluster as well as those outside its borders. It is possible that these two different clusters are an evidence of two unrelated, chronologically distinct phases of development of the settlement that functioned for at least two hundred years. More research into this matter is needed, and, above else, a better exploration of the site, beyond the metallurgical production zone, is required.

As mentioned before, the characteristic feature of the 'huge' slag-pit furnace cluster was a high density of bloomeries alongside its western border. The features discovered here formed complex, often multi-level stratigraphic sequences. Pits of the younger furnaces were dug into the older ones which in turn had also been dug into even older ones. Thus, the state of preservation at the time of discovery differs between features. The oldest features had often been almost completely destroyed. Their only remains are the bottoms of the pits – circular in shape, with black fill containing sparse pieces of slag. They were usually registered only after fully excavating the younger features. It is difficult to assess, however, if the features were destroyed on purpose, e.g., to prepare room for new units or if it happened by accident during the construction of new furnaces. Younger features were characterized by the presence of slag blocks. Some of the blocks were preserved in full, others were damaged to various degrees – either by the younger features or perhaps much later, e.g., by field cultivation in the modern times. In most cases, the outlines of the upper parts of the pits dug into the deep dark cultural layer were not visible. They could only be distinguished at their lowest part, i.e., at the level of the sandy sterile ground. Their construction was then mostly recreated based on the shape of the lateral surface of better preserved slag blocks which gave an inverted image of the walls of the pit. The pits usually measured 30–40 cm in diameter at the opening and were 40–60 cm deep. They were usually conical in shape, sometimes cylindrical. At times, they had an additional side channel. In many cases, the shape of slag blocks was irregular and disjointed at the top, possibly a result of a disturbance into the pit. It is speculated that this digging in was intended to enlarge the pit. A separate question is when it was done – before or after the smelting begun

[4] Based on surface prospection, geophysical surveys and excavations, S. Woyda, who researched the Milanówek/Falęcin site, estimated the number of smelts at over 15,000. It should be emphasized that this estimation applies to the entire area of the site. In the parts of the site covered by the geophysical survey, that number was certainly lower. In the areas excavated in the 1970s and 1980s that lay within the range of the slag-pit furnace cluster, the number of furnaces per are differed from 180 (near the border) to 60 (several tens of meters from the western border of the cluster). Assuming a high density of around 90–100 furnaces per are in the entire area of the magnetic anomaly, the number of furnaces is unlikely to be more than 6–7 thousands.

(cf. *Woyda 2002*, 131; *Orzechowski 2013*, 103). No traces of any attempts at protecting the wall of the pit (e.g., with clay lining)[5], as can be observed in other regions (*Bielenin 1973*, 55–56; *Orzechowski 2013*, 97–98), were found during the excavations.

Fragments of fired clay from the broken down shafts were found in the area of the furnace cluster described. Some of them were found *in situ*, i.e., where they were at the moment of the shaft collapse after smelting had been finished. Others were found in the secondary deposit, mainly in the cultural layer. The preserved fragments allowed for a reconstruction of the shaft structure and for a specialist study into the subject. The aim of the research was to determine the methods of preparing the raw material, establish its composition and origin, and also to recreate the temperature in the shaft during the smelting process. Furnace shafts in Milanówek/Falęcin[6] were made of clay bands. Raw material used in their construction was tempered with shredded grass and/or straw and sand. Mineralogical analyses indicate that the material originated from clay outcrops situated near the site (*Kowalczuk et al. 1980*, 20–23). Clay bands measured approximately 10–20 cm in height and from 6–10 cm (at the bottom of the shaft) to 3–4 cm (near the top of the shaft) in thickness. The bottom clay bands contained small holes, through which air could flow into the shaft. They were usually vitrified on the inside. The bands in the upper parts of the shaft were only fired. Fragments from different parts of the shafts were included in a specialist study (*Daszkiewicz – Bobryk 1994*; *Daszkiewicz – Jelitto 1994*).[7] Two samples were obtained from the bands constituting the bottom of the shaft, one from the middle part and one probably from the vicinity of the top of the shaft. In order to determine the temperature affecting the interior walls of the shaft, the research material was divided into pieces that were then re-fired in different temperatures. The samples were compared with regards to colour and ceramic characteristics before and after firing. After firing, the fragments were also subjected to a derivatographic analysis, X-ray phase analysis and observation in the scanning electron microscope. As the result of the research conducted and with an assumption that shaft parts were used only once, a range of temperatures affecting the inner shaft walls during smelting was determined. For the top and middle parts of the shaft, the temperatures were 950–1000 °C and 900–950 °C respectively. In the case of the two samples from the bands at the base of the shaft it was determined that they were fired in the temperatures of 900–970 °C and 980–1000 °C. The latter two values are surprisingly low and raise doubts. The inside surface of the samples from the bottom parts of the shaft is vitrified, which was not observed in the samples from the upper parts of the shaft.

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[5] Contrary to *S. Woyda*'s (*2005*, 149) opinion, it was not necessary as clearly proved by the research conducted in the recent years by the friends and employees of the Muzeum Starożytnego Hutnictwa Mazowieckiego (Museum of Ancient Mazovian Metallurgy) in Pruszków. Their experimental research into the reconstruction of the furnace and the smelting process, based on the local archaeological material, showed that none of the several dozen experimental furnaces had been destroyed during the smelting process due to a collapse of unsupported pit walls.

[6] As was the case in other settlements of the Mazovian Centre of Metallurgy (*Woyda 2002*, 134, fig. 26).

[7] The research into the temperatures affecting the shaft walls of the Mazovian furnaces began in 1980. Two out of five shaft fragments that were analyzed back then came from the settlement in Milanówek/Falęcin. Based on the structural changes in the loamy materials, it was concluded that one of them was fired in the temperature of approx. 800–900 °C (*Kowalczuk et al. 1980*, 16). Unfortunately, there is no information from which part of the shaft the sample had been obtained, which limits further use of these results. It probably came from the upper parts of a shaft as indicated by the description of its structure which does not mention a liquid phase.

It is unlikely that fragments so different with regards to their morphology could form in similar conditions. This is supported by the results of a research[8] into materials discovered at a settlement site in Biskupice, Pruszków County, and situated approx. 3 km to the east of Milanówek/Falęcin. Four samples obtained from different parts of a shaft were analysed – all of them had their inside surface vitrified. The results achieved (1000–1100 °C; 1010–1100 °C; 1100–1200 °C and ca. 1200 °C) indicate visibly higher temperatures at the hearth level than could be observed based on the analyses of the samples from Milanówek/Falęcin. They are similar to the findings of *Hensel* (*1986*), who determined, based on the analyses of a slag block from Milanówek/Falęcin, that the temperature during the smelting approximated 1100 °C (see below). In this light, the results of the analysis of the shaft parts from the settlement discussed herein are disputable and should certainly be verified on a bigger sample of archaeological material.

The main goal of the previously mentioned physicochemical analyses of slag was to try and recreate the bloomery process that took place in the settlement in Milanówek/Falęcin, and the Mazovian region in general (*Hensel 1986*). The analysis was preceded by establishing the chemical composition of two iron ore fragments from the area near Milanówek. The samples were characterized by a high level of phosphorus content (P_2O_5 2.7–3.78 %) and low iron content (Fe_2O_3 23.0–30.0 %) (*tab. 1*, nos. 1, 2). Three slag blocks from the site in question were analysed. They were observed under a microscope and subjected to a thermal analysis. Their composition was also determined. Additionally, the melting point of slag in an argon and air atmosphere was measured. The analysed slag contained high levels of P_2O_5 (4–6 %) and slightly lower of CaO (2–4 %)[9] (*tab. 2*). The maximum melting effect when heated in the neutral atmosphere was achieved at the temperature of 1160–1180 °C, and when cooled in the neutral atmosphere – at the temperature of 1030–1080 °C. The values are lower than in the case of the slag from the Holy-Cross Mountains which melted in the temperatures between 1150–1220 °C (lately *Orzechowski 2013*, 76). According to *Hensel* (*1986*, 63, 78), low melting point of slag, and, consequently, the temperature of the smelt, in the furnaces from Milanówek/Falęcin, was a result of using ore with high phosphorus content and utilizing lime as flux. More so, Hensel saw lime as means to de-phosphorize the iron during the smelt (*Hensel 1986*, 63; cf. *Woyda 2005*, 146). However, the possibility to precipitate phosphorus with calcium oxide in an ancient bloomery has been questioned by other researchers (*Piaskowski 1981*, 439–444; see also *Orzechowski 2013*, 73–75). They emphasize that the presence of a few percent of CaO in the contents of the Mazovian slag could be attributed a specific composition of local ore rather than be an indication of an intentional action.

Geologists studying local ore have seen this problem slightly differently. An advanced field reconnaissance was undertaken in the area of the western Mazovia in the 1970s and the beginning of the 1980s, with a goal of identifying the supply network of the local iron

[8] What is important, the analysis was done as a part of the same programme, by the same group of researchers and using the same equipment.

[9] Supplementing Hensel's research on the chemical composition of slag are the analyses done by E. Nosek on two slag blocks from Milanówek/Falęcin. First block contained 3.68 % CaO and 0.91 % P_2O_5 (averages based on 3 samples). The second one showed significantly higher content of phosphorus oxide – 2.69 % (average based on 2 samples); in this case CaO was not marked. Analysis report in the Science Department Archive of MSHM, inventory no. MSHM/ADN/221 (see also *Woyda 2002*, tab. 5).

No.	No. of sample	V_2O_5	SiO_2	FeO	MnO	Cr_2O_3	Fe_2O_3	Al_2O_3	TiO_2	CaO	MgO	P_2O_5	NiO	CuO
1	R2	–	55.5	0.7	1.2	0.01	23.0	2.4	0.19	0.8	0.1	2.7	0.02	0.02
2	R3	–	24.0	0.7	13.5	0.01	30.4	3.4	0.15	2.2	0.3	3.78	0.03	0.01
3	5	indefinite	53.2	indefinite	2.75	indefinite	23.24	indefinite	indefinite	0.77	0.61	0.4	indefinite	indefinite

Tab. 1. Chemical composition of bog iron ore from vicinity of Milanówek/Falęcin (nos. 1–2 acc. *Hensel 1986*; no. 3 acc. *Kowalczuk et al. 1980*).
Tab. 1. Chemické složení bahenní železné rudy z okolí Milanówek-Falęcin (č. 1–2 podle Hensela (*Hensel 1986*; č. 3 podle *Kowalczuk et al. 1980*).

No. of sample	SiO_2	FeO	MnO	Cr_2O_3	Fe_2O_3	Al_2O_3	TiO_2	CaO	MgO	P_2O_5	NiO	CuO
Block I												
1	18.6	49.2	1.6	–	18.7	1.2	0.04	2.9	1.7	5.0	0.04	–
2	21.5	46.1	1.8	–	17.4	1.4	–	3.9	0.6	7.1	0.03	–
3	15.3	51.6	1.4	–	19.9	1.6	0.08	2.7	1.1	5.5	0.03	–
4	18.7	48.2	1.7	–	18.9	1.5	0.02	4.0	1.0	5.5	0.06	–
5	23.6	45.1	1.7	–	13.8	1.7	0.09	3.9	1.0	7.4	0.06	–
6	25.9	46.6	1.5	–	14.5	2.9	0.23	3.0	1.0	5.4	0.08	–
7	14.8	35.5	1.2	–	35.3	2.1	0.18	2.3	0.8	4.6	0.08	–
8	18.1	49.8	1.7	–	18.2	1.3	0.18	3.1	0.6	5.9	0.07	–
9	21.0	49.7	1.7	–	13.5	1.0	0.14	4.3	0.8	7.3	0.08	–
Block II												
1	22.2	46.7	3.0	–	16.7	1.5	0.07	3.2	0.9	4.6	0.09	–
2	22.1	48.8	2.9	–	15.0	3.2	0.12	3.5	1.0	4.7	0.10	–
3	22.4	48.6	2.5	–	20.6	1.8	0.09	3.2	0.8	4.5	0.10	–
4	22.8	48.2	2.9	–	17.4	3.0	0.07	2.8	1.1	4.1	0.13	–
5	16.9	53.1	2.0	–	19.6	1.4	0.11	2.2	1.3	2.7	0.07	–
6	30.1	38.9	2.8	–	16.2	2.8	0.18	2.6	0.7	4.2	0.13	–
7	22.9	47.7	2.8	–	17.9	2.7	0.18	2.8	0.9	4.2	0.11	–
8	20.6	49.6	2.9	–	15.9	1.8	0.10	3.8	0.8	4.6	0.13	–
9	20.8	46.4	2.9	–	17.7	3.0	0.09	4.0	0.08	5.2	0.13	–
Block III (VI)												
1	16.6	38.3	0.68	0.02	32.1	1.7	0.16	1.4	0.2	2.56	0.05	0.02
2	21.0	48.4	1.10	0.02	12.7	1.7	0.16	3.7	0.3	6.78	0.07	0.02
3	20.8	44.9	1.07	0.02	15.8	2.2	0.16	3.4	0.03	6.87	0.05	0.02
4	19.2	30.0	0.94	0.01	30.7	1.7	0.13	3.2	0.3	5.43	0.06	0.02
5	25.6	39.1	1.13	0.01	18.2	1.8	0.19	3.4	0.5	4.40	0.07	0.02
6	12.9	55.0	0.88	0.01	19.9	0.9	0.09	2.4	0.2	3.82	0.05	0.02
7	22.8	43.1	1.10	0.02	17.0	1.8	0.03	4.8	0.22	6.6	–	–
8	21.0	50.0	1.10	0.04	14.0	1.8	–	3.6	0.23	5.8	0.03	–
9	20.3	50.2	0.90	0.02	14.8	1.2	–	4.1	0.15	6	0.02	traces

Tab. 2. Chemical composition of slag-blocks from a settlement in Milanówek/Falęcin (acc. *Hensel 1986*).
Tab. 2. Chemické složení struskových bloků ze sídliště v Milanówek-Falęcin (podle *Hensel 1986*).

smelting centre. Initially, the research encompassed the areas in the direct vicinity of the iron production sites (e.g. *Kowalczuk et al. 1977*, 13–22; see also *Leciejewicz 1978*). Next, the survey spread to the entire area covered by the local settlement cluster of the Przeworsk Culture. In the years 1979–1980, a team of geologists prospected an area close to 200 km^2, where they made multiple[10] test pits alongside almost all of the watercourses running in this region (*Kowalczuk et al. 1979*; *1980*). As a result, present day deposits of bog ore were localized and their size established.[11] A dozen samples of raw material were extracted in order to determine their chemical composition. The local bog ore consists of limonite. Presently, it creates vast outcrops sometimes covering many hectares. It is usually found in form of rocky concentrations or lumpy layers. Its characteristic feature is its high porosity. Individual deposits are internally varied, both in terms of morphology as well as chemical composition (composition of sample from vicinity of Milanówek/Falęcin: *tab. 1*: 3). On average, they contain 38 % of Fe_2O_3 and approx. 37 % of SiO_2 as well as low amounts of other oxides, e.g., CaO – 1.3% on average (0.7–6.45 %); P_2O_5 – 0.8 % on average (0.4–1.6 %). According to the researchers (*Kowalczuk et al. 1980*, 8–9), due to its high acidity – it contains less than 40 % of Fe_2O_3 and more than 30 % of SiO_2, – it would have been impossible to smelt iron from the local ore without using any type of flux (e.g., CaO).

What is mainly indicated when discussing the part lime played in the bloomery process in Mazovia is the presence of lime kilns registered in the local settlements. They were discovered at all of the better researched sites. Four features of this type were found in Milanówek/Falęcin. Two of them were located next to the western border of the great slag-pit furnace cluster (*fig. 4: II*; *6: C*). There were a dozen post holes registered around them which may be an evidence of some kind of a surrounding structure, e.g., a roof. Another kiln, partially destroyed by later features, was located in the central part of furnace sequence (*fig. 4: III*). The fourth kiln, only partially investigated, was registered during the rescue excavation in 2009. It was situated between the two furnace clusters. The first three features were oval or circular in shape, 2–2.5 m in diameter, with a semicircular cross-section, and depth of approx. 1.5 meters. Their construction consisted of a hollow with stone-lined walls dug into ground, and, most probably, of a clay dome towering over it, from which multiple pieces of daub were recovered. The kiln discovered in 2009 lacked any stone structure, which differentiates it from the rest. Layers of lime were found in the bottom parts of all these features. Raw material used for its production probably came from the local marl (marlstone) deposits (*Woyda 2005*, 146; see, e.g., *Palmirski 1880*, 534).

When considering the production and utilization of lime by the inhabitants of the settlement, one more feature connected with this matter should be mentioned here. It was discovered in the central part of the 'huge' slag-pit furnace cluster. Its remains indicate that it used to be a square building measuring 11 × 4 m with clay-covered walls constructed

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[10] The test pits were dug every 200–300 m, at the both sides of the watercourses, in the area of their floodplains. Once bog ore deposits were discovered in a given place, the number of open pits would be increased. 1080 test pits were dug in 1979. While no precise number is known for 1980, considering smaller scope of the survey, there were probably slightly fewer of them than the year before.

[11] Near the settlement in Milanówek/Falęcin, vast deposits of bog ore were found alongside the small tributary of the river Rokitinica, approx. 1 km east of the site, and – slightly smaller ones – alongside the river Rokitinica approx. 2 km west of the settlement. In the direct vicinity of the settlement, bog ore was found in only one of the test pits.

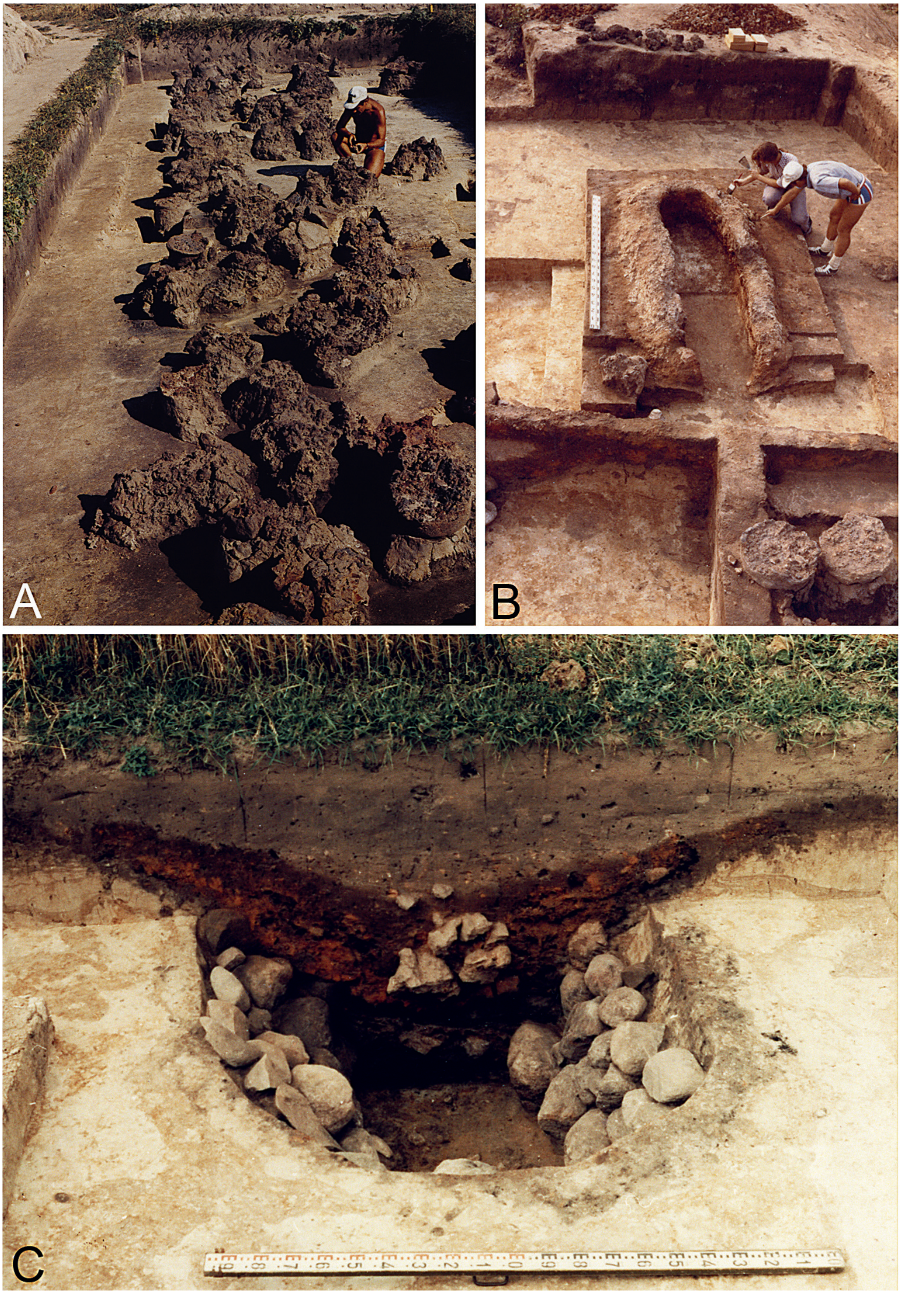

Fig. 6. Milanówek/Falęcin. A – view on trench I (photo Archive of MSHM); B – trench III – 'horseshoe-shaped' furnace during exploration (photo Archive of MSHM); C – trench II – lime-kiln during exploration (photo Woyda).
Obr. 6. Milanówek-Falęcin. A – pohled na sondu I (foto Archiv MSHM); B – sonda III – podkovovitě tvarovaná pec během průzkumu (foto Archiv MSHM); C – sonda II – vápenická pec během průzkumu.

from posts (*fig. 4: III*; *fig. 6: B*). A large, strongly elongated, slightly oval in shape furnace, 2.7 m long and 1.2 m wide, was situated in the western part of the building. It was dug slightly into the ground and was initially covered by a massive clay dome built over a wooden frame. At its base, the walls of the dome were 0.4 m thick. An opening in the eastern part of the dome allowed for the manipulation of the charge. After removing the remnants of the destroyed part of the dome, a uniform layer of lime about 10 cm thick deposited on clean, strongly annealed sand was discovered inside the furnace. Several pottery sherds and a single nodule of magnetic slag or iron were found in the top part of the lime layer. The function of the feature described is still unclear. *Woyda* (*2002*, 131; *2005*, 156) interpreted features of this type (most often called 'horseshoe-shaped')[12] as furnaces used to re-heat iron blooms in contact with lime. It is difficult to agree with this idea, more so that the author did not support it with any arguments. In the most recent literature on the subject, attention is drawn to the post-reduction phases of iron smelting (*Bielenin 1992*, 132; *Woyda 2002*, 136–137; *2005*, 154–158; *Orzechowski 2013*, 81–91). They included, among others, multiple re-heating and hammering of the raw bloom in order to remove the remains of slag and charcoal. It is assumed that hearths, where the smelted blooms were re-heated, were used for that purpose. Such hearths are characterized by the presence of distinctive lumps of slag, which dripped off the heated bloom, as well as of occasional iron flakes in their fill; however, no traces of lime have been found there. Conversely, no traces of activities related to iron metallurgy have ever been found in the features interpreted as 'reheating furnaces' by S. Woyda. However, traces of lime (or a similar substance)[13] have been observed in the better preserved of the so-named features. The remarks above indicate that furnaces from Milanówek/Falęcin as well as analogous features from neighbouring settlements cannot be directly associated with any of the phases of the iron smelting process. It would rather appear that they are a different type of a lime kiln.

The features discovered in Milanówek/Falęcin are evidence of a local production and utilization of lime. In the current state of research, however, it is unknown if the need for lime in the iron smelting was the reason for its production. The presence of lime kilns next to bloomeries may have different origins, e.g., it may be a result of separating the entire production zone, not just the metallurgical workshop, from the inhabited parts of the settlement. Lime production was an important part of the economy of that time, and shallow deposition of marl in the western Mazovia made it easy to exploit. Hence, the discovery of lime kilns in the local settlements should not come as a surprise. As it is, further research into the utilization of lime in the bloomery process is required. Small scale analytical research that has been conducted up to this moment on the randomly selected material should be complemented with a series of modern analyses. What would be of fundamental importance are the comparison studies of chemical composition between the slag blocks and

[12] Similar features described also as 'reheating' or 'niche' furnaces were discovered in several other Mazovian metallurgical settlements, e.g., Reguły, Pruszków County, feature 1/are 27/2007; feature 1/are 29/2007, Biskupice, Pruszków County, feature 1/are 35/sector 10/1979; Stare Babice, Warsaw West County, feature 54/2006 – research by MSHM, documentation and artefacts in the museum collections.

[13] Only material from a feature in Biskupice (feature 1/are 35/sector 10/1979) was the subject of chemical composition analysis. The composition of the sample tested (39.1 % CaO) corresponds with that of the lime obtained from the four 'common' lime kilns discovered at the same site (CaO content in the range of 35.5–48.2 %) – analysis report W. Rusek and A. Żurada in the Archives of MSHM.

bog ore deposits found within the boundaries of the site, which, in theory, should be the closest match to the raw material utilized when the ancient settlement was in use. Fast regeneration of the local bog iron deposits means that starting material used for analyses was composed of samples that could have precipitated in the last several hundred years. Consequently, their composition might differ significantly from the raw material available in the ancient times.

Archaeological research in Milanówek/Falęcin was focused on the area of the production zone. Thus, the excavated area is dominated by production related features. Remnants of a building found in the trench IV, and several pits of undetermined purpose found next to this building and in the western part of trench II, are the only exceptions. The feature construed as a building was square in shape and measured around 16 m^2. Remnants of a stove made of stone, clay and pieces of slag blocks were found in its northern part. Numerous animal bone fragments, two weaving weights and a significant collection of pottery sherds, some of which – found in the vicinity of the stove – were re-fired, were recovered from the fill of the building. Ceramic material is mostly composed of sherds of thick-walled clay vessels with coarse surface. Scarce pieces of vessels with thick, non-facetted rims characteristic of the second ceramic phase of the Przeworsk Culture (e.g., *Dąbrowska 1973*, 499, 520; *1988*, 30–31; *2008*, 63–64; *Andrzejowski 2010*, 3) as well as pot sherds ornamented with incised lines made with a comb[14], date this feature probably to the late stage of the Late Pre-Roman Period. The time when the building was in use constitutes gives a *terminus post quem* for the bloomeries whose pits were dug into this structure.

This is linked inseparably with the matter of dating the Milanówek/Falęcin settlement and establishing the time period when its metallurgical workshop, manifested by the 'huge' slag-pit furnace cluster, was actually in use. Studying the chronology of the site is made more difficult by the small scope of the excavations limited only to the production zone. The next remarks are then based on a very humble collection of data, and as such can only be considered initial observations that must be verified in the course of future research. Pottery sherds discovered in a thick (20–40 cm in depth) cultural layer that was registered in all the excavated areas, as well as the ceramic material found in the building described above were the main source of material used for relative dating of the explored part of the site. The biggest collection is composed of highly fragmented sherds of big thick-walled clay vessels with a coarse body surface and a smoothed part near the rim, corresponding with the groups III and V of *T. Liana*'s (*1970*) classification. Some of the rims were thickened to a greater or lesser degree, others have edges that are indistinct or only slightly bent out. Such vessels can be encountered both in the Late Pre-Roman Period as well as in the Roman Period, usually in its early phase (*Liana 1970*, 439). Amidst the scarce examples of thin-walled pottery, vessels with thick rims, characteristic of the second ceramic phase of the Przeworsk culture dating to the phase A3 (*Dąbrowska 1988*, 30–31), are predominant. A small collection is composed of vessels showing characteristics of an even older style, namely vessels with thick facetted rims that appear in the phases A1-A2 as well as at the beginning of the phase A3 (*Dąbrowska 2008*, 8). What is peculiar in the ceramic

[14] This ornamentation is seen as an imitation of the decorative patterns used by the people of the La Tène Culture (*Dąbrowska 2008*, 75).

material obtained is the small number of thin-walled vessels typical of the younger phase of the Early Roman Period and the beginning of the Late Roman Period such as vases and bowls with a biconical body, vessels with a distinct foot, etc. (see *Liana 1970*, 438–440, tabs. I–II). Only few fragments of wheel-made pottery were found either. Such pottery is encountered relatively often in local settlements from the Late Roman Period, e.g., Biskupice, Pruszków County (MSHM collection) or Izdebno Kościelne, Grodzisk Mazowicki County (*Machajewski 2016*, 235–244); Kraśnicza Wola, Grodzisk Mazowiecki County (MSHM collection). The data above indicate that the part of the Milanówek/Falęcin site studied so far was utilized in the Late Pre-Roman Period and the Roman Period. Small participation of vessels characteristic of the phases A1-A2 and the forms clearly typical of the Late Roman Period allows the dating to be narrowed to the latest phase of Pre-Roman Period to the beginning of Late Roman Period.

Trying to establish when the vast metallurgical workshop was formed is a separate matter. Woyda thought that the settlements in the area of the Mazovian Centre of Metallurgy were founded for the purpose of production. Thus, he dated the beginning of the local metallurgy to the same time as the oldest settlement horizon of the Przeworsk Culture people in this area (*Woyda 2005*, 122), i.e., at the end of the phase A1 or in the phase A2 (lately *Dąbrowska 2008*, 101–104). The idea of the contemporaneity of the developed metallurgical production and the solidification of the local settlement of the Przeworsk Culture was mostly based on the supposition that the clear division between the production and habitation zones must have been a result of a preconceived vision that directed the establishment of new settlements (*Woyda 2002*, 122; *2005*, 134–135; see also *Orzechowski 2013*, 216–217). In this light, the beginning of an intense iron smelting production in Milanówek/Falęcin should be placed in the phase A3 at the latest. The results of the research conducted at the settlement site do not fully support the above-mentioned statement. In the excavated area of the 'huge' slag-pit furnace cluster, most of the pits were dug into the cultural layer. The bottoms of many features did not even reach the sterile ground, and the top surface of the slag blocks, which would have been situated at the level of activity at the site at that time, were registered around 20–40 cm above the bottom surface of the said cultural layer. This also applies to the nethermost features situated alongside the sharp western border of the furnace cluster that were often preserved only in part and usually disturbed by later furnace pits. If *Woyda*'s (*2002*, 128) supposition – that the furnaces were constructed in straight rows in the first phase of metallurgical activity – is correct, then it should be stated that the oldest part of the excavated area of the furnace cluster was established in a place that must have been previously used by local population. However, the origin of this cultural layer is difficult to determine. Numerous pieces of slag and daub discovered in the layer indicate that it was mostly formed at the time when the furnace field was already in use.[15]

The presence of an anthropogenic layer older than the furnaces raises doubts about the simultaneous beginning of habitation and metallurgical centre at this site. However, this

15 Archaeological material from the, mostly uniform, cultural layer is divided into collections obtained from the consecutive ares. At this moment, it cannot be stated which of the artefacts come from the lower and which from the upper levels of the layer. It makes it impossible to determine the characteristics of the oldest level of the layer into which the pits had been dug.

matter requires further in-depth studies. Attempts at absolute dating (e.g., radiocarbon dating[16]) of the remnants of the furnaces will be of key importance. The inability to date even relatively, using classic methods, the majority of the furnaces themselves is the reason that the rhythm of the metallurgical production is being closely connected with the pace of the settlement development at this site. As it is, at the present state of research, the beginning of the intensive iron production in Milanówek/Falęcin can be seen in the Late Pre-Roman Period, and its peak in the Early Roman Period. It corresponds to the situation registered in the other, better researched, settlements in the region of the Mazovian Centre of Metallurgy (*Woyda 2005*, 131).

The site presented here is one of the most important settlements of the Przeworsk Culture people in the western Mazovia. The results of the research conducted at the site are, in many places, a reference point for the studies of the economy of local populations, especially with regards to the iron metallurgy in the region. They have also confirmed the validity of non-destructive prospection of iron smelting sites. A complete study of obtained materials, and, in long term, resuming the large-scale archaeological exploration of the site will be of crucial significance to further research. Excavations so far have only covered a limited area focused solely in the production zone of the settlement, a result of a drive to explore this newly discovered phenomenon – a local iron smelting centre. The favourable location of the site, situated away from the rapidly expanding infrastructure of small suburban towns near Warsaw, protects it from severe devastation. The presence of a cultural layer partially situated below the present-day field cultivation level is also of great significance. Features located in or under the layer are all well preserved. By employing modern technology not available several decades ago, future studies at the site will let us examine it more thoroughly and verify if any of the previously stipulated theses have in fact been true.

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Abbreviation: MSHM – Muzeum Starożytnego Hutnictwa Mazowieckiego (Museum of Ancient Mazovian Metallurgy) in Pruszków

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[16] In the late 1970s and early 1980s, two samples were dated by calculating levels of the isotope C-14: one obtained from a lime kiln and one from a slag-pit furnace. The results indicating the 6th century B.C. indeed differ from the chronology established based on the artefactual material and have been stated as dubious (*Woyda 1981*; cf. *Pazdur 1990*, 98–99, tabs. 1: 17–18; 3).

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