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THE LORDS OF FLINT
100TH ANNIVERSARY OF THE DISCOVERY OF THE PREHISTORIC STRIPED FLINT MINES IN KRZEMIONKI

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Editorial

The earliest research on the siliceous raw materials in the territory of Poland dates back to the first years after World War I. A patriarch of these studies was an archaeologist Stefan Krukowski (1890–1982). Together with Jan Samsonowicz (1888–1959), then a young geologist, they undertook a grand survey focused on flint deposits and prehistoric exploitation sites. The year 2022 brings a centennial celebration of their most prominent discovery: Krzemionki (Fig. 1). Exactly on July 19th, 1922, J. Samsonowicz realized that the unusual landscape of Krzemionki is a remnant of a prehistoric flint mine; he later wrote about this: "It came out that the mentioned pits are prehistoric mining shafts, filled with debris and soil" (Samsonowicz 1923: 22, translation by the Editors).

This discovery, or actually a correct interpretation of the previous observations, was a turning point in the studies on the Central European prehistory. It initiated a series of archaeological excavations, created new research fields, and prompted further development of studies over the prehistory of flint mines in Poland and abroad (e.g., Przychodni and Jedynak 2022). Currently, in European archaeology, flint mines constitute a separate type of archaeological sites (Lech 2012) as well as a basis of a well--defined research field with its own methodology. The best tangible evidence of that is the Commission on Flint Mining in Pre- and Protohistoric Times of the International Union of Prehistoric and Protohistoric Sciences (Union Internationale des Sciences Préhistoriques et Protohistoriques – UISPP), founded in 2006. The first plenary meeting of the Commission was held on September 3rd–4th, 2007, in the Institut d'art et d'archéologie at the Université de Paris 1 – Panthéon-Sorbonne, France. The event was organized by Pierre Allard, Françoise Bostyn and François Giligny, and focused on a topic of *Archaeology of the pre- and protohistoric flint mining: a contemporary perspective*. Since that moment, ten more meetings already took place in a number of countries. The 9th International Conference of a particular topic: *The flint mining studies: archaeological excavations – extraction methods – chipping floors – distribution of raw materials and workshop products* was organized in Poland by the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Warsaw, Institute of Archaeology Nicolaus Copernicus University in Toruń, Institute of Geological Sciences, Polish Academy of Sciences and Archaeological Museum and Reserve "Krzemionki" at 19–21th September 2019 (Fig. 2). The conference was held at the Krzemionki museum and reserve (Fig. 3). The motivation to hold the meeting there was enlisting of the Krzemionki (as the Prehistoric Striped

Fig. 1. Archaeological Museum and Reserve "Krzemionki" 17 July 2022. Celebration of the 100th anniversary of the discovery of the Krzemionki mines. Promotion-education stall of the Institute of Archaeology and Ethnology, Polish Academy of Sciences. Photo: D. H. Werra.

Flint Mining Region), at the UNESCO World Heritage list on July 6th, 2019, almost a hundred years after its discovery (1922). The speakers presented various papers around the theme of this conference (Werra *et al.*, 2019) and participated in tours at the mining site, both on the surface and underground. Other excursions were organized to the nearby Borownia flint mine (Lech 2021) and the settlement at Ćmielów "Gawroniec hill" (Balcer 2002), both of which are included in the protected area's range. The last day of the conference was dedicated to visiting the Polish Jura region's flint mines in Udorka valley (Fig. 4; Sudoł-Procyk *et al.*, 2021).

Most of the papers published here were presented in preliminary form at the conference mentioned above. The first two papers in the volume are dedicated directly to the history of the Krzemionki flint mining. In *The Centenary Jubilee of the Discovery of Prehistoric Striped Flint Mines in Krzemionki* (pp. 9–21), Andrzej Przychodni and Artur Jedynak present a hundred years-long history of this exceptional heritage monument. The authors shortly present a series of archaeological research, protection and ownership transformation of the site. They describe its way to the UNESCO World Heritage Site list and the celebration of the 100th anniversary of the discovery, that took place this

Fig. 2. Poster promoting the 9th International Conference UISPP Commission on Flint Mining in Pre- and Protohistoric Times 19-21 September 2019. Graphic elaboration: Ł. Figura.

year (July 16–24th, 2022), as well as other events accompanying these celebrations. Then, Magdalena Malak presents the publication history of the striped flint mine in Krzemionki within the first years after the discovery of the site, until 1939 in *Krzemionki in the Literature Published in the Years 1923–1939* (pp. 25–38).

The next two papers are related to the research methods used in the study of prehistoric flint mines. The first paper in this group, by Artur Jedynak and Piotr Wroniecki, *Non-invasive Investigation of Segment C of the Krzemionki Exploitation Field. Initial Research Results* (pp. 39–59), illustrates the results of non-invasive research that has been undertaken in the southern arm of the Krzemionki exploitation field. The second one, *Re-working the Past: Evidence for Late Neolithic and Early Bronze Age Flint Extraction at the Early Neolithic Mines of Sussex* (pp. 61–86) by Jon Bączkowski, summarises the evidence for Late Neolithic and Early Bronze Age flint extraction at the Southern English mines. The paper attempts to define the Late Neolithic and Bronze Age flint working activity at the mines and question if this activity was associated with new episodes of shaft-mining or informal methods of extraction.

The next three papers concern a problem of flint mining as a source of knowledge about prehistoric communities. In the first paper, *At the Turn: Flint Mining as an Element of Social Changes in the Second Half of the Fifth Millennium BC in Western Lesser Poland* (pp. 87–108), Elżbita Trela-Kieferling and Damian Stefański provide a description of the problem of flint mining in western Lesser Poland in relation to technological change in lithic production, so-called "the metric change" – the shift in the length of flint blades. Next, in *Workshop Places at Chessy (Seine-et-Marne Dpt., France): Contextual and Technological*

Fig. 3. Participants of the 9th International Conference UISPP Commission on Flint Mining in Pre- and Protohistoric Times. Photo: T. Witkowska.

Aspects (pp. 109–125), Anne Hauzeur and colleagues present results of recent excavations at Chessy (France). Analysed materials for workshop places allowed the authors to distinguish places of different functions. The last paper in this group is *The Flint Quarry of Pozarrate (Treviño, Spain) in the Iberian and Early European Neolithic mining context* (pp. 127–147) by Antonio Tarriño and colleagues. The paper presents results of a recent research on the Early Neolithic flint quarry of Pozarrate (Treviño, Burgos) in the north of Spain. The paper presents very interesting new findings as well as radiocarbon dates.

The last group of papers concerns a problem of identification and determination of siliceous rocks. In the first text, *Mapping Natural Exposures of Siliceous Marls and Cherts as Potential Zones of Raw Material Acquisition. The Case of the Eastern Polish Carpathian Foothills and the Rzeszów Settlement Region (SE Poland) in the Neolithic and Bronze Age. Preliminary Results* (pp. 149–161), Andrzej Pelisiak presents barely known raw materials (siliceous marls and cherts) from the area of southeast Poland. In *Striped Flint in Archaeological Materials Around the Outcrops of the Kraków-Częstochowa Striped Flint Variety* (pp. 163–185), Magdalena Sudoł-Procyk with colleagues present the state of knowledge about a striped flint variety from the Ryczów Upland (southern Poland). Those newly discovered outcrops have opened a discussion on the issues of the provenance of striped flint and the ways it was used by the prehistoric communities inhabiting the central part of the Kraków-Częstochowa Upland. Finally, in *Prehistoric Stone Raw Materials from the Bükk Mountains in Northeastern Hungary* (pp. 187–229), Norbert

Fig. 4. Participants of the 9th International Conference UISPP Commission on Flint Mining in Pre- and Protohistoric Times visiting the mine of chocolate flint in the Udorka Valley (Kraków-Częstochowa Upland). Photo: M. Krajcarz.

Faragó and colleagues present an outline of the current state of information concerning the prehistoric use of the diverse silicified source materials of the Bükk Mountains.

The volume ends with two reviews of monographs dedicated to two prehistoric flint mines. The first review by Hubert Binnebesel concerns a monograph published in 2020, dedicated to a mine site named "Za garncarzami" in Ożarów (central Poland). The second one by Dagmara H. Werra concerns the monograph on Neolithic flint workshops of the Bębło mining complex (southern Poland), published in 2021. Both these monographs present archival archaeological research and the publishing of both books was possible thanks to the co-financing of the Ministry of Culture and National Heritage of Poland and the National Institute of Cultural Heritage. We recommend to give a special attention to both these reviews, mainly because they deal with all the issues raised in this volume. The readers will find there chapters concerning the history of research at the site, methodology applied to a prehistoric flint mine, as well as the problems of flint mining as a source of knowledge about prehistoric communities and the problems of identification and determination of siliceous rocks.

Finally, we extend special thanks to all the reviewers of this volume for their time and commitment; the volume could not have been completed without their cooperation and assistance. The list of reviewers includes: Jon Bączkowski (Toruń), Dariusz Bobak (Rzeszów), Françoise Bostyn (Paris), Janusz Budziszewski (Warsaw), Pavel Burgert (Praha), Jean-Philippe Collin (Brussels), Tim Kerig (Kiel), Adrián Nemergut

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The English language correction of articles was done by Paul M. Barford in consultation with the volume editors, which hopefully allowed us to avoid substantive errors. Nonetheless, we take responsibility for errors that remain.

Dagmara H. Werra
Marzena Woźny
Maciej Krajcarz
Magdalena Sudoł-Procyk

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The Centenary of the Discovery of the Prehistoric Striped Flint Mines in Krzemionki

Andrzej Przychodni[a] and Artur Jedynak[b]

Undoubtedly, the exploitation field in Krzemionki, situated within the properties of the present villages of Sudół, Stoki Stare and Ruda Kościelna, constitutes a unique relic – a monument of prehistory whose preservation in as good state as possible accompanied with skilful facilitating public access to it is going to be the subject of our concern throughout the upcoming century. On one hand, one can find it surprising that the monument did not become a symbol equally recognizable to the public as the Biskupin fortified town. On the other, it is a source of satisfaction that the whole range of activities connected with the monument have not caused any significant alterations to the site (while admitting that they might possibly occur along with the increasing popularization and commercialization of the Krzemionki mines). Of course, some interference has taken place here. Luckily, taking into account the number of intact mining shafts and the extent of the post-mining landscape still visible today, their scale has not caused much loss. It seems that in the case of this archaeological monument, a successful compromise has been obtained. This merges efforts to retain it in a state that is as little changed as possible, while gaining knowledge in the course of research and finally the need for presenting this knowledge and the monument itself. If it is possible to maintain this situation, this will mean that the long-term activities of several generations within various circles working in the service of the Krzemionki monument have had the proper effects.

The discovery made on July, 19th 1922 by the geologist Jan Samsonowicz initiated a series of events, including archaeological research, conservation work and

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ownership transformations of the land on which the site lies that have extended over as long as 100 years. They have led to better knowledge about the site, its protection and making it available to visitors and finally – declaring it a UNESCO World Heritage site.

The first surface survey work was started in 1923 by Stefan Krukowski and Zygmunt Szmit, whereas the first excavation research was conducted two years later by Józef Żurowski. The exploration of subsequent shafts by Z. Szmit and S. Krukowski allowed an initial diagnosis of the characteristics of the site. As a result of the excavations and surface research which was being conducted also around Krzemionki village, the first monograph of the mines by S. Krukowski came into being in 1939. Simultaneously, there also appeared the problem of securing the exploitation field against damage caused by limestone extraction to produce lime. After enacting a new Law on the Protection and Care for Historical Monuments in 1928, the process of creating an archaeological reserve started. Through the use of state funds, the contributions of individual donors, with the support of local authorities and industrial plants as well as thanks to the commitment of the Polish Country Lovers' Society, a part of the exploitation field was acquired from private owners and put under protection.

After the Second World War, the biggest challenge for Krzemionki researchers and conservationists became to secure vandalized shafts and to provide documentation in addition to protecting the exploitation field. As early as in 1945, the mines became registered ancient monuments. In 1953, intensive conservation works were started by Tadeusz Żurowski. In their course, the shafts number 1, 2 and 3 became successfully secured and were covered with special ferroconcrete domes. The underground portions of these mines were explored and prepared for being shared with limited numbers of tourists. In the process of the research, a Neolithic drawing was discovered. It is created with charcoal on a limestone pillar in one of the mines. A graphic reproduction of this drawing became the logo of the Krzemionki Museum in 2012. The biggest innovation introduced during this time was the integration of archaeological research with conservation work being carried out underground with the participation of mining methods. This way, between 1959 and 1961, Shaft 4 was examined and preserved. It is one of the best explored mining features in the area of the whole exploitation field.

Concurrently with the research in the 1950s and 1960s, the extension of forms of protection of the monument was progressing. The total area of the reserve was expanded to over 300 ha. Properties in Krzemionki village were bought, and the majority of the place passed into state ownership. This is the only case in the history of Poland when for the good of an archaeological monument, a whole village has been displaced. The post-war years brought also multiple changes in the administration of the complex. Until

Fig. 1. View of the excavation of pillar-chamber mines seen from the tourist route. Photo: K. Cybulska.

1952 (and between the years 1968–1978), the monument was governed by the State Archaeological Museum in Warsaw, between 1953 and 1967 by the Provincial Monument Conservator, whereas since 1979 the museum and mines have been a branch of Historical and Archaeological Museum in Ostrowiec Świętokrzyski.

After a short episode of research work in the area of mine number 5 (1969–1970), the next substantial work was carried out from 1979 onwards by a separate archaeological mission of the State Archaeological Museum. The research aims here were to provide information on the widest part of the exploitation field along the east–west line, and then making the explored mines accessible to the public in the form of an underground tourist route. This way, much new information was provided about the geology of the striped flint deposit as well as various types of mines related to its exploitation. Between 1983 and 1985, an underground gallery in the area of mines no. 1, 2 and 3 was prepared by deepening the original excavation that had been under study since the interwar period. Finally, in 1990, the next route of similar length was opened to visitors. It was marked out around the mine number 7. An innovation introduced in the second stretch was sinking a gallery in solid rock, around the chamber of the mine. It led only to minimal disturbance in the original monumental substance in the course of providing some insights into its interior (Fig. 1).

The method of integrating the rock layers that are typical for Krzemionki's rock mass that was developed in the meantime is also worthy of note. Low-pressure injections with a limestone-based binding preparation, formulated by the engineer Adam Krawczyk, became a major means of protecting the roofs of historic mining tunnels – especially where newer interferences took place. Employing this method, together with classic mining methods of support, comprises effective prevention of rock falls in the area of the prehistoric pillar-chamber mines and the chambers of the Great Limekiln that are preserved as the remnants of mining activity from the beginning of the 20th century.

The next, intensive stage of scientific research and investment works, fell in the opening years of the 21st century. At that time, the Historical and Archaeological Museum in Ostrowiec Świętokrzyski started the process of joining the two then-existing underground tourist routes into one unit. In the years 2001–2002, a ventilation-evacuation shaft and an exhibition tunnel over 150 metres long were bored. Within the next two years, archaeological research examined about 200 m^2 of the underground spaces in the area of the chamber and pillar-chamber mines. The work enabled the examination of one of the world's biggest flint mines – the chamber mine No. 795. The new, underground tourist route opened to the public in 2004 is 465 m long. Its integral part are also some elements displayed overground, having been successively made available to the public in the period 2001 to 2009. These include: an exhibition over Shaft no. 7 along with the reconstruction of flint workshops, exhibition of the security protections of shafts and miners' paths, a wooden observation catwalk over the exploitation field as well as the excavation of an opencast niche-corridor mine (No. 6). The tourist route additionally embraced some reconstructions made outside the exploitation field. They consist of a display depicting the buildings of part of a prehistoric miners' settlement, now including two reconstructed buildings of the Funnel Beaker Culture, two others of single dwellings of the Globular Amphora and Mierzanowice Cultures and a reconstruction of a megalithic tomb of the Funnel Beaker Culture.

Over the course of recent years (since 2011), the Historical and Archaeological Museum has completed two massive infrastructure projects, which included the construction of a new museum building in Krzemionki, preparing a permanent archaeological exhibition, renovation of the underground route with entrance and exit pavilions and finally making the route available to the disabled (Fig. 2). Both the projects were carried out with the financial support of the European Union with contributions ensured by the local authorities of Ostrowiec County.

Fig. 2. Part of a permanent archaeological exhibition "The Lords of Flint. Everyday life of the prehistoric miners of the Kamienna river valley". Photo: K. Cybulska.

Fig. 3. Geophysical research in the area of the southern zone of the "Krzemionki" exploitation field in 2021. Photo: A. Jedynak.

Fig. 4. A coin „The centenary of the discovery of Krzemionki prehistoric striped flint mines complex”, issued by the National Bank of Poland, nominal value 50 zł, silver, diameter 4.5 cm, design by U. Walerzak. Photo: NBP.

Between the years 2015–2018, together with the specialists from the National Heritage Institute in Warsaw and independent experts, the Krzemionki Museum prepared an application for the Krzemionki Prehistoric Striped Flint Mining Region to be entered on the UNESCO World Heritage list. In July 2019, the status of World Heritage site was bestowed to the “Krzemionki”, “Borownia” and “Korycizna” mines as well as to the Neolithic settlement “Gawroniec”. Between 2019 and 2022, in cooperation with the National Heritage Institute and the Giant Mountains Foundation, the Museum prepared a project of a cultural park which is to embrace the whole prehistoric region of flint exploitation upon the Kamienna river with legal protection. This was an initiative of the local governments that declared they would introduce such a form of protection for the components of the above mentioned World Heritage sites and their buffer zones as early as in 2019. In terms of ensuring the proper, ongoing protection for the components proposed as a UNESCO World Heritage Site, the Museum constantly cooperates with Świętokrzyskie Provincial Monument Conservator in Kielce. Further archaeological research of prehistoric mining with related settlement is also in progress (Fig. 3).

The year 2022 brought the 100th anniversary of the discovery of the Krzemionki mines. Due to the uniqueness of this place – as one of the best preserved prehistoric mining sites in the world and the only Polish archaeological monument listed as

Fig. 5. A postcard issued on the occasion of the centenary of the discovery of Krzemionki. Project by J. Fleszar-Haspert.

a World Heritage Site – the celebration of the jubilee became a festival of the Polish archaeological community and of all committed to this site.

The inauguration of the celebration took place on July 16th in the presence of MPs, local officials and some representatives of the Ministry of Culture and National Heritage. A particularly numerous group of those that came for the festivities were the representatives of scientific, museum and monument-protection related institutions. An important agenda item was the promotion of a silver 50-złoty coin which was issued on the occasion by The National Bank of Poland (*NBP*; Fig. 4). In addition to that, the Polish Post Office (*Poczta Polska*) presented a jubilee postcard dedicated to the anniversary of the discovery (Fig. 5).

On the same day, a three-day outdoor event titled "The Krzemionki Meetings with Stone Age" began. It presented the everyday life of Krzemionki miners and popularized archaeology along with the archaeological heritage. With regard to the jubilee, the event in 2022 had a very rich programme and a record number of participants. In the area

Fig. 6. The staging of neolithic funeral rites, presented during "The Krzemionki Meetings with Stone Age". Photo: B. Janiczek.

of the reconstruction of the prehistoric settlement, there were some stalls devoted to experimental archaeology, giving demonstrations of prehistoric craft. There was also the staging of a depiction of the funeral rite and other elements of spiritual culture of the New Stone Age in the area of Krzemionki (Fig. 6). Among the presented Neolithic activities there could be found flint craft, pottery, salt making, kindling, copper smelting, amber processing, tools and weapons production as well as food making and herbalism. Presentations in the settlement were conducted both by individual performers and representatives of various institutions or associations, including: The Museum of Cracow Salt Mines in Wieliczka (*Muzeum Żup Krakowskich w Wieliczce*), The Rydno Ancient Settlement Association (*Stowarzysznie Praosada Rydno*), The "Krak" Brotherhood of Vistula Warriors (*Bractwo Wojów Wiślańskich "Krak"*), Archeo MJP, Mr. Wilson Bushcraft.

An important element of the event, revealing the secrets of the office work of an archaeologist, but also depicting other fields of study defined as auxiliary ones, was the "Archaeological Laboratory". Representatives of a few scientific institutions, among them: the Institute of Archaeology and Ethnology, Polish Academy of Sciences – Cracow branch (*Instytut Archeologii i Etnologii PAN – Oddział w Krakowie*),

Fig. 7. "Archaeological Laboratory" – a part of "The Krzemionki Meetings with the Stone Age", dedicated to the methods of archaeological research and auxillary sciences. Photo: B. Janiczek.

Adam Mickiewicz University in Poznań, University of Warsaw, Wrocław University of Environmental and Life Sciences, the Marie Curie-Skłodowska University in Lublin and Montefortino Prospection and Digitalization (*Montefortino Prospekcja i Digitalizacja*), presented non-invasive methods of exploring archaeological monuments as well as some secrets of the work of archaeozoological, geoarchaeological or paleobotanic researchers (Fig. 7).

A two-day session devoted to various monuments, interesting discoveries and research methods indicated the idea of popularization the archaeological and mining heritage as well as the idea of presenting the results of scientific research to the public. Lecturers from different regions and centres presented research on the presence of two important crop plants: poppy and flax in the Globular Amphora Culture, the discovery of the exact sites of some ancient cities known only from historical sources, zooarchaeological research or the history of discoveries of the most interesting archaeological sites on the Polish eastern Baltic seaside. A complementation of the presentation was an outdoor exhibition titled "From the Stone Age settlement to the Cultural Park – the Settlement of Seal Hunters in Rzucewo, Puck Commune", prepared by

Fig. 8. Katarzyna Kerneder-Gubała during a popular-scientific lecture is presenting the results of research undertaken in the prehistoric mines in Orońsko. Photo: B. Janiczek.

the Centre of Culture, Sport and Tourism in Puck Commune (*Ośrodek Kultury, Sportu i Turystyki w Gminie Puck*). On the second day, there were presentations of: research methods in aerial archaeology, lead, silver and zinc mines in Tarnowskie Góry, plus the system of management of underground waters – UNESCO World Heritage Site, the natural virtues of the exploitation field's surface in Krzemionki, chocolate flint mines in Orońsko (Fig. 8) and the press image of Krzemionki in the interwar period.

On July, the 19th – the anniversary of the day of discovery– celebrations in front of Jan Samsonowicz's monument took place. Delegations of Ostrowiec County Office and other local government institutions along with the delegation of our Museum laid flowers in honour of Krzemionki's discoverer. Afterwards, a historic show produced by the "Huzar" company was presented and it depicted Jan Samsonowicz's arrival to Krzemionki as well as the realities of geological and archaeological research in the opening years after Poland regained its independence (Fig. 9). The next weekend of celebrations was devoted to megalithic cultures and this was due to an archaeological festival: "A Time Machine. The Builders of Megaliths" that took place between 23th and 24th of July and was organized in cooperation

Fig. 9. The reconstruction of an outdoor archaeological-geological workshop from the 1920s, presented during a historical performance "Jan Samsonowicz's arrival to Krzemionki". Photo: B. Janiczek.

with the Association of Artists and Cultural Organizers of Kuyavia and Dobrzyń Land from Izbica Kujawska (*Stowarzyszenie Środowisk, Twórców i Animatorów Kultury Kujaw i Ziemi Dobrzyńskiej z Izbicy Kujawskiej*). The most important aspects of the everyday life of people of the Globular Amphora Culture were presented in the area of the Neolithic settlement reconstruction. This population were the builders of the largest Polish megalithic tombs and the initiators of striped flint mining in Krzemionki. Simultaneously, two vernissages of exhibitions took place inside the Museum. One of them, prepared by the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Warsaw was devoted to Prof. Zygmunt Krzak – the researcher of megaliths, prehistoric religions, but also flint mines and settlements in Krzemionki area. The other one, titled "Stones. The Megaliths of Europe" is a display of the Italian photographer Franko Storti's photos depicting several dozen megalithic sites from several European countries. The exhibition came into being owing to the commitment of the representatives of the Association of Artists and Cultural Organizers of Kuyavia and Dobrzyń Land. An popular lecture devoted to the megalithic idea and to the research of Funnel Beaker Culture tombs in

Fig. 10. The dismantling of a slag-pit furnace in order to obtain iron in the course of an experiment carried out during the "Ostrowiec Festival of Prehistoric and Ancient Culture". Photo: K. Dziewięcki.

Słonowice, given by Dr Krzysztof Tunia, served as a symbolic summary of the issues mentioned on the 23th of July.

Other interesting events in the series of celebrations were also some trips, botanic workshops and an archaeological walk across the reserve grounds. As there are no such trips in a standard Museum's offer, it was an unusual opportunity to get familiar with the rich natural and cultural heritage of Krzemionki under the guidance of scientific workers of the University of Łódź and the Historical and Archaeological Museum in Ostrowiec Świętokrzyski. The range of attractions available to the visitors was enriched by some promotion-education stalls, prepared by the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Warsaw, the National Museum of Przemyśl Land in Przemyśl, the Archaeological Museum in Cracow, the Kostrzyca Forest Gene Bank, the Association of Artists and Cultural Organizers of Kuyavia and Dobrzyń Land as well as the Publishing House and *Profil-Archeo* Archaeological Lab from Pękowice. On the occasion of the Krzemionki Holiday two publications came into existence. "The Krzemionki Herald" ("Kuryer Krzemionkowski") – a guide to the jubilee stylized as press of the interwar period (in July and August there were two issues prepared and the next is intended for September), and "Stones. The Megaliths of Europe" including information about the author of the photos, the phenomenon of megaliths and a selection of pictures presented at the above-mentioned exhibition.

The last week of July, 2022 did not see an end to the celebrations of the 100th anniversary of the discovery of prehistoric striped flint mines in Krzemionki. On August, 13th–15th, the next event took place and it was titled "Ostrowiec Festival of Prehistoric and Ancient Culture". It familiarized the public with the archaeological heritage of the Kamienna River Valley – from the Neolithic Period till the Period of Roman Influences within the wider cultural background – this also referring to lands situated outside Poland's present borders. Around 180 workshop and presentation leaders came from various Polish centres and institutions, but also from the Czech Republic (the *Familia Gladiatoria Taurus* groups and *Marobudum Project*). The Festival referred to the annual event with the same title from last year. At that time, the visitors were presented some information about the remains left by people of various cultures from prehistory and ancient times, both in Krzemionki and in Ostrowiec Świętokrzyski, but also in the Kamienna Valley. These include coin deposits, loose finds, settlement remnants, burial grounds and manufacturing sites, among others connected with iron production in the period of Roman influences (Fig. 10).

The celebrations of the jubilee of the discovery of the Krzemionki mines are held under the patronages of: the President of the Republic of Poland – in the centenary of the regaining of Polish independence, the Minister of Culture and National Heritage, the Marshal of the Świętokrzyskie Province and Governor of Ostrowiec County. The event is subsidized from the budget of the Ministry of Culture and National Heritage. An archaeological conference titled "Krzemionki: 100 years since its discovery", scheduled for October, is going to be the closing event of the celebrations. It will summarize a century of research, work on making the monument available to the public and of actions aiming at preserving it for future generations.

Archaeological Museum and Reserve Krzemionki

KRZEMIONKI

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Krzemionki are a relic of prehistoric mining. A visit there is an unique opportunity to see the original Neolithic and Early Bronze Age striped flint mines. In 2019 Krzemionki Prehistoric Striped Flint Mining Region was inscribed on UNESCO World Heritage List.

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Krzemionkowski region prehistorycznego górnictwa krzemienia pasiastego wpisany na Listę Światowego Dziedzictwa w roku 2019

Sudół 135a, 27-400 Ostrowiec Świętokrzyski

www.krzemionki.pl

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Krzemionki in the Literature Published in the Years 1923–1939

Magdalena Malak[a]

This article presents the literature referring to the striped flint mine in Krzemionki published within the first few years after the discovery of the site until 1939. The exceptional significance of the mine in Krzemionki inspired many scholars and authors of both scientific as well as popular-scientific texts. Information about this prehistoric mine also appeared in articles related to disciplines of science other than archaeology, as well as in the general press and a sightseeing guide.

KEY-WORDS: Krzemionki, prehistoric flint mining, Stefan Krukowski, Jan Samsonowicz, history of archaeology

Krzemionki in the Holy Cross (Świętokrzyskie) Mountains on the northern edge of the Lesser Poland Uplands is one of the most valuable locations on the archaeological map of Central Europe. The esteem of the site is evidenced by numerous publications, most of which appeared after World War II, when the research in Krzemionki was carried out on the greater scale (e.g., Żurowski 1960; 1962a; 1962b; Rajewski 1971; Bąbel 1975; 2014; 2015; Borkowski 1992; 1995; Lech 1992; 2016; 2020; 2021; Zalewski 1992; 2012; Jedynak and Kaptur 2008; 2016; Piotrowska 2014; *Krzemionki* 2018). This paper, however, concentrates on presenting the earliest articles dated to the Interwar Period, describing the discovery of the site, and the first research and conservation activities undertaken there.

The discovery of the unique striped flint mine in Krzemionki was associated with Stefan Krukowski (1890–1982; Fig. 1), who designed a research programme on the exploitation and utilisation of siliceous raw materials in the prehistory of Poland, starting from the Late Palaeolithic until the Early Bronze Age. These undertakings were stimulated by earlier papers by the German prehistorians, Gustaf Kossinna (1858–1931) and Georg Wilke (1859–1938), published in successive

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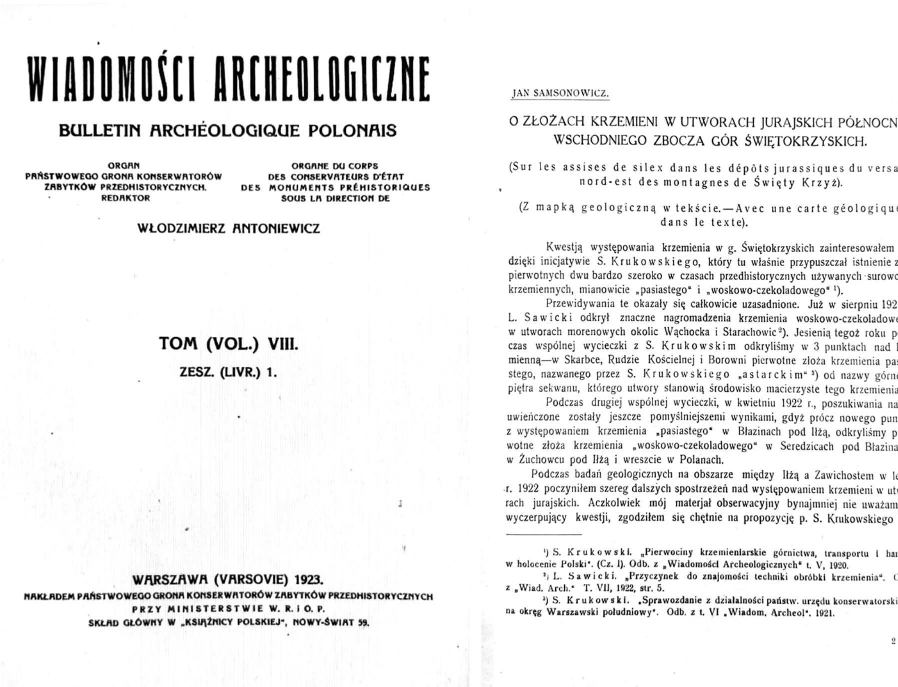
Fig. 1. Stefan Krukowski (1890–1982) in 1935. After: Lech 1992: 150.

Fig. 2. Jan Samsonowicz (1888–1959), photo taken in *c*. 1930. Public domain photo.

volumes of *Mannus* from 1917 and 1918 (Kossinna 1917; 1918; Wilke 1917). The above-mentioned scholars formulated various considerations on the origins and distribution of artefacts made of striped flint, axes in particular, in the context of migration of the Neolithic Indo-German communities (Piotrowska 2014: 24–29). In the years 1920 and 1922, Krukowski referred to the findings of these German prehistorians in two important papers dedicated to flint mining, exchange and distribution (Krukowski 1920; 1922). He questioned the opinion of Kossinna, who localised the striped flint deposits in Eastern Galicia (today's western Ukraine), instead indicating the Lesser Poland Upland as the possible area of occurrence of deposits of this specific raw material. Moreover, Krukowski expressed his doubts about the identification of a few artefacts allegedly made of striped flint, due to the lack of comparative and petrographic analyses of the raw material, and criticised the approach based on the assumption that the simple presence of a banded pattern on an artefact determines the classification of a siliceous material as striped flint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SKŁAD GŁÓWNY W „KSIĄŻNICY POLSKIEJ", NOWY-ŚWIAT 59.

JAN SAMSONOWICZ.

O ZŁOŻACH KRZEMIENI W UTWORACH JURAJSKICH PÓŁNOCNO-WSCHODNIEGO ZBOCZA GÓR ŚWIĘTOKRZYSKICH.

(Sur les assises de silex dans les dépôts jurassiques du versant nord-est des montagnes de Święty Krzyż).

(Z mapką geologiczną w tekście.—Avec une carte géologique dans le texte).

Kwestją występowania krzemienia w g. Świętokrzyskich zainteresowałem się dzięki inicjatywie S. Krukowskiego, który tu właśnie przypuszczał istnienie złóż pierwotnych dwu bardzo szeroko w czasach przedhistorycznych używanych surowców krzemiennych, mianowicie „pasiastego" i „woskowo-czekoladowego" [1]).

Przewidywania te okazały się całkowicie uzasadnione. Już w sierpniu 1921 r. L. Sawicki odkrył znaczne nagromadzenia krzemienia woskowo-czekoladowego w utworach morenowych okolic Wąchocka i Starachowic [2]). Jesienią tegoż roku podczas wspólnej wycieczki z S. Krukowskim odkryliśmy w 3 punktach nad Kamienną—w Skarbce, Rudzie Kościelnej i Borowni pierwotne złoża krzemienia pasiastego, nazwanego przez S. Krukowskiego „astarckim" [3]) od nazwy górnego piętra sekwanu, którego utwory stanowią środowisko macierzyste tego krzemienia.

Podczas drugiej wspólnej wycieczki, w kwietniu 1922 r., poszukiwania nasze uwieńczone zostały jeszcze pomyślniejszemi wynikami, gdyż prócz nowego punktu z występowaniem krzemienia „pasiastego" w Błazinach pod Iłżą, odkryliśmy pierwotne złoża krzemienia „woskowo-czekoladowego" w Seredzicach pod Błazinami, w Żuchowcu pod Iłżą i wreszcie w Polanach.

Podczas badań geologicznych na obszarze między Iłżą a Zawichostem w lecie r. 1922 poczyniłem szereg dalszych spostrzeżeń nad występowaniem krzemieni w utworach jurajskich. Aczkolwiek mój materjał obserwacyjny bynajmniej nie uważam za wyczerpujący kwestji, zgodziłem się chętnie na propozycję p. S. Krukowskiego na-

[1]) S. Krukowski. „Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski". (Cz. I). Odb. z „Wiadomości Archeologicznych" t. V, 1920.

[2]) L. Sawicki. „Przyczynek do znajomości techniki obróbki krzemienia". Odb. z „Wiad. Arch." T. VII, 1922, str. 5.

[3]) S. Krukowski. „Sprawozdanie z działalności państw. urzędu konserwatorskiego na okręg Warszawski południowy". Odb. z t. VI „Wiadom. Archeol". 1921.

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Fig. 3. The cover page of the journal *Wiadomości Archeologiczne* from 1923 contains an article by Jan Samsonowicz addressing the issues of Jurassic flints.

since such patterning could be observed in other variants of flints as well (Krukowski 1920: 201–203; 1922: 55).

In the research programme on flint extraction, namely in field surveys, Krukowski was supported, among others, by Jan Samsonowicz (1888–1959; Fig. 2) geologist from the Polish Geological Institute in Warsaw. The latter came from the surroundings of Ostrowiec Świętokrzyski and conducted geological studies in the Holy Cross Mountains (Piotrowska 2014: 31).

On July 19th, 1922 in the area of Krzemionki colony, just to the south of the village of Magonie, Opatów district, Samsonowicz discovered traces of shafts dug by prehistoric miners. As he later wrote, this was possible "thanks to a very fortunate coincidence that this is also the area from which limestone is extracted nowadays" (Samsonowicz 1923: 22). Extraction of limestone by the contemporary local community caused an uncovering of some parts of corridors and chambers, which opened an opportunity for Samsonowicz to visit the underground structures and make his first

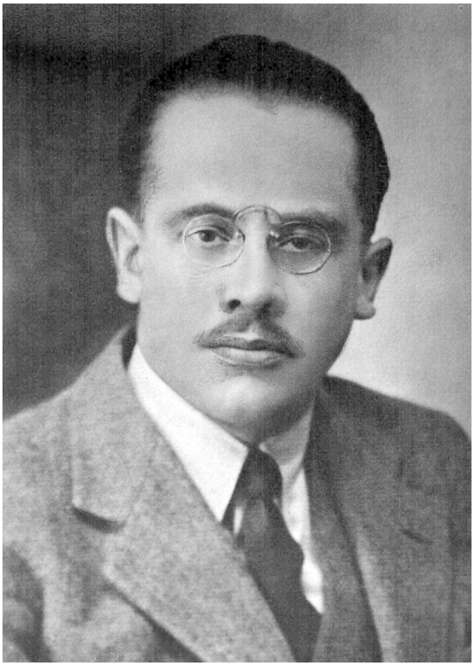
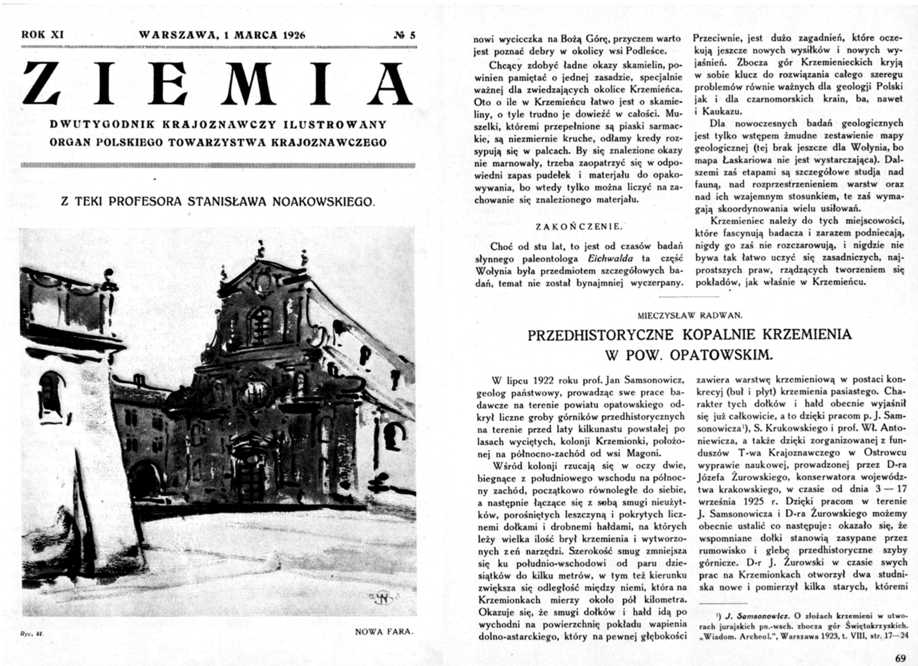


Fig. 4. Józef Żurowski (1892–1936) in *c.* 1930. Public domain photo.

observations. In 1923, in his paper dedicated to the outcrops of Jurassic flints in the Holy Cross Mountains (Fig. 3), he reported a discovery of several hundred mining shafts, complemented with his observations on their location, structure and functioning, as well as the nature of the flint materials found within (Samsonowicz 1923: 22). He also provided a geological map with the localisation of striped flint deposits and the locations of their mining extraction in antiquity (Samsonowicz 1923: 21).

In the very same year, together with his colleague, Zygmunt Szmit (1895–1929) Krukowski visited Krzemionki (which he called "Opatowskie" to differentiate it from a similarly-named source of flint just south of Cracow). These scholars carried out fieldwork on the complex, gathering several trunks full of flint artefacts spread over the surface of the site, which were then sent to Warsaw (Bąbel 1975: 165). The latter scientist returned to Krzemionki in 1927 but his work at that time, conducted on a much smaller scale, was interrupted. Unfortunately, the results of these investigations have remained unpublished (Bąbel 1975: 165). The first excavations in Krzemionki were carried out on September 3rd–17th, 1925 by Józef Żurowski (1892–1936; Żurowski 1929: 220; Fig. 4). He was a conservation officer for prehistoric monuments for the Cracow voivodeship, and a specialist in the field of the Neolithic (Piotrowska 2014: 39). The results of these archaeological studies, supported by observations made by Samsonowicz, were published in 1926 in the journal entitled *Ziemia* [The Earth] (Fig. 5), released biweekly by the Ostrowiec division of the Polish Tourist Society [Polskie Towarzystwo Krajoznawcze, PTK], which had also financed the excavations. The author of this publication was an engineer named Mieczysław Radwan (1889–1968; Fig. 6), a member of PTK in Ostrowiec, and a specialist in the field of metallurgy and history of technology. According to the information provided in this article, Żurowski counted in total as many as nearly 500 mining shafts, only within the area of Krzemionki. In the course



ROK XI WARSZAWA, 1 MARCA 1926 № 5

ZIEMIA

DWUTYGODNIK KRAJOZNAWCZY ILUSTROWANY
ORGAN POLSKIEGO TOWARZYSTWA KRAJOZNAWCZEGO

Z TEKI PROFESORA STANISŁAWA NOAKOWSKIEGO.

Ryc. 44. NOWA FARA.

nowi wycieczka na Bożą Górę, przyczem warto jest poznać debry w okolicy wsi Podleśce.

Chcący zdobyć ładne okazy skamielin, powinien pamiętać o jednej zasadzie, specjalnie ważnej dla zwiedzających okolice Krzemieńca. Oto o ile w Krzemieńcu łatwo jest o skamieliny, o tyle trudno je dowieźć w całości. Muszelki, któremi przepełnione są piaski sarmackie, są niezmiernie kruche, odłamy kredy rozsypują się w palcach. By się znalezione okazy nie marnowały, trzeba zaopatrzyć się w odpowiedni zapas pudełek i materjału do opakowywania, bo wtedy tylko można liczyć na zachowanie się znalezionego materjału.

ZAKOŃCZENIE.

Choć od stu lat, to jest od czasów badań słynnego paleontologa *Eichwalda* ta część Wołynia była przedmiotem szczegółowych badań, temat nie został bynajmniej wyczerpany. Przeciwnie, jest dużo zagadnień, które oczekują jeszcze nowych wysiłków i nowych wyjaśnień. Zbocza gór Krzemienieckich kryją w sobie klucz do rozwiązania całego szeregu problemów równie ważnych dla geologji Polski jak i dla czarnomorskich krain, ba, nawet i Kaukazu.

Dla nowoczesnych badań geologicznych jest tylko wstępem żmudne zestawienie mapy geologicznej (tej brak jeszcze dla Wołynia, bo mapa Łaskariowa nie jest wystarczająca). Dalszemi zaś etapami są szczegółowe studja nad fauną, nad rozprzestrzenieniem warstw oraz nad ich wzajemnym stosunkiem, te zaś wymagają skoordynowania wielu usiłowań.

Krzemieniec należy do tych miejscowości, które fascynują badacza i zarazem podniecają, nigdy go zaś nie rozczarowują, i nigdzie nie bywa tak łatwo uczyć się zasadniczych, najprostszych praw, rządzących tworzeniem się pokładów, jak właśnie w Krzemieńcu.

MIECZYSŁAW RADWAN.

PRZEDHISTORYCZNE KOPALNIE KRZEMIENIA W POW. OPATOWSKIM.

W lipcu 1922 roku prof. Jan Samsonowicz, geolog państwowy, prowadząc swe prace badawcze na terenie powiatu opatowskiego odkrył liczne groby górników przedhistorycznych na terenie przed laty kilkunastu powstałej po lasach wyciętych, kolonji Krzemionki, położonej na północno-zachód od wsi Magoni.

Wśród kolonji rzucają się w oczy dwie, biegnące z południowego wschodu na północny zachód, początkowo równoległe do siebie, a następnie łączące się z sobą smugi nieużytków, porośniętych leszczyną i pokrytych licznemi dołkami i drobnemi hałdami, na których leży wielka ilość brył krzemienia i wytworzonych zeń narzędzi. Szerokość smug zmniejsza się ku południo-wschodowi od paru dziesiątków do kilku metrów, w tym też kierunku zwiększa się odległość między niemi, która na Krzemionkach mierzy około pół kilometra. Okazuje się, że smugi dołków i hałd idą po wychodni na powierzchnię pokładu wapienia dolno-astarckiego, który na pewnej głębokości zawiera warstwę krzemieniową w postaci konkrecyj (buł i płyt) krzemienia pasiastego. Charakter tych dołków i hałd obecnie wyjaśnił się już całkowicie, a to dzięki pracom p. J. Samsonowicza[1]), S. Krukowskiego i prof. Wł. Antoniewicza, a także dzięki zorganizowanej z funduszów T-wa Krajoznawczego w Ostrowcu wyprawie naukowej, prowadzonej przez D-ra Józefa Żurowskiego, konserwatora województwa krakowskiego, w czasie od dnia 3 — 17 września 1925 r. Dzięki pracom w terenie J. Samsonowicza i D-ra Żurowskiego możemy obecnie ustalić co następuje: okazało się, że wspomniane dołki stanowią zasypane przez rumowisko i glebę przedhistoryczne szyby górnicze. D-r J. Żurowski w czasie swych prac na Krzemionkach otworzył dwa studniska nowe i pomierzył kilka starych, któremi

[1]) *J. Samsonowicz.* O złożach krzemieni w utworach jurajskich pn.-wsch. zbocza gór Świętokrzyskich. „Wiadom. Archeol.", Warszawa 1923, t. VIII, str. 17—24

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Fig. 5. *Ziemia* vol. 11, no. 5 from 1926 with the first page of Mieczysław Radwan's paper about the mine in Krzemionki.

of his investigations, he explored two shafts and identified a few more that were being devastated at that time by limestone exploitation. He also removed rubble from several dozen metres of corridors, thanks to which he encountered several extraction points. Moreover, Żurowski confirmed the observation previously made by Samsonowicz concerning the connections between corridors from various shafts, at some points constituting distinctive storeys, as well as the manner of flint exploitation in particular corridors (Radwan 1926: 70). This article also contained information about Gawroniec Hill, near the locality named Ćmielów, some 10 km to the south of Krzemionki, where a workshop producing axes was discovered.

This publication provided a comprehensive presentation on the contemporary state of knowledge of the time about this site, covering the results of research carried out by Samsonowicz, Krukowski and Żurowski (Radwan 1926). The information contained within this work laid the groundwork for other papers describing or mentioning the mine in question that were published later on. Unfortunately, it did not include documentation and plans created by Żurowski (Bąbel 1975: 165). This lack is even more severe due to the fact that this scholar had passed away before World War II started, during which his entire documentation from this site was lost.

The paper by M. Radwan was referred to by Bożena Stelmachowska (1889–1956), an ethnographer who quoted the flint mine in Krzemionki in her overview of the prehistoric mining in the Stone Age (Stelmachowska 1927: 45). This article was published in volume II of the popular science journal entitled *Z Otchłani Wieków* [From the Abyss of the Ages] of 1927, published by the Prehistoric Department of the Museum of Greater Poland in Poznan. Radwan's paper was also mentioned by Żurowski himself, in his reports on work conducted in Krzemionki, while the latter took up the position of a conservation officer for prehistoric monuments in the years 1924–1926 (Żurowski 1929: 220).

In 1928, the flint mine in question was discussed by Włodzimierz Antoniewicz (1893–1973) in a comprehensive study on the archaeology of Poland in prehistoric and early historical times. In the context of the Nordic Culture industry, he mentioned the discovery of a striped flint mining exploitation spot dated to the Neolithic in the locality which he named Magonie, Opatów district (Kielce Voivodeship at that time). The author provided information on the nature of the deposit, the structure of shafts and mining methods, as well as the functioning of prehistoric mining (Antoniewicz 1928: 60–61).

Fig. 6. Mieczysław Radwan (1889–1968) in *c.* 1930. Source: http://radwan.org.pl/files/show/296

After his work of 1923, Stefan Krukowski was for a while not interested in further investigating this Neolithic site (Krukowski 1939: 113). He decided to return to Krzemionki in 1928 as a curator (Piotrowska 2014: 40). To a great extent, he was driven by the necessity to protect this complex, destroyed at that time not only due to limestone exploitation but also by the activity of local looters who obtained striped flint for sale (Krukowski 1939: 114).

At the beginning of 1928, Krukowski wrote a preliminary characterisation of the mine for the manager of the State Board of Inspectors of Prehistoric Remains, Roman Jakimowicz

(1889–1951), who then took up the position of the director of the State Archaeological Museum in Warsaw. This report aimed at "revealing and formulating arguments for rationalisation of the protection over the site, and then, commencing works to transform it into an archaeological reserve" (Krukowski 1932: 53). This work, based on observations made by Krukowski in Krzemionki in 1923, was published in 1932 in volume XI of the archaeological journal entitled *Wiadomości Archeologiczne* [Archaeological Information]. The author accurately pointed out the greatest value of Krzemionki, which was the well-preserved and unique landscape shaped by the activity of prehistoric miners. This landscape included mining waste heaps, hollows left by shafts, extensive workshops, as well as sinkholes; the latter being the only source of water in the Neolithic Age. The relics of mining production, in the author's opinion, evidenced the advanced organisational level of the community exploiting the site, with the number of shafts and the scale of production considerably exceeding those known from some other prehistoric flint mines in Europe (Krukowski 1932: 54–55).

Stefan Krukowski also undertook some attempts to disseminate information about this exceptional site amongst a wider audience, always stressing the necessity to protect it and make it accessible for visitors. For this purpose, he wrote another article that was published in 1933 in the cultural and social journal entitled *Tygodnik Ilustrowany* [Illustrated Weekly] (Fig. 7). He also wrote other such popular-science papers, which were published in the general press in the inter-war period (Lech 2016: 245). In a similar tone was the paper by Józef Kostrzewski (1885–1969), published in 1934 in the Poznan journal *Ilustracja Polska* [Illustration of Poland]. This article described 40 centuries of mining in the territory of Poland, and its greatest part was dedicated to the flint mine in Krzemionki. He presented the contemporary state of knowledge on this site and stressed its exceptional nature (Kostrzewski 1934: 7, 15). On a few other occasions, Kostrzewski mentioned the existence of several hundred Neolithic mining shafts in Krzemionki in his papers addressing the issues of the Neolithic cultures and distribution of flint artefacts (Kostrzewski 1935: 64; 1939: 145). Similar information referring among other things to the structure of mines and the manner of exploitation of flint deposits in Krzemionki, was given in 1932 in the Cracow journal entitled *Kuryer Literacko-Naukowy* [Literary-scientific Courier]. The author of this article on prehistoric flint mines was an archaeologist, Jan Fitzke (1907–1940; Fitzke 1932: IV).

As was mentioned above, the information on the discovery of the remains of prehistoric mining was published in papers related to disciplines of science other than archaeology. In this respect, one can name an article on the anthropo-geographical evolution of the Kielce-Sandomierz Upland written by a geographer, Stanisław Lencewicz (1889–1944; Lencewicz 1936: 69). The exceptional cognitive values of he


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TYGODNIK ILLUSTROWANY

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O NAJWYBITNIEJSZYM POMNIKU PRADZIEJÓW W EUROPIE ŚRODKOWEJ

Fig. 7. *Tygodnik Ilustrowany* from March 19th, 1933, containing the article by Stefan Krukowski.

flint mine in Krzemionki were also stressed in a book dedicated to the history, geography and attractive sightseeing locations in the Sandomierz Land and the Holy Cross Mountains written by the social activist and a traveller, Aleksander Patkowski (1890–1942; Patkowski 1930).

Until 1938, the work carried out in Krzemionki focused mostly on securing, tidying up and protecting the area, as well as purchasing land where the prehistoric mining field had been primarily localised. As early as 1928, a guardian was hired to look after the reserve. His duty was to protect and monitor the part of the acquired mining field, and therefore, save it from the destructive consequences of limestone exploitation (Piotrowska 2014: 39, 47). Moreover, despite the lack of appropriate financing and unfavourable weather conditions, excavations were carried out (Krukowski 1939: 119; Piotrowska 2014: 41). In 1929, Krukowski succeeded in exploring three shafts located within the land managed by the local authorities of the Magonie village. On the walls of the mining pits here, he discovered schematic drawings made with charcoal by the prehistoric miners (Bąbel 1975: 170–171). Due to the

ważniejszych obiektów wykopaliskowych w terenie. Podobną rzecz dałoby się z łatwością zorganizować dla kół krajoznawczych.

Jeśli by się udało istotnie zachęcić krajoznawców polskich do wydatnej współpracy z obecnymi czynnymi ośrodkami badawczymi w naszych miastach uniwersyteckich i gdyby nadto uznali za pilną potrzebę obsadzenie swych muzeów regionalnych dobrymi a płatnymi fachowcami, to możnaby śmiało twierdzić, że archeologia polska wysunie się na czoło europejskich badań nad pradziejami ludzkości, boć już i teraz nie brak głosów uznania szeregu uczonych zagranicznych dla rezultatów badań szczupłej garski polskich prehistoryków.

Trzeba tu na koniec dodać, że przyśpieszenie rozwoju naszej prehistorii jest absolutną koniecznością, a nie żadnym luksusem. O bycie i znaczeniu narodów nie decydują dziś bynajmniej tylko te nauki, których zdobycze można stosować w praktyce życia codziennego. Twierdzenie to staje się oczywiste, jeśli się uwzględni, że propaganda polityczna wielu państw, zmierzająca do ugruntowania swych roszczeń terytorialnych, czy też podstaw obowiązujących »artykułów wiary politycznej«, wprzęga do swego rydwanu wszystkie nauki humanistyczne bez wyjątku, przy czym jedno z czołowych miejsc zajmuje prehistoria.

KONRAD JAŻDŻEWSKI

KRZEMIONKI OPATOWSKIE POMNIK GÓRNICTWA PIERWOTNEGO, PREHISTORII I PRZYRODY NIEOŻYWIONEJ

Krzemionki opatowskie to miejscowość w powiecie opatowskim w województwie kieleckim, obejmująca kopalnię przedhistoryczną krzemienia, jej pobliskie równie dawne urządzenia pomocnicze i zbiorniki naturalne wody ongiś konsumcyjnej, oraz małe otoczenie tego wszystkiego.

Krzemionki opatowskie leżą między Bałtowem (pow. Iłża) od północy (5 km), a Ćmielowem od południa (9 km), na ziemiach wsi Magonie, Krzemionki (eponimiczne), Stoki Stare i w lesie Krzemionki, który między rolami Krzemionek i Stoków Starych. Należą do gminy Ruda Kościelna.

Znajdują się w dorzeczu Kamiennej. Tam, gdzie jej dolina biegnie, jak południk. Są poza doliną Kamienej, 2 km na Z. od niej i od wsi Boria. Rozłożone na rzecznej wysoczyźnie, na równinnej części wododziału tej rzeki i jej dopływowej wodący. Najmniejsza odległość od Wisły — dwadzieścia kilka km na W.

O 9 km na południowy zachód — Ostrowiec, jedno z większych przemysłowych miast województwa. Ze stacji kolejowej Ostrowiec Świętokrzyski wiedzie ku Krzemionkom droga bita, wydłużana sposobem samodziałowym na Bałtów. Teraz droga urywa się w Jeleniej Górze o ½ km od Krzemionek opatowskich. Tędy najwygodniejsze połączenie ze światem.

I. PRZYRODA
I RAMY PRZYRODZONE GOSPODARKI.

1. Sytuacja geograficzno-geologiczna. Ogólna — Łysogóry, zwane też górami Świętokrzyskimi. Jak wiadomo, nie są to góry, lecz niskie resztki gór właściwych, jakie istniały w odległej geologicznej przeszłości. Są częścią systemu górskiego hercyńskiego, starszego od Alp i Karpat, zachowanego w Europie pod postacią szczątków, zwanych górami Środkowymi. Pierwotne góry Łysogór uległy naturalnemu niszczeniu, obniżaniu, bądź zrównywaniu, jak przy Krzemionkach opatowskich. Stało się to przed erą czwartorzędową (antropozoiczną), w której początkach zjawili się najpierwotniejsi ludzie.

Krzemionki opatowskie są położone w tzw. północnym zboczu Łysogór. To zbocze jest pojęciem tektonicznym, dotyczy starych utworów podłoża, a słabo wyraża się w łagodnych formach powierzchni ogólnej. Zbocze wyciągnięte między Pn.-Z., a Pd.-W., nieprzymierzając na linii Orońsk (między Szydłowcem i Radomiem) — Zawichost. W obrębie »zbocza« Krze-

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Fig. 8. *Ziemia* vol. 22, no. 9–10 from 1937, containing the first part of the article by Stefan Krukowski.

poor state of preservation of the underground structure, the shafts were released for limestone exploitation (Krukowski 1939: 55–58). Nevertheless, another three shafts, this time in Krzemionki, were secured against destruction. They were then studied by Krukowski in the following years (Bąbel 1975: 170–171).

In 1939, Stefan Krukowski published a monograph of the site, a summary of the contemporary state of knowledge on the striped flint mine in Krzemionki (Krukowski 1939; Fig. 9). This work was an extension of two comprehensive articles that he had published in 1937 in a monthly journal entitled *Ziemia* [The Earth] (Krukowski 1937; Fig. 8). The publication of this monograph was financed by the Museum of Technology and Industry, supported by the State Archaeological Museum in Warsaw and in association with the periodicals *Ziemia* [The Earth] and *Przegląd Górniczo-Hutniczy* [Mining and metallurgy Review]. In this book, Krukowski presented the site in question in a broader context, including discussions of the geological, natural environment-related, historical and social issues. He included an accurate


S. KRUKOWSKI

KRZEMIONKI OPATOWSKIE

WARSZAWA 1939

NAKŁADEM MUZEUM TECHNIKI I PRZEMYSŁU
PRZY WSPOŁUDZIALE PANSTWOWEGO MUZEUM ARCHEOLOGICZNEGO,
MIESIĘCZNIKA „ZIEMIA" I MIESIĘCZNIKA
„PRZEGLĄD GORNICZO-HUTNICZY"

Fig. 9. Cover page of the monograph dedicated to Krzemionki from 1939.

description of the various elements of the mining architecture, the structure and functioning of shafts, underground mining pits, methods and tools for flint extraction, as well as ventilation and lighting systems. He also raised the issues of the organisation of work, the distribution of finished and semi-products, as well as spatial relationships between the mines and surrounding settlements. The author also included his reflections on the religion of the miners and the symbolism of the elements of art found on the walls of the mining pits, though now they may be considered too far-reaching. The monograph ended with a presentation of a detailed programme of protection of this complex, altogether with information on what had been done up to date, and what was required to be done in the future. Based on the above-mentioned monograph, another comprehensive article by Franciszek Banasiak was published in 1939 in the journal *Polska Zbrojna* [Armed Poland]. In this paper, the ancient complex in Krzemionki, in the area of which the raw materials were extracted, processed, used for the production of particular products, and finally, traded, was, quite accurately, compared with the "Central Industrial Region" being developed in contemporary Poland.

The publication of Krukowski's monograph of Krzemionki was the culmination of the first stage of studies upon this extraordinary site, one of the most famous monuments of prehistoric mining, the significance of which must be considered on the European scale. At present, it remains a valuable source of knowledge on the functioning of the mine. It is also the most important item position in the entire bibliography dedicated to the striped band flint mine in Krzemionki from the Interwar Period.

During World War II, all archaeological investigations on the site ceased. A new chapter in the studies of the Krzemionki mining site opened after the ending of the War in 1945.

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Non-invasive Investigation of Segment C of the Krzemionki Exploitation Field. Initial Research Results

Artur Jedynak[a] and Piotr Wroniecki[b]

Non-invasive research has been undertaken in the southern arm of the archaeological area of the Krzemionki exploitation field, which is one of the least excavated of its regions. Geophysical prospection covered an area of 3.5 ha, and in addition, an area of more than 5 ha was examined by surface collection. The image of the underground structures was obtained thanks to a comprehensive comparison of the results of magnetic, earth resistance and GPR measurements, as well as the distribution of archaeological finds on the ground surface. The study was supplemented with data obtained from the analysis of archival aerial photos and Airborne Laser Scanning (ALS) derivatives. On the basis of these complementary data, it was possible to create a general image of the distribution of archaeological sources in the study area. When trying to determine the potential range of the exploitation field, the most legible results were obtained from earth resistance survey and magnetic gradiometry methods. In the most fully explored fragment of the area, anomalies suggesting the presence of prehistoric mining facilities are located in a strip 40–60 m wide, running in the NW-SE direction. Surface studies showed the presence of anthropogenic limestone debris in a zone of similar width (50–75 m) and the direction of its course, while the spread of flint and erratic stone finds turned out to be even greater (a belt 70–90 m wide). Geophysical surveys indicate the possibility of the existence of flint workshops and settlement facilities around the mining field. This can be confirmed in future by further systematic studies of its surroundings.

KEY-WORDS: Krzemionki, exploitation field, non-invasive research, striped flint

The Krzemionki striped flint mines are one of the most important monuments of prehistoric mining in the world. They functioned throughout much of the Neolithic period and at the beginning of the Bronze Age (3900–1600 calBC). Discovered

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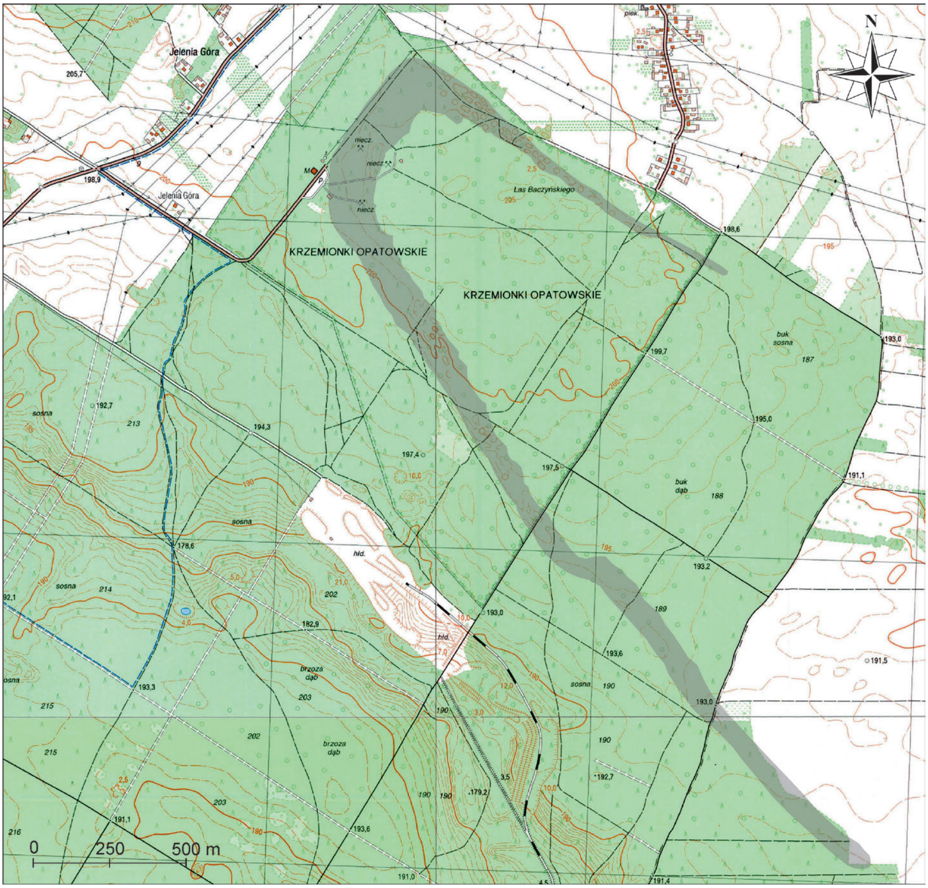

Fig. 1. Approximate extent of the Krzemionki exploitation field drawn on the basis of the Digital Terrain Model and previous interpretations (including Bąbel 2015 and Borkowski and Michniak 1992) on the basis of the topographic map 1: 10000, Sudół and Boria sheets, ed. Geokart-International Rzeszów 2002–2003.

in 1922, the exploitation field covers about 4000 mines, representing the majority of prehistoric flint extraction techniques. The largest of them, chamber mines, reached a depth of 9 m with several hundred square metres of underground workings (Bąbel 2008: 90–91). In the period of functioning of the Globular Amphora culture (3100–2400 calBC), the polished striped flint axes produced here were distributed to customers living in a large part of Central Europe. In addition to the distinctive size of the mining area and the state of preservation of the underground workings, other

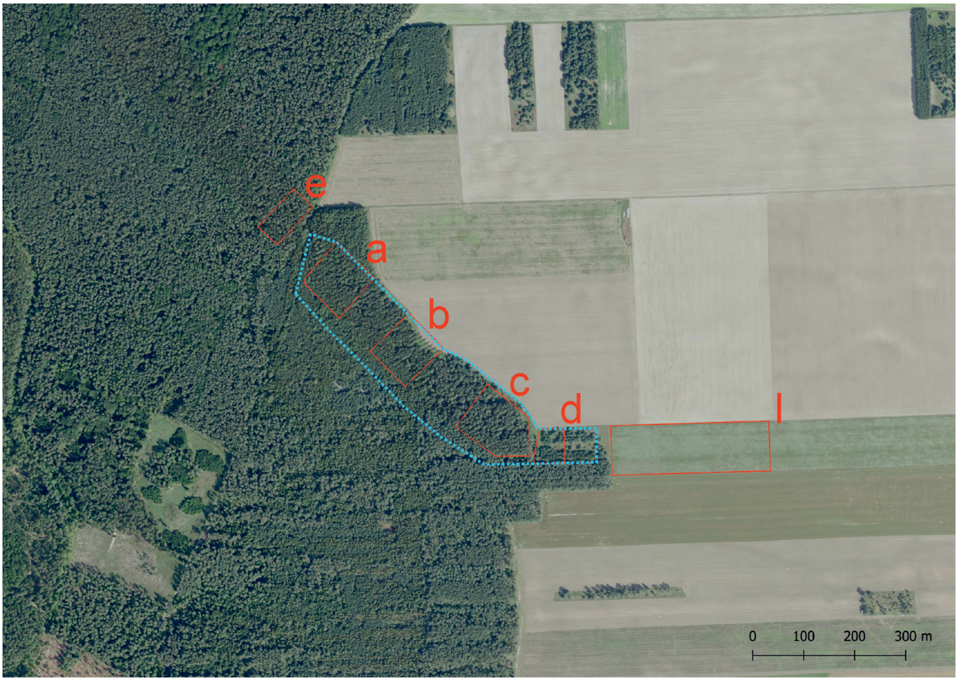

Fig. 2. Zones selected for geophysical research (red outline), surface survey (blue outline) and the approximate extent of the exploitation field (hatching) on the basis of a modern orthophotomap.

noteworthy components of the site include the post-mining landscape in the form of spoil heaps and shaft hollows, as well as the presence of relics of communication routes, flint workshops and wooden structures of mining infrastructure. These unique features were the basis for the inclusion of the monument on the UNESCO World Heritage List in 2019.

The Krzemionki mining field covers an area of 78.5 ha, 20 to 200 m wide and almost 4.5 km long. Its parabolic shape results from the location of the shafts at the edge of the Magonie-Folwarczysko Jurassic syncline and the outcrop of striped flint (Fig. 1). The post-mining topography is not visible everywhere, which makes it difficult to clearly define its boundaries. In many places, as a result of modern, intensive agricultural activity, the boundaries of the zone of spoil heaps and shaft hollows have disappeared. This applies especially to areas of the site characterised by shallow exploitation, i.e. the pit and niche mine zones located on the outer boundaries of the exploitation field and at its south-eastern end (Bąbel 2015: 16–17). One such area is the so-called segment C, i.e. a part of the southern arm of the exploitation field that extends from the line of a clear geological fault to its edge (Borkowski 1995: 51–53; 2000a: 128, Fig. 2, 186). It was its most eastern part, deforested and cultivated at least from the 18th century, that was covered by non-invasive archaeological research in 2021 as part of the Protection of Archaeological Monuments program managed by the National Heritage Board of Poland and co-financed from the budget of the Minister of Culture and National Heritage (Fig. 2).

THE AIM OF THE RESEARCH AND ITS ENVIRONMENTAL AND ARCHAEOLOGICAL CONTEXT

The Krzemionki site is located in the area of the Iłża Foothills (Przedgórze Iłżeckie), an area built of Jurassic and Cretaceous rocks, covered with Tertiary and Quaternary formations, including loams, sands and, to a small extent, loess. The relief of the area is varied, the landscape is upland and submontane. There are also undulating plateaus and periglacial lowlands with eskers and kames. The area is crossed by the valleys of the Iłżanka and Kamienna rivers, the latter creating picturesque limestone gorges. There are also loess landscapes with ravines. The most common soils in the region are rendzinas and lessive, rusty and podzolic soils made of glacial sands, as well as lessive and black soils formed in loess, and marshy meadows. The potential vegetation cover consists of mixed pine-oak and pine forests, Central European oak-hornbeam forests, open lowland oak forests, riverside willow-poplar and ash-elm riparian forests. There are also semi-natural xerothermic steppe grasslands in the area. Today, forests cover over 40% of the area, and the remaining part is agricultural land (Strzyż 2021: 419–420).

The oldest, surface formations in the eastern part of the area of the Iłża Foothills, where the site of Krzemionki is sited (in Bodzechów and Ćmielów municipalities), are the rocks of the Upper Jurassic, arranged in two sets of beds. In those dated to the Oxfordian, there are platey limestones, shales and marly limestones with flints, above which there are compact limestones with flints, reef-coral limestones, and above them oolite limestones with striped flints. In the other set of beds, dating to the Kimmeridgian, there are mainly oolite limestones, marls and marl limestones, and numerous layers of shelly limestones. Tertiary formations (karstic clays and weathered sands) occur mainly south of the prehistoric mining field, in the area of the so-called Sudolska Valley, and are usually associated with karst forms that arose in the Miocene layer. Quaternary sediments are more common, among which the predominant element are layers associated with the Central Polish glaciation. These are tills as well as sands and

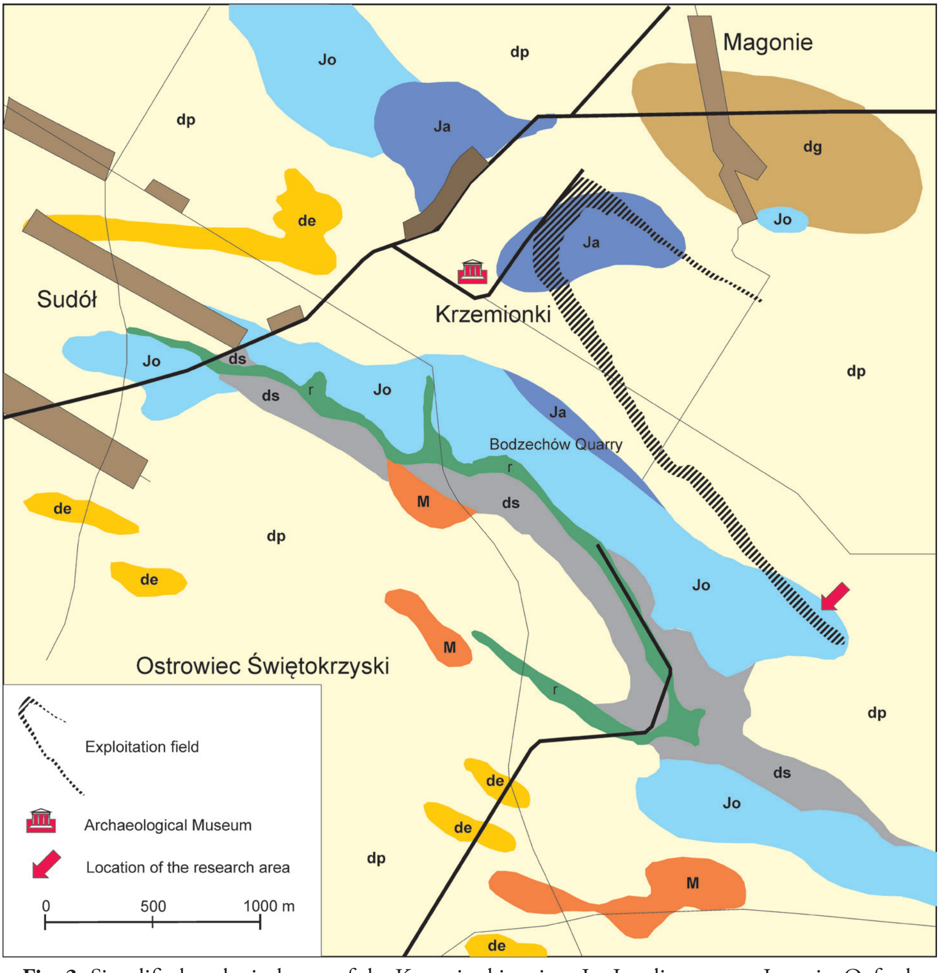

Fig. 3. Simplified geological map of the Krzemionki region: Jo, Ja – limestones, Jurassic, Oxford, dp – sands of glacial accumulation with boulders, Pleistocene, de – aeolian sands, Pleistocene / Holocene, ds – alluvial sands and silts, Pleistocene / Holocene, dg – glacial till, Pleistocene, M – karstic clays, Miocene, according to J. Fijałkowski 2000.

gravels with hydro-glacial and glacial boulders that cover most of the area in question and shape the present-day landscape (Fijałkowski 2000: 3–5, Fig. 2, 3; Fig. 3).

The project discussed in this paper was conducted in the area of the "Krzemionki Opatowskie Nature Reserve" and in its vicinity. Prehistoric flint exploitation had shaped not only the surface relief of the landscape, but also the stratigraphy of the shallowest geological layers that differed from the natural pattern. The weathered clay and limestone rubble taken from deeper seams caused a change in the humidity and the abundance of minerals in the area of the exploitation field, and thus favoured the development of certain plants and animals. In the post-mining areas, a subcontinental oak-hornbeam forest with xerothermic grasslands has developed. However, in their surroundings, in post-agricultural areas, there is mainly a subboreal mixed coniferous forest (Barga-Więcławska 2016; 28–34). The research area was mostly forest areas and overgrown former farmlands, hence there was a great difficulty in carrying out the work, especially with the use of measuring equipment. The main goal was to investigate the least studied part of the exploitation field, and in particular to answer two basic questions:

– what is the actual extent of the area covered by prehistoric mining works?
– are the mines themselves accompanied by other types of archaeological features related to the prehistoric flint mining or other structures on the Krzemionki site?

Obtaining more complete archaeological knowledge about the south-eastern edge of the site would also facilitate the conservation protection of this fragment of the monument, especially in the context of emerging threats in its vicinity in the form of plans for the location of large mining investments nearby (Jedynak 2020).

For the first time, an indicative outline of the mining area, identical to the extent of limestone outcrops with striped flint, was presented by Jan Samsonowicz on the Opatów sheet of the General Geological Map of Poland that he compiled (Samsonowicz 1934). Subsequent researchers, including Stefan Krukowski, Zygmunt Krzak, Tadeusz Żurowski, Wojciech Borkowski, and Jerzy Tomasz Bąbel, copied the shape of the southern fragment of the exploitation field (Krukowski 1939: 1, Fig. 1; Krzak 1961: 31, Fig. 2; Żurowski 1962; Borkowski 1995: 58, Fig. 38; Bąbel 2015). W. Borkowski and Ryszard Michniak, authors of a study devoted to the geology and methods of flint mining, devoted more attention to this part of the Krzemionki mines. They divided the entire area into zones that differed in terms of the type and depth of the extraction carried out there. In Segment C, which coincides with part of the current research area, they saw a shallow exploitation through the use of pit and niche mines analogous to the neighbouring part of Segment B (Borkowski and Michniak 1992: 31).

Unfortunately, we do not have any geological and archaeological profile of the studied area because no excavations have ever been carried out here. The nearest excavated features (5/1416 and 10/1441) are located approximately 1150 m to the north-west, in segment B2. The profile of the 10/1441 trench shows the stratigraphy of the geological deposits lying here up to a depth of 7.5 m. Jurassic limestones appear here already at a depth of about 1.8 m. The upper parts are humic

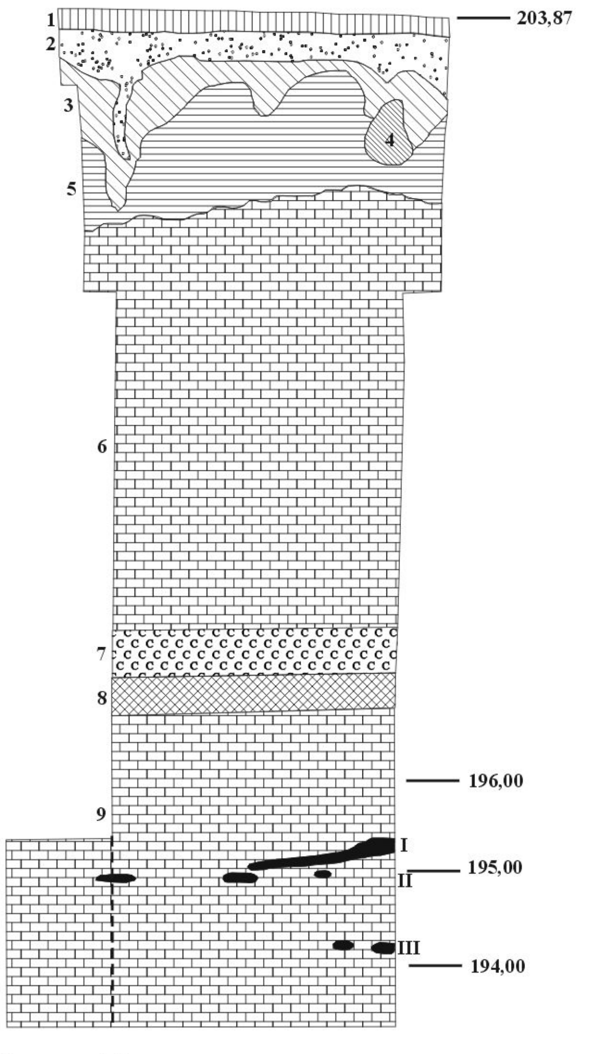

Fig. 4. Geological profile characteristic for the Krzemionki region: 1 – forest humus, 2 – sand, 3 and 4 – clay, 5 – limestone weathering, 6 – pelitic limestones, 7 – limestones with benthic fish burrows, 8 – oolitic limestones, 9 – pelitic limestones, fine-grained, I-III – flint beds according to J. Bąbel 2015.

layers (depth 0 – 0.25 m), sand (depth 0.25 – 0.5 m) and moraine clay gradually turning into calcareous weathering (from 0.5 to 1.8 m). The first flint bed occurs at a depth of 7.5 m (Borkowski 1995: 52, Fig. 36). This is the typical image of the stratigraphy of the Krzemionki exploitation field, and the individual profiles differ mainly in the thickness of the Pleistocene and Holocene layers (cf. Borkowski 1995: 48–49, Fig. 26–29, 31, 32; Bąbel 2015: 47, Fig. 39; Fig.4).

The most information about the geology of the reserve is provided by the work of Jerzy Fijałkowski, who described the profiles of a dozen or so outcrops and quarries located to the west and south of the study area. Their analysis shows that the Quaternary layer, made of humus, sand and weathered clay mixed with limestone rubble, has a thickness here of up to 2 m, but more often it is thinner and is from 1 to 1.5 m. Below, there are different types of Oxford limestone (Fijałkowski 2000: 11).

The key work undertaken in the area in question during the present project consisted of an earth resistance survey conducted by Tomasz Herbich and the accompanying excavation sampling survey (trial trenching) carried out by the Team for the Study of Prehistoric Flint Mining of the State Archaeological Museum in Warsaw in 1989. These surveys were carried out in an area where the relief features of the post-mining landscape were unpreserved. The multi-level profiling of the area covering both the exploitation field itself and fragments of the surrounding area showed differences in the electrical resistance of the layers that had not been disturbed by human activity compared with the places where mining had taken place. This made it possible to define the approximate extent of prehistoric flint mines and to select sites for the excavation survey test pits. The excavations located on the edge of the defined mining zone revealed the backfills of two mining shafts (Herbich 1993). Based on the positive results of these studies, further exploration of the southern part of the Krzemionki exploitation field is planned.

RESEARCH METHODS, SCOPE AND RESULTS

In 2021, archaeological work was carried out using several non-invasive methods. These were geophysical methods (earth resistance, magnetic and Ground Penetrating Radar GPR) combined with surface prospection and the analysis of the Digital Terrain Model made on the basis of airborne laser scanning and archival aerial photos. The results obtained by each method were compared. The proposed techniques of prospection have already been applied with positive results to research on prehistoric flint mining landscapes, including at Krzemionki (cf. Herbich 2000; Misiewicz 2000; Borkowski 2000b; Welc *et al.*, 2014; 2016; Mieszkowski *et al.*, 2014). However, this project was the first time that these several methods were used simultaneously and the obtained results integrated into a GIS project.

In the preliminary stage, 6 zones with the designations from a to e and l were designated for geophysical exploration. Finally, four (b, c, e and l) with a total area of 3.5 ha were selected for fuller study. Only in zone e had the prehistoric post-mining landscape survived. Measurements within this segment of the site were carried out to compare the results with other zones, where heaps and shaft hollows have not survived. An area of 3.5 ha was examined by GPR and magnetic methods, while the electrical resistance method was employed over an area of 1 ha. The surface collection prospection covered an area exceeding 5 ha. Zones a, b and c, which were located in a forest, required to a different degree, additional preparation for research (removal or thinning of the undergrowth). Zone l was located in the meadow area of a forestry aircraft landing site (Fig. 2).

Geophysical Investigations

The part of the site covered by the research included both forest and open areas (the latter comprising that grass strip of a landing field), which made accessibility to both the measuring devices together with their operator very varied (Fig. 5). In general, it can be assumed that the terrain was very difficult to research, which was reflected not only in the field activities, but also in the quality of the measured signal of geophysical measurements. Nevertheless, efforts were made to conduct the measurements in such a way as to obtain the most uninterrupted, long measurement profiles, which is favourable for the readability of the results. Three geophysical methods were used in the research, including GPR, magnetic measurements and earth resistance. Geophysical surveys were performed along with geodetic measurements, so all measurements and results were integrated by GIS for the purpose of data management, creation of site plans and data interpretation.

Geophysical surveys as a set of non-invasive archaeological prospecting techniques enable the recognition of the natural features of subsurface layers without interfering with the soil structure. Based on the results of the prospection, it is possible to indicate the places of potential presence of archaeological features related to past human activity and the transformation of the landscape as a result of these activities. The selection of methods and their specifications, including the accuracy of geophysical and geodetic measurements during the work, aimed at obtaining the fullest possible set of data presenting disturbances caused by subsurface structures. The interpretation of this information is based on the analysis of the contrast between the natural geological background and the visible changes in the values of the measured features (cf. Aspinall *et al.*, 2008; Conyers 2013; Schmidt 2013).

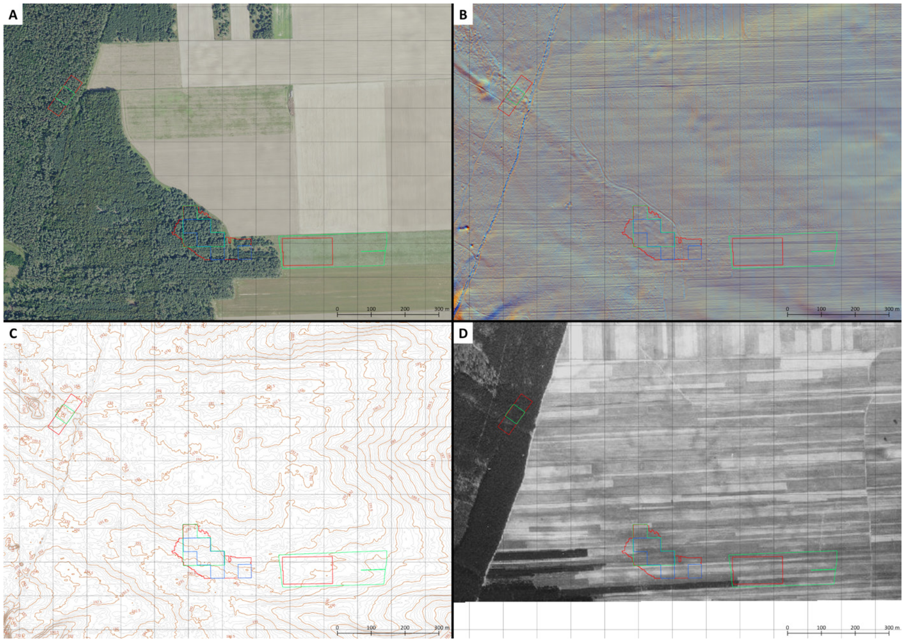

Fig. 5. Location of geophysical research, red outline – magnetic research; blue outline – earth resistance survey; green outline – GPR surveys, superimposed on various backgrounds, A) contemporary orthophotomap; B) hillshaded terrain model based on ALS; C) contour plan; D) archival orthophotomap from 1964.

The GPR method (Figs. 6c and 6d) allows creating a three-dimensional image of what is underground up to the maximum measurement depth of the antenna employed. During the research, an antenna with a frequency of 400 MHz was used, allowing measurement to a depth of approx. 3.5 m. The results are presented in the form of radar profiles, which are most often visualized in the greyscale convention. They show the result of the depth measurement in the form of XYZ, where Z is the reflection of the electromagnetic wave below the ground surface. Properly prepared by means of specialized filtration, the radarogram is processed into the form of time-slices that show the distribution of anomalies on a plane, depending on the depth, in a manner comparable to magnetic or electrical resistance maps. In total, 236 profiles with a total length of just over 34,574 metres (34.57 km) were made. The GPR profiles were made at least every 1.5 m (on average every 1 m).

Magnetic measurements were also used in the project (Fig. 6a). Measurements of the distribution of the magnetic field values allow the indication of the distribution

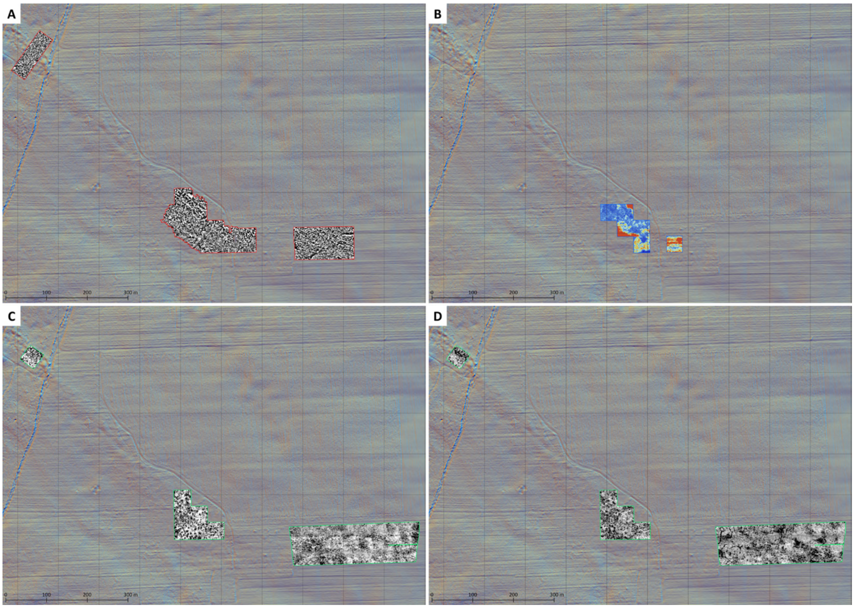

Fig. 6. Compilation of the results of various research methods used during the research in 2021, A) visualization of greyscale gradiometric data, negative readings in white, positive readings in black; B) visualization of earth resistance data, 0.5m Wenner array, low readings in blue, high readings marked in red; C) visualization of radar measurements converted to a time-slice at a depth of about 40 cm; D) visualization of radar measurements processed into a time-slice at a depth of about 120 cm.

of geophysical anomalies and to estimate the range and nature of the archaeological characteristics of the site. Measurements were taken using a Bartington Grad 601–2 dual probe fluxgate magnetometer in parallel profiles with a measurement density of 1m x 0.25 m.

Earth resistance measurements were also made in the profiling mode (Fig. 6b). This technique complementarily enriches the image of subsurface structures with information on approximate depth, constituent material and thickness. Measurements are recorded in a regular, dense grid, thanks to which it is possible to examine multi-layer objects as well as to conduct wide-area prospecting. Based on the results, high- and low-resistance zones are distinguished, which can be associated with backfills, ditches and any stratigraphic disturbances, as well as with the existence of non-conductive structures. Electrical resistance measurements were carried out using the network of polygons designed for the magnetic measurements. Data were recorded using the Geoscan Research RM–15D Advanced device in a Wenner electrode configuration with a depth profile of up to 0.5 m and a measurement density of 1 x 1 m.

The research area was divided into polygons, the tops of which were fixed in the field with wooden pegs. For this purpose, a GPS RTK instrument and a robotic laser total station were used, which allowed for embedding the points of the designed measuring grid with an accuracy of 3 cm. The tops of the polygons were measured into the National Geodetic Coordinate System (PUWG 92; EPSG: 2180).

The GPR surveys detected anomalies of various nature throughout the surveyed area. The eastern area - the landing site - is characterized by a large number of small, larger circular and more complex examples of GPR anomalies, especially at its western end. Undoubtedly, the identified features look very promising and require further individual investigation. The central area (zone c) is also characterized by a rich set of anomalies, in this case of rather small size. It cannot be ruled out that the source of some of these are natural features, e.g., the root system of trees, but attention is drawn to the mapped groups of anomalies arranged in a circular pattern around a central anomaly and anomalies that coincide with the magnetic data. Despite its small size, the western area, which occupies the area of this part of the site with the visible relief of the post-mining landscape (zone e), includes a number of anomalies among which are two circular features that are located at the foot of small terrain unevenness related to the remains of mine spoil heaps.

The magnetic survey revealed numerous anomalies that can be attributed to anthropogenic activities and require further investigation. Among the disturbances probably caused by archaeological structures are increases in the value of the magnetic field. In the northern part of the central area (zone c), a complex of anomalies of this type was registered, which shows similar spatial and morphological features to those known from other studies and features related to Neolithic flint mining. It can therefore be assumed that they determine the real range of the area covered by the flint mining. In the eastern part (zone l), a large number of anomalies of various types were also noted, with particular intensity at the northern and western borders. Undoubtedly, in many cases they are potential archaeological features and they require further exploration both in terms of obtaining new information about the registered anomalies and the investigation of the wider landscape context. On the other hand, as noted above, the study of the western area (zone e) was aimed at obtaining data for a comparative analysis of newly detected features with known and existing ones. The visualizations of the survey results show the correlation of magnetic anomalies with some topographic anomalies, demonstrating clearly that the cavities of mining shafts generate changes in the magnetic field. However, in the case of the potential mining facilities detected in the levelled central part of the study area, the differences are small and most probably result from the poorer state of preservation. No earthworks of spoil heaps have survived in the central part, so it can be

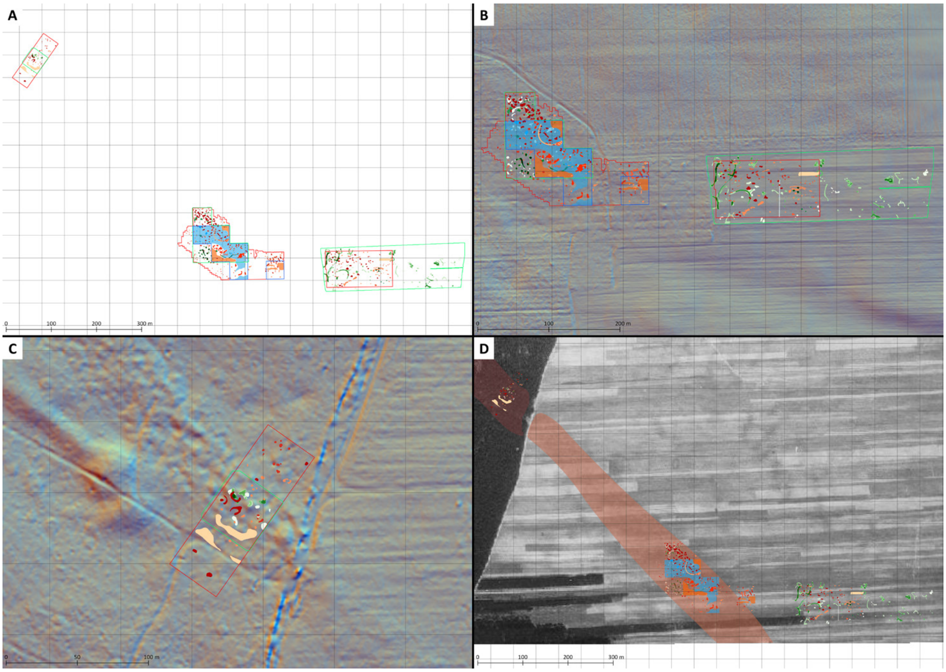

Fig. 7. Map of geophysical anomalies recorded during the research in Krzemionki in 2021 overlaid on various basemaps, A) 50 m grid; B) hillshaded terrain model based on ASL; C) hillshaded terrain model based on ASL; D) archival orthophotomap from 1964.

assumed that the sources of magnetic anomalies are shallower than in zone e. This has a positive effect on the detection of this type of objects.

The electrical resistance method found a background with low apparent soil resistance in the middle of the western part of the research area (zone c). This is surrounded on the south and north-east by parts of high resistance zones that extended beyond the investigated area. Within the low-resistance zone, there are clusters of magnetic anomalies interpreted as potential remnants of prehistoric mining features. The small eastern research area (zone d) is characterized by linear disturbances of the apparent soil resistance. They can be associated with contemporary forestry or agricultural activities rather than with potential archaeological features.

Each of the methods used produced a lot of information about the properties and nature of the detected anomalies that could be interpreted as potential anthropogenic structures of different natures, shapes and depths (Fig. 7). The magnetic and electrical resistance methods produced information about the position of anthropogenic structures and stratigraphic disturbances as well as their physical properties (that is the values of their magnetic susceptibility and electrical resistance). The GPR survey revealed the underground structure of anomalies causing disturbances and their depth of occurrence. In this case, anomalies were recorded at a depth of 0.3–0.5 to approx. 1.8 m. The comparison of the results of these methods allows for the mutual complementation of information about the disturbances detected, which is an undoubted advantage of each program employing the integrated use of geophysical methods in the non-invasive determination of the archaeological potential of the area studied.

Surface Collection Survey

The fieldwalking surface survey covered a strip of land approx. 600 m long and 75 to 100 m wide. The research area was difficult to access, due to the fact that it is covered mostly with dense undergrowth and pine thickets with a large number of windbreaks. These conditions meant that it was necessary to apply a survey method that was more precise than the standard survey method (*Archeologiczne Zdjęcie Polski* [English: Polish Archeological Record]) employed in Poland (Oniszczuk *et al.*, 2019). The method of work consisted of dividing the entire research area into parallel strips of land, approximately 30 metres wide, and crossing them several times while examining the ground surface precisely. The position of the finds were logged using hand-held GPS devices. The artefacts were divided into two categories: flint and stone finds and limestone fragments with anthropogenic features (sharp-edged related to mining operations).

The spatial registration of relics related to flint production was to determine the range of flint processing sites and possible clusters that could be interpreted as areas of flint workshops. If a find was spotted, the area within a few meters around it was searched more carefully. Not all the artefacts were collected and a selection was made in the field with the focus on the forms giving chronological clues.

In the case of finds of limestone debris, this material was not collected, and only its presence and spatial distribution was documented. Information was recorded on the size of the rock fragments (3 categories) and the amount of mining debris (4 categories) present at the site. Efforts were also made to register the presence of till on the surface. In principle, such observations were to allow for the precise determination of the range of mining activities, and, under favourable circumstances, also for a general assessment of the depth of the mine.

The surface work conducted yielded information on the dispersion of finds and other traces related to prehistoric mining activities. During the survey, 60 points of occurrence of archaeological finds and 58 findspots of anthropogenic limestone debris were recorded. In the work, 157 items were collected, mainly flints, and a small group of glacial pebbles with traces of use. The material had been unevenly distributed throughout the area covered by the project. There were clear areas where they were denser on the ground and other areas where they were largely absent. Undoubtedly, this state of affairs is the result of unequal access to the research area. Most of the material was obtained in the central part of the research area (zones b and c and their vicinity). When observing the distribution of the finds, certain regularities can be noticed. The finds were located in a strip 70–90 m wide. This largely coincides with the range of the exploitation area known from the literature in this part of the Krzemionki mining field, and is even larger. Numerous pieces of worked flint were also observed in the arable fields directly adjacent to the survey area to the north, which may indicate the presence of flint workshops in this area too.

Flint and stone artefacts define the zone of mining and production activities, while the extent of anthropogenic limestone debris is important to determine the extent of the mining area itself. It is grouped into two distinct zones with a width between 50–75 m and determines the location of the mine workings in this place (Fig. 8).

The obtained flint material, including fragments of concretions, allows for a general description of the raw material found in this region. Apart from three small fragments of chocolate flint (plus one indefinite one), the finds consisted of fragments of striped flint. Pieces of nodules with preserved opposite outer surfaces are 4 to 10 cm thick, but single fragments of flint suggest the presence of larger and more massive raw materials. The discovered finds were mostly heavily covered with a light patina, which is typical for material from flint mines. The cross-sections show striped and non-striped zones typical of this material, the often thick (from 4 to 8 mm) white outer halo and the clear presence of a grey, non-striped inner zone are noteworthy. The flints from the south-eastern edge of the Krzemionki mining field are therefore similar to concretions occurring in the area of the "Ostroga" mine in Ruda Kościelna (Budziszewski and Michniak 1989: 170–175). In the study area, there were also fragments of concretions with a dominant striped zone, with a thin white halo and a small, inner grey zone. They resemble the finds from Segment A of the Krzemionki mining field. The collected flints mostly show a high degree of cracking. It is waste material that showed its shortcomings at the first processing attempts and was rejected. It cannot therefore be used to assess the quality of the material in the original deposit.

Flint objects constitute approximately 95% of the collected artefacts. During the analysis, they were divided into basic categories. The breakdown is as follows: 22 fragments of nodules, 67 flakes, 60 fragments of industrial waste and 8 pieces at the early stages of creating cores, the so-called roughouts. This is typical material from

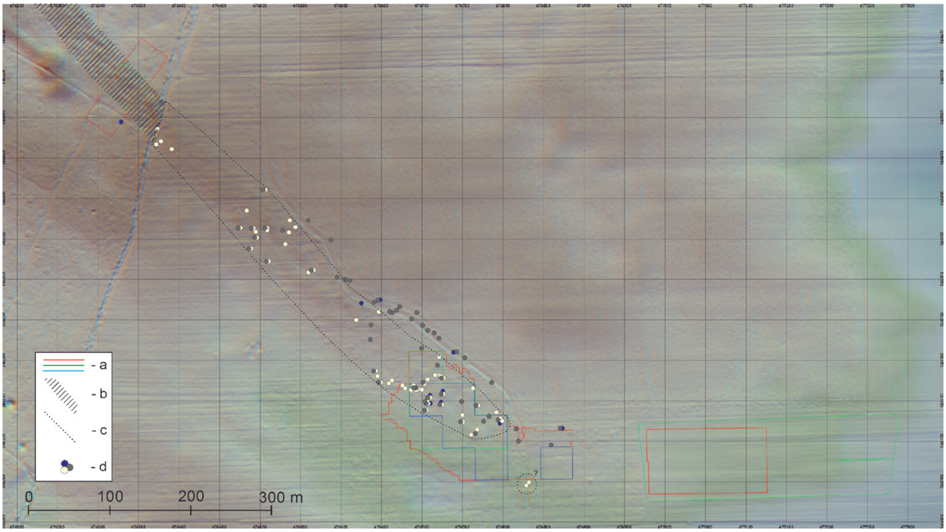

Fig. 8. Area of surface survey with the spread of finds: a – the boundaries of the geophysical research areas, b – the extent of the preserved post-mining landscape in the mining field, c – the hypothetical range of the levelled fragment of the exploitation field determined on the basis of the spread of archaeological material and the DTM analysis, d – the location of archaeological finds and anthropogenic limestone debris (grey – flint finds, blue – erratic rocks, white – limestone fragments).

mining flint workshops. The most interesting group of artefacts are the roughouts, which are mostly of tetrahedral forms, obtained by dividing concretions into smaller fragments created in the form of parallel slices. Usually, in their case, the extent of processing is very small and is limited to a few flakes removed from one or two faces. Most of the finds from the group in question have material defects in the form of tectonic cracks, which prevented further, effective processing to obtain a tool (axe). One of the items in this category can be described as a very early stage in the shaping of a bifacial axe. It shows the multidirectional processing associated with an attempt to form a blade and the preliminary knapping of one of the side edges. Unfortunately, due to a raw material defect, the roughout disintegrated in the early stage of the tool's production (a large part of the butt side had fallen off) and was abandoned.

The most numerous category in the collection of flint relics are flakes. Most of them are so-called flakes of the first series, or struck from concretions at the earliest stage of work. On the upper surface they have fragments of the cortex that originally covered the raw material. The remaining finds show individual negatives of earlier removed flakes, and in a few cases a few such flake scars. Characteristics of the use

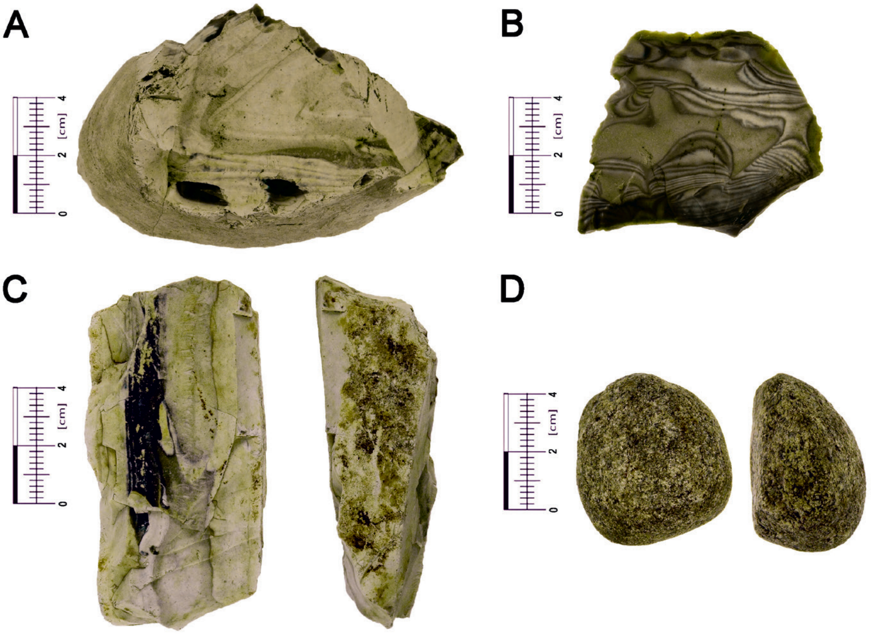

Fig. 9. Examples of raw material, flint and stone tools from the area of surface survey carried out in 2021: A – fragment of concretion; B – flake; C – roughout of a tetrahedral core tool; D – hammerstone and smoother made of granite glacial pebble.

of a hard hammerstone are visible on a significant part of the flakes: clear bulbs of percussion and erailleur scars on the underside. Individual finds have traces of further processing in the form of retouched edges. Usually this is an irregular, often toothed retouch, which was probably created accidentally as a result of rubbing the edge of the flake with a hard object. Only in two cases is it a more regular retouching, indicating the intention to make a tool.

The group of nine erratic rock relics consists of granite, quartzite and other pebbles with surfaces with visible traces of grinding or crushing arising when using them to prepare flint tools. On the basis of macroscopic observation, three of them were defined as hammerstones and smoothing stones. The others require closer observation. At this stage of the research, it can only be stated that their presence in the exploitation field is not accidental, because this type of erratic rocks is typical material for making flint tools in mining workshops (Fig. 9).

DIGITAL TERRAIN MODEL ANALYSIS AND AERIAL PHOTOGRAPHY

An important element of the non-invasive research that was used to verify the data obtained during geophysical research and surface exploration was the use of Digital Terrain Model analysis. The surface relief model shows the almost complete levelling of the land by agriculture. The boundaries between different arable plots are even visible. Inequalities that could be interpreted as remnants of the post-mining relief survived only in the central part of the study area, currently poorly accessible for surface research. What is visible, however, is a longitudinal structure running along the extension of segment B of the mining field with preserved spoil heaps and shaft cavities. It forms a gentle "step" in the surface relief, less than 1m tall and running along the axis of the research area in the NW-SE direction, almost completely invisible in the field, but very clear in the cross-sections. The step is no longer visible over about half of the length of the surface surveyed area. The location of the discovered fragments of sharp-edged limestone debris is consistent with the position of this structure, but the spread of other finds on the surface seems not related to it. Its presence probably reflects the course of the limestone outcrop with striped flint around which the mining was focused. Looking south-east, it disappears under younger settlements. In the literature, it is precisely the submergence of the outcrops under the increasingly thicker Quaternary cover that has been referred to as the main reason for the gradual narrowing and disappearance of the mine belt (Borkowski and Michniak 1992: 31).

Also analysed were aerial photographs available from the resources of the Central Office of Geodesy and Cartography. Those of most use were taken in 1964, e.g., before the expansion of the forest to the south-eastern edge of the mining field, and show a darker strip of land with lighter spots in the area of the former arable fields, east of the dense forest cover. It stretches along a NW-SE line and is 700 m long and 90–100 m wide. Further to the south-east there are lighter and darker linear soil features, which most likely reflect the outcrops of the Jurassic strata of the border of the Magonie-Folwarczysko syncline. They almost exactly mark the line on which the prehistoric striped flint mines are located: Księża Rola Mała and Duża and Ostroga (Fig. 10).

CONCLUSIONS

The implemented project was undertaken in the field of heritage protection. The registration of archaeological and potentially archaeological structures, both in the area

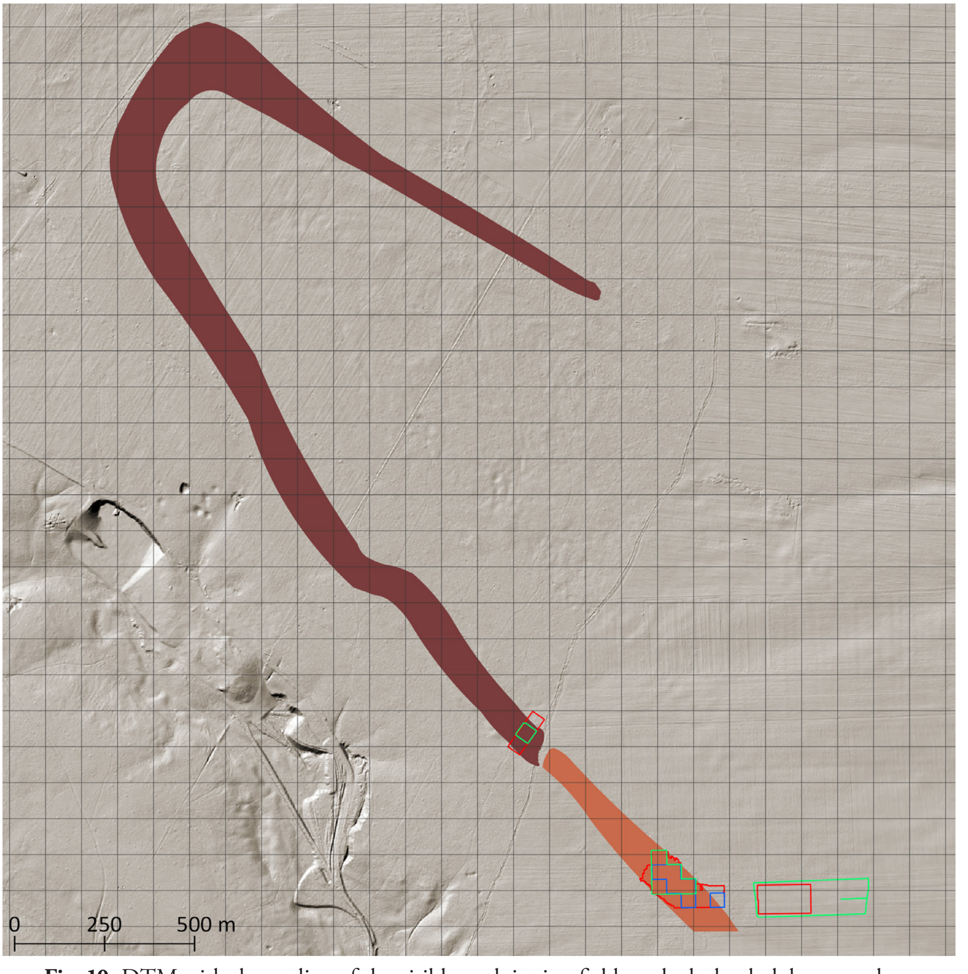

Fig. 10. DTM with the outline of the visible exploitation field marked, the dark brown colour indicates the extent of the field based on the ASL data; the light brown colour was used to mark the extent of the field based on the interpretation of soil discriminants visible on the archival orthophotomap from 1964 and the geophysical measurements.

previously defined as an exploitation field and outside, will allow for planning activities aimed at strengthening the protection not only of this part of the Krzemionki monument but also its landscape. One of them will be the currently proceeded extension of the entry in the register of monuments to the so-called buffer zone (surroundings) of a World Heritage property.

The fieldwork and analytical work using all the applied prospection methods reported here have resulted in the identification of a number of potential archaeological structures. An image of the subsurface structures was obtained through a comprehensive diagnosis of the archaeological sources. These can be distinguished on the basis of the mutually complementary results of the analysis of aerial photos (including archival photos), ALS images, magnetic gradiometry and earth resistance measurements, GPR measurements and surface surveys. An important aspect is the repeatability of registration of the same subsurface structures using several methods, thanks to which there are indications that the subject of the analysis are actual archaeological structures. On the basis of these complementary data, it is possible to initially create a general picture of the distribution of archaeological sources in the study area. When trying to determine the potential range of the exploitation field, the most readable results were obtained from earth resistance and magnetic investigations. In the most fully explored area (zone c), anomalies suggesting the presence of prehistoric mining sites are located in a strip 40–60 m wide, running in a NW-SE direction. In the remaining zones, they did not provide such a clear picture, however, changes were recorded that can be interpreted at this stage of the research as archaeological features. The surface studies showed the presence of anthropogenic limestone debris in an area of similar width (50–75 m) and the direction of its course, while the spread of flint and erratic stone finds turned out to be even greater (70–90 m). At this stage of work, it is not yet possible to determine the exact extent of the exploitation field in the southeast segment of the mining complex. The distribution and nature of the surface finds and the results of geophysical research indicate the possibility of the presence of flint workshops and settlements around it. This can be confirmed by expanding the area of non-invasive research combined with the integration of data from other activities, including excavations.

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Re-working the Past: Evidence for Late Neolithic and Early Bronze Age Flint Extraction at the Early Neolithic Mines of Sussex

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This paper will summarise evidence for Late Neolithic and Early Bronze Age flint extraction at the Southern English mines, beginning with a brief synopsis of their chronology and followed by a summary of mine lithics. It is argued that understanding later mining is equally important as examining its beginning, because the Neolithic is framed by the pursuit of flint from deep mines with significant episodes of extraction at its beginning and end. A focus is maintained on the flint mines located in the county of Sussex because these are the best researched of the English mines. This research represents a limited study of the Late Neolithic/Early Bronze Age activity at the Early Neolithic mines, because it is far from exhaustive. Nonetheless, this paper will attempt to define the Late Neolithic and Bronze Age flint working activity at the mines and will question if this activity is associated with new episodes of shaft-mining or informal methods of extraction, such as quarrying or surface collection of earlier mine waste.

KEY-WORDS: mining, axes, lithics, Late Neolithic, Early Bronze Age, Sussex

INTRODUCTION

In total, there are eleven confirmed flint mines (Fig. 1) in England dating to the Neolithic period *c.* 4000–2200 calBC, all are located on chalk geology in the south and southeast of the island (Barber *et al.*, 1999). An additional mine is also located in the northeast of Scotland at the Den of Boddam, which is dated to the Late Neolithic period, *c.* 3300–2900 calBC (Saville 1995).

In England, the largest group of mines, seven in total, are found along the southern coast in the county of Sussex and are all dated to the Early Neolithic period, *c.* 4000–3300 calBC. These southern mines comprise two regional groups. The first,

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Fig. 1. Location of British flint mines. Graphic elaboration: J. Bączkowski.

larger, Worthing Group includes the mine complexes at Blackpatch, Church Hill, Cissbury and Harrow Hill. The Chichester Group includes the complexes at Long Down, Nore Down and Stoke Down. Outside of Sussex, there are two flint mines, Easton Down, Wiltshire and Martin's Clump, Hampshire, which are located close to each other on Salisbury Plain. Several undated shallow pits have also been discovered in Wiltshire at Durrington, which may represent a small mine complex (Booth and Stone 1952). Lastly, Grime's Graves, the largest and best known British mine complex, is located in the east of England, close to Thetford, Norfolk.

The southern British flint mines are characterised by deep mine workings composed of mineshafts, up to 12 m deep, joining a subterranean gallery system from which raw flint was extracted from seams located (Barber *et al.*, 1999) within the chalk bedrock of the Cretaceous system (145–66 Mya). Typically, the main product of the mines was bi-facially worked axeheads. Away from the flint mines, axeheads were often transformed by intensive polishing into prestige items that were exchanged and occasionally placed as votive deposits in pits or natural places, such as wetlands (Edmonds 1995; Holgate 2019).

The research history of the British mines is long and there is little to be gained from detailing it here (see Barber *et al.*, 1999). In summary, the first excavation of a flint mine was carried out at Grimes Graves in 1868 by Canon William Greenwell (Greenwell 1870), followed in the mid-1870s by Augustus Lane Fox Pitt Rivers (Lane Fox 1876) who opened a mineshaft at Cissbury. Fieldwork carried on throughout the 20th century, including further investigations of Grimes Graves (Armstrong 1934) and in Sussex on Church Hill, Blackpatch and Cissbury, all directed by John Pull (see Russell 2001), as well as at Harrow Hill by Dr Eliot Cecil Curwen (Curwen and Curwen 1926). In the mid-20th century, small-scale archaeological excavations were undertaken at Stoke Down (Wade 1922), at Long Down (Salisbury 1961), and at Easton Down and Martin's Clump (Stone 1931; 1933). The last sizable excavations were carried out across the 1970s and 1980s, including Grimes Graves by Roger Mercer (Mercer 1981) and Harrow Hill by Gale Sieveking (McNabb *et al.*, 1996). Lastly, in the mid-1980s, Robin Holgate undertook small-scale fieldwork on Harrow Hill and Long Down (Bączkowski and Holgate 2017).

A BRIEF CHRONOLOGY OF BRITISH FLINT MINING

Initial attempts to date the mines drew on contemporary knowledge of lithic typologies, specifically, Reginald Smith, Keeper of British and Medieval Antiquities at the British Museum, argued that the mines were Palaeolithic in date (Smith 1912).

The debate was largely resolved in 1933 with the publication of "The Age of British Flint Mines" (Clark and Piggott 1933), which compared artefacts from mines with those recovered from Neolithic monuments, such as causewayed enclosures. Doubt still persisted amongst some archaeologists (Armstrong 1934), and it was not until the 1950s that the mines were fully accepted as Neolithic.

Early Neolithic Radiocarbon dates

The majority of radiocarbon dates from British flint mines have been obtained from material recovered from their excavation, including assemblages of red deer (*Cervus elaphus*) antler picks and animal bone, which were fashioned into implements for use in mining including picks, punches and shovels.

To date, a total of 50 radiocarbon dates have to date been obtained for the British mines via various research programs (Burleigh *et al.*, 1969, Burleigh 1975; Bowman *et al.*, 1990; McNabb *et al.*, 1996; Barber *et al.*, 1999; Ambers and Bowman 2003; Bączkowski and Holgate 2017; Edinborough *et al.*, 2019; Teather 2019). Collectively, these dates show that mining commenced close to the start of the 4th millennium BC at the southern mines (Barber *et al.*, 1999), shortly after the transition from the Mesolithic to the Neolithic at 4000 calBC (Collard *et al.*, 2009; Whittle *et al.*, 2011). This Early Neolithic extraction does not appear to have continued for more than 200–300 years at the majority of mines, although exceptions to this chronology include Cissbury where mining appears to have continued into the 37th century BC (Teather 2019).

There is an absence of deep mining throughout the Middle Neolithic in England, the exception being a small and shallow mine complex located north-west of the Durrington Walls Henge in Wiltshire (Booth and Stone 1952). The Den of Boddam in Scotland is also dated to the Middle Neolithic and comprises of hundreds of 'bell-pits', so-named because they are generally wider at their base than top (Saville 1995). Deep mines were probably not developed at the Den of Boddam due to the unstable character of the gravel geology.

The next and final phase of extraction began in the Late Neolithic *c.* 2900–2200 calBC and continued into the Early Bronze Age *c.* 2200–1600 calBC. At present the only deep mine dating to these periods is Grimes Graves where mining began in the Late Neolithic, *c.* 2660 calBC, and continued until *c.* 2200 calBC, with a second phase of simpler pit extraction lasting between *c.* 2000–1800 calBC, in the Early Bronze Age period (Healy *et al.*, 2014).

At present, the only Bronze Age radiocarbon dates obtained directly from a flint mine in Southern England are from Shaft 4 on Church Hill (Figs. 2 and 3: Teather 2019: 43–46). The material dated from Shaft 4 includes a wooden bowl dated to

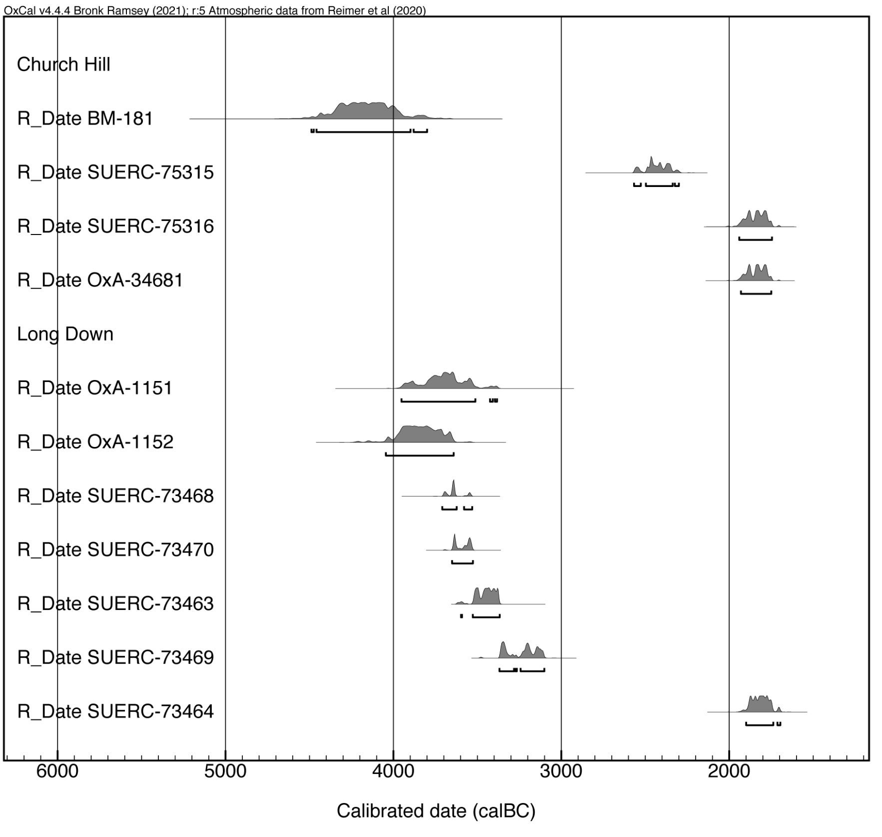

Fig. 2. Church Hill and Long Down calibrated radiocarbon dates.

1937–1751 calBC (95% probability, SUERC–75316, 3521 ±34 BP), and a pig mandible dated to 2526–2307 calBC (95% probability, SUERC–75315, 3940 ±34 BP). A third radiocarbon date was obtained from the bone of a field vole (*Microtus agrestis*) contained within an owl pellet found in a gallery associated with Shaft 4, dated to 2132–1921 calBC (95% probability, OxA-34681, 3639±29 BP). These artefacts may relate to a later re-cut and extraction from an earlier mineshaft (Barber 2005: 103–106), as an antler pick from another gallery associated with Shaft 4 excavated by Pull indicates an Early Neolithic date of 4490–3810 calBC (95% probability, BM-181, 5340±150 BP; Barber *et al.*, 1999: 81).

Elsewhere, a set of radiocarbon dates obtained from the Long Down mines are of interest (Bączkowski and Holgate 2018; Figs. 2 and Table 1). Of the seven dates,

Table 1. Church Hill and Long Down catalogue of radiocarbon dates.

SITE	Lab Code	14C AGE	14C STD	MATERIAL	CONTEXT	REFERENCE
Church Hill	BM-181	5340	±150	Antler (*Cervus elaphus*)	Unknown gallery	Teather 2019; Edinborough *et al.*, 2019
Church Hill	SUERC-75315	3940	±34	Tooth (*Sus scrofa*)	Shaft 4, Layer 4, 4ft.	Teather 2019; Edinborough *et al.*, 2019
Church Hill	SUERC-75316	3521	±34	Wood (*Populus*)	Shaft 4, Layer 6	Teather 2019; Edinborough *et al.*, 2019
Church Hill	OxA-34681	3639	±29	Microtus agrestis	Shaft 4 Galleries	Teather 2019; Edinborough *et al.*, 2019
Long Down	OxA-1151	4900	±100	Antler (?*Cervus elaphus*)	Unknown shaft excavated by R. Holgate	Barber *et al.*, 1999; Bączkowski and Holgate 2017
Long Down	OxA-1152	5050	±29	Antler (?*Cervus elaphus*)	Unknown shaft excavated by R. Holgate	Barber *et al.*, 1999; Bączkowski and Holgate 2017
Long Down	SUERC-73468	4863	±32	Antler (?*Cervus elaphus*)	Unknown shaft excavated by J. Salisbury	Bączkowski and Holgate 2018; Edinborough *et al.*, 2019
Long Down	SUERC-73470	4828	±32	Antler (?*Cervus elaphus*)	Unknown shaft excavated by J. Salisbury	Bączkowski and Holgate 2018; Edinborough *et al.*, 2019
Long Down	SUERC-73463	4681	±32	Antler (?*Cervus elaphus*)	Unknown shaft excavated by J. Salisbury	Bączkowski and Holgate 2018; Edinborough *et al.*, 2019
Long Down	SUERC-73469	4544	±32	Antler (?*Cervus elaphus*)	Unknown shaft excavated by J. Salisbury	Bączkowski and Holgate 2018; Edinborough *et al.*, 2019
Long Down	SUERC-73464	3493	±32	Antler (?*Cervus elaphus*)	Unknown shaft excavated by J. Salisbury	Bączkowski and Holgate 2018; Edinborough *et al.*, 2019

obtained from red deer antler pick fragments from the upper fill of a mineshafts excavated by Salisbury in the 1950s (Salisbury 1961), five are Early Neolithic and date to *c.* 3710–3368 calBC (95% probability). Of the other dates, one is later Early Neolithic or early Middle Neolithic, *c.* 3369–3102 calBC (95% probability, UERC-73469, 4544±32 BP), and the other is Early Bronze Age, *c.* 1900–1695 calBC (95% probability, SUERC–73464, 3493±32 BP). Middle Neolithic activity on Long Down is also supported by the presence of Peterborough Ware pottery (Drewett 1983), although the nature of this activity is uncertain, whilst the Early Bronze Age date could be associated with flint working based on the recycling of previous mine waste, as discussed in detail below.

THE EVIDENCE AND CHARACTER OF LATER ACTIVITY AT THE SOUTHERN BRITISH MINES

This paper will now outline and review evidence of Late Neolithic/Early Bronze Age flint working and other evidence, including possible extraction features. This review is not intended to be a comprehensive study of all the flint mining material, due to the size and dispersed nature of the archives held across multiple British museums. Instead, this paper focuses on the results of research carried out for this author's PhD (Bączkowski 2021). This research was based on the comparative study of assemblages and analysis, including the recording of weight, type and percentages, of more than 40.000 lithics recovered from the mines on Cissbury, Harrow Hill, Stoke Down and Long Down. Walkover surveys were also undertaken at Harrow Hill and Long Down.

The objective of this research was to characterise flint working activities at the mines through the examination of the lithic assemblages. Whilst the majority of the examined lithics, as detailed below, were Early Neolithic in date and associated with bi-facial axehead production, a smaller amount were not and are dated to the Late Neolithic/Early Bronze Age. As surprisingly little research has been carried out on the later lithics from the mines, it was decided to study these in detail and question their relationship with the Early Neolithic deep mines, as well as examining how they might provide information on the social and cultural practices taking place within the vicinity of the mines.

Developing narratives on the later activity at the mines is also important for understanding the wider social and cultural changes that were taking place in Late Neolithic/Early Bronze Age communities across the British Isles (Pearson 2009; Allen *et al.*, 2012. Pearson *et al.*, 2019). This is notable, as the mines were being revisited when the worldview of communities in both southern England and East Anglia were being transformed by the arrival of The Beaker people and a transition to bronze (Healy 2012; Pearson *et al.*, 2019).

Late Neolithic to Early Bronze Age flintwork

The majority of the lithics recovered from the mines and their immediate environs are Early Neolithic and are almost exclusively associated with bi-facial axehead production (Bączkowski 2021). Research carried out for this author's PhD of almost 40,000 lithics recovered from the mines on Church Hill, Harrow Hill, Stoke Down and Long Down (Fig. 3), indicated that 73% of the assemblages comprised of waste from bi-facial axehead production, which is almost certainly Early Neolithic in date. In total 26% of the examined assemblages cannot be directly associated with bi-facial axehead production and is not clearly Early Neolithic in date. The analysis of the Late Neolithic/Early Bronze lithics present in the Early Neolithic mine assemblages, as discussed next, reveal the form and character of this flint working.

The Long Down flintwork assemblage

As with other Sussex flint mines, the main product on Long Down were bi-facial axeheads, along with smaller amounts of single-piece sickles and long blades, which are all clearly Early Neolithic in date. The most obvious non-Early Neolithic lithics present in the Long Down assemblage are ovate and discoidal forms (Fig. 4), which are typically Late Neolithic/Early Bronze Age in date (Butler 2005). Similar forms were also produced at Grimes Graves where they were interpreted as blanks for discoidal knives (Saville 1981; Gardiner 1988), which are confidently dated to the Late Neolithic/Early Bronze Age (Healy *et al.*, 2014).

Several of the ovate examples in the Long Down assemblage appear to have been formed on the flint working waste from Early Neolithic mining, because they contain later flake removals that have removed the earlier white patinated surface, exposing the non-patinated dark blue to black colour of the raw flint. This white patination takes many millennia to form and is due to contact between the raw flint and highly calcareous deposits and is common in Early Neolithic flintwork. Therefore, it is likely the Long Down ovates demonstrate the recycling of mine waste from Early Neolithic spoil-heaps during the Late Neolithic/Early Bronze Age periods. The radiocarbon dates give some limited indication for the dating of this activity, as outlined above.

The Stoke Down flintwork assemblage

The Stoke Down struck flint assemblage was recovered by Major Wade in the 1920s, who excavated three mineshafts up to 3.6 m in depth (Wade 1922). Although it

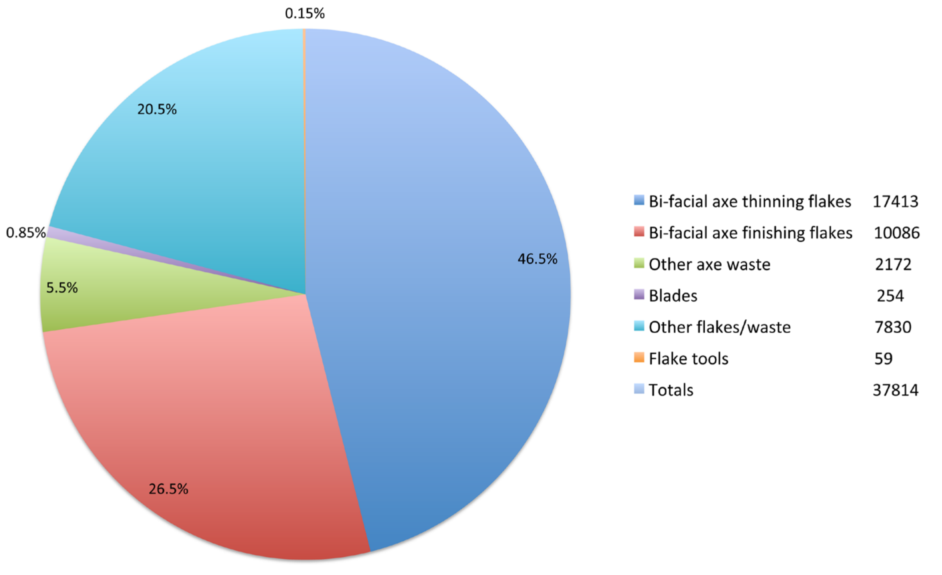

Fig. 3. Combined flintwork totals from Church Hill, Harrow Hill and Long Down (source: Holgate 1989; Bączkowski and Holgate 2017).

was only possible to examine part of the Stoke Down assemblage, the findings of its analysis echoed those of other researchers, who had highlighted that it was not typical for an assumed Early Neolithic flint mine (Healy 2011). Analysis of the Stoke Down material comes with a caveat, in that it only contains select pieces with little debitage, unlike the Long Down and Harrow Hill assemblages both recovered by Holgate who also collected debitage (Bączkowski and Holgate 2017). Nonetheless, the Stoke Down assemblage is of note as it is an oddity for Sussex mine assemblages because it contains a notable amount of later flintwork dated to the Late Neolithic/Early Bronze Age periods.

Included in the assemblage are pieces that are characteristic of Late Neolithic/Early Bronze Age technologies (Fig. 5). These pieces include probable discoidal knife blanks and flaked knives, an assemblage that is similar to types being produced at Grimes Graves (Saville 1981). A finely worked knife is typical of Late Neolithic flint working. It has argued that such knives were often specially produced to be polished and subsequently deposited in pits or burials, echoing the treatment of Early Neolithic bi-facial axeheads and indicating they may have had meaning beyond domestic tools (Edmonds 1995: 102–103; Gardiner 2008).

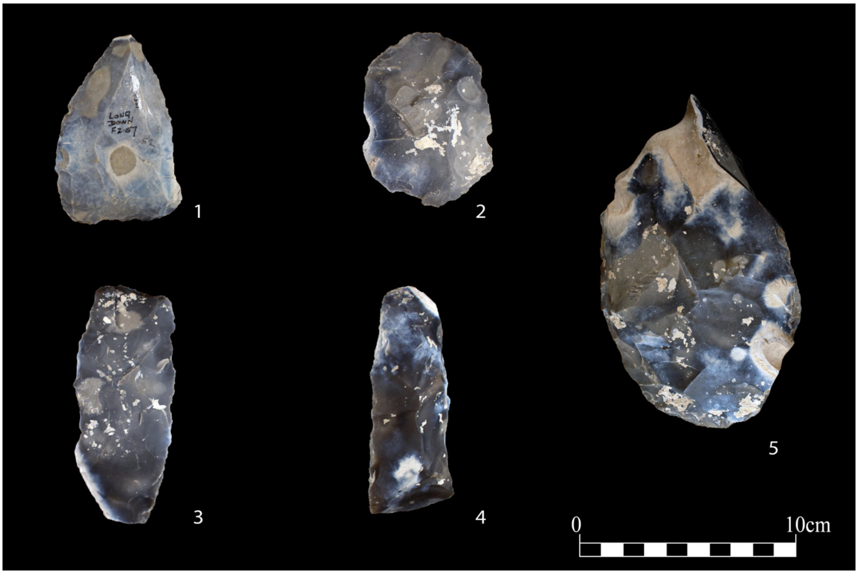

Fig. 4. Select pieces from the Long Down flintwork assemblage. Key: 1 – Flaked knife; 2 – Discoidal knife; 3-4 – Small picks; 5 – Ovate blank. Photo: J. Bączkowski.

Fig. 5. Select pieces from the Stoke Down flintwork assemblage. Key: 1 – Discoidal knife; 2-3 – Flaked knives; 4 – Ovate knife; 5 – Ovate blank. Photo: J. Bączkowski.

A number of both core and flake axehead roughouts are also present in the Stoke Down assemblages, which are much finer than the typically robust Early Neolithic axehead roughouts collected from the mines. One previously documented axehead (Wade 1922), not currently present in the assemblage is a waisted axehead, a distinctive form of Middle to Late Neolithic axehead typified by an outward flared cutting end (Field 2011; Healy 2011). Notably, in the Middle Neolithic, such waisted axes were placed within funerary deposits in round barrows (Gibson and Bayliss 2010; Gibson *et al.*, 2011). In the Late Neolithic period, waisted axes were also produced at the Grimes Graves mines (Craddock and Cowell 2004), possibly as prestige items for export.

Finally, a number of flake cores are present in the assemblage. The cores tend to be large and reasonably crude with single faces and only limited evidence of platform preparation. The cores are mixed in date with several characteristic of the Early Neolithic and others more typical of the Late Neolithic.

Currently, there are no radiocarbon dates for the Stoke Down mines and therefore further comment on the chronology of extraction at the site is difficult. The character of the assemblage, with both Early Neolithic/Late Neolithic pieces, may infer that the mining on Stoke Down began in the Early Neolithic but that flint working and possible mining activity was also undertaken in the Late Neolithic and Early Bronze Age periods. This later period of flint working and possible extraction activity at Stoke Down is contemporary with mining at Grimes Graves (Healy *et al.*, 2014).

Other Sussex mine flint work assemblages

Aside from Long Down and Stoke Down, the lithic assemblages from the other Sussex flint mines are widely distributed between many museums and institutes, especially those from Cissbury, Church Hill and Blackpatch. Assessment of the Harrow Hill assemblage recovered by Holgate (Bączkowski and Holgate 2017) recorded a number of scrapers, knives and ovates more typical of a Late Neolithic/Early Bronze Age date. There was also some evidence of earlier flakes from bi-facial axe production being recycled in the later periods (Bączkowski and Holgate 2017). However, it is unclear if there was any renewed deep mining on Harrow Hill beyond the recycling of earlier material that was probably quarried from old spoil heaps.

Much of the lithic assemblage from Church Hill is missing and the archives held by museums, including Worthing Museum and Art Gallery, contain only selected pieces such as complete axeheads and also axehead-roughouts (Russell 2001). The radiocarbon dates from Church Hill indicate that extraction and production of lithics occurred during the Late Neolithic and Early Bronze Age, *c*. 2900–1600 calBC, some 700–800 years after mining stopped.

Evidence of Late Neolithic to Early Bronze Age extraction?

Beyond the radiocarbon dates and lithics, there is almost no evidence of mining or quarrying features dating to the Late Neolithic or Early Bronze Age present at any of the Sussex mines. In part, this is because of excavation bias with many of the historic excavations only focusing on the deep mines, which, apart from Church Hills Shaft 4, all produce consistent Early Neolithic radiocarbon dates. Notably, it was also on Church Hill that Pull excavated a number of large pits and other features that appeared to be later than the Early Neolithic (Russell 2001: 122–129). The best example excavated by Pull was Pit A (Fig. 6), which contained Beaker period pottery and flintwork including an ovate axe, indicating that the feature dates to the Early Bronze Age (Russell 2001: 122–125). Such features could evidence later extraction on Church Hill as similar simple pits were also recorded at Grime's Graves, which date to the Early Bronze Age (Healy *et al.*, 2014).

Elsewhere in Sussex the only other non-deep mine workings were documented on Harrow Hill, where Holgate opened two adit like drift-mines just to the south of the main mine complex (Bączkowski and Holgate 2017). It was not possible to date the drift-mines and although they appeared broadly contemporary with the Early Neolithic mines (Bączkowski 2019a), this is far from conclusive.

Both Chichester group mines, Long Down and Stoke Down, may offer limited evidence of later extraction. Within the main mine complex on Long Down, several elongated hollows can be observed possibly cutting across the spoil heaps of the earlier deep mines (Fig. 7). The date of the features are unknown and they could relate to Early Neolithic deep mineshafts sunk within the congested area of the main mine complex, making them marginally later than the spoil heaps from earlier workings. Alternatively, they could represent open-cast quarries exploiting the earlier spoil heaps in the Late Neolithic or Early Bronze Age periods. Both the radiocarbon dates and lithics outlined above offer limited evidence of activities dating to these periods and the presence of later extraction features should not be ruled out on Long Down.

Lastly, the deep mines on Stoke Down are unusual for Sussex mines as they did not appear to join galleries, but were composed of single mineshafts with minimal undercutting at their bases to extract flint (Wade 1922). This alone cannot directly infer the dating for the Stoke Down mines because similar non-galleried 'pit shafts' were recorded at Easton Down (1932), which clearly date to the Early Neolithic (Edinborough *et al.*, 2019). However, along with the Late Neolithic/Early Bronze Age lithics, the presence of single mineshafts could indicate that some later extraction occurred on Stoke Down, with the Early Neolithic material being residual in the later workings. It is also worth noting that simple mineshafts and pits were recorded at

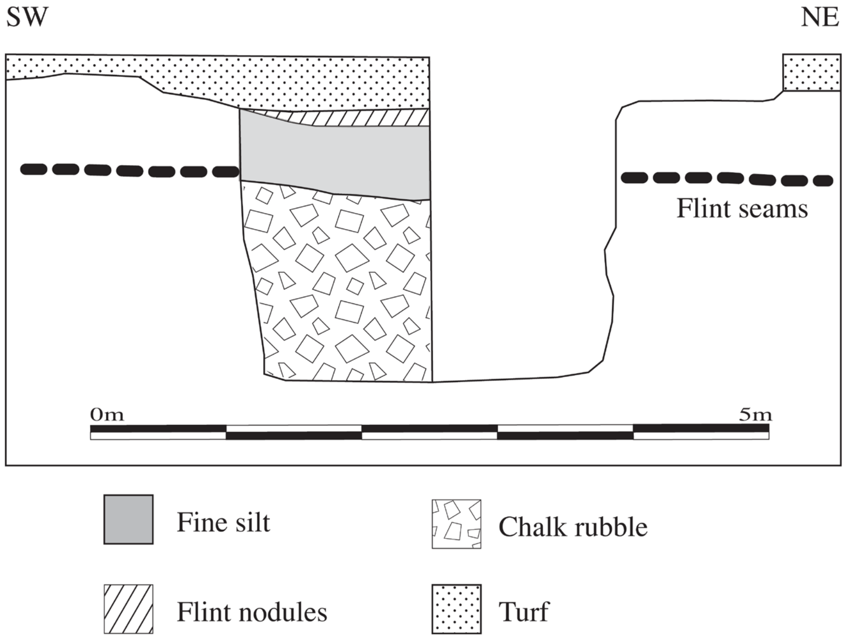

Fig. 6. Church Hill pit excavated by J. Pull, half section and profile. Graphic elaboration: J. Bączkowski, adapted from M. Russell 2001: Fig. 76.

Grimes Graves (Longworth *et al.*, 2012), which are later, and also contemporary with the deep galleried mines (Healy *et al.*, 2014).

DISCUSSION

The latest radiocarbon dates show that the initial phase of Early Neolithic deep mining across southern Britain began close to 4000 calBC and lasted for some 200–400 years (Edinborough *et al.*, 2019). There follows a significant gap in mining, almost a 1000 years, before resumption of deep mining at Grimes Graves in the Late Neolithic and then the Early Bronze Age.

Analysis of the lithics undertaken for this paper has shown the existence at all the examined Sussex mines of Late Neolithic/Early Bronze Age pieces in varying amounts, including discoidal knives, a dagger and the waisted axehead. As detailed, some of the pieces have evidence of being produced on older waste flakes from

Fig. 7. A Long Down quarry extracting earlier mine waste? Photo: J. Bączkowski.

bi-facial axe production but others, including the waisted axe from Stoke Down could have been produced from newly extracted flint.

There is no direct evidence of deep mines being opened in Southern England, unlike at Grimes Graves. Instead, this later flint working appears to be based on the recycling of mine waste from the Early Neolithic spoil heaps. It is also possible that the Early Neolithic mineshafts may have been re-opened, as indicated by the radiocarbon dates from Shaft 4 on Church Hill and the lithics recovered from the Stoke Down mineshafts, containing both Early Neolithic and Late Neolithic/Early Bronze Age forms. At present, without new fieldwork, it is difficult to fully understand the character of this later activity. However, this paper has shown later activity took place at the Sussex mines and by recognising the evidence new discussions and themes can be formed on the mining narrative.

The production of the lithics at the Sussex mines, which share affinities with the forms produced at Grimes Graves (Saville 1981; Bishop 2014), shows that the mines once again became the focus of flint working activity. However, there are key differences between Early Neolithic and Late Neolithic/Early Bronze Age mining. The differences are most notable in the lithics being produced, as the Early Neolithic mines are almost solely focused on the manufacture of bi-facial axeheads and occasionally single piece sickles (Bączkowski 2021). This is in contrast to the Late Neolithic/Early

Bronze Age flint working at the southern mines and Grimes Graves, where more diverse lithics were produced, including ovate and discoidal knives, arrowheads and a range of other implements (Saville 1981; Bishop 2014).

The production of discoidal forms is also recorded across Sussex and the South-east of England at many non-mining sites, including Beachy Head where they were produced in reasonably large amounts on nodules sourced from surface deposits of Clay-with-Flints (Gardiner 1988; 2008). A similar pattern is repeated in Norfolk with discoidal forms not only produced at the Grimes Graves complex, and within its wider environs (Robins 2002), but also at many other sites away from the mines (Healy 1998). Overall, it appears that the mines were therefore part of wider Late Neolithic uptake and increase in the production of discoidal and ovate forms, which appear to have been produced as 'prestige items' that were often distributed and deposited far from their original source (Edmonds 1995; Gardiner 2008).

Evidence of the production of discoidal and ovate forms at the Sussex mines therefore links them not only to Grimes Graves, but also to a European wide tradition of producing ovate, double-edged blades and daggers in the mid-third millennium (Edmonds 1995; Frieman 2014; Frieman and Erikson 2015). Across Europe, these forms were produced at specialist production sites, including Grand-Pressigny in the Massif Central, France (Mallet *et al.*, 2004), but also notably from mined flint at Alborgand and Hillerslev in northern Jutland, Denmark (Becker 1959) and also at Kvarnby and Södra Sallerup, Malmö, Sweden (Berggren *et al.*, 2016). The knife industry of Kvarnby and Södra Sallerup is of particular interest as there is currently no evidence of new mines being opened. Instead, and similar to the Sussex mines, the acquisition of flint was from the spoil heaps of earlier Neolithic mines (Berggren *et al.*, 2016).

In Britain, the renewed interest in the mining landscape began in the Late Neolithic period and continued into the Early Bronze Age. There is no evidence of deep mining in the Middle Neolithic until Grimes Graves in the late 3rd millennium BC. The reasons for this break are unclear, but it seems likely the Early Neolithic flint mines in southern England ceased production as the demand for axeheads waned after an initial period of extensive woodland clearance was undertaken to open the landscape for newly imported agricultural practices (Woodbridge *et al.*, 2012).

The chronology is similar across Continental Europe, with many deep mines dating and confined to the Younger Neolithic, *c.* 4400–3500 calBC (Kerig *et al.*, 2015), such as Rijckholt-St. Geertrud, Limburg, The Netherlands (Felder *et al.*, 1998) and Jablines, Seine-et-Marne, France (Bosytn and Lanchon 1992). The rate of deforestation across Europe is nuanced and regionally variant, although it is widely accepted that by the late 4th millennium BC, many areas had been cleared of trees for agriculture (Roberts *et al.*, 2018). Therefore axes were not always the main products of the Continental mines, with blades also being produced in large numbers, such as at Rijckholt (Felder *et al.*, 1998).

During the final Neolithic, *c.* 3400–2900 a second peak in mining, as seen in Britain, is also observed in Continental Europe (Kerig *et al.*, 2015), with large-scale mine complexes, such as Krzemionki (Ostrowiec Świętokrzyski district, Poland; Bąbel 2008) and Spiennes (Mons district, Belgium; Collet *et al.*, 2008), appearing to increase output. There is also limited evidence for later activity at Rijckholt, with one Beaker period radiocarbon date and possible shallow pit mines, although the evidence is far from certain (De Grooth *et al.*, 2011).

In wider society, the second peak in mining is contemporary with the spread of the Chalcolithic, a process of economic intensification that that created new world views, not only driven by the adoption of bronze but also by increasing socio-economic complexity due to population growth and more structured settlement expansion, as is the case in the British Isles (Heyd 2012; Pearson *et al.*, 2019). One lithic form, flint daggers, are particularly linked to the Chalcolithic and Early Bronze Age periods, with a long production tradition from the late fourth to the second millennium in Continental Europe, but a much shorter lifespan in Britain, limited to the late third millennium (Frieman 2014). It is therefore of significance that at least one knife-like dagger was recorded in the Stoke Down assemblage.

The reasons for the chronological ebbing and waning of deep mining are much debated, as is the need to deep mine. Currently, an increase in supply and demand of raw flint needed for both axeheads and blades due to larger populations is perhaps the most accepted model (Kerig *et al.*, 2015; Edinborough *et al.*, 2019). Although the cultural need for mining interwoven with ideological and social practices is also argued, with mining interpreted as a cultural activity not solely focused on economic demand, but instead as a ritualised activity integral to Neolithic belief systems (Holgate 1995; Barber *et al.*, 1999; Russell 2000; Bączkowski 2019b; Topping 2019; 2021). It is certainly the case that the allure of exotic material, in this case flint obtained from deep subterranean sources, added to the metaphysical qualities of mining via engagement with the "underworld" and "otherworldly" environments (Mökkönen *et al.*, 2017).

As a cultural tradition and ritualised activity, mining may have formed part of a yearly routine for nascent Early Neolithic communities in southern Britain (Bączkowski 2021). Whilst mining events were underway social and cultural bonds may have been maintained and transmitted, information and material culture could have been traded, relationships between communities, individuals and ancestral landscapes may have been managed and re-established, and finally knowledge may have been shared and new skills taught (Edmonds 1995; 1999; Bączkowski 2019b; Topping 2019). Overall, it seems likely mining was undertaken for many social, cultural and economic reasons, and its meaning may have changed and developed through the working life of a flint mine.

A cultural model of mining is especially compelling for Britain where there is an abundance of easily accessible natural flint resources, such as from rivers and cliffs, which negates the need for deep extraction (Gardiner 1990; Barber *et al.*, 1999). It is noted that the end of mining in southern England is associated with a shift of axe production to the utilisation of abundant surface deposits (Gardiner 1990). The assumed transition away from deep mines in the Middle Neolithic does not explain the start of mining at Grimes Graves in the Late Neolithic, which may have began and continued as a reaction to the start of Chalcolithic (Healy 2012). As this paper has shown, in southern England the Early Neolithic mines once again became the focus of flint working in the Late Neolithic and Early Bronze Age periods, a pattern repeated not only at Grimes Graves with new deep mines being opened, but also across Continental Europe with increased mining and the recycling of previous mine waste.

The reason for engagement with the spoil of earlier and long abandoned flint mines, rather than open new ones is not clear. Re-cycling of mine waste could be purely functional, as the mines were convenient sources of good quality raw flint that required minimal extraction effort. Alternatively, the locations of the mines and the material from them could have retained special meaning for these later communities long after Early Neolithic mining had ceased. For example, southern English flint mines may have been considered ancestral landscapes (Edmonds 1999; Topping 2021). The allure of sourcing exotic stone is well documented in the Neolithic, mostly from remote stone sources such as the jadeite from the Italian Alps (Pétrequin *et al.*, 2015) and greenstone from the mountains of the Lake District, England, including the Langdale Pikes (Bradley and Edmonds 1993). Notably greenstone was sourced from the Langdale Pikes in the Early Bronze Age as a raw material for Beaker bracers or wrist guards (Woodward and Hunter 2011), demonstrating that the material itself, previously sourced for the manufacture of Neolithic axeheads, may have retained special significance for later communities (Bradley *et al.*, 2019).

This attraction may not apply to mine waste as there is nothing alluding to its exoticness, inasmuch as it was not sourced from remote locales. Instead, the waste material, which would have been recognised as resulting from earlier mining and flint working, and the mine complexes themselves may have been associated with the ancestors. The process of selecting and re-working older flintwork into new forms, such as knifes, may have also been a symbolic act that resulted in a "special" class of artefact (Bradley 1990). This activity is not limited to the Sussex mines and was also recorded at the Langdale stone quarries (Bradley and Edmonds 1993), where evidence of the quarrying and the re-cycling of earlier Neolithic waste heaps was undertaken long after the initial phase of extraction had ceased.

Support for the attraction to abandoned flint mines and discarded mining material can also be found in the wider environs of the Sussex mines, where many Bronze Age round barrows were constructed, as on Blackpatch, Stoke Down and Church Hill. On Stoke Down a series of possible burial mounds have been surveyed close to the mines that are likely to date to the Late Neolithic/Early Bronze Age periods (Barber 2014). Engagement with older monuments is also a phenomena noted across Europe (Bradley 2002). Although this activity is often focused on burial sites, with successive communities re-using older sites (Bradley 2002), it is likely that the pockmarked landscapes of flint mine complexes may have been also been considered as ancestral burial grounds for later communities, most notably in the Bronze Age and Iron Age.

This re-use of an ancestral landscape is perhaps most evident at Blackpatch and Church Hill (Fig. 8) where numerous burial mounds, features and pottery dating to the Late Neolithic/Early Bronze Age have been discovered (Russell 2001). A series of burials were also found at Blackpatch (Fig. 9), not only in round barrows formed within the mine spoil mounds, but also including human bones and cremations directly placed in the top of mineshafts (Russell 2001). Intriguingly, large nodules were placed over the top of the central burials in several of the round barrows, showing their clear association with mining waste and possibly also inferring new episodes of mining at Blackpatch (Barber 2005; 2014). Such use of mine waste to cover human burials and associated deposits supports the hypotheses that the Early Neolithic, or even possibly new mining waste, was considered symbolic. This symbolic meaning may explain why mine waste was chosen and curated into new forms of lithics, as detailed in this paper.

One barrow close to the Blackpatch mine complex, Barrow 9 (Fig. 9), contained Beaker pottery, a flint axe and knife and had possibly been capped with densely packed flint nodules (Wessex Archaeology 2006). It is possible that the barrow mirrors the form of the abandoned flint mines, demonstrating the importance of the earlier pockmarked landscape to later communities who chose to bury their dead close to the mineshafts and incorporate structural and physical elements of the mines into their burial monuments.

Other activities within the vicinity of the Early Neolithic mines include a Bronze Age settlement, excavated by the Curwens in the 1930s, that was located some 800 m south of the Harrow Hill mine complex (Curwen 1934; Russell 2001). Significantly, the Curwens also discovered an Early Neolithic pit that contained flintwork associated with the neighbouring mine (Bączkowski 2019c). A Bronze Age rectangular enclosure was also constructed on Harrow Hill (Hamilton and Manley 2001), which

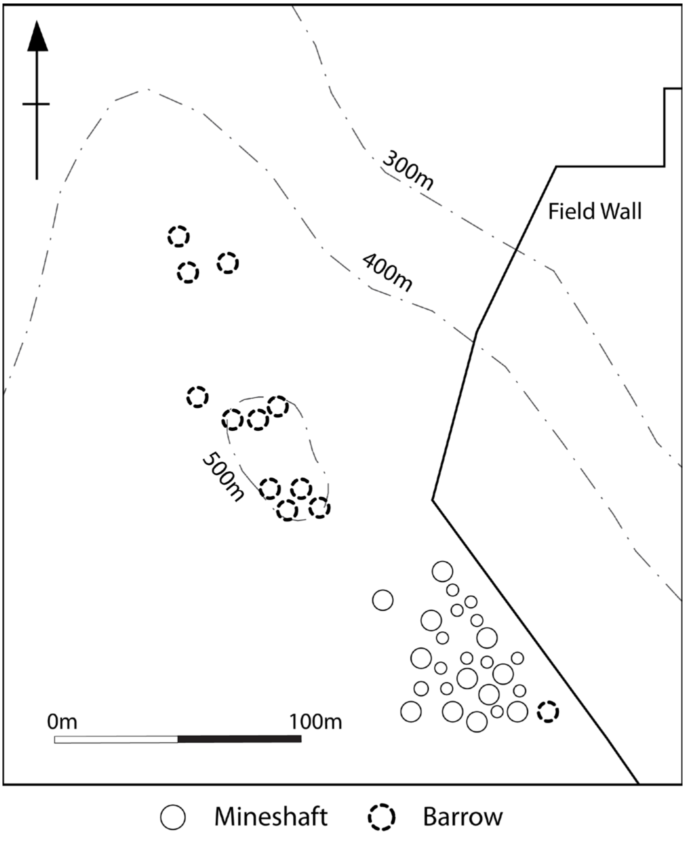

Fig. 8. Survey of Church Hill showing relationship between Neolithic mine complex and Late Neolithic/Early Bronze Age barrows. Graphic elaboration: J. Bączkowski, adapted from M. Russell 2001: Fig. 88.

partially covers the earlier mine complex. Lastly, probable Bronze Age roundhouses were constructed within the Easton Down mine complex (Stone 1931).

Overall, it is unknown if new mining took place in Sussex. At present there are no radiocarbon dates from the Late Neolithic or Early Bronze Age recovered from an entirely closed mining context. Many of the dates, such as from Church Hills Shaft 4 and from the top of the mineshaft on Long Down are mixed with other, mostly earlier dates. Such mixing may favour the theory that any new extraction activity could have been limited to quarrying and re-cycling of earlier waste via extraction from spoil heaps or by re-cutting old mineshafts, as may have been undertaken on Stoke Down.

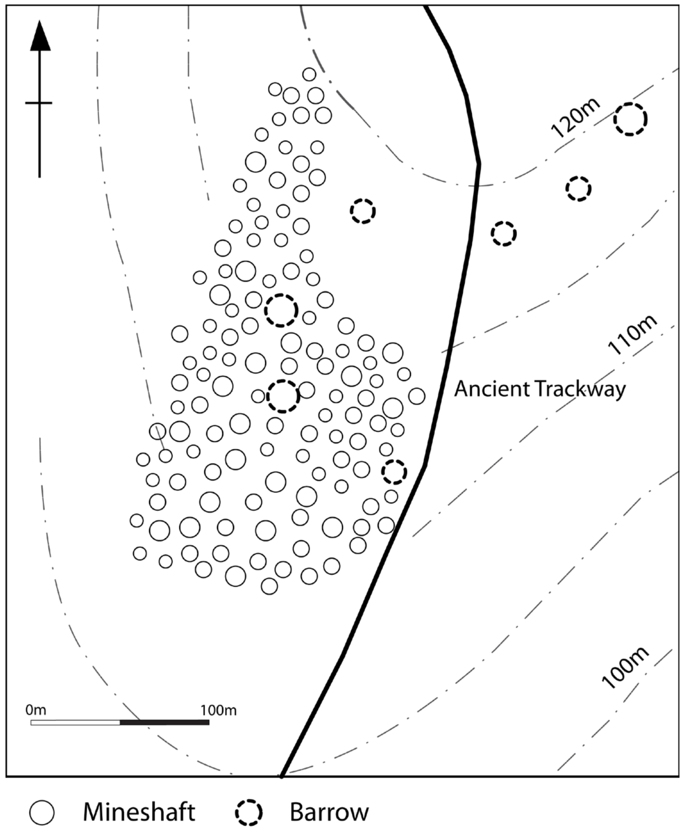

Fig. 9. Survey of Blackpatch showing relationship between Neolithic mine complex and Late Neolithic/Early Bronze Age barrows. Graphic elaboration: J. Bączkowski, adapted from M. Russell 2001: Fig. 23.

However, the presence of later mining should not be ruled out at any of the Sussex mines as such a small sample of mineshafts have been explored, less than 20 of an total *c.* 1000 plus recorded mine workings across six complexes. It is worth remembering that, as Grimes Graves demonstrates, the communities still retained knowledge of mining and were fully capable of opening and working deep mineshafts.

Finally, it is notable that the activity presented here also reflects wider social and cultural trends in the mid-third millennium for the production of finely worked flint objects, including discoidal forms, knives and axes (Edmonds 1995: 100–110). Renewed interest in the production of such flint objects has been proposed as the reason for mining at

Grimes Graves (Bishop 2014), with groups travelling to, and gathering at the mines to produce specialist flint objects (Bishop 2014; Healy *et al.*, 2014). In Norfolk, the location of Grime's Graves, such activity may have substituted a wider Late Neolithic trend for large-scale communal monument construction, such as henges, because these are lacking in the region (Bishops 2014). It may be no coincidence that such monuments are also largely absent in the Late Neolithic of Sussex. This could infer that later activity at the mines replicated the cultural need for gatherings based on community activities, including quarrying alongside the specialist production of fine flint objects. Such social and cultural activity directly connects later extraction activity with the earlier need to deep mine. Therefore, the British Neolithic is bookmarked by deep mining and associated extraction at both its start, *c*. 4000 calBC, and at its end, *c*. 2200 calBC.

The precise reason there is a renewed interest in the mines is not clear, but it may be the case that, as cultural ideologies shifted towards the Bronze Age, mining once again became important to communities. These communities continued to maintain a Neolithic tradition of activities on deep mining sites, including even opening new deep mines at Grimes Graves and also re-engaging with Early Neolithic mines, as in Sussex. Mining would have been a tradition that was anchored in the Neolithic and was important for retaining social and cultural links, which were perhaps beginning to be eroded by the arrival of new communities, namely the Beaker people, and the increasing production of bronze implements and ornaments (Pearson *et al.*, 2019). Therefore, the opening of new deep mines, and also the renewed extraction activity in Sussex, appears to have been carried out in an unstable world within which mining may have offered stability and a connection to old traditions and ancestors that were increasingly becoming a distant memory.

CONCLUSION

Despite of the lack of clarity on later activity at the Sussex mines, it remains important to acknowledge its existence and what it can tell us about the importance of mining to both Late Neolithic and Early Bronze Age communities. The evidence outlined in this paper has shown that, in Sussex, there was renewed interest in the earlier mines, activity that is contemporary with mining at Grimes Graves and reflecting wider trends of specialist lithic production in a world in flux due to the introduction of bronze. Overall, this paper has shown that there are further horizons of complexity to the Sussex flint mines that are, at present, under-researched and under-represented in the literature.

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At the Turn: Flint Mining as an Element of Social Changes in the Second Half of the Fifth Millennium BC in Western Lesser Poland

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In the second half of the fifth millennium BC, a new model of supply and processing of siliceous rocks appeared in western Lesser Poland (Małopolska). The existing methods of production of blades and flakes from small cores obtained at a short distance from the settlement were supplemented by those enabling the production of much longer blades from cores made from raw material obtained by mining. The significant increase in the size of lithics meant that this moment was referred to as "the metric change" (Polish: *przełom metryczny*). It was assumed that this was due to internal technological development within the early Neolithic communities of the Lengyel-Polgár cycle. This paper introduces a different explanation for this phenomenon. It is argued that the new model of supply appeared as an already developed model that was implemented by experienced outsiders. A thesis that the indicated technological caesura is not categorical and new patterns in a relatively small area could co-exist with previous ones.

KEY-WORDS: flint mining, lithic technology, Neolithic, Eneolithic, radiocarbon chronology, Lesser Poland

THE PROBLEM OF FLINT MINING IN WESTERN LESSER POLAND (MAŁOPOLSKA)

This paper discusses the problem of flint mining origins in western Lesser Poland (Fig. 1), which is locally perceived as a feature of the early Eneolithic (Kadrow 2017: 83). Due to the change in the length of the flint blades being the first

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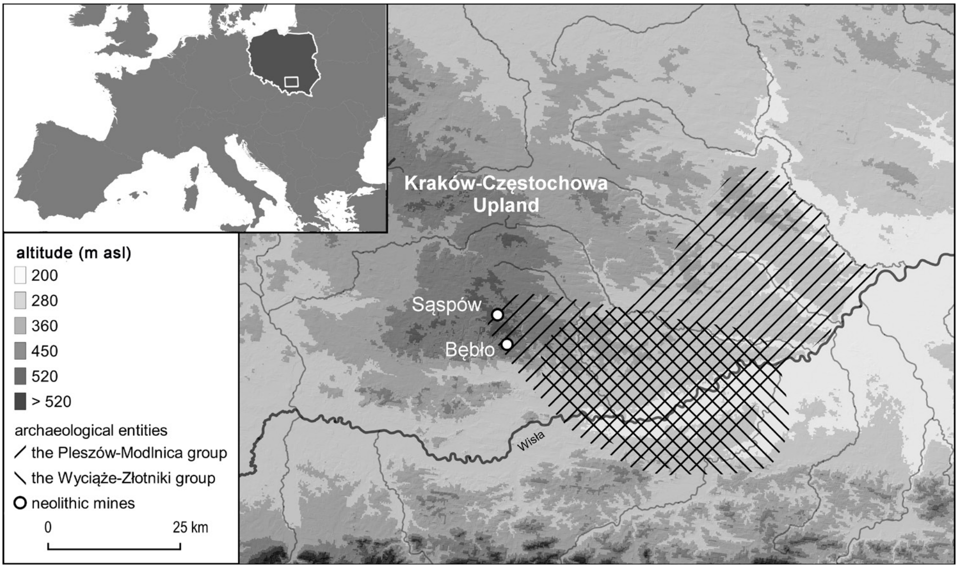


Fig. 1. Range of the Modlnica and Wyciąże-Złotniki groups of the Lengyel-Polgár cycle.

recognized feature, the emergence of this new, much more advanced production and supplying system is described by the term "metric change" (Budziszewski 1999: 256). It was defined by Witold Migal (2006: 387) who wrote: "The Polish literature on the subject stresses the metric change that occurred when Neolithic peoples began producing blades up to 34 cm long, with an average length of about 22–25 cm". Nevertheless, the situation was much more complex and it marked succession broader change in the lithic strategy. The Early and Middle Neolithic concept (Kozłowski 1969: 138; Balcer 1983: 94; Kaczanowska 2006: 30) was replaced with the Early Eneolithic one (Table 1). That profound technological transformation has usually been linked in Lesser Poland with the Modlnica phase of the Lengyel-Polgár cycle (Dzieduszycka-Machnikowa 1970: 462; Dzieduszycka-Machnikowa and Lech 1976: 136; Kaczanowska and Lech 1977: 15; Lech 1981: 124; 1987: 112; 2006: 414; Balcer 1983: 115). Migal (2006: 387) also considers "large-sized blades" to be of key importance within the Neolithic communities of the Lengyel-Polgár cycle, and associates them with the Wyciąże-Złotniki group and the influence of the Tiszapolgár and Lublin-Volynian culture communities. The beginning of the production of long blades is therefore closely related to other changes that together make up the Eneolithic phenomenon (Kadrow 2015: 248; Wilk 2018: 485).

Table. 1. The metric change in the technology of flint working in the Lengyel-Polgár cycle.

	technology BEFORE the metric change	**technology AFTER the metric change**
cores	– making use of natural forms and surfaces – narrow flaking surface – poor initial preparation: cortical flaking surface, no crests – flaking surface repaired with lateral crests – platform resharpened with a large flake – platform edge trimming	– platform formed with a single large removal – denticulated platform edge – lateral crests – maintaining the standard shape and size – deposits of cores
core processing	– soft punch – technique of the primary blade in the initial stage of exploitation	– pressure, punch – no platform edge trimming – strong reduction of the platform after each blow – great skill resulting from specialisation
blades	– unparallel edges – thick items because the flaking surface was distinctly rounded – triangular cross section – marked bending of blades made in the initial stages of core processing – flat butt – negatives of platform edge trimming	– regular blades (parallel sides and interior ridges) – significant length – uniform thickness – flat butt – en éperon (angular) butt obtained with a hard punch – small bulb – lip under the bulb – weak ripples (more dense where a punch was used)

The metric change can hardly be viewed there as resulting from technological evolution, and examples from the areas south of the Carpathians indicate that the diverse techniques of reduction could not have developed without profound social changes. In Bulgaria, small numbers of medium and macro blades have been dated to a relatively early period (the Slatina site associated with the Karanovo I culture; Gurova 2012: 8); therefore, the crucial question is when the production of long blades began in western Lesser Poland and what gave the impulse to introduce flint mining on a large scale. Manolakakis (2017: 275) states: "All available evidence – rare extraction sites, specialised knapping workshops, high level of technicity – points to specialised production limited to a small number of workshops", and: "The relatively small quantity of long blades produced raises questions regarding the mechanisms of apprenticeship, transmission and maintenance of know-how throughout the entire Chalcolithic".

Additionally, flint mining should not be interpreted solely in economic terms. Prehistoric communities saw the mines as a source of flint nodules, but they valued their ritualistic function as well (Barber 2006; Weeler 2011; Lech *et al.*, 2015; Topping 2017; Oliva 2019). The mines may have been landmarks that served as monuments in the Neolithic (Barber 2006: 174; Kerig *et al.*, 2015: 116) and the Early Bronze Age (Lech *et al.*, 2015: 222; Oliva 2019: 189). In his detailed discussion of flint mines in England, Topping (2017: 212ff) compares archaeological findings with ethnographical data and states that rituals covered the whole mining *chaîne opératoire*, starting from the activities preceding the extraction itself (hearths used in ceremonial purification). Research into the mines in Rijckholt, Spiennes and most of Sussex has shown that the observances may have determined the choice of flint seems to be mined, impelling the workers to pass over the first flint-bearing layers, easier to extract (Weeler 2011: 309). In Cissbury, Blackpatch, Easton Down and Grime's Graves, ceramic or stone deposits and human or animal bones have been recorded in contexts suggesting their sacrificial character. In the mines of Rudna Glava and Krumlovský Les, offerings were made during the mining as well, the gifts being placed on the bottom of the galleries or in special recesses (Barber *et al.*, 1999: 61; Borić 2009: 201; Oliva 2019: 111). The abandonment of the mine shafts required another set of observances that included multi-stage backfilling (Topping 2017: 212; Oliva 2019: 188) or making human sacrifices (Barber 2006: 175). The rituals accompanying flint mining and the changes resulting from social specialisation: the gradual formation of the group of miners and knappers, constitute a subject in its own right, separate from the economic role of flint mines in the Middle Neolithic.

Long blades were primarily treated as prestige objects embedded in the network of social and symbolic relations (e.g., Libera and Zakościelna 2013: 290; Kadrow 2016: 656; Manolakakis 2017: 277). Budziszewski (2006: 324) notes that in Central Europe "the first metallurgic centres developed parallel with the centres of flint knapping, resulting probably from the same socioeconomic processes". The earliest indication of the new era in western Lesser Poland may be traced to the Modlnica group and the Wyciąże-Złotniki group (Wilk 2018: 486). So, the essential question concerns the state of the relationship between both cultural units and the Lublin-Volhynian culture, which is indicated as the first to adopt the Eneolithic mode, which according to Stanisław Wilk (2018: 485) consists of components such as "the metallurgy of copper and gold, and its far-reaching trade; the beginnings of societal stratification observed in the elitism of some burials and their clear diversification in terms of sex; changes in beliefs seen in creating separate cemeteries and situating them away from settlements; changes in settlement structure – the disappearance of tells, use of draft animals". Accordingly, research into the origin of long blade production should focus on the time when long blades made of Volhynian flint started to be present in assemblages dated to the Lengyel-Polgár cycle. At that time, they circulated via Lublin-Volhynian communities in the form of finished products (Kozłowski 2006: 54; Libera and Zakościelna 2011: 89). Zakościelna (2006: 90) emphasises a link between the Lublin-Volhynian culture and "the huge demand for high-quality flint". She points out, too, that the Lublin-Volhynian culture had access to "external models", e.g., those from the south, and used them gladly. Since the turn of phases II and III, outcrops of Volhynian flint were not readily available. This forced Lublin-Volhynian communities to use chocolate or Jurassic flint (Zakościelna 2006: 90) but Volhynian flint continued to be imported. However, the crucial question is who was the consumer?

At present, we have no irrefutable evidence that Volhynian flint was brought to the Modlnica group, and Volhynian flint artefacts mentioned in the literature should probably be associated with the Wyciąże-Złotniki group (Libera and Zakościelna 2011: 88, Fig. 1). Items made of Volhynian flint have been recorded in Kraków-Nowa Huta Pleszów, Dziekanowice and Wężerów, but a detailed analysis of their contexts shows that none of the features containing them was a closed assemblage. Sites 17–20 in Kraków-Nowa Huta Pleszów form a vast multicultural complex with settlement features and graves within crest II of the Pleszów terrace. Due to the construction of a metallurgical conglomerate plant in that area, archaeologists responsible for the salvage excavation in 1953–1981 were pressed for time, and the contexts of many items seem unreliable (Kaczanowska and Tunia 2009: 268). Features associated with the Lengyel culture have been dated both to the "early and the middle phase of that culture" (Kaczanowska and Tunia 2009: 269), but some burials documented there may come from the younger phase, the Wyciąże-Złotniki group (Grave XVI in Feature 818; Kaczanowska and Tunia 2009: 76). A similar multi-stage settlement has been identified at Site 1 in Dziekanowice. The outline of the burial pit of Feature/Grave 24 was practically indiscernible during the excavation; moreover, the original arrangement of the bones was found to have been disturbed (Jaśkowiak and Milisauskas 2001: 124). Feature 15 in the immediate vicinity contained ceramics of the Funnel Beaker culture (Jaśkowiak and Milisauskas 2001: Plates 15, 18), while the cultural layer contained a quadrilateral axe, flakes with traces of polishing and retouched tools made from large blades, including a blade with a tang. Kozłowski (2006: 54) relates artefacts from a settlement pit in Wężerów, including items made of Volhynian flint with "the existence of a settlement of the Tiszapolgár population".

When characterizing the raw material background for the discussed processes, it should be noted that in Lesser Poland, good quality flint suitable for the production of larger blades and axes could only be obtained by mining. However, according to Alicja Kochman, Jacek Matyszkiewicz and Michał Wasilewski (2020: 4) who presented an extensive description of local Jurassic raw materials, and Michael Brandl (2013: 172), flint concretions obtained by the mining method from bedded limestones have average dimensions of 10 cm to 15 cm, less often 20 cm, which limited the size of the finished products. Therefore in the case of blades, we have to speak of mediolithic instead of macrolithic production. The Olkusz Upland within the southern Kraków-Częstochowa Upland covers two Neolithic sites interpreted as mining areas: Site 4 in Bębło, Wielka Wieś district, formerly referred to as Bębło-Zachruście or Bębło, Site I (Trela-Kieferling 2021a), and Site 18 in Sąspów, formerly referred to as Sąspów I (Dzieduszycka-Machnikowa and Lech 1976). At Site 4 in Bębło, small irregular flint concretions were formed in weathered clays within karst karren covered by a layer of humus and clayey loess (Przybyła *et al.*, 2021: 25). The site was excavated to a small extent by Albin Jura, Stanisław Kowalski, Janusz Krzysztof Kozłowski and Jacek Lech; most artefacts at the Archaeological Museum in Cracow come from Jura's surface surveys carried out in the 1930s (Kowalski and Kozłowski 1958: 350; Lech and Leligdowicz 1973; Lech 1981: 65; Trela-Kieferling 2018: 421). The items in the Bębło collection were shaped by uniform techniques of core preparation and reduction and by consistent methods of debitage production. Although they have provided no material for radiocarbon dating, their typological and comparative analysis has shown that the techniques of core preparation and reduction used in Bębło and at the nearby mine in Sąspów were very similar (Trela-Kieferling 2021b: 49ff). It may therefore be assumed that both areas of flint mining and knapping were linked to groups of the Lengyel culture in the period following the metric change.

CHRONOLOGY

While constructing the chronological framework for the phenomena discussed here, several elements have to be considered (Fig. 2). First of all, it should be emphasized that there are obvious obstacles that severely limit the possibility of creating an indisputable and precise time frame. This is mainly due to the small amount and insufficient quality of the radiocarbon dates, which are often derived from older investigations. Additionally, because of specific mining activity, like at the Sąspów site, the context from which they were obtained is hard to unequivocally define.

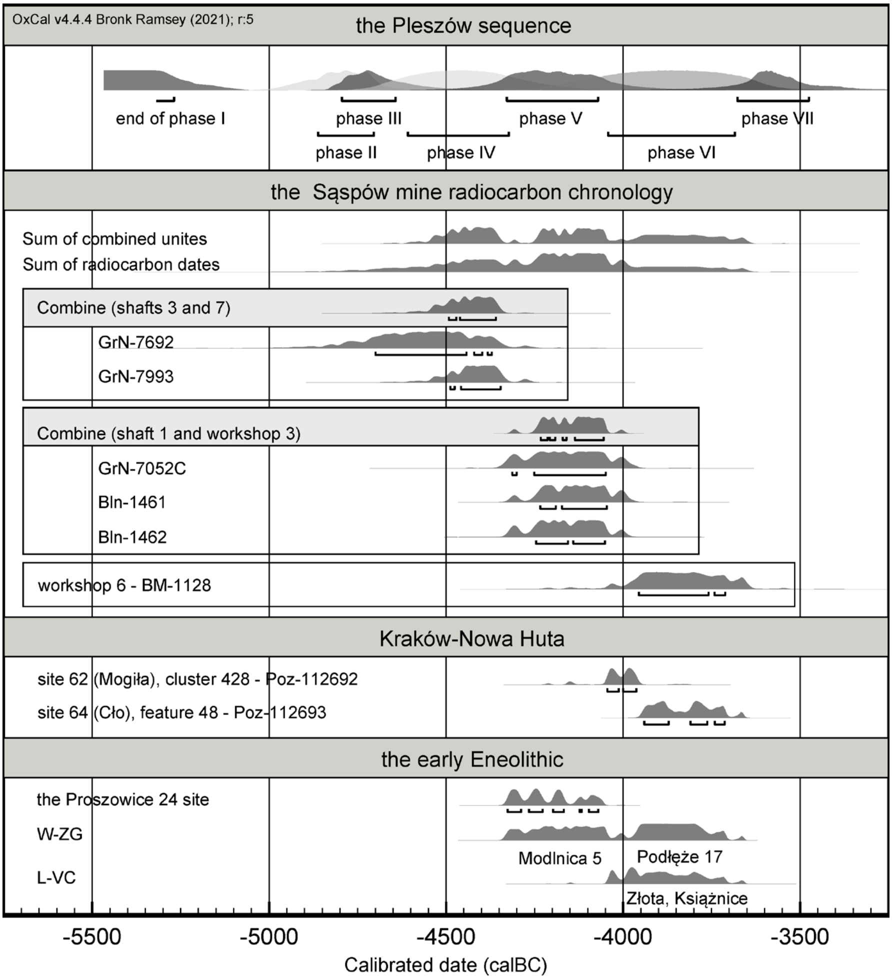


Fig. 2. The radiocarbon chronology of individual phenomena of the Early Eneolithic against the background of the Pleszów sequence. The Pleszów sequence. Linear Pottery culture (LBK): I – music note phase, II – Želiezovce phase; Lengyel-Polgár cycle (LPC): III – Samborzec-Opatów group, IV – Pleszów group (PG), V – Modlnica group (MG), VI – Lengyel-Polgár cycle (LPC)/Funnel Beaker culture (FBC?); Funnel Beaker culture (FBC) – VII.

Other factors are the materials sampled, which include charcoal, organic sediments and bones. Another issue is that precise calibration of the entire obtained probability distribution of radiocarbon dates is currently impossible. The list of the most important

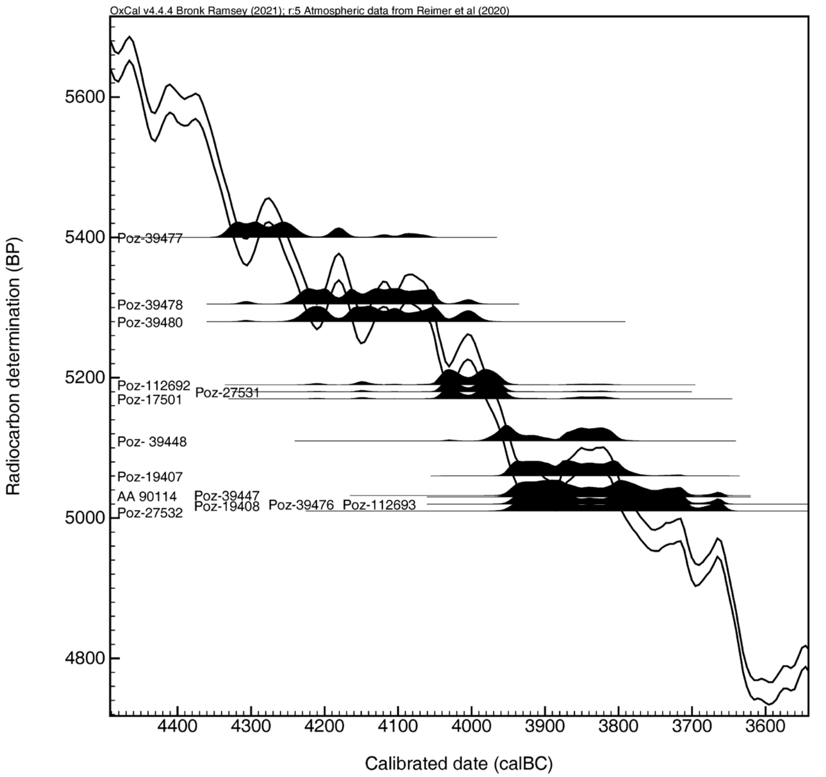


Fig. 3. Radiocarbon dates discussed in the text against the calibration curve (IntCal20).

ones shows that the flattening in the calibration curve between 4300–4000 BC (phase Pleszów IV), even with high precision of dates, does not allow for an accurate determination of a sequence of cultural facts (Fig. 3). The dates (Table 2) were calibrated with the OxCal software v4.4 (Bronk Ramsey 2009) working with the IntCal20 atmospheric curve (Reimer *et al.*, 2013).

The first element in this study involved a sequence model for cultural facts documented within the stratified organic sediments from the oxbow lake at the foot of the loess terrace close to the agglomeration of sites 17–20 at Kraków-Pleszów (Mook 1985; Godłowska *et al.*, 1987). Palynological analysis revealed intense Neolithic settlements, the chronology of which covers almost the entire Early and Middle Neolithic, as well as the Eneolithic, making it a key local chronological benchmark (Wasylikowa *et al.*, 1985).

Table. 2. A list of radiocarbon dates used in the analysis.

Site	Context	Lab code	14C Age	SD	Sampled material	Reference
Sąspów 18 (I)	shaft 3	GrN-7693	5700	135	-	Lech 1981
Sąspów 18 (I)	shaft 7 (?)	GrN-7993	5575	75	-	Lech 1981
Sąspów 18 (I)	shaft 1	GrN-7052C	5325	90	charcoal	Lech 1975; 1981
Sąspów 18 (I)	shaft 1	Bln-1461	5295	60	charcoal	Lech 1981
Sąspów 18 (I)	workshop 3/1970	Bln-1462	5325	60	charcoal (hearth)	Lech 1981
Sąspów 18 (I)	shaft 6 workshop 2/1970	BM-1128	5046	102	charcoal (hearth)	Burleigh 1975; Lech 1981
Książnice 2	grave 7	Poz-27531	5180	35	human bone (rib)	Wilk 2016
Książnice 2	grave 8	Poz-27532	5010	50	human bone (rib)	Wilk 2014
Złota „Grodzisko I"	grave 390	Poz-17501	5170	40	human/ animal bone	Sałacińska and Zakościelna 2007
Złota „Grodzisko II"	grave 101	Poz-19407	5060	30	human/ animal bone	Sałacińska and Zakościelna 2007
Złota „Grodzisko II"	grave 122	Poz-19408	5020	40	human/ animal bone	Sałacińska and Zakościelna 2007
Bronocice	grave VI	AA 90114	5032	41	human bone; AMS	Milisauskas *et al.*, 2016
Podłęże 17	feature 1674A; thin ditch with W-ZG pottery	Poz-39448	5110	35	charcoal; AMS	Nowak 2017 (Supplementary Data)
Podłęże 17	feature 2051; thin ditch of the La Tène culture with admixture of the W-ZG pottery	Poz-39447	5030	40	charcoal; AMS	Nowak 2017 (Supplementary Data)
Podłęże 17	feature 1827D; ditch with W-ZG pottery	Poz-39476	5020	40	charcoal; AMS	Nowak 2017 (Supplementary Data)
Modlnica 5	feature 4071; bottom part	Poz-39477	5400	40	charcoal, Fraxinus excelsior; AMS	Grabowska and Zastawny 2011

Site	Context	Lab code	14C Age	SD	Sampled material	Reference
Modlnica 5	feature 4071; ceiling part	Poz-39478	5305	35	charcoal, Fraxinus excelsior; AMS	Grabowska and Zastawny 2011
Modlnica 5	feature 54 (burial within a settlement pit)	Poz-39480	5280	40	charcoal, Fraxinus excelsior; AMS	Grabowska and Zastawny 2011
Proszowice 24	grave	Poz-34765	5370	40	human bone	Nowak 2017 (Supplementary Data)
Kraków-Nowa Huta Mogiła 62	cluster 428 (grave)	Poz-112692	5190	40	human bone	unpublished
Kraków-Nowa Huta Cło 65	feature 48 (grave III)	Poz-112693	5020	40	human bone	unpublished
Pleszów	core ID, layer PL-7a, b, phase VI	GrN-9267	4755	35	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987
Pleszów	core ID, layer PL-6, phase V	GrN-9182	5380	60	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987
Pleszów	core I bis, layer PL-3/ PL-4a, phase III-1	GrN-9268	5830	45	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987
Pleszów	core I bis, layer PL-2c, phase II	GrN-9270	5905	40	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987
Pleszów	core I bis, layer PL-2c, phase II	GrN-9269	5910	40	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987

Site	Context	Lab code	14C Age	SD	Sampled material	Reference
Pleszów	core I, layer PL-2c, phase II	GrN-9184	5958	50	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987
Pleszów	core I bis, layer PL-2b, hiatus between phase I and II	GrN-9183	6050	40	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987
Pleszów	core I, layer PL-2b, hiatus between phase I and II	GrN-9272	6075	40	wood+ peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987
Pleszów	core I bis, layer PL-2b, hiatus between phase I and II	GrN-9271	6255	40	peat	Mook 1985; Wasylikowa *et al.*, 1985; Godłowska *et al.*, 1987

As shown above, the technological change was linked with the Modlnica group. However, according to the authors of this paper, archaeological material associated with this unit does not corroborate that. Additionally, there are hardly any chronological markers that would unambiguously define its chronology. Until now, it was based on the Pleszów stratigraphy, as well as a series of contradicting radiocarbon dates from Feature 416 at site 62 in Kraków-Mogiła (Godłowska and Gluza 1989). Therefore it was decided to date two finds, considered as burials – Kraków-Nowa Huta Cło, Site 64, Grave III (Feature 48) and Kraków-Nowa Huta Mogiła, Site 62, Cluster (Grave) 428. The association with the Modlnica group was based on the analysis of ceramics carried out by the authors of the research. Both features contained a selection of flint products, which provided important arguments concerning the methods of flint-making at that time.

Kraków-Nowa Huta Cło, Site 64, Grave III (Feature 48)

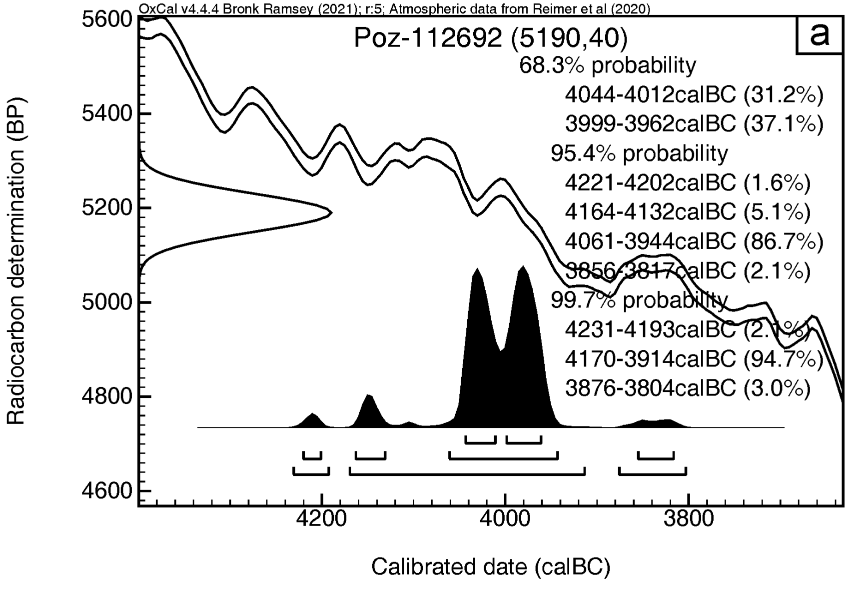
The feature was identified during an excavation carried out in 1997 (Kaczanowska and Tunia 2009: 266). The oval pit became visible at a depth of 80 cm; the burial was uncovered at 90–100 cm. The body, probably of a young man (20–30 years old), had been deposited on the right side with the arms and legs pulled up. The bones were very poorly preserved (Wróbel 2002: 11). The burial was accompanied by two flint artefacts: a burin and a blade, placed in its immediate vicinity. Although Kaczanowska does not consider those items as burial goods, she links all the finds: those from the bottom of the pit and those from the fill, "solely with the Lengyel culture". The burial in Feature 48 is associated with the period of the Pleszów-Modlnica group (Kaczanowska 2006: 51). Samples of the human bones were radiocarbon dated at the Poznan Radiocarbon Laboratory in 2019. The date for Feature 48 at Site 65 in Kraków-Nowa Huta Cło (Poz-112693) has been estimated at 5020 ± 40 BP (Fig. 4).

Feature 48 contained 19 flint items, three of them considerably burnt, made of brown Jurassic flint from around Cracow, including a distinctive spall: a partly cortical flake formed perhaps during the repair of the striking platform (preserved fragments of two blade negatives); two burins: a strongly burnt single blow (length 45 mm, width 14 mm, thickness 7 mm) made from a partly cortical blade with the burin removal noticeable on its distal end (Fig. 5:1); an angle burin on a break (length 35 mm, width 26 mm, thickness 11 mm) with a single burin negative, made from a thick wide blade (preserved central part of the blade; Fig. 5:2); a fragmentarily preserved endscraper (Fig. 5:3) made from a partly cortical large flake, with a fragmentarily preserved crest and an abrupt narrow arched front, its crumbled edge forming a serrated line due to the secondary burning of the item; a blade and nine fragments of blades (five butt parts, two central parts, two distal parts; Fig. 5:4–13) and four flakes.

Most flint artefacts seem to have undergone the same technological procedure. The stylistic and metric properties of the blades suggest that the items were produced before the metric change. The blades and the blade burin have narrow arched butts with a distinct lip and a small bulb. The artefacts are relatively slender, thin (the maximum thickness is 7 mm) and not very long (the maximum length is 55 mm), with parallel lateral edges. The large flake from which the endscraper was formed had been produced in the preliminary phase of core reduction; there are remnants of a crest and cortical surface in its distal part. The blade from which the angle burin was shaped differs somewhat from the other items as its Jurassic flint is grey and opaque. The artefact was recovered from a depth of 70–80 cm, e.g., slightly above the outline of the pit. It has survived fragmentarily, which precludes its precise description.

Kraków-Nowa Huta Mogiła, Site 62, Cluster (Grave) 428

The salvage excavation occasioned by a planned motorway was carried out in 1969 (Kaczanowska and Tunia 2009: 274). It uncovered a human skeleton considered by the researchers, despite some doubts, to be a burial. The bones of a 30- or 40-year-old



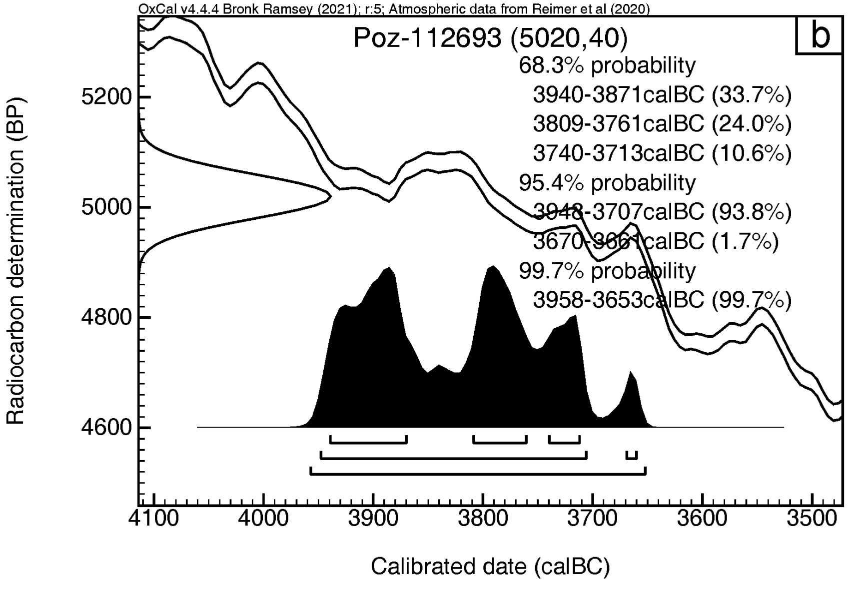


Fig. 4. Calibration of radiocarbon dates: a – Kraków-Nowa Huta Mogiła, Site 62, Cluster (Grave) 428; b – Kraków-Nowa Huta Cło, Site 64, Grave III (Feature 48).

man were found at a depth of 190–200 cm at the bottom of a settlement pit. Artefacts came from a cone-shaped deposit (150 cm deep) covering the bones. Samples of the human bones from Feature 428 at Site 62 in Kraków-Nowa Huta Mogiła (Poz-112692) have been radiocarbon dated to 5190 ± 40 BP (Fig. 5).

All recovered artefacts (8 items) were made of light or dark brown Jurassic flint from around Cracow: a residual flake core (Fig. 5:14): a small boat-shaped item used also as a hammer; its striking platform, divided into passive and active parts with a markedly serrated edge, was repaired with removals of small core tablets starting at the flaking surface; the last flaking surface was formed on the broader face; two butt parts of relatively big blades (length 36 and 44 mm, width 21 mm, thickness 6 mm): a partly cortical item with a relatively broad butt and a convex bulb bearing distinct scars, trapezoidal in cross-section (Fig. 5:15); an item with a narrow arched butt characterised by a distinct lip and a small bulb, polygonal in cross-section (Fig. 5:16); three fragments of flakes and two chunks with single removals.

Another element of the chronological framework is a visualisation and comparison of radiocarbon dates from the Sąspów mine, which, despite multiple doubts, is the only available argument in the discussed issues. Sąspów was chronologically ascribed to the successive phases of the Lengyel-Polgár cycle in the 1970s and the 1980s, when radiocarbon dating was obtained for four sites of the Pleszów-Modlnica group and the Wyciąże-Złotniki group: Kraków-Mogiła 62, Kraków-Pleszów, Sąspów, and Złotniki (Dzieduszycka-Machnikowa and Lech 1976: 151; Lech 1981: 63, 181; Godłowska *et al.*, 1987: 37). Shaft 3 in Sąspów, the earliest one, was then considered to have been related to Samborzec-Opatów settlement or with Malice settlement (Lech 1981: 179). Shaft 7 was linked to Malice settlement (Nowak 2009: 109), Workshop 3/1970 came presumably from "the Modlnica phase or possibly the Pleszów phase", while Shaft 6 and Workshop 2/1970, viewed as the youngest features, were dated to the final phase of the mine, contemporaneous with the Wyciąże-Złotniki group (Lech 1981: 185ff). The long consistent exploitation of the Sąspów shafts should be corroborated by artefacts formed according to diverse Middle Neolithic technological models within various groups of the middle and late Lengyel culture. Although one can argue for the "continuation and uninterrupted gradual development" of the flint industry at that time (Kaczanowska 2006: 49), flint knapping in those Lengyel groups differed considerably in the choice of core types, the character of debitage, and the metric properties of the products (Balcer 1983: 81, 95, 115; Nowak 2009: 150). With so many obscurities, the explanation may be sought in various areas, e.g., in the social function of the mines, the access to know-how or the quality of raw material. However, this text focuses on the verification and reinterpretation of chronometric evidence. A new approach to the radiocarbon dating of the Sąspów shafts

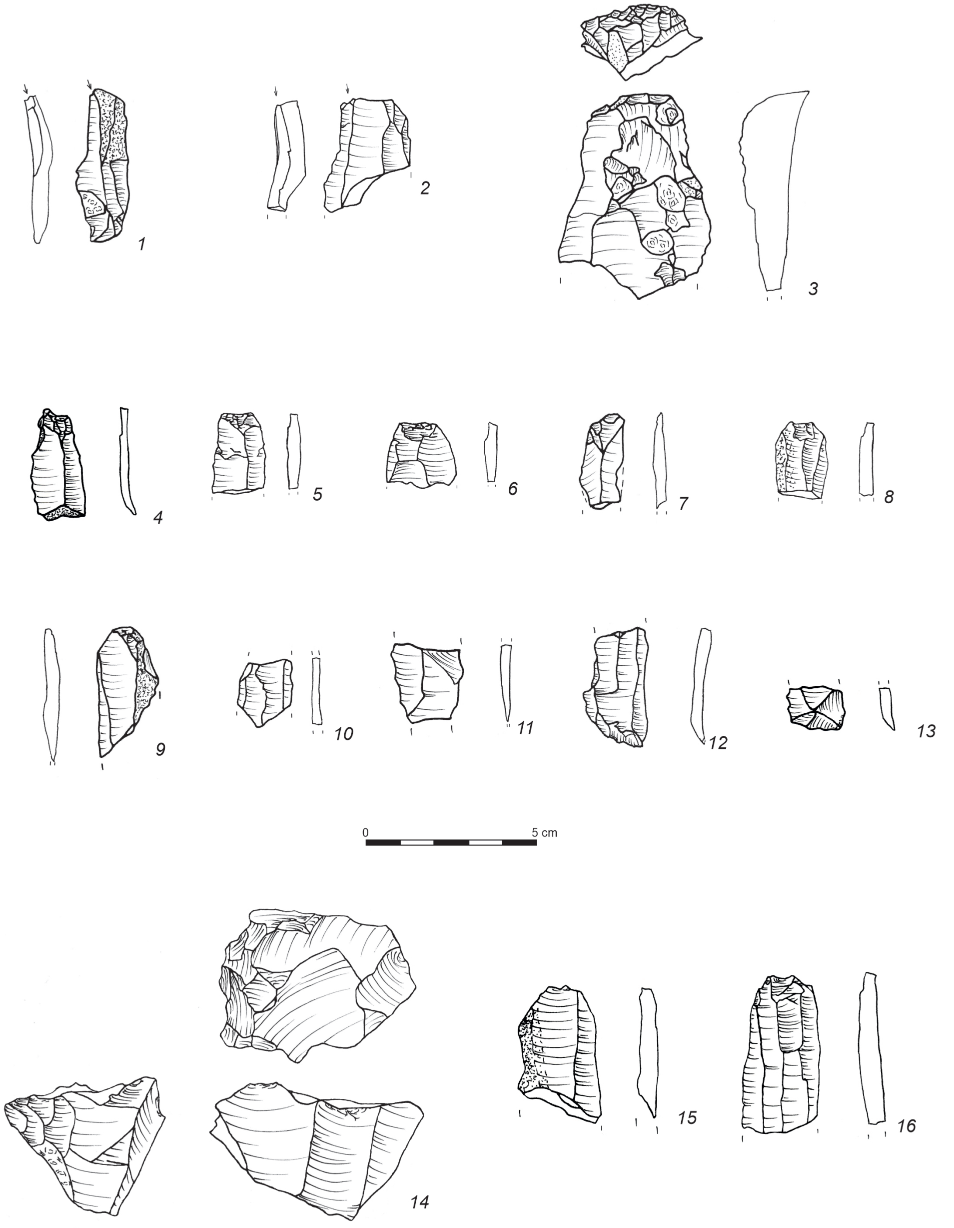


Fig. 5. Lithics: 1-14 – Kraków-Nowa Huta Cło, Site 64, Grave III (Feature 48); 15-17 – Kraków-Nowa Huta Mogiła, Site 62, Cluster (Grave) 428.

(Lech 1981: 81) would be particularly helpful here. Naturally, flint mine shafts are difficult to date due to several factors that can distort (reduce) their age, such as re-exploitation of old shafts; subsequent use of raw material abandoned in earthworks at the shafts; a limited range and usually a small amount of substances suitable for the dating (charcoal from fires or torches, mining tools made of bone or antler); few fragments of pottery. All those factors may have affected the dating of the Sąspów mine. With no dates for the Bębło shafts and with some doubts about the presumably long operation of the mine in Sąspów, an absolute chronology of the mine shafts in Lesser Poland may not be possible without new radiocarbon dates. In total, six radiocarbon dates were obtained from shafts and workshops (Lech 1981: 185). Their visualisation was presented in the form of a probability distribution and the sum of these probabilities (Fig. 2). This chart indicates that the site area could have been used even by Linear Pottery cultures (the II phase), as well as the earliest communities of the Lengyel-Polgár cycle, both of which can be correlated with III phase of the Pleszów sequence. However, it must be noted that the date from shaft 3, which supports such chronology, is characterized by a relatively large standard error, which covers three successive phases of the sequence from Pleszów (II–IV) resulting in its value for establishing the chronology being limited. In this article, based solely on radiocarbon dates, the existence of three chronological phases of the Sąspów mine is assumed. The phases are determined by combinations of radiocarbon dates from shaft 3 and the hypothetical shaft 7; combinations of relatively consistent radiocarbon dates from shaft 1 and workshop 3; and the radiocarbon date from workshop 6 respectively. They indicate subsequent chronological intervals: 4550–4300 BC (second half of the Pleszów IV phase); 4300–4000 BC (Pleszów phase V) and 4000–3650 BC (Pleszów phase VI). Phases established in such ways are the basis for further considerations. As mentioned above, production wastes recorded at the site point to unchanging technology, which suggests a relatively narrow chronology. Almost all cores produced in the workshops located by the mines show the implementation of the same flint processing strategy. They are similar in terms of the preparation and exploitation techniques which allowed the production of fairly standardized blades with a length of 8 cm to 10 cm (Trela-Kieferling 2021b: 196).

Another piece of argumentation is the assumption that the commencement of mining in western Lesser Poland was not the result of the internal development of the methods of flint-production of the Linear Pottery cultures, but was the outcome of the implementation of a new cultural pattern, which should be associated with the emergence of the Eneolithic in southern Poland. Therefore, it should be linked with the crystallization of archaeological units of the Wyciąże-Złotniki group and the Lublin-Volhynian culture. Initially, their chronology was established between 4000–3800, which matches the chronology of the youngest phase proposed for the mine. However, the first determinants of the early Eneolithic appeared much earlier (Nowak 2014: 250). The first of such is the settlement at site 5 in Modlnica, which can be considered an early stage of the Wyciąże-Złotniki group (Grabowska and Zastawny 2011; Nowak 2016; 2017). The feature 4071, which provided charcoal for radiocarbon dating, and yielded several lithics with average dimensions of over 7 cm (the longest being 11.8 cm; Wilczyński 2011: 519). The second indicator is the burial discovered recently at site 24 in Proszowice which was richly equipped with copper products (Marcin M. Przybyła personal communication; Wilk 2016; Nowak 2017).

Based on the above assumptions, it should be expected that the mining activity in Sąspów took place during the second chronological phase and probably continued in the third phase. The first chronological phase is undoubtedly the most difficult to interpret. Currently, it should be assumed that this is a trace of indefinite penetration of the site by the Lengyel-Polgár cycle communities, which is misleading due to the complicated archaeological context and should be excluded. However, if the mine exploitation limit was to be extended to the period from approx. 4500 BC, it then would be one of the first archaeologically tangible elements of the early Eneolithic. Such a long sequence could be confirmed by the observations of other mining centres. For instance, in Great Britain and Ireland, when Neolithic populations increased in the mid-fifth millennium BC, flint mining accelerated due to the rising need for the production of axes (Shennan *et al.*, 2017: 78). The research team of the NEOMINE project points out that the extent of flint mining decreased only in the mid-third millennium BC when copper metallurgy gained great popularity (Shennan *et al.*, 2017: 78). Analysis of the dates proposed for mining sites in Western Europe (Bretteville-le-Rabet Jablines, Seine-et-Marne, Jandrain--Jandrenouille, Petit-Spiennes, and Camp-a-Cayaux, Rijckholt-St. Geertruid) has shown that the mines were all used between 4500 and 3000 cal BC, with the shared period of their exploitation *c*. 3800 cal BC (Wheeler 2011: 306).

The above considerations are backed by the chronological outline of new impulses in western Lesser Poland marking the period of the early Eneolithic which are locally identified with the Lublin-Volhynian culture and the Wyciąże-Złotniki group settlements (Wilk 2016; Nowak 2014; 2017).

CONCLUSIONS

Neolithic flint mining in western Lesser Poland ought to be seen in the context of the social order evolving under the impact of new cultural patterns that emerged at the turn of the middle Neolithic and the early Eneolithic (Kadrow 2017). These changes are clearly visible in the lithic production (Table 1). The chronology of that period remains an interesting subject of study (e.g., Kaczanowska 2006: 52; Kozłowski 2006: 60; Nowak *et al.*, 2007: 463; Nowak 2010: 83; 2014: 250; 2017: 260; Grabowska and Zastawny 2011: 129ff; Wilk 2016: 22). New research concerning the Carpathian Basin shifts the beginning of the Eneolithic in the region towards the middle of the 5th millennium. It was also pointing out the non-linear development of these communities (Raczky and Siklosi 2013: 570). This new framework may also be applied to refine the chronology of the Eneolithic phenomena in Lesser Poland which was in a sphere of influence radiating from that centre.

The chronological framework proposed by the authors, if accepted, would require a re-evaluation of the premises for associating the technological transformation of flint knapping with the Modlnica group which has to be viewed as contemporaneous with the Wyciąże-Złotniki group (Nowak 2014: 276). So, the question is whether that change might not have taken place in the Wyciąże-Złotniki group and whether both mines and their workshops should not be ascribed to that cultural unit? There are no arguments supporting the opinion that flint knapping in the Wyciąże--Złotniki group resulted directly from the technological development of stylistic achievements of the older cultural units (Kozłowski 2006: 54), contrary to the Modlnica group. Moreover, the relatively late chronology of the Modlnica group, as well as the suggested continuation of older technological threads, which could be confirmed by the new radiocarbon dates presented, indicate a more complex picture of flint--making during this period. Therefore, the "metric change" term could potentially apply to only a fraction of the overall picture. If dating the Wyciąże-Złotniki group to 4300–3600 BC is correct (Nowak 2010: 82; 2017; Grabowska and Zastawny 2011; Wilk 2018: 492), flint mining in Bębło and Sąspów may be viewed as a response to the new demands of the latest of the Lengyel-Polgár cycle communities. This response may also be considered to run parallel to the Lublin-Volhynian culture. The metric change can thus be seen as another trace of local social transformation that was triggered by a Tiszapolgár impulse.

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Workshop Places at Chessy (Seine-et-Marne Dpt., France): Contextual and Technological Aspects

Anne Hauzeur[a], Gilles Monin[b], Harold Lethrosne[c], Paul Fernandes[d] and Vincent Delvigne[e]

Recent excavations at Chessy (Seine-et-Marne department, France) have revealed knapping areas for axe head production in Bartonian (Eocene) silicite close to the mining complex of Jablines. They are attributed by the associated set of tools and the archaeological background to the later part of the Paris Basin Middle Neolithic (*c*. 4300–3700 BCE).

The main characteristics of the knapping places are bifacial shaping to produce axe head preforms. Petrographical analyses show at first examination a close relation to the same silicite beds as those exploited at Jablines. Beside this, some of the artefacts indicate another way of raw material gathering which could match with the Bartonian silicite procurement on a larger scale.

The workshop places may be distinguished as places of different function, mostly devoted to the first steps of preparation (roughing and shaping processes), but another to shaping stages, and a last one essentially concerned with the finishing of manufacturing rough-outs. Considering the very rare fragments of preforms collected on the site and the high quality of the rejected waste products, the skill level was high. From the first flaking of the block, contrary to what is usually inferred, indirect percussion was used since the first flaking of the block.

These workshops add to the information from the other known similar places in this region of the Marne area, including the mining complex of Jablines itself. There were no settlements next to the mines, but in the surrounding areas, and the related distance remains to be explained.

KEY-WORDS: Île-de-France, Middle Neolithic II, silicite workshops, indirect percussion, territory

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INTRODUCTION

In May to July 2016, a development-led excavation operated by SARL Paléotime took place at Chessy –"ZAC des Studios et Congrès" (Seine-et-Marne departement) prior to an extension of the EuroDisney Park (Hauzeur 2018). The investigation covered an area of 20,230 m² and revealed – amongst other features – the presence of chipping areas devoted to the production of axe heads from Eocene (Bartonian) silicites.

The knapping places are located/set up on the plateau overlooking the meanders of the river Marne to the south, in a rich archaeological context of other workshops, settlements, enclosures, and graves dated from the Early to the Final Neolithic (*c*. 5000–2500 BCE; Fig. 1). This part of the Marne valley is well known because of the presence of one mining site at Jablines –"le Haut Château" (Seine-et-Marne department) excavated in 1989–1990 prior to the construction of the TGV North line (Bostyn and Lanchon 1992) and also excavations on several workshops in the area (unpublished).

The sedimentary context of the excavation is that of the upland silts or silts of the plateaus (*Limon des plateaux*) characterised here by a important hydromorphy and a high clay content (up to 26%). A second unit above is a succession of brownish pedogenic layers (B horizon) the top of which contains the artefacts. This level is not influenced by the ongoing pedogenic processes suggesting the existence of an erosion phase in between, confirmed by a consequent lack of artefacts in the workshops as shown by the refitting.

THE WORKSHOP PLACES

The distribution of material found at Chessy is organised in five clusters each representing a place devoted to the shaping of Bartonian silicite axe heads.

The main clusters are located in the northern part of the excavation area. There is one concentration (F13), with smaller "satellite" clusters of material around it, defining a southern sector. Adjacent to it, there are another four, of smaller size ("F17", "H17", "F18" and "F19"), defining a northern sector (Fig. 2 and 3). A total 17,985 objects have been counted, including debris, blocks, flakes and chips to which can be added 55,524 micro-chips and small fragments and debris less than 20 mm coming from the sieving. Part of the latter material (debris) is the consequence of a drainage system set up in the 20th century and crossing the concentration. The results of the granulometric and taphonomic analyses, combined with the vertical projection of the georeferenced

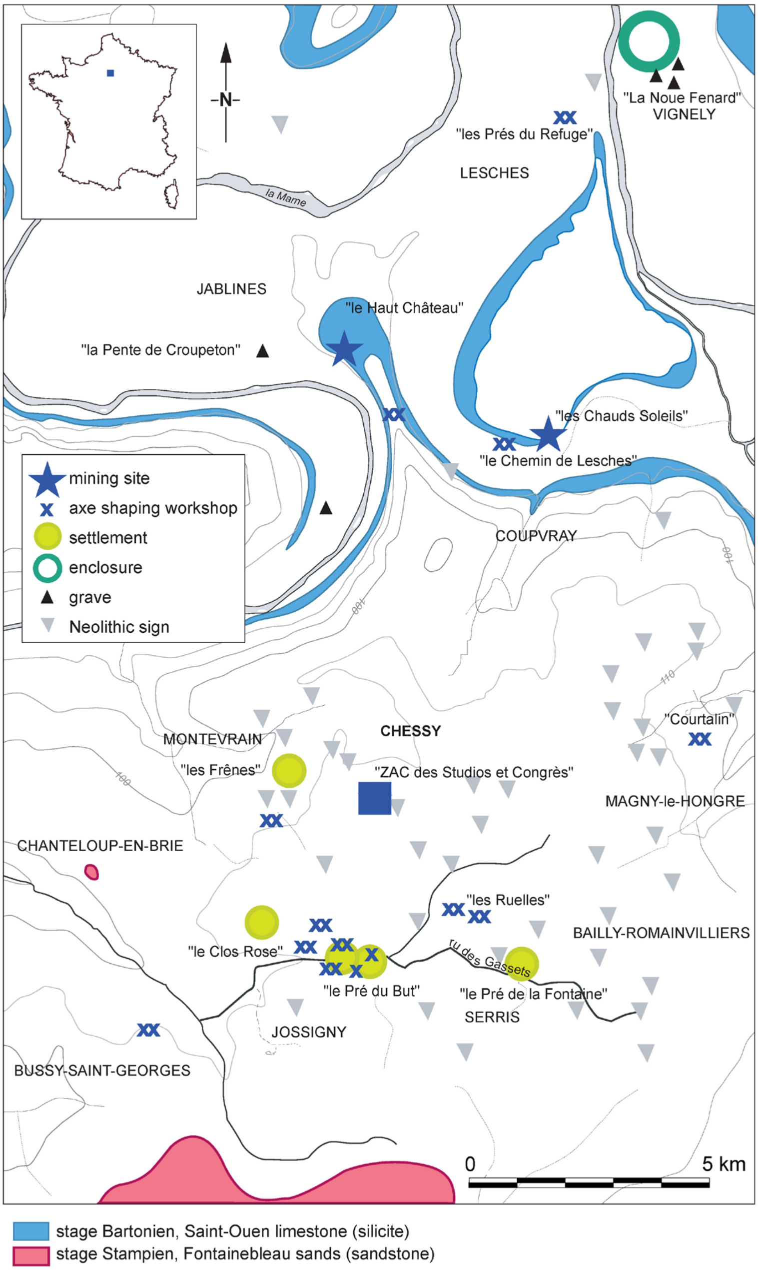


Fig. 1. Geological and archaeological context of the workshops at Chessy – 'ZAC des Studios et Congrès'. Data according to Y. Le Jeune, UMR 8591, V. Brunet, Inrap; modified and completed.

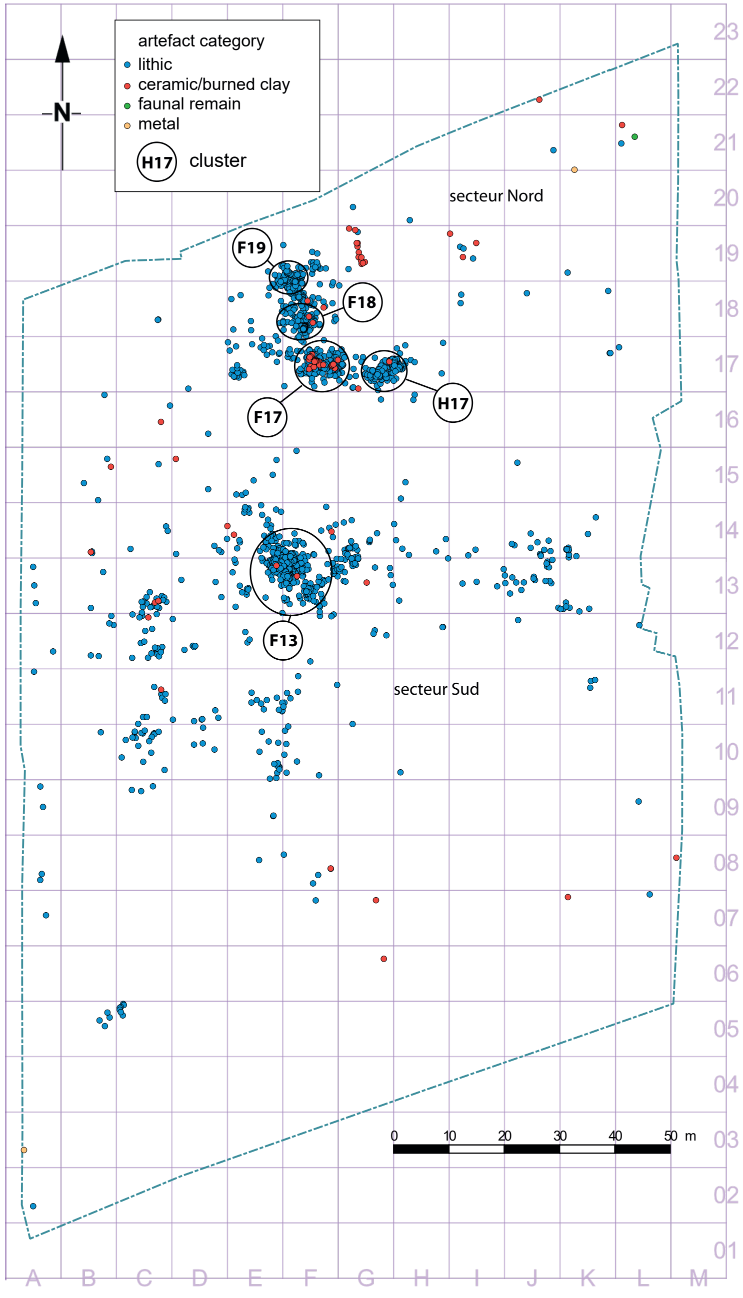


Fig. 2. Spatial distribution of the lithic material with the labeled five clusters in the excavations.

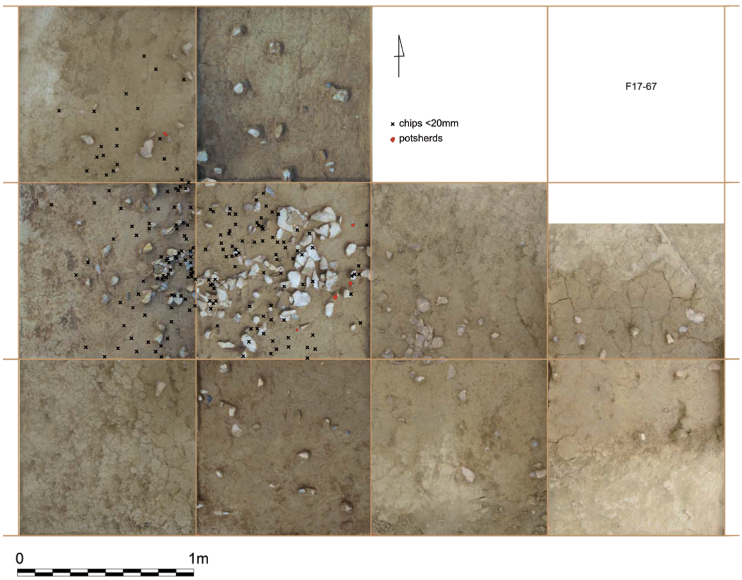
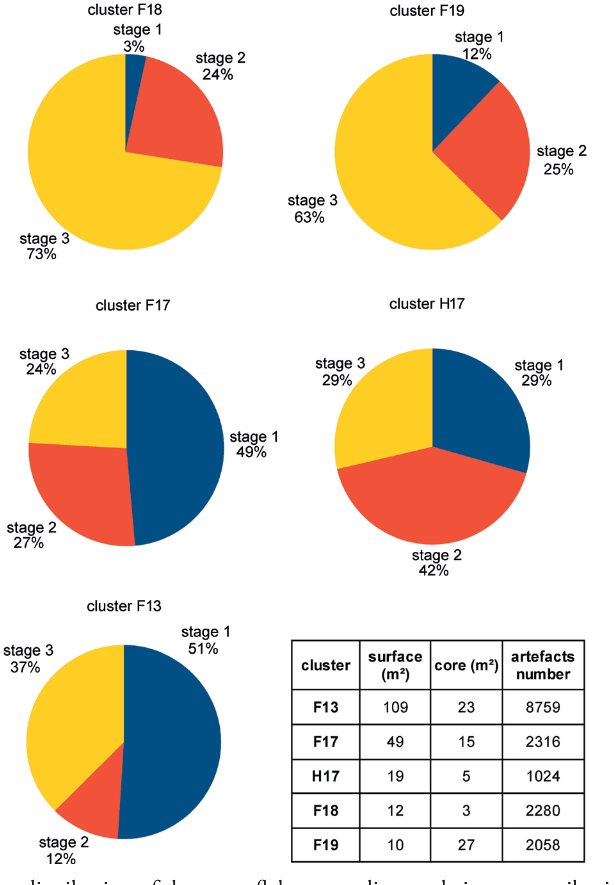


Fig. 3. Zenithal view of excavated square metres from the chipping floor "F17".

finds, show dense concentrations of material constituting the actual core of the clusters and a more diffuse spread of finds spread over several metres. The clusters, or at least what remains of them, show an accumulation of objects of about 10 to 15 cm of thickness. The dilatation is more significant in the most northern clusters, "F18" and "F19", reflecting the effects of post-depositional sedimentary processes operating on the north characterised by a more heterogeneous and more dispersed material.

The study of these different spots shows that all the stages of the *chaîne opératoire* from the first flakes –concerning flat nodules more than the slab-shaped blocks – to the finishing stages (see section 3.2. for definition of the stage) are present everywhere (Fig. 4). But there are relative differences in the waste assemblies that shows that they were produced by one stage rather than another. The clusters "F17" and "F13" differ from the others in the predominance of the first roughing out (stage 1) with very large (cortical) flakes (size over 80 mm). In contrast, "F18" and "F19" are clusters dominated by a majority of thin medium(50–80 mm) to small sized (20–50 mm) flakes coming from the regularization or finishing steps of the preforms (stage 3).

The representativeness of these stages varies from one cluster to another and this raises the question of the significance of these notable differences. Too many elements are missing to enable the complete shaping process to be reconstructed.



cluster	surface (m²)	core (m²)	artefacts number
F13	109	23	8759
F17	49	15	2316
H17	19	5	1024
F18	12	3	2280
F19	10	27	2058

Fig. 4. Relative distribution of the waste flakes according to their stage attribution among the clusters, with the total number of pieces taken into consideration.

In the case of all the clusters, several blocks of raw material were knapped. They can be distinguished on the basis of macroscopic sorting and partial petrographic analysis of the waste flakes. In "F17" for example, estimating the minimal number of shaped blocks at around ten according to the "family" or groups of similar raw material, the number of waste flakes per block is very low (< 135 flakes), in the case of a full *chaîne opératoire* including chips smaller than 20 mm. Experimental series conducted by Jacques Pélegrin on morphologically similar blocks but in Upper Cretaceous flints give between 800 to 1750 g of shaping waste (Augereau 1995: 149–150; only mass is available). Another experiment done in the 1980s with a Grime's Graves nodule gave

242 complete flakes bigger than 20 mm and about 1750 g of waste (Burton 1980: 132). Important gaps in the material, underlined by a low rate of refitting (10% of the artefacts ≥ 50 mm for "F17"), which varies greatly according to the raw material groups and the initial size of the blocks, reflect an important truncation of the series, hindering comparisons with the previous data. Nevertheless, a spatial differentiation of the processing can be suggested according to the spot assemblages. This concerns the roughing phase and mainly the largest blocks. The assumption is that the initial step, designed to lighten the blocks, took place closer to the extraction site. It seems also that the different phases of the *chaîne opératoire* are split between different clusters, between roughing, thinning and shaping on one hand, and regularizing and finishing on the other.

Taken together, the clusters seem to form a coherent whole (working hypothesis), with places more specialised in one or another of the shaping stages. This observation raises the question of the concomitance of the operations on all the blocks represented by these clusters. Were several knappers working in a chain on a set of nodules brought back from the extraction site, or were a few of them making several times and quickly a round trip, knapping in a workshop according to their moods? The only few refittings carried out between "F17" and "H17" at least support the hypothesis of a block moving during its shaping between knappers ... unless it was the knapper moving with their block. Is the production of axe heads the work of one specialised knapper going through the whole process on one block or could it have been the result of two or more workers operating together (Pélegrin 2012: 90)? Given the state of our knowledge on the knapping data (collected material and technical process) at Chessy, these questions are difficult to answer.

Despite such issues, it can be argued with almost certainty that all the clusters located on the site are indeed contemporary (in a cultural group time scale), and that there are not several generations of knappers frequenting this place over decades, although the presence of distinct technical clusters on the excavated site could imply knappers from different communities.

FOCUS ON SOME CHARACTERISTICS

Origin of the raw material

Petrographical analyses conducted on a sample of 108 pieces belonging to the different groups of Bartonian blocks identified macroscopically revealed a gathering of raw material coming from the geological layers (defined as type F717), and a very slight contribution of material gathered on the ground surface near the extraction site (similar petrofabric to F717).

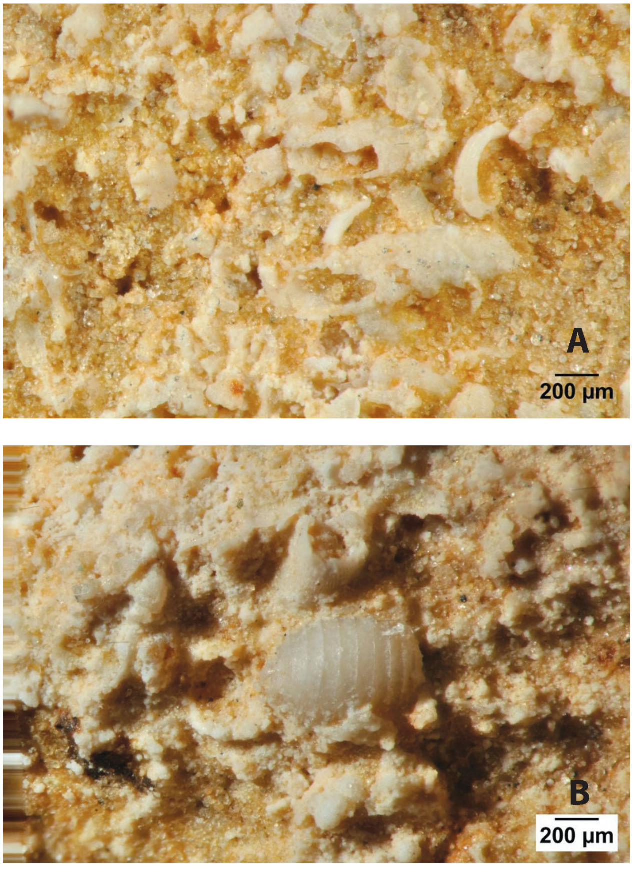


Fig. 5. Well preserved bioclasts at the surface of the cortex of waste flakes. A. Characeae stems; B. Gyrogonites.

Type F717 has an irregular cortex, sandstone to limestone with alveoli. The lack of cementing and damage as well as numerous fossils in high relief on the surface confirm that the silicite nodules of Chessy had been collected in primary position (Fig. 5). Two microfacies can be distinguished by the dominant frequency of Gyrogonites and Characeae stems on one hand, and the ostracodes on the other.

The raw material procurement compares with that of the mining area of Jablines – "le Haut Chateau" (Bostyn and Lanchon 1992) and probably also Coupvray – "les Chauds Soleils" (Seine-et-Marne department; Arnette 1961: 74–80) located at about 5 km as the crow flies in the Marne valley. This assumption is supported by our field surveys around the two mining sites. Chessy is therefore part of a vast mining area exploiting similar silicite types in a local way.

Indirect percussion evidence and level of know-how

The classical scheme proposed by French researchers for the shaping of axe preforms ready to be polished is divided into three main stages (Bostyn and Lanchon 1992: 170; Augereau 1995; 2004: 79; synthesis in Pélegrin 2012): 1. Roughing a first bifacial shape; 2. Morphological regularization of this shape creating (bi)convex sides and thinning process; 3. Straightening the sides and the cutting edge. For each of them one or several knapping techniques were applied, respectively: 1. Direct percussion and the use of hammerstones; 2. Direct percussion and the use of organic (soft) hammers – indirect percussion has been rarely observed at the end of this stage (Pélegrin 2012); 3. Use of organic percussion, indirect percussion and pressure (Pélegrin 2012).

While trying the refittings on the "F17" and "H17" clusters, we made some original observations on the knapping techniques and the shaping methods. The corpus for the refittings comprised large flakes and flake fragments of 50 mm or over (N = 412 in "F17"; N = 171 in "H17"). This knapping waste was distributed in 7 raw material families for "F17" and 9 for "H17". In these groups of large flakes, virtually all the material represents the first and second shaping stages. We could perform a knapping technique diagnosis of over 217 flakes from "F17" and 61 from "H17" (meaning a butt was present on practically all these flakes, although we could not perform an appropriate diagnosis on every flake with a butt). Besides the stone hammer percussion (hard hammer or soft stone) associated with the first stage, we identified organic percussion mostly associated with stage 2, and surprisingly, indirect percussion associated with stages 1 and 2 (Fig. 6). In "F17" and "H17", 10% of the large flakes collection have been refitted, three refittings involved flakes from the two clusters (C family, Fig. 6), and we could observe differences in shaping techniques between the two clusters. In "H17", organic percussion was the main technique used for phase 2 while in "F17" this technique is applied to the same phase but mostly to the finest grained silicites (Fig. 6).

Some major criteria and morphological characteristics allowed us to discriminate organic and indirect percussion. Dihedral butts (Fig. 8, PT2608, PT2652) and the few spur butts (Fig. 8, PT2646) observed are organic percussion discriminators. When the flake butt removed a large part of the bifacial edge, the contact area on the butt dihedral ridge is defined by a diffuse bulb and radial fissures (Fig. 8, PT2608). For each flake we observed the butt was well prepared, abraded and softened, on the larger flakes the softening (*doucissage* in French) was heavy. So the knappers showed particular attention to every flake removal using organic percussion. The flake profiles

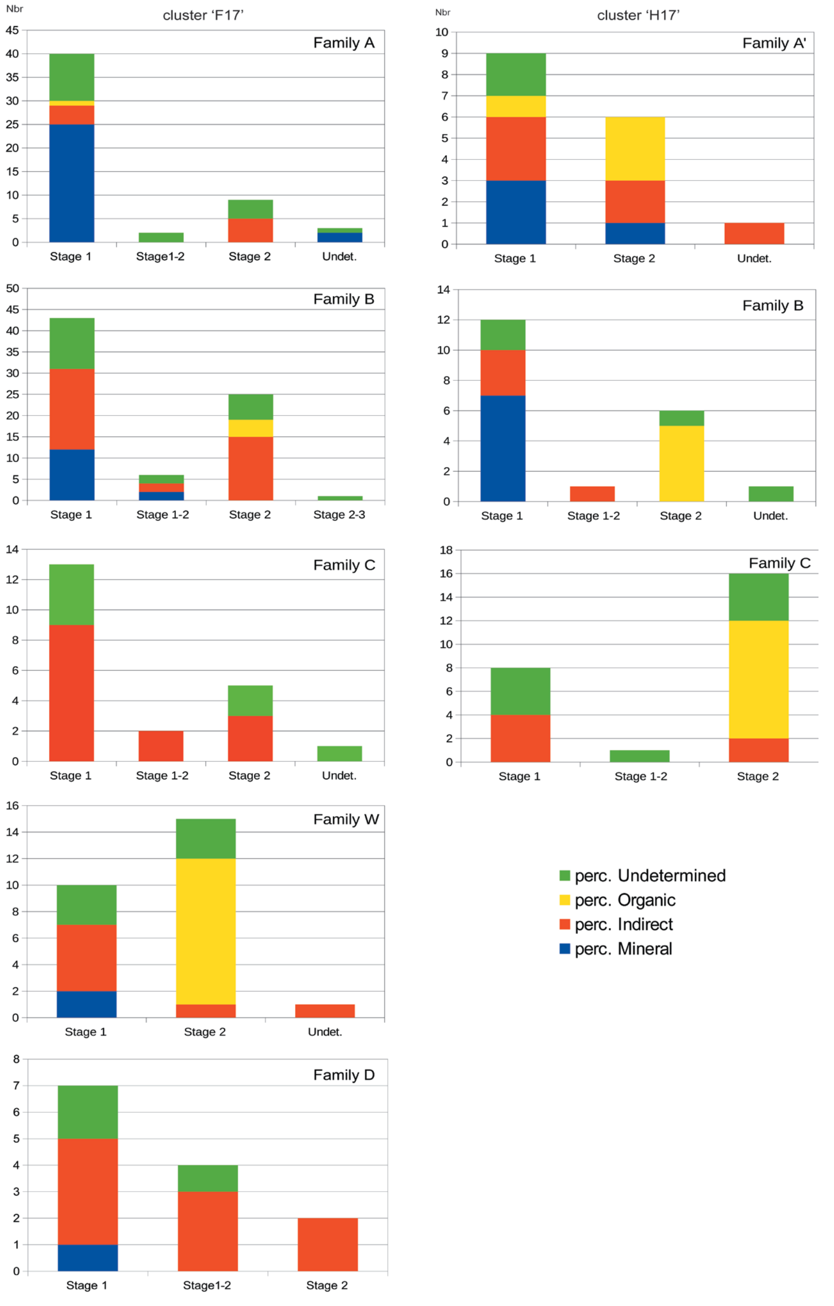


Fig. 6. Shaping technique diagnosis for some raw material families from clusters "F17" and "H17".

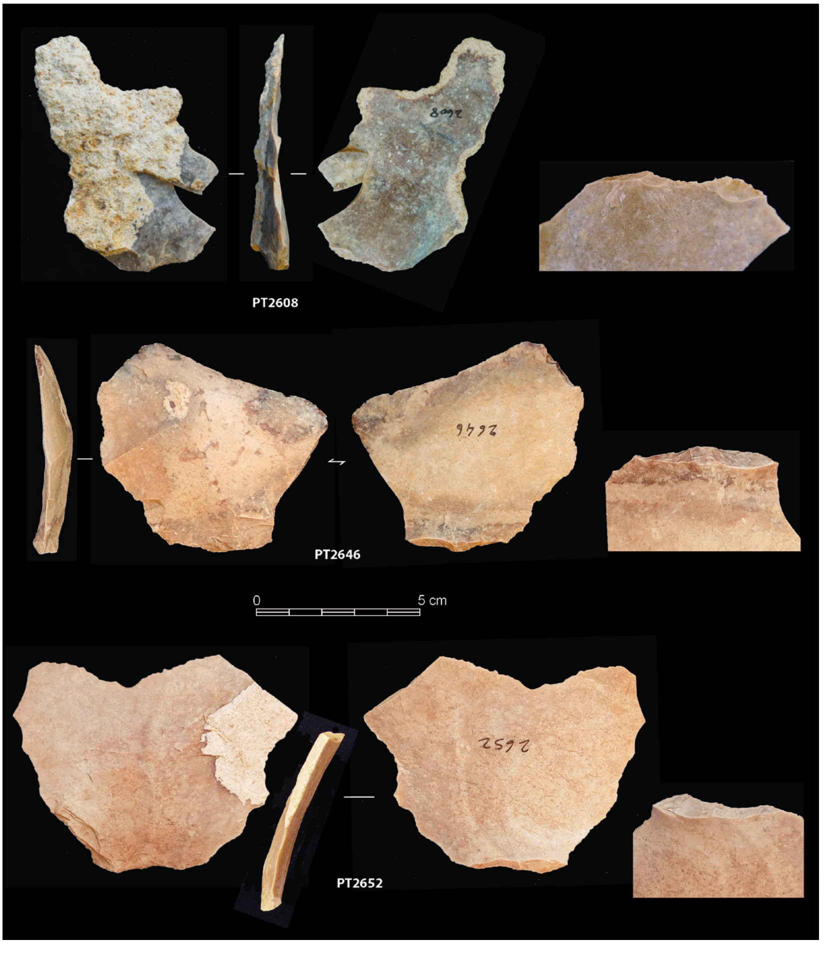


Fig. 7. Evidence of organic (direct) percussion in cluster "F17" at stage 1 (PT2608) and stage 2 (PT2652, PT2646).

obtained with this technique are regularly slightly arched. Removed from surfaces with a low transversal convexity, these flakes usually show divergent edges (Fig. 8). On the other hand, indirect percussion allows the use of a negative bulb as a striking platform initiating a fracture where an organic hammer could not strike without touching the sides of the concavity (Pélegrin 2012; Fig. 7). Using hammerstones on concave butts is also possible, in this case we referred to other diagnosis criteria such as the hammer size needed to remove the flake compared to the butt morphology

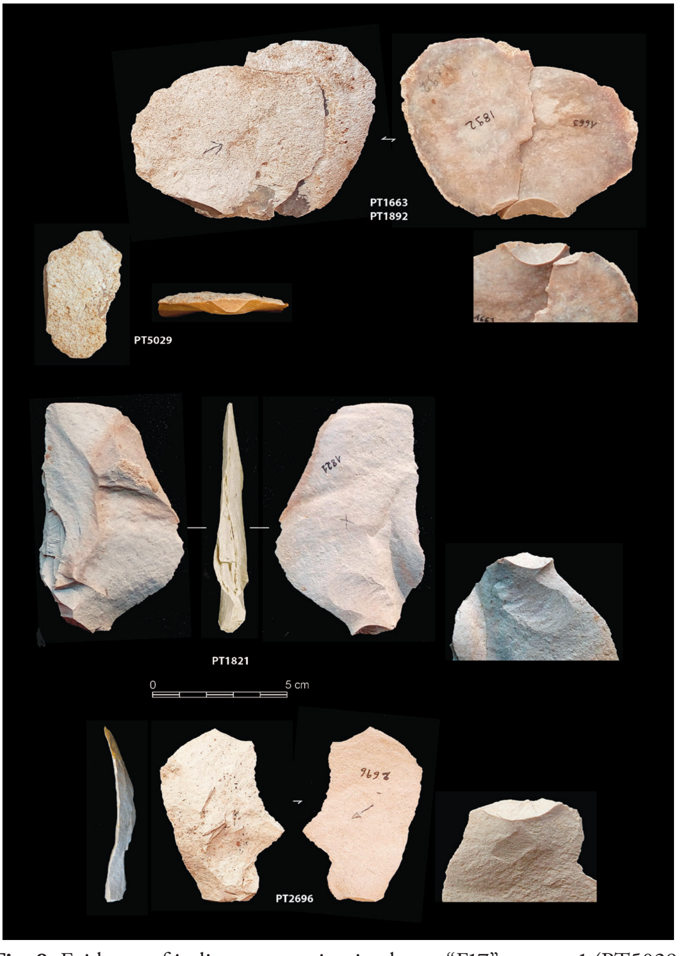


Fig. 8. Evidence of indirect percussion in cluster "F17" at stage 1 (PT5029; refitting PT1663-PT1892) and stage 2 (PT2696, PT1821).

and the flake size together with the general characteristics of the flake (butt preparation, profile, regularity). The other types of butts associated with indirect percussion are plane or rarely faceted. Circular or oval punch prints can be present on every type of butt, potentially bringing confusion with direct percussion. Some may think that butt lips indicate organic percussion use (Fig. 7 and 8), as a matter of fact they are mechanical marks of bending fractures due to a low angle between the striking platform and the knapped surface (Bertouille 1989), actually they can result from any percussion technique. Because organic percussion needs a low angle between the striking platform and the knapped surface to be efficient, butt lips are associated with this technique, but they cannot be considered as exclusive indicators. As the knapper chose precisely the point of fracture initiation by positioning the punch, indirect percussion does not require the same intensity in butt preparation as organic percussion. So in "F17" and "H17" abrasion was not systematically applied because not systematically needed (Fig. 7, PT1821), when it was the action was rudimentary and never finished with softening. The mechanical advantage of indirect percussion over direct percussion is that the shock wave is channelised through the punch and so goes less sideways at the strike point and stays more centred. The results are more regular products, like second Mesolithic and Neolithic blades and bladelets showing very straight parallel edges and ridges. On the cortical flake of low transversal convexity PT1663 (Fig. 7) the conchoidal fracture is diverging in the proximal part then goes straight with parallel edges in the mesio-distal part before the convex termination. This flake characteristic differentiates it from flake PT2608 (Fig. 8). On flake PT2696 (Fig. 7) the mesial shoulder created by an oblique ridge had no effect on the parallelism of the edges. Its typical concavo-convex profile and its concave butt, bearing a small protuberance on its left side, argue for indirect percussion. Mostly in cluster "F17" we observed elongated flakes (length > 2 x width), bearing parallel edges and /or ridges, related to phase 2, or, to an early phase 2 removing cortex and avoiding phase 1 (cf. infra). Resulting from a convexity working, these flakes always show the variability of butts associated with indirect percussion described previously. They never bear dihedral or spur butts nor elaborated butt preparations, their profiles are arched or concavo-convex.

The quantity of classified flakes with traces of indirect percussion reaches 54% in F17 (N = 217), and those indicating organic percussion only 15% of them. For "H17", organic percussion was used in 41% of the classified material (N = 61) and indirect percussion for 35%. So cluster "F17" was more specialised in indirect percussion shaping than "H17". A quick examination of large flakes from cluster "F13" indicates an appreciable use of indirect percussion too. These three major clusters of material from phase 1 and 2 shaping are unified by the same use of techniques.

In "F17", we observed in some families of raw material a tendency pointing to an early shaping phase 2 working convexity at the same time as removing cortex, using organic (Fig. 8, PT2628) and indirect percussion (cf. supra). This lack of roughing-out by thick flake removals, probably means the transverse sections and / or dimensions of some blocks were close to those of the required preforms.

Some straight flakes obtained by indirect percussion relative to thinning and regularizing a plane surface (Fig. 7, PT 1821) indicates plano-convex shaping and probably the making of adzes. Was indirect percussion use a favourite technique to shape adzes preforms at Chessy? The only complete abandoned preform found in cluster "F19" is for an adze.

At Chessy, compared to the amount of flake waste, the lack of discarded preforms (one complete with an irregular edge in "F19", a burnt fragment in the same cluster, plus another fragment used as hammer in "F17") raise the question of the skill of the knappers. Our main hypothesis is that skilled knappers used several techniques on good quality silicites to shape axe and adze preforms.

BEYOND THE WORKSHOPS OF THE MARNE AREA: LANDSCAPE MANAGEMENT

One question leads to another: can we explain why the knappers specifically settled in this location, some five kilometres as the crow flies from the nearest outcrops and with no known settlement in the immediate vicinity? What were the reasons for choosing this location when they could have settled much closer to the sources of raw materials, without having to travel great distances, loaded with raw or tested blocks? This phenomenon seems to be recurrent, and even more important since the Middle Neolithic II workshops at Jossigny – "le Pré du But" and at Montévrain – "le Clos Rose" (Seine-et-Marne department; Brunet and Blaser 2015: 141–151) are even further away from these sources (Fig. 1). A notable point at Chessy – as often is the case for this kind of site – is the almost total absence of ceramics and implements attesting to daily domestic life in the vicinity. Indeed, the tools collected in the silicite artefact clusters or just around them are directly or indirectly related to the knapping activities, between bush hammers (*boucharde* in French) for the finishing of axe heads (12 items) and denticulated or other tools (22 items) interpreted as for maintaining the efficacity of knapping tools in organic material for example. Outside the clusters, 44 typologically defined tools have been discovered, mostly denticulated, splintered and hammered pieces made from shaping flakes or reusing polished tools. A fragment of a leaf-like arrowhead discovered in the cluster "F13" and a complete one outside of the clusters are characteristic of the Michelsberg culture (Manolakakis and Garmond 2011) but were still in use in this part of the Paris Basin till the Recent Neolithic (Renard 2010). The few other objects of more domestic use (like endscrapers or re-touched flakes) are more than sufficient for the daily needs of one or more knappers, who are installed for the day at the different places, with limited food requirements. This is presumably the case at Chessy, whereas this scenario could be qualified for the other knapping sites in the area, where the flake *debitage* may be associated with the manufacture of axe heads. At Chessy, there is no production of blades or flakes. Most of the tools are made from the shaping of blanks, and the few cores (5 items) present on the site, as well as the few other siliceous rock objects, are diachronic with respect to the shaping workshops, making a clear association between them and the production of axe heads. A few other tools are typologically distinct and have also been considered as disconnected from the workshops and not contemporaneous.

Settling in such a place, the knappers would have made compromises concerning having the shortest possible distance between the outcrops or mines and the workshops, combined with the latter not far away from a settlement that allowed the continuation of daily work and to reduce the constraints of material life such as subsistence. Perhaps they came to the workshop sites for some days of intensive work while organising a light dwelling. The relative proximity to the sandstone outcrops – situated several kilometres further in the heart of the plateau – for the polishing phases of the axe heads seems to have been also a decisive point in the choice of location for their workshops. Despite substantial erosion, evidence of these choices would have been perceptible; but at Chessy we can affirm that they are absent, at least on the excavated surface. But an absence of evidence is not an evidence of absence.

If one wonders about the relative distance of the workshops on the plateau from the lithic resources, it should nevertheless be noted that workshops exist near the Jablines mines and at Coupvray. The knapping workshops at "la Pente de Croupeton" in Jablines, on the other hand, are devoted to the production of blades and flakes in relation to the settlement of Blicquy – Villeneuve-Saint-Germain (Aisne department; Early Neolithic). The knapping and shaping places at Coupvray – "le Chemin de Lesches" (Seine-et-Marne department) are dated to the Recent Neolithic and were dedicated to the roughing and regularization of bifacial blanks (Brunet 1994), while the clusters closer to the river seem to be oriented towards domestic production. A mixed situation of flake and axe head production is also noticed at Lesches – "les Prés du Refuge" (Seine-et-Marne department) during the Final Neolithic (Brunet *et al.*, 2004). These observations require us to leave the question of chronological attribution open, especially as most of the workshops in the region have not been precisely dated.

In the light of the date of production of Bartonian silicite axe heads at Jablines, all the workshops in the region are attributed by their excavators to the French Middle Neolithic II (see for example Brunet and Blaser 2015). The exploitation of silicites at Jablines took place between the end of the 5th to the 3rd millennium (Pazdur in Bostyn and Lanchon 1992: 233–234). The chrono-cultural attribution of the Chessy potsherds is weak, and the absence of charcoal or charred botanic remains means there is no possibility of absolute dating. An attribution to the Middle Neolithic II is very probable, but we cannot exclude a later phase of the Neolithic. The evidence is unclear, especially as there are no closed features such as pits related to these periods on the site.

The presence of a Middle Neolithic II enclosure at Vignely – "la Noue Fenard" (Seine-et-Marne department; Lanchon *et al.*, 2006) in the area of the mineral resources, mines and workshops with tools made from the same material adds an argument for connecting the workshops in a territorial production network during the Middle Neolithic II, referring to similar settlements involving large-scale land management in other regions, such as the Seine/Mauldre confluence (Giligny and Bostyn 2016), the middle Oise and the Aisne valleys or the Mons basin in Belgium (Aubry *et al.*, 2014).

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The Flint Quarry of Pozarrate (Treviño, Spain) in the Context of Iberian and Early European Neolithic Mining

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This paper presents the current state of research on the Early Neolithic flint quarry of Pozarrate (Treviño, Burgos) in the north of Spain. This site is part of the Prehistoric Flint Mining Complex of Treviño. The geological features of the territory made it a suitable place for the exploitation of the Treviño flint since Paleolithic times, especially during the Neolithic. Recent research at the site has revealed interesting findings, such as antler and dolerite mining equipment and different

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flint tools, among other recoveries. Radiocarbon dates indicate an Early Neolithic activity which makes Pozarrate one of the few flint procurement sites in the Iberian Peninsula from this period. Moreover, a considerable number of elements link Pozarrate to the Early European Neolithic flint mining phenomenon.

KEYWORDS: Treviño Flint, prehistoric mining, Early Neolithic, Iberian Peninsula

INTRODUCING THE MINING COMPLEX OF THE TREVIÑO FLINT, IN THE SIERRA DE ARAICO-CUCHO

Throughout Europe, there are many documented examples of the phenomenon of prehistoric flint extraction and mining that show certain similarities and a form of homogeneity between the mining sites. There are, of course also noticeable differences, reflecting the considerable social, economic, and ideological diversity of the human groups that exploited these specialized archaeological contexts. Labouring to extract flint involved an enduring transformation of landscapes, in contrast with the frequently small-scale, dispersed, and mobile residential patterns, whether carried out through small-scale, part-time, maybe seasonal, long-term actions, or through the efforts of some few generations involving large-scale actions, as seen for some European Neolithic mining events (Capote and Díaz-del-Río 2019).

In this context, whilst opencast quarrying of outcrops and shallow deposits was carried out, perhaps even as the first episodes of extraction at mining sites (Barber *et al.*, 1999: 33) as reported for some Palaeolithic and Mesolithic sites (e.g., Negrino *et al.*, 2006; Oliva 2011; Osipowicz *et al.*, 2019), extensive flint mining seems to be a largely Neolithic phenomenon. According to the radiocarbon dating, the peak of mining activities occurred during the fourth millennium BC, but the best-known mines and circulating products are mainly dated to the third millennium BC (Longworth and Varnell 1996; Mallet *et al.*, 2004).

The flint mining complex of Treviño is located in the territory of Condado de Treviño (Burgos, Spain). The outcrop area is delimited by the boundaries of the Sierra de Araico-Cucho mountains, located in the Upper Ebro Basin, an area (Fig. 1) that provided easy contacts between the Bay of Biscay (Atlantic coastal zone), the Middle Ebro open valley (towards the Mediterranean) and the northern Meseta (interior highlands of Iberia and the Duero Basin).

There are some key features that help to interpret a flint mining complex, such as coherence in the structure and nature of their remains; the lack of overlapping extractive structures; some systematic technical reiterations of the operative chains;

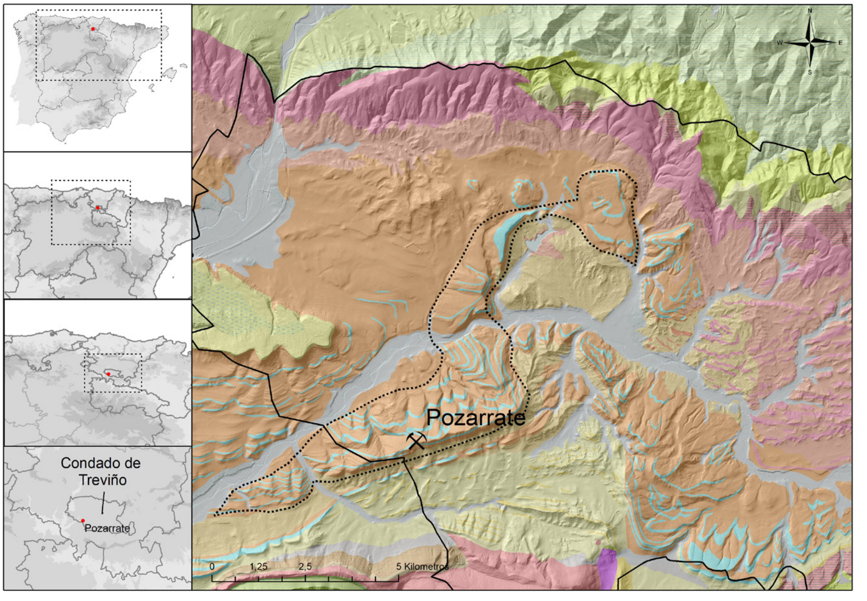


Fig. 1. Location of the Pozarrate site, the Sierra de Araico-Cucho and the Neolithic Flint Mining Complex of Treviño within the Iberian Peninsula. Image of the Spanish Ministry of Science Research Project PID2020-118359GB-I00 "Treviño Flint".

sets of statistically identical radiocarbon dates (dating apparently different mining events); the reffiting of some of the rejected extracted flint (Capote and Díaz-del-Río 2019); or the planned procurement of tools in advance (Clutton-Brock 1984: 15–16; Felder et *al.*, 1998: 47). In the current state of the archaeological research at the Sierra de Araico-Cucho, we can observe most of these characteristics at the site. Furthermore, there are other aspects to take into account in order to describe this study area as a mining complex. The first common element is the presence of the so-called Treviño flint (Tarriño 2006a), the common name for the silicifications found in the Sierra de Araico-Cucho mountains. Secondly, there is undated evidence for ancient flint procurement along all the mountain ranges of Araico-Cucho, even in more recent times for use in threshing equipment (see Elorrieta and Berjón 2017).

Archaeological work in the Sierra de Araico-Cucho started in the 1950s and 1960s, when D. Estavillo collected several superficial finds, mainly dolerite hammer stones, and located several sites related to the extraction of flint (Estavillo 1975; Ortiz *et al.*, 1990, Tarriño 2005; Tarriño 2006a). Thirdly, a LiDAR survey carried out at a resolution of: 1m/pixel (obtained from the cartographic server Geoeuskadi) resulted in the identification of a number of crescent-shaped associated structures at the top of the mountain range, coinciding with the area of the primary Treviño flint outcrop (Tarriño *et al.*, 2014; 2022). Despite the fact that most of these structures are difficult to observe in the field, on LiDAR images we can recognize eight of them of about 25–30 metres in diameter which overlap from the lowest part of the hill to the top, along a section of 160 metres. The mining structures are best accessed through individual interventions, but direct stratigraphic relationships between neighbouring structures are generally absent where the surface traces are less well preserved (Capote and Díaz-del-Río 2019), as in the case of the surveyed section of the Treviño flint mining complex.

From 2010 to the present, we have been excavating the first of the eight crescent-shaped structures, called Pozarrate. Therefore, the aim of this text is to present the current state of research on this mining structure (novel in terms of typology regarding its associated radiocarbon chronology) and the results of the fieldwork, as well as the preliminary research on the quarry of Pozarrate and its comparison with the evidence of other European prehistoric mines.

THE EARLY NEOLITHIC QUARRY OF POZARRATE

The first archaeological structure that is being excavated is Pozarrate (Fig. 2). After the fieldwork, we can confirm that it is a flint quarry from the Neolithic period that was totally filled by a dump. To determine and analyse the quarry's structure, a trench was dug perpendicular to the stratification in the lower dump. The flint layer exploited has a direction of N180° and a dip of 21° towards the north. The exploitation front in the deepest part of the quarry is more than five metres high. Two phases of infilling were identified in the quarry. The first dump is associated with the earliest lineal extraction work along the geological flint layer, with an orientation of N90º approximately. The exploitation front in the west of the prehistoric quarry is more than twelve metres long and more than three metres high, including the appearance of a big burnt limestone structure, which we have called pyrobreccia, currently under study, and three small anthropogenic cavities in the rock (Tarriño *et al.*, 2022: Fig. 4a).

This mining feature is the oldest one of its type discovered until today in the Iberian Peninsula (5050–4370 cal. BC; Tarriño *et al.*, 2011; 2022). Currently, work is focussing on clearing the extraction front and we have already discovered that it is more than twelve metres long and more than three metres high. In the eastern cross-section, the clear stratigraphy shows three levels of archaeological deposits, including a superficial level (Tarriño *et al.*, 2022; Fig. 3).

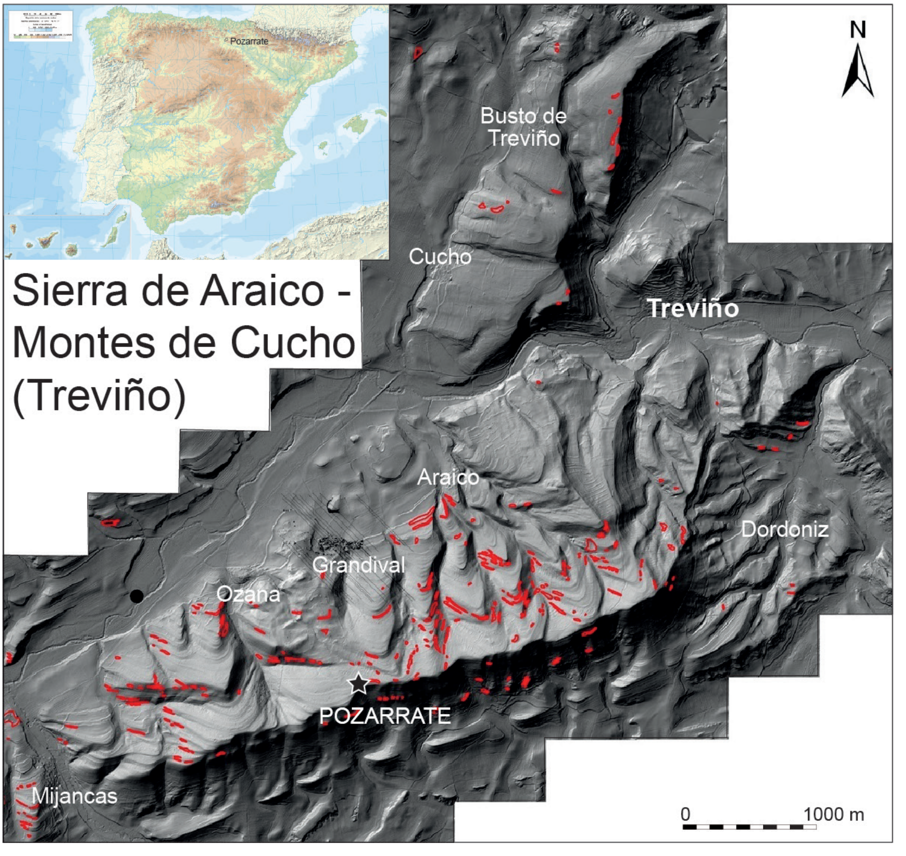


Fig. 2. Situation of the Pozarrate excavation on the northern slope of the Sierra de Araico near the top (star). Other anthropogenic signs of prehistoric flint procurement are marked in red after a LiDAR survey, defining the prehistoric flint mining complex of the Treviño flint. Image of the Spanish Ministry of Science Research Project PID2020-118359GB-I00 "Treviño Flint".

ARCHAEOLOGICAL FINDINGS AT POZARRATE

As is consequent with an extraction site, the flint remains in Pozarrate are very abundant. The study of the lithic technology is based on the preliminary analysis of 13,634 pieces, with a total weight of 494 kg. The lithic assemblage was classified into nodules, fragments, debitage products, cores and retouched tools, only 4.3% of the material belong to the superficial level, 28.3% to level 1, and 67.5% to level 2.

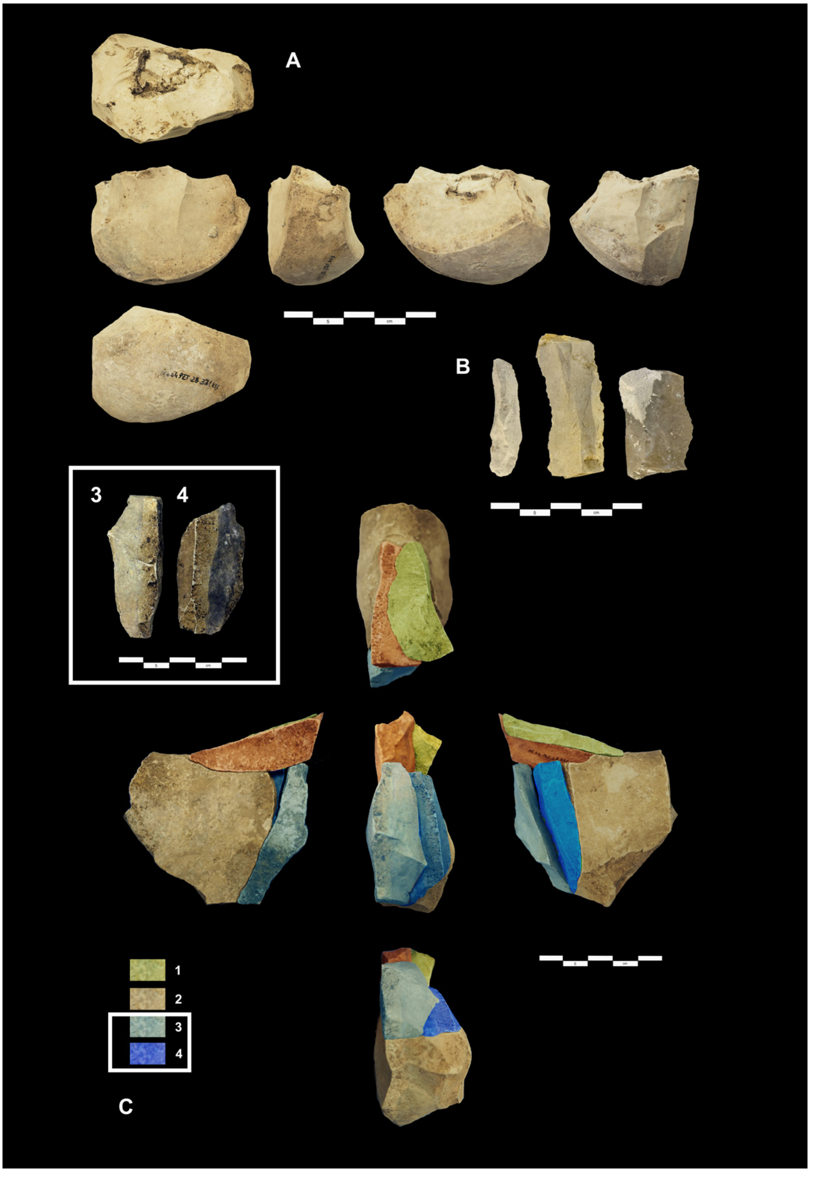


Fig. 3. Archaeological findings at Pozarrate: flint. A. Exhausted core with a unipolar parallel series of blade tendency products; B. Examples of some blade-like byproducts abandoned in the mine. C. Refitted group of five pieces (core and debitage elements) from an orthogonal reduction scheme with blade-like products defined by colours and detail of products 3 and 4. Image of the Spanish Ministry of Science Research Project PID2020-118359GB-I00 "Treviño Flint".

The nodules are more abundant at the surface level, as this was the place of abandonment of the discarded material. Among all the categories, the percentage of fragments (64.24%) is the highest as a consequence of the presence of natural internal fractures in the material and breaks occurring during the extraction and testing process. As a consequence of both flake production and blade cores preparation, the best represented products of the debitage are flakes (99.77%), much higher than blades and bladelets (0.23%). Very few elements from the beginning (crests) and maintenance (flanks, edges, core tablets, etc.) phases of the reduction sequences have been recorded.

The identification of the production of the cores in a mine or quarry is difficult considering that many of them are by-products of testing the quality of the nodules or were broken, or they were reduced by inexperienced knappers as seems to have been the case. The reduction scheme of almost half was unidentified in 59 of the 130 analyzed cores from Pozarrate (45%). The rest show a systematic orthogonal reduction scheme of parallel series of blows that reveals the clear intention of producing blades or blade-like products of different sizes in 70% of the cases (51 pieces). The rest of the cores were devoted to the production of flakes (30%; 20 pieces). Although blade production is difficult to assess due to the previously mentioned factors, it is demonstrated by the presence of refittings; discarded blades, crests and rejuvenation core flakes (Fig. 3).

Most of the cores were abandoned in the early phases of the reduction process. Nevertheless, there are some cases in which reduction reached the exhaustion of the core, or technical or raw material difficulties arose in more advanced phases of the work. The scarcity of cores and by-products compared with the total number of pieces suggests testing of nodules on site, with an occasional production of blanks and transporting of the best quality nodules to knapping workshops outside Pozarrate. The occasional production on site corresponds to testing and learning and the need for tools related to tasks on the mining site.

Among the retouched pieces, scrapers, notches and denticulates are the most common types; probably related to wood or antler work and maintenance tasks on the mining tools. It is interesting to observe that 10% of the blanks of the configured tools show obtuse angles at the butt, possibly linked to percussion with mining hammer stones during nodule extraction. Finally, there is evidence of alternate bec perforators, a recurring tool in regional Neolithic assemblages.

We can note that the vast majority of flint material shows mechanical damage associated with processes involving trampling and tumbling. It also shows high percentages of patina and thermal stress. In this sense, an experiment on flint damage by thermal stress has been developed (Hernández *et al.*, 2020) and this has permitted to reinforce the idea of "fire attack", but also some insights about a possible stabilization of the quarry front by the creation of a so-called pyrobreccia, as in quarrying strategies seen in other ancient mining structures (e.g., Tarantini 2005).

The weight of the dolerite fragments recovered until now exceeds 52 kg. This corresponds to more than 550 elements and all of them have been spatially located in the quarry. There are 15 hammer stone tools, with another 22 big fragments of hammers representing approximately 45 kg (86% of the total recovered; Fig. 4.1 and 4.2).

At least 10 of the identified hammer stones show signs of technical configuration (generally notches and picking) to adapt them to hafting and mining. This aspect appears in other Neolithic sites in Europe like Bad Sulzburg (Goldenberg *et al.*, 2003).

According to the modifications described in dolerite hammer stones, these can be assigned to the first stages of the previously developed typologies for this mining tool type (e.g., Pickin 1990; Léchelon 2001; Hunt Ortiz 2003: 285). For now, we can provisionally classify the dolerite tools recovered from Pozarrate as unmodified, or modified to adapt its shape by trimming and notching (with one, two or more notches). After confronting archaeological data with ethnographic and experimental approaches to check some hypotheses about quarrying activities (Hernández *et al.*, 2020), we are inclined to think that the weight and affordance of blanks could determine the design of different quarrying hammer stones.

In the case of antler mining tools, more than fifteen large pieces (Fig. 4.3) have been documented, with a multitude of fragments directly related to extractive work. These pieces show some technological modifications and functional features (these are currently under study). Also, a scapula, probably from a *Cervus* sp., was found in the lower level, on the rocky bed (Fig. 5).

Finally, there was also some procurement of Treviño flint in post-Neolithic times at Pozarrate, mainly evidenced by the presence of fragmented pottery (very few pieces generally of a size less than 4 cm), at high levels in the stratigraphical sequence (intermediate and removilization levels), sometimes associated with metal objects. Four metal pieces found within the assemblage of Pozarrate consist of three bronze sheet fragments and one small iron blade (Tarriño *et al.*, 2022). The cultural affiliation of the ceramics is currently to be determined.

THE TREVIÑO FLINT: CHARACTERIZATION AND ARCHAEOLOGICAL DISTRIBUTION

The flint extracted in Pozarrate is the nodular variety. It is a very fine-grained flint of exceptional quality for knapping. It was formed in a Miocene lacustrine depositional

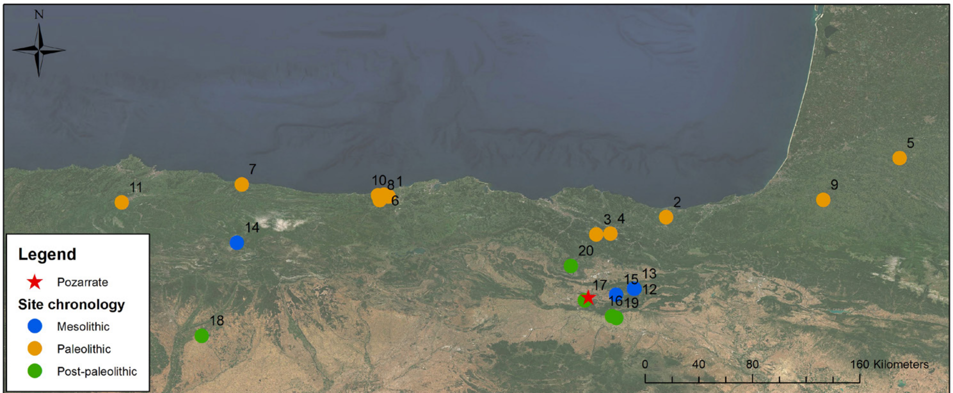
Fig. 4. Archaeological findings at Pozarrate: 1) and 2) dolerite hammerstones at the time of their archaeological recovery. An intensive but non-destructive cleaning protocol is currently being developed to avoid damaging the surfaces prior to conducting its techno-functional study; 3) antler. Image of the Spanish Ministry of Science Research Project PID2020-118359GB-I00 "Treviño Flint".

Fig. 5. Scapula, presumably cervid, at the time of its recovery. Image of the Spanish Ministry of Science Research Project PID2020-118359GB-I00 "Treviño Flint".

environment and contains bioclasts (ostracods and small gastropods and *Charophyta* algae). It has a high percentage of silica (>98 %) and its main impurities are carbonate and organic matter (Tarriño 2006a). The matrix is opaque with colours in the yellowish-red range (Munsell 10YR). When the flint is patinated, it acquires whitish-yellowish colours and the presence of "Liesegang rings" are visible. The cortex is very thin and smooth, rarely exceeding 2 mm in thickness. In the case of the better-quality flints, this cortex is reduced to a minimum thickness (patina type).

The distribution of Treviño flint predates the beginning of the mining processes carried on at the Sierra Araico-Cucho. The first archaeological sites where items of raw material from Treviño have been identified are those located in the Basque-Cantabrian Basin (Fig. 6), on sites such as Amalda, Axlor and Bolinkoba, dating from the Middle Palaeolithic (Tarriño 2003; González-Urquijo *et al.*, 2005; García-Rojas 2014; Arrizabalaga and Iriarte-Chiapusso 2015).

It is from the beginning of the Upper Palaeolithic when the number of remains associated with the Treviño flint sources multiplied (Fig. 6). There are many sites in the Basque-Cantabrian Basin where this variety has been identified (Tarriño 2000; 2006a; 2011a; 2011b; 2013; Tarriño and Aguirre, 2002; Elorrieta 2016; Sánchez *et al.*, 2016). Furthermore, in contrast to the previous period, remains of Treviño



ID	Site	Chronology	ID	Site	Chronology	ID	Site	Chronology	ID	Site	Chronology
1	*Altamira*	Paleolithic	6	*Cualventi*	Paleolithic	11	*Las Caldas*	Paleolithic	16	*El Sotillo*	Post-paleolithic
2	*Amalda*	Paleolithic	7	*El Cierro*	Paleolithic	12	*Atxoste*	Mesolithic	17	*Larrenke sur*	Post-paleolithic
3	*Axlor*	Paleolithic	8	*El Linar*	Paleolithic	13	*Kanpanoste*	Mesolithic	18	*Las Choperas*	Post-paleolithic
4	*Bolinkoba*	Paleolithic	9	*Isturitz*	Paleolithic	14	*La Uña*	Mesolithic	19	*San Martín*	Post-paleolithic
5	*Brassempouy*	Paleolithic	10	*Las Aguas*	Paleolithic	15	*Mendandia*	Mesolithic	20	*San Sebastian Sur*	Post-paleolithic

Fig. 6. Distribution of Treviño Flint by sites and its chrono-cultural adscription. Image of the Spanish Ministry of Science Research Project PID2020-118359GB-I00 "Treviño Flint".

flint are beginning to be identified throughout the Cantabrian region, even reaching Asturian sites such as El Cierro and Las Caldas (Corchón *et al.*, 2009; Tarriño 2016; Martín-Jarque *et al.*, 2019) or Cantabrian sites such as Altamira, El Linar, Las Aguas or Cualventi (Tarriño *et al.*, 2013; Tarriño *et al.*, 2016). This variety is also identified in some sites in the south of France and north of the Pyrenees, such as at Brassempouy or Isturitz (Tarriño and Normand 2002; Tarriño *et al.*, 2007; Elorrieta 2016; Elorrieta and Tarriño 2016).

Treviño flint continued to be collected during the Holocene, as Mesolithic groups continued to make extensive use of this variety (Fig. 6) in sites such as Aizpea, Mendandia, Kanpanoste or Atxoste (Tarriño 2001; Tarriño 2006b; Soto 2014), but it also appeared in areas further away from the Cantabrian Mountains, such as at La Uña (León), although in limited quantities (Herrero-Alonso 2018).

With the transition to producer societies and the beginning of the mining activity at Treviño, the raw material from the exploitation evidences long-distance exchange, becoming an economic axis of connection for the northern area of the peninsula. However, some specific studies have been carried out on the collection of raw material from the Neolithic and during the development of the dolmen phenomenon in the north of the Iberian Peninsula (Fig. 6), as in the case of dolmens such as San Sebastián Sur, El Sotillo or San Martín (Álava), among others (Tarriño and Mujika

2004; Tarriño *et al.*, 2009). In addition, in sites of these later chronologies, we also find cores evidencing exploitation processes, such as those identified in the northwest of the Duero basin (Fuertes-Prieto *et al.*, 2018).

POZARRATE IN CONTEXT: OTHER NEOLITHIC MINING ACTIVITIES ATTESTED IN IBERIA AND EUROPE

There are very few well-attested Early Neolithic flint mines or quarries within the Iberian Peninsula. Together with Defensola (Italy), they can be geographically ascribed to a broader Mediterranean region within the European mining phenomenon (Consuegra and Díaz-del-Río 2018). Other Iberian archaeological sites contemporary to Pozarrate are Casa Montero (Madrid), in the hinterland, with a large field of mining shafts and similar radiocarbon dates, suggesting the flint procurement would only last a century, between 5317 and 5230 cal BC (2σ) (Díaz-del-Río and Consuegra 2011: 226), during the Early Neolithic period, and Montvell (Castelló de Farfanya, Lleida), in the northeastern part of Iberia, the only excavated Neolithic flint quarry in northeastern Spain (Catalonia). Although no radiocarbon dates have been published yet for this site, a chronological span has been suggested that would extend to the epicardial or postcardial Neolithic ware (Terradas *et al.*, 2019), based on the presence of continental molluscs in the stratigraphy, and radiocarbon dating from the adjacent Les Auvelles site, with a chronology between 4516 and 3983 cal BC (2σ), in the Early--to-Middle Neolithic transition (Oms *et al.*, 2019). Procurement activities were performed with the use of consecutive quarry fronts, by taking the flint nodules out of the slopes of the Serra Llarga mountains (Terradas and Ortega 2017).

Other sites with possible evidence of Neolithic mining, to be confirmed, also provide interesting data. One such site is La Leandra (La Muela, Zaragoza), which has been the subject of intense surveys (Picazo *et al.*, 2018) to detect the very subtle traces of ancient trenches that could be prehistoric, probably from the Neolithic (Picazo *et al.*, in press), underneath some circular depressions in the lower part of the slopes that seem to be filled with limestone blocks, gravel, patinated flint remains, sandstone and quartzite hammer stones and other debris, corresponding to 18th-19th flint procurement structures (Picazo *et al.*, 2020), or the Portuguese sites of Pedreira do Aires and Monte das Pedras, in the Lisbon region (Andrade and Cardoso 2004; Andrade 2011), the evidence from which leads its researchers to ascribe both sites to the end of the regional Neolithic or the beginnings of the Chalcolithic (Andrade and Matias 2011).

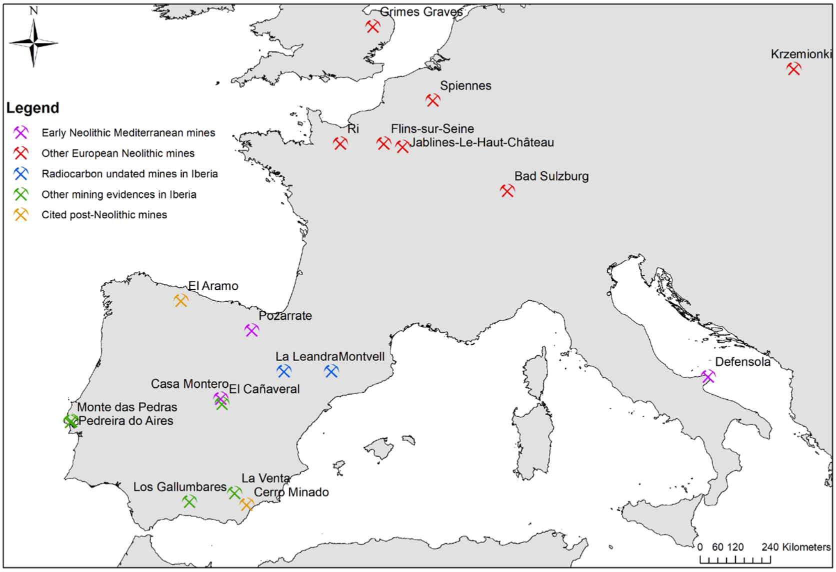


Fig. 7. Iberian and European mining sites referred to in the text. Image of the Spanish Ministry of Science Research Project PID2020-118359GB-I00 "Treviño Flint".

Flint mining exploitation strategies during the Neolithic period are the result of the adaptation of human groups to the geology and natural environment of the outcrops, as a consequence of specialized tasks that accumulate considerable technical knowledge, transmitted from generation to generation (Castañeda 2018). The main objective of these communities was to extract the raw material without spoiling it, in the most planned, efficient way that was safe for the individuals involved. According to its morphology, in the Iberian Peninsula two extraction systems have been documented: the excavation of shafts, as seen in Casa Montero, and creation of an open-air quarry, as in the examples of Pozarrate, Montvell and small areas of Casa Montero (where they are part of a mixed procurement system that combines quarry fronts with the digging of shafts; Díaz-del-Río *et al.*, 2018: 57). In an open-air quarry system, the disposition of the strata where the raw material is found, at different degrees of inclination along the slope, determines the effort required to access flint nodules. Regarding this aspect, Pozarrate and Montvell share a similar morphology, as they are composed of consecutive trenches, potentially covered with the debris generated by a subsequent exploitation trench higher up.

As in the case of other Early European Neolithic flint mining complexes (Fig. 7), in the Iberian ones, there are two models of exploitation: nodule testing with scarce evidence of on-site reduction and complete or almost complete reduction at the mine. Examples of the first exploitation model are Pozarrate (Tarriño *et al.*, 2011; 2014) and Montvell in Spain (Terradas and Ortega 2017; Terradas *et al.*, 2017), together with Defensola A (6990±80 BP, 5993-5652 cal. BC 2σ), in Italy (Galiberti 2005). The second model of complete or almost complete reduction on site took place more often as in Casa Montero (Consuegra *et al.*, 2018) in Spain, Jablines-Le-Haut-Château (Bostyn and Lanchon 1992) and Flins-sur-Seine (Giligny and Bostyn 2016) in France, Spiennes (e.g., Collet and Woodbury 2007; Collet *et al.*, 2016) in Belgium among others. Indeed, at Pozarrate, evidence of lithic production is scarce when quantitatively compared with the total amount of extracted flint, since it was probably conditioned by immediate needs related to quarrying activities. Regarding the objectives of the lithic production, it seems that Early Neolithic examples of flint quarrying and mining from Southern Europe were devoted to blade and bladelet production as at Casa Montero, Defensola and probably Pozarrate, contrary to Central Europe's later mines, which produced mostly axes. In fact, the main activity that all flint mining archaeological establishments have in common is the organized supply of the raw material, frequently associated with lithic production areas in immediate or close surroundings.

As for the mining tools, those classified as hammer stones are made of harder materials than the materials that the quarry is made of, allochthonous to the lithology of the sites of the mines: quartzites in Casa Montero (Capote 2011), dolerites in Pozarrate and quartz, quartzite and hornfels in Montvell (Terradas *et al.*, 2017), among others. The typologies identified include more or fewer modifications from natural forms (large pebbles and blocks from primary outcrops). In general, the Early Neolithic tools present fewer modifications compared to the standardized characteristics, such as polish and central grooves, more typical of those of epi or post-Neolithic times. In the case of Casa Montero, raw materials were collected from nearby terraces within a maximum radius of 2 km and were used without any previous modification (Capote 2011). However, in the case of the Pozarrate site, the sources of the material used occur in diapiric outcrops located at a greater distance (approx. 10l'15 km). It would seem that there was considerable effort expended to collect the dolerite blocks from which the hammer stones would be made, some of them weighing more than 9 kg.

According to the evidence, macrolithic tools in flint were recycled from byproducts of lithic reduction. Both in Casa Montero and Pozarrate, pieces of flint have been documented that were used as wedges and picks, and in Pozarrate and La Leandra some cores have been reused as hammer stones and mauls of oval form and deep splintering all around their edges. Neolithic miners, therefore, took advantage of the mine's own raw material to continue with the extraction of the flint they wanted to access. In some other European Neolithic mines such as Defensola (Galliberti 2005) or Spiennes (Collet and Woodbury 2007) flint picks have also been used.

Regarding the use of bone materials, in Pozarrate, more than fifteen large antler pieces have been documented, with a multitude of fragments directly related to extractive work. Meanwhile, at Casa Montero, three small horn fragments (<4 cm) that cannot be related to work in the mine have been documented (Terradas *et al.*, 2011), as well as seven sharp objects made of bone and twenty-one pieces related to personal adornment that correspond to bone rings or matrices to obtain them (Yravedra *et al.*, 2008). In European mining contexts, antler picks are usual, as in the case of Ri (Tsobgou *et al.*, 2011).

Finally, pottery appears in Casa Montero and Pozarrate. In the first, ceramics are distributed in 23 shafts, including practically complete containers (Consuegra *et al.*, 2018), while in Pozarrate, there are only few very small fragments located at specific points high up in the stratigraphy.

CONCLUSIONS

The Treviño flint mining complex relates to a greater area in which flint procurement occurred from the Palaeolithic to post-Neolithic times following different extraction strategies that, before the archaeological works performed at Pozarrate, were known only by survey and indirect evidence, such as the Treviño flint distribution all along the Cantabric region. The abundance, quality and accessibility of flint levels made this place a perfect procurement place.

The discovery of the Pozarrate flint quarry has indicated the importance of the phenomenon of Early Neolithic flint procurement by huge modification of landscape that occurs in Europe from the beginning of this critical chronological period. Until then, there was only one example in the Iberian Peninsula.

The Pozarrate quarry is associated with at least seven other crescent-shaped dumps of about 25–30 m diameter, extending deep in the ground over linear trenches. This type of structure is unique at the moment in the Iberian Peninsula. The only excavated dump was dated from 5050–4370 cal. BC.

The raw material extracted in Pozarrate is a very fine-grained nodular flint of exceptional quality for knapping. The variety exploited is a nodular flint with bioclasts from the Miocene. Its wide distribution in the Cantabrian region during prehistory allows us to consider this flint as a tracer of long-distance exchange.

Flint remains in the site reveal a light transformation of nodules that appear mostly to have been tested on site and transported to other places to reduce them. Blade production seems likely to have been the aim of lithic production. A few tools were made on site in connection with the peripheral tasks carried out during the mining process. Transport of both nodules and blades without on-site reduction seems to be the most frequent strategy used in Mediterranean Early Neolithic flint mining contexts.

One of the most important features of the site is the assemblage of mining tools, consisting of more than forty dolerite hammers, some flint cores reused as hammers and more than fifteen large antler fragments (the largest set of antler tools found in Iberia). Procurement of hard stones for use on the mining site and reutilization of flint elements are common strategies in European Neolithic flint mining.

Early Neolithic flint mining contexts of the Iberian Peninsula, although scarce, were specialised places, in which adaptation strategies to geological formation were developed employing open-air quarries and the excavation of deep shafts.

The Pozarrate quarry shows several elements that link it to the European phenomenon of flint mining. It reinforces the idea of the complexity of flint mining in the Neolithic and that it is expressed in a heterogeneous way with a variety of strategies from the beginning of the Neolithic. Flint mining became a critical strategy for Early Neolithic groups and may be considered one of the elements that characterized this period of history.

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Mapping Natural Exposures of Siliceous Marls and Cherts as Potential Zones of Raw Material Acquisition. The Case of the Eastern Polish Carpathian Foothills and the Rzeszów Settlement Region (SE Poland) in the Neolithic and Bronze Age. Preliminary Results

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The Neolithic and Bronze Age communities that settled the eastern Carpathian Forelands and Carpathian Foothills used a variety of local and non-local siliceous raw materials. Raw materials identified in the archaeological record differ in quality and usefulness for making tools. Obsidian, Jurassic flint from the Cracow-Częstochowa Upland, chocolate flint, or Świeciechów and Volhynian flints represent the best quality. On the other hand, some local raw materials were also in use, most popular among them being siliceous marls and cherts. Sources of siliceous marls and cherts are known from many locations in the Dynów, Strzyżów and Przemyśl foothills. Moreover, systematic field surveys in this area have provided new information on the availability of cherts and siliceous marls at many new locations in the region. They appear in the primary autochthonous, secondary autochthonous, and more rarely in sub-autochthonous or residual, sources. Exposures on steep hill slopes and dissected river valleys provide easy access to the best quality raw materials in the primary autochthonous sources. Raw materials from secondary autochthonous sources in the riverbeds were also available, but they were of lesser quality than those from the exposures. The aim of this paper is to present natural exposures of siliceous marls and cherts and discuss them as a potential source of raw materials for the Neolithic and Bronze Age communities inhabiting loess areas of the eastern Carpathian foreland (Rzeszów Settlement Region).

KEY-WORDS: Carpathians, lithics, cherts, siliceous marls, natural sources, Neolithic, Bronze Age

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INTRODUCTION

South-eastern Poland covers a number of regions and landscape zones from the semi-lowland areas in the north to the mountains in the south. The most favourable for early agricultural communities was its central part – the loess belt of the eastern Polish Carpathian Foreland, covered by the most fertile soils in the region. This zone was densely settled from *c.* 5500 BCE, which is the beginning of the Neolithic in this area. From about 3800 BCE, the lower parts of the Eastern Carpathian Foothills were incorporated into the oecumene of agrarian communities as well (Pelisiak 2018a).

The Neolithic and Early Bronze Age communities that inhabited the eastern Carpathian Forelands and Carpathian Foothills used several kinds of siliceous raw materials of varying provenience, which differed in terms of their quality and usefulness for knapping and tool-making. The group of highest quality non-local raw materials comprises obsidian, Jurassic flint from the Kraków-Częstochowa Upland, chocolate flint, together with Świeciechów and Volhynian flints (Kozłowski 1970; Kaczanowska and Lech 1977; Kaczanowska 1985; Czopek and Kadrow 1988; Kadrow 1990; 1997; Zakościelna 1996; Kukułka 1997; 1998; 2001; Valde-Nowak 1999; 2000; Valde-Nowak and Gancarski 1999; Mitura 2004; 2006; 2007; Dębiec 2005; Szeliga 2009; Pelisiak and Rybicka 2013; Dębiec *et al.*, 2014; Dobrzyński *et al.,* 2014; Pelisiak 2017a; 2017b). Another group of stone raw material used in SE Poland consists of local lithics, including those originating from Carpathian sources (Valde-Nowak 1995; 2013; Pelisiak 2016a; 2016b; 2018c). The so-called Dynów marl was probably first recognized in Neolithic materials found near Wesoła village, Brzozów district, in the Dynów Foothills (Dagnan-Ginter and Parczewski 1976), and the sources of this raw material were suggested to be in the Baryczka River valley close to Nozdrzec, Hłudno, Wesoła and Barycz villages (Brzozów district; Parczewski 1986).

Numerous items made of the so-called Dynów or siliceous marls are known from sites of all Neolithic and Early Bronze Age cultures in SE Poland, including the Linear Pottery culture sites in Zwięczyca 3 (actually part of the city of Rzeszów; Dębiec *et al.*, 2014), Cieszacin 41, Jarosław district (Dębiec *et al.*, 2015), Rzeszów 16 (Kadrow 1990) and Rzeszów 117 (Czopek *et al.*, 2014); the Malice culture sites (e.g., Rzeszów 31); the Funnel Beaker culture site in Przybówka 1, Krosno district (Gancarski *et al.*, 2008); the Corded Ware culture sites in Szczytna 6, Jarosław district (Pelisiak 2017a) and Średnia 3, Przemyśl district (Jarosz 2002); the Mierzanowice culture sites in Boratyn 17, Jarosław district (Nowak 2016), Kańczuga 5, Przeworsk district (Koperski and Kostek 1997) and Jarosław 158 (Pelisiak and Rybicka 2013); and the Otomani-Füzesabony culture sites in Trzcinica 1, Jasło district and Jasło 29 (Valde-Nowak and Gancarski 1999). Moreover, numerous blades, flakes, rectangular axes, and waste from their preparation or repair have been discovered as single finds, as have bifacial axes (Dagnan-Ginter and Parczewski 1976; Valde-Nowak 1988; Pelisiak 2013; 2017b). An exceptional site was discovered on Cergowa Mountain (Mała Cergowa) near Dukla, Krosno district. Exposures of lithic raw materials and remains of workshop sites show exploitation of these silicities at least in the Late Neolithic (Budziszewski and Skowronek 2001).

Among the lithic artefacts described as made of siliceous marl or Dynów marl, some differentiation of physical features of the raw materials used can be observed (differences in colour, weight, and compactness). These differences may stem from the state of preservation of some artefacts (weathering may have changed the mineral composition of raw material used – see Budziszewski and Skowronek 2001: 157) or from them possibly being made from a rock other than siliceous marl. This second possibility is suggested by the results of tests in which the raw material of some of the analysed artefacts did not positively react with a 5% solution of HCl. The results show that more than 50% of the analysed artefacts, which were previously described as made of Dynów/siliceous marl, were in fact made of another raw material, probably yellowish or grey-yellowish hornstone chert (e.g., Pelisiak 2018b; 2018c). As a consequence, the group of artefacts made of so-called Dynów or siliceous marl and cherts may comprise items made of several different raw material varieties. Moreover, both the siliceous marls and the cherts may have come from different sources, with each source having its own different chemical composition and physical properties.

The results of the tests conducted so far provide inspiration for (1) testing more raw material samples and more artefacts previously described as made of siliceous marls, and for possible corrections of raw material qualification of lithic artefacts (2) mapping the natural exposures of siliceous marls and cherts as potential zones of raw materials acquisition; (3) identifying places of acquisition of raw material in prehistory and locations of siliceous marl and chert workshops. This paper refers to the results of systematic field prospection for raw material sources performed in 2016–2019 in six sampled areas of the Dynów Foothills (Fig. 1).

METHODS

The mapping of natural exposures of knappable lithic raw materials suitable for making tools (siliceous marl and chert) in the Dynów Foothills, an area close to a fertile loess zone inhabited from the Early Neolithic onwards, began in 2016. Settlement sites in the region often yield axes, flake tools, and waste of these raw materials during excavations, and such finds are also common on the surface. Cherts and siliceous

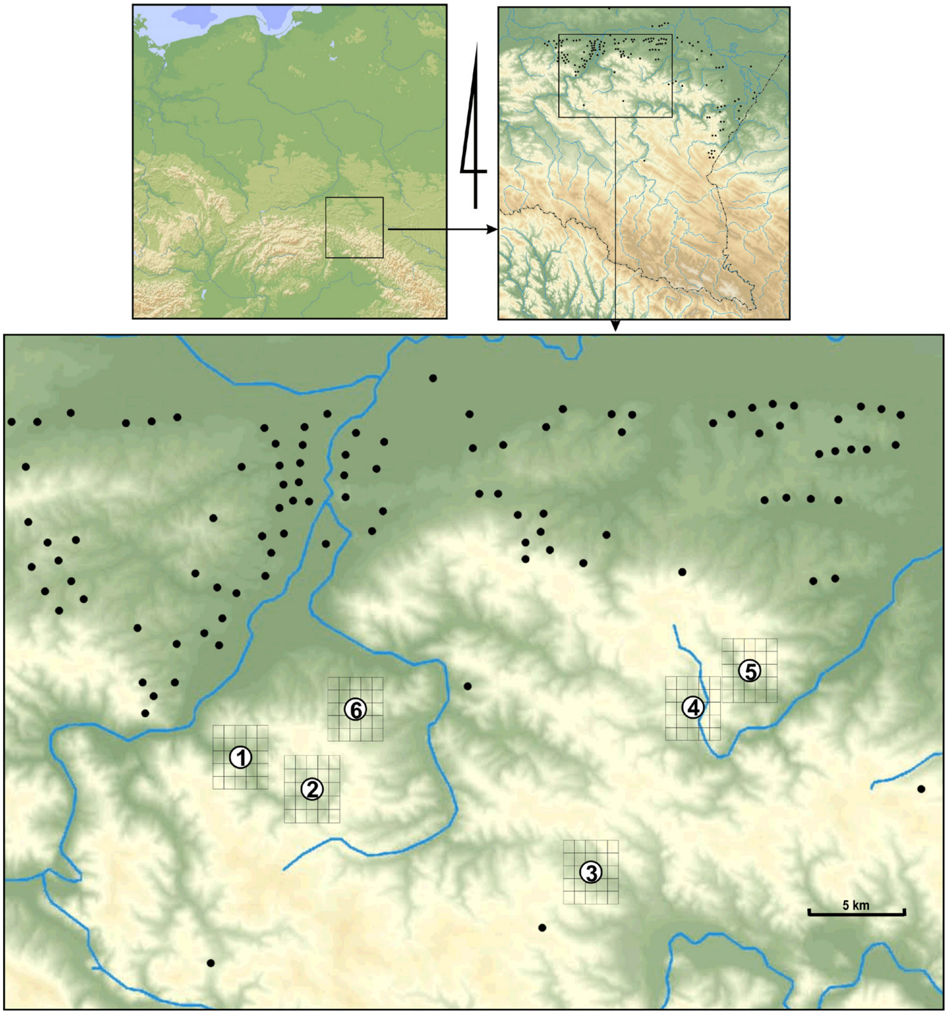

Fig. 1. Example of the Neolithic inhabitation of the loess sub-Carpathians zone (dispersion of the LBK sites in the Rzeszów LBK settlement region – black pot symbols mark LBK sites) and the part of the Dynów Foothills examined for lithic sources. 1. Central and lower part of the Lubenka stream basin, its tributaries beds and valleys, and their close surrounding. 2. Upper part of the Lubenka stream valley and in surrounding near Straszydle quarry. 3. Surrounding of Ulanica village close to the Ostrówek stream. 4. The Tarnawka stream valley and its close surrounding. 5. The Husówka stream valley and its close surrounding. 6. The Hermanówka stream valley and its close surrounding. Graphic elaboration: A. Pelisiak.

marls were commonly used, but their physical characteristics generally precluded their application in the production of blade cores, blades, and blade tools.

The research on sources of lithic raw material presented here followed this procedure:

1. Analysis of geological maps and information on the siliceous raw materials and their natural exposures described in the geological publications. Both siliceous marls and yellowish and grey-yellowish cherts are present in many locations in the Dynów, Strzyżów and Przemyśl foothills as well as in other parts of the eastern Polish Carpathians (e.g., Wdowiarz 1949; Gucik 1961; Kotlarczyk *et al.*, 1977; Leszczyński *et al.*, 1995; Rajchel and Myszkowska 1998; Leszczyński 2003; 2004; Garecka 2008; Górniak 2011). The sources and uses of these raw materials have also already been discussed in the context of prehistory (e.g., Dagnan-Ginter and Parczewski 1976; Parczewski 1986; Valde-Nowak 1995; 2013; Budziszewski and Skowronek 2001; Pelisiak 2016a; 2016b; 2018c). Moreover, systematic field surveys for lithic raw material resources in the eastern Polish Carpathians have provided new information on the availability of cherts and siliceous marls at many localities in the region (Fig. 2; Pelisiak 2016a; 2018b; 2018c).
2. Analysis of the topography and relief of the Dynów Foothills, geomorphology, and watercourse valleys in this area, and analysis of LiDAR pictures for identification of natural exposures, availability of the natural sources of raw material, potential places of raw material acquisition in prehistory and possibilities of transporting the raw material and/or stone items from acquisition places to the settlements located in the loess zone.
3. Systematic field surveys oriented towards (a) the verification and complementation of the results of the above analysis, and (b) the mapping of all potential raw material sources available for prehistoric peoples.
4. Collecting samples of raw material for lithotheca, macro- and microscopic analysis, and for petrographic, physical, chemical, and ichnological analysis.

OUTCROPS AND NATURAL OPENINGS

The field surveys for lithic raw material sources carried out in 2016–2019 were concentrated in the nearby vicinity of the loess zone of the southern Carpathian Foreland, densely inhabited from the beginning of the Neolithic. Several parts of the Dynów Foothills, up to 25 kilometres from settlement sites known from the loess areas between Rzeszów and Łańcut, were subjected to systematic research. The hilly landscape of the foothills is characterized by folded and napped flysch covers of the Outer Carpathians (Kotlarczyk 1988; Kuśnierek and Ney

Fig. 2. Lubenia village (surrounding of the Lubenka stream valley). Example of primary autochthonous sources of cherts. Photo: A. Pelisiak.

1988; Bąk 2007) and the Skole Nappe, dissected by numerous ravines and watercourse valleys.

Field work was focused on natural openings, quarries, and watercourse valleys, primarily on their fragments characterized by the steep slopes, steep cliffs, steep slopes undercuts, on the river and stream beds, and on the ravines which dissect the hills. Six areas were initially selected for field examination: (1) the central and lower part of the Lubenka stream basin, its tributaries' beds and valleys, and their immediate surroundings (the nearest Linear Pottery culture sites [LBK] are located at a distance of 4 km; Fig. 2); (2) the upper part of the valley of the Lubenka stream and the surroundings of the Straszydle quarry (the nearest LBK sites are located at a distance of 7 km; Fig. 3); (3) the surroundings of Ulanica village close to the Ostrówek stream (the nearest LBK single find was discovered at a distance of 4 km; the nearest LBK settlements are located at a distance of 25 km; Fig. 4); (4) the valley of the Tarnawka stream and its immediate surroundings (the nearest LBK sites are located at a distance

Fig. 3. Upper part of Lubenka stream valley in Straszydle village. Example of primary autochthonous sources of cherts. Photo: A. Pelisiak.

of 6 km; Fig. 5); (5) the valley of the Husówka stream and its immediate surroundings (the nearest LBK sites are located at a distance of 4 km); and (6) the valley of the Hermanówka stream and its immediate surroundings (the nearest LBK sites are located at a distance of 4 km).

A variety of chert and siliceous marl types occur in the examined areas. It should also be underlined that some varieties of chert and siliceous marl show almost the same macroscopic characteristics, which makes them highly similar one to another. In fresh condition, the colour of the chert and siliceous marls can be light-yellow, almost white, from grey-yellow to grey, or from light brown to dark brown. They are compact, predominantly dull, non-transparent, and sometimes with a mild waxy shine. The fracture is platy-flaky or conchoidal, granular-looking or coarse grained. The cortex is non-existent or is very thin.

Siliceous marls and cherts in all examined areas occur in various topographic and geomorphological positions. According to Zsolt Mester's classification (Mester 2013: 12),

Fig. 4. Ulanica village close to the Ostrówek stream. Example of primary autochthonous sources of cherts. Photo: A. Pelisiak.

they appear in primary autochthonous, secondary autochthonous and more rarely in sub-autochthonous or residual sources. They are displayed in a vertical or nearly vertical position due to tectonic influence, as continuous and discontinuous layers, in the form of lenses or irregular, more or less flat, pancake-shaped blocks. The layers are typically 25–30 cm thick, but some are significantly thinner – from 1 to 3 cm. Some layers of siliceous marl and cherts (excluding layers of black menilite hornstone) are not well--delineated from the adjacent layers. Such a position makes it easy to access and extract blocks of raw material.

FINAL REMARKS

There are various potentially significant sources of siliceous marls and cherts suitable for manufacturing chipped and polished tools in each of the examined areas. Exposures

Fig. 5. Taranawa village (Tarnawka stream valley). Example of primary autochthonous sources of siliceous marls. Photo: A. Pelisiak.

of cherts and siliceous marls on steep slopes of the hills and dissecting river valleys offer easy access to the best quality raw material in the primary autochthonous sources. This positioning made the raw material relatively easy to reach and extract. Raw materials from secondary autochthonous sources in the riverbeds were also obtainable, but they were of worse quality than those from the exposures.

Cherts and siliceous marls were available in many locations in the region and each settlement could exploit a number of sources. The distance from the Neolithic and Early Bronze Age settlements located in the sub-Carpathian loess zone to the nearest sources of these raw materials was about 4 km in a straight line. Moreover, chert and siliceous marls were available in many locations in the region, and it is possible that every settlement exploited several different sources.

Pieces of raw material of suitable quality could be removed from the source area and taken to other sites for further processing. However, it should be noted that so far no prehistoric places of extraction and manufacturing of siliceous marl and chert artefacts have been discovered in the examined areas. On the other hand, hypothetical mines such as small and shallow open-air galleries or pits could have been cut into steep slopes of river valleys and hills. It is worth emphasising the low archaeological visibility of traces left by such extractions, and their vulnerability to destruction by a variety of natural and anthropogenic processes (e.g., landslides, erosion).

The field prospection for lithic raw material sources will continue. Chemical and physical analyses of raw material samples from the sources and of artefacts from the archaeological contexts have also been undertaken. The problem of key importance and the main goal of this research is to characterise and define the raw material from particular sources (to collect comparative raw materials) and to identify the sources of raw materials used for production of artefacts found on the Neolithic and Early Bronze Age sites in the region. The initial results are promising.

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Striped Flint in Archaeological Materials Around the Outcrops of the Kraków-Częstochowa Striped Flint Variety

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Many varieties of siliceous raw materials can be found in the territory of Poland. Known exclusively from in situ outcrops in the Holy Cross Mountains area until recently, striped flint is distinctive in terms of its technical and visual features. The authors present the state of knowledge about the variety of striped flint from the Ryczów Upland, the outcrops of which were found only about a decade ago. New data obtained from the central part of the Kraków-Częstochowa Upland has cast interesting light on the issues of the origin of striped flint and the ways it was used by the prehistoric communities inhabiting the region. Identifying the sites of siliceous rocks outcrops, extraction and distribution are extremely important at not only the local but also trans-regional level.

KEY-WORDS: Kraków-Częstochowa striped flint, Kraków-Częstochowa Upland, prehistoric settlement, distribution of raw materials

INTRODUCTION

Amongst the various types of siliceous raw materials in Poland, there are few distinctive in terms of excellent technological properties and aesthetic values. Within this group we may place the Świeciechów flint, chocolate flint, and especially the striped

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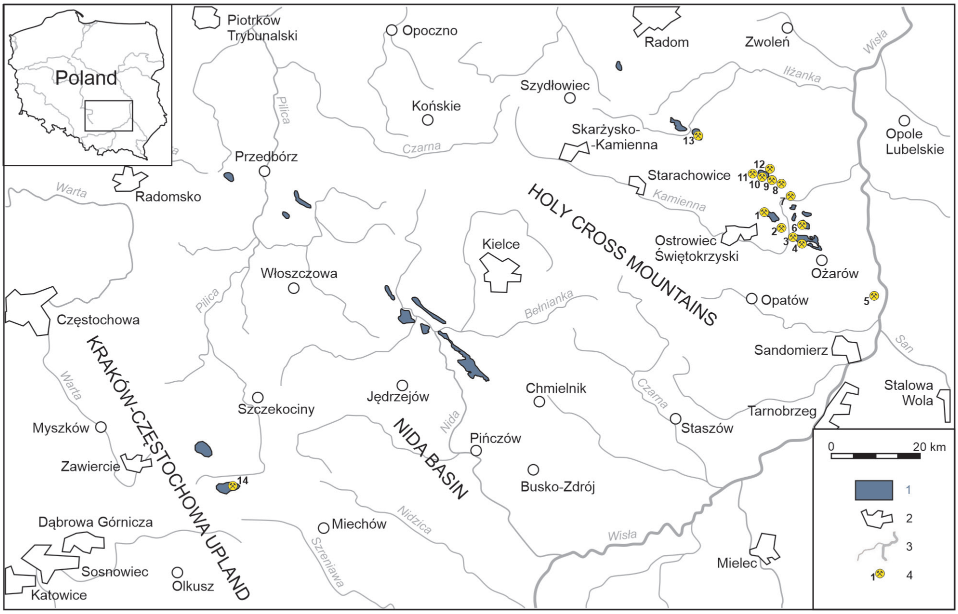

Fig. 1. Localization of known outcrops of rock bearing chocolate silicites (after Krajcarz *et al.*, 2012b, modified by authors) and the most important points of prehistoric exploitation of striped flint. Key: 1 – Upper Jurassic rocks with striped silicite; 2 – major towns and cities; 3 – major rivers; 4 – prehistoric points of exploitation of striped flint (1 – Krzemionki Opatowskie, 2 – Ruda Kościelna, 3 – Łysowody, 4 – Korycizna, Śródborze, Wojciechówka, 5 – Zawichost, 6 – Wiktoryn, 7 – Skarbka Dolna, 8 – Wólka Bałtowska, 9 – Eugeniów, 10 – Stary and Nowy Olechów, 11 – Karolów, 12 – Wodąca, 13 – Błaziny, 14 – Cisowa).

flint. This paper is dedicated to the latter, the striped flint (also banded flint, Polish: *krzemień pasiasty*). The qualitative and aesthetic properties of this raw material were appreciated from the prehistoric times.

There is a well-recognised zone of striped flint outcrops (Fig. 1) on the north-eastern margin of the Holy Cross (Świętokrzyskie) Mountains, extending from the Iłża River to Krzemionki Opatowskie and to Śródborze village (Krukowski 1923; Samsonowicz 1923; 1934; Budziszewski and Michniak 1984). Outside of this region, outcrops of this raw material were partially mapped in the south-western margin of the Holy Cross Mountains (Fig. 1), e.g., in the surroundings of Siedlce, Bocheniec, and Małogoszcz (Krajcarz and Krajcarz 2009). In both regions the striped flint occurs at the same stratigraphic position and in a similar limestone lithofacies.

Similar limestones are also known from the eastern edge of the Kraków--Częstochowa Upland, which made this region promising enough to extend studies on the occurrence of striped flint outcrops to that region too. Until now, our survey has focused in the central part of the Upland, the microregion of the Ryczów Upland (Krajcarz *et al.*, 2014). The research was initiated in 2007 and has been continuously carried out until present.

The issue of occurrence and utilisation of local raw materials in the southern part of the Ryczów Upland had already been tackled in the 1990s by Andrzej Pelisiak and Jerzy Kopacz (Kopacz and Pelisiak 1992; Pelisiak 2003; 2006). They distinguished several areas of the occurrence of Jurassic chert, in particular their variety G, among other places in the area of the Barańskie Hills and the Krztynia Valley. Striped flint shares some similar traits with the G variety of Jurassic chert, as well as with the so-called chert from Wierbka (Krajcarz *et al.*, 2012b; 2014). However, in this paper we focus only on the "typical" striped flint (see section 3). The outcrops of this raw material have been found until now only in the south-eastern part of the Ryczów Upland (Krajcarz *et al.*, 2014; Fig. 2). Some artefacts made of striped flint were described at nearby archaeological sites (Krajcarz *et al.*, 2012b; 2014; Sudoł-Procyk 2020; Sudoł-Procyk and Krajcarz 2021; Sudoł-Procyk and Cyrek in press) and this suggests that the local striped flint could have been known and used by prehistoric communities. In recent years, our knowledge on the occurrence of striped flint in the region has enlarged, both in terms of outcrops that could serve as raw material sources, and in the form of artefacts within archaeological assemblages. The aim of this paper is to summarize and synthesize this knowledge and to present a preliminary model of the prehistoric procurement and distribution of striped flint within the region.

STRIPED FLINT OUTCROPS IN THE RYCZÓW UPLAND

The striped flint variety from the Ryczów Upland is known as the "Kraków--Częstochowa striped chert". It was found during a field survey conducted by Maciej T. Krajcarz and Magdalena Krajcarz in 2008, and then it was described by Krajcarz *et al.* (2012a; 2012b). It occurs in the topmost Upper Oxfordian chalky limestone. Natural exposures of outcrops of this material do not currently exist. The best artificial outcrop known is on a ski slope in Cisowa village, which is being refreshed every several years by the owner with the use of bulldozers. After such refreshment, many fresh nodules can be easily collected. The collection from the Cisowa ski slope serves as a type locality of the Kraków-Częstochowa striped chert

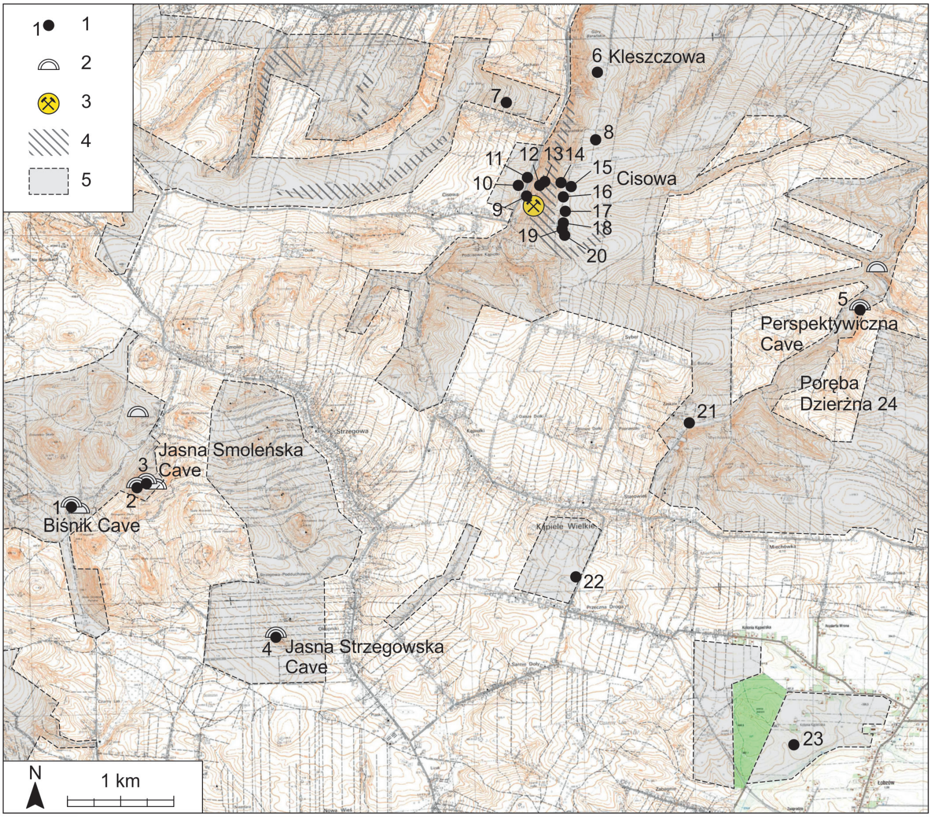

Fig. 2. Location of the striped flint outcrop in the central part of the Kraków-Częstochowa Upland and sites with assemblages of this raw material. Drawning: M. T. Krajcarz, M. Sudoł-Procyk. Key: 1 – sites with striped flint artefacts; 2 – larger caves; 3 – possible striped flint extraction point in Cisowa; 4 – outcrops of the striped flint; 5 – area covered by survey. Sites: 1 – Biśnik Cave; 2 – Shelter above the Zegar Cave; 3 – Jasna Smoleńska Cave; 4 – Jasna Strzegowska Cave; 5 – Perspektywiczna Cave; 6, 8, 12–20 – sites in the area of the village of Kleszczowa; 7, 9–11 – sites in the area of the village of Cisowa; 21–22 – sites in the area of the village of Kąpiele Wielkie; 23 – site in the area of the village of Zabagnie.

and is stored in the Institute of Geological Sciences, Polish Academy of Sciences (Warsaw, Poland) and in the Institute of Archaeology, Nicolaus Copernicus University in Toruń (Toruń, Poland). Apart from this outcrop, this flint can be found in the soil, regolith and within the colluvial mantle on nearby hills. The currently known range of its occurrence covers: the slope in Cisowa, where the ski slope is situated; the plateau above the slope (occupied by agricultural fields belonging to Kleszczowa village), known as the Barańskie Hills; the slopes and plateau of the next hill situated to the west; and the alluvia of the valley of a temporary stream in Cisowa village (Fig. 2). Isolated and weathered specimens have also been found in Middle Pleistocene fluvioglacial sands and Cretaceous marine sands within a ~10 km radius around the outcrops, and these likely represent redeposited clasts.

MACRO- AND MICROSCOPIC CHARACTERISATION OF THE RAW MATERIAL

The characterisation of the Kraków-Częstochowa striped chert given below follows the description proposed by Krajcarz *et al.* (2014). The characterization is based on the collection coming from the type locality in Cisowa. Nodules are rounded, spherical, slightly flattened, sometimes weakly branched, and vary in size from a few centimetres to several dozen centimetres. The cortex is thin (1–5 mm, 2 mm on average) and smooth, white, dusty, clearly separated from the inner silica body and the outer rock.

Inside the nodule, within the silica body, there is usually an ellipsoidal nucleus consisting of light grey, opaque, matt and relatively coarse-crystalline silica (see a schematic structure at Fig. 3 and photographs in Figs. 4–11). In some specimens, the nucleus is large and may fill nearly the entire nodule (Fig. 3c). However, some specimens lack such a nucleus at all (Fig. 3a). Around the nucleus, or within the entire internal space in the case of specimens lacking the nucleus, there is a nearly pure silica material. In nucleus-bearing specimens, one to several series of concentric growth bands are often developed within the silica body around such a nucleus. Unconformities may occur between the series of bands. This internal structure is typical for bedded cherts, the type of chert described from Kraków-Częstochowa Upland by Matyszkiewicz and Kochman (2020) and Kochman *et al.* (2020): a nucleus represents an initial chert concretion and the silica around represents growth bands.

The silica body outside of the nucleus is dark, from grey to black, slightly transparent to opaque, matte or with slight silky to glassy lustre. The silica body is relatively pure and usually lacks any intercalations, such as fossils, intraclasts or limestone fragments. Three subtypes of the silica body can be distinguished: specimens with a uniform dark colour (usually in specimens without the nucleus; Fig. 3a); specimens with concentric alternate light-dark banding (usually in specimens with a nucleus; Fig. 3b); and specimens with thin and slightly banded silica mass around the large nucleus (Fig. 3c). The second type resembles the typical striped flint from the Holy Cross Mountains, but usually the banding is weaker, as individual bands are fuzzy and thicker than in the Holy Cross Mountains specimens. Dark bands are usually thin (around 1 mm) and well separated from the light bands. The light bands are wider (2–7 mm), usually darker in the central part and progressively lighter distally. Right below the cortex there is usually a zone of silica body that is whitish and banded. In some specimens, the banding in this zone seems independent from a general concentric banding of the nodule, and repeats the shape of the external surface of the nodule.

In weathered specimens, the silica substance is covered with a dull and opaque, milky white or grey-white patina, sometimes with a pattern of grey or bluish spots and lines. Weathered cortex usually changes its colour towards yellowish white or orange, sometimes with dark brown spotting.

Three of the most common types of the Kraków-Częstochowa striped chert are depicted in Fig. 3, but intermediate forms occur as well. These three types may represent various horizons within the parent rock; however, access to exposures in situ is limited. In the type locality at the ski slope in Cisowa, all three types were found scattered together in the reworked soil and regolith.

In terms of knapping properties, the chert in question is a very good raw material. It seems to be a better knapping material than the striped flint from the Holy Cross Mountains. This is probably due to the less distinct banding and greater homogeneity. Knapped surfaces display a conchoidal fracture with poorly marked waves.

In transmitted light, the Kraków-Częstochowa striped chert gives a similar image to the Holy Cross Mountains striped flint. The siliceous matter is transparent and contains inclusions of scattered, fine, dark brown fibres, which locally reduce transparency and are responsible for the macroscopic light bands. In the stereoscopic observation, in water immersion, this chert shows features intermediate between the striped flint from Krzemionki Opatowskie and variety G of the Kraków-Częstochowa cherts from Pradła (for their characterization see Přichystal 2009). In most specimens, there are black acicular microfossils (see Krajcarz *et al.*, 2014), which are typical of the Holy Cross Mountains striped flint (Přichystal 2009), but they are less common. The amount of white "suspension" is also clearly lower. The Fe-oxide accumulations, typical of the G variety, are present, but they are almost always associated with microfossils, especially with silica spicules. Some specimens show greasy spots, typical of the G variety chert.

Similarities to both materials, namely the Holy Cross Mountains striped flint and the G variety of the Kraków-Częstochowa cherts, suggest that the Kraków-Częstochowa striped chert may represent a transitional form between these two varieties. If so, the Holy Cross Mountains striped flint occurring over 100 km to the north-east, and the G variety being found further to the north of the Ryczów Upland, may represent the extreme end-members within one widely extending stratum of chert.

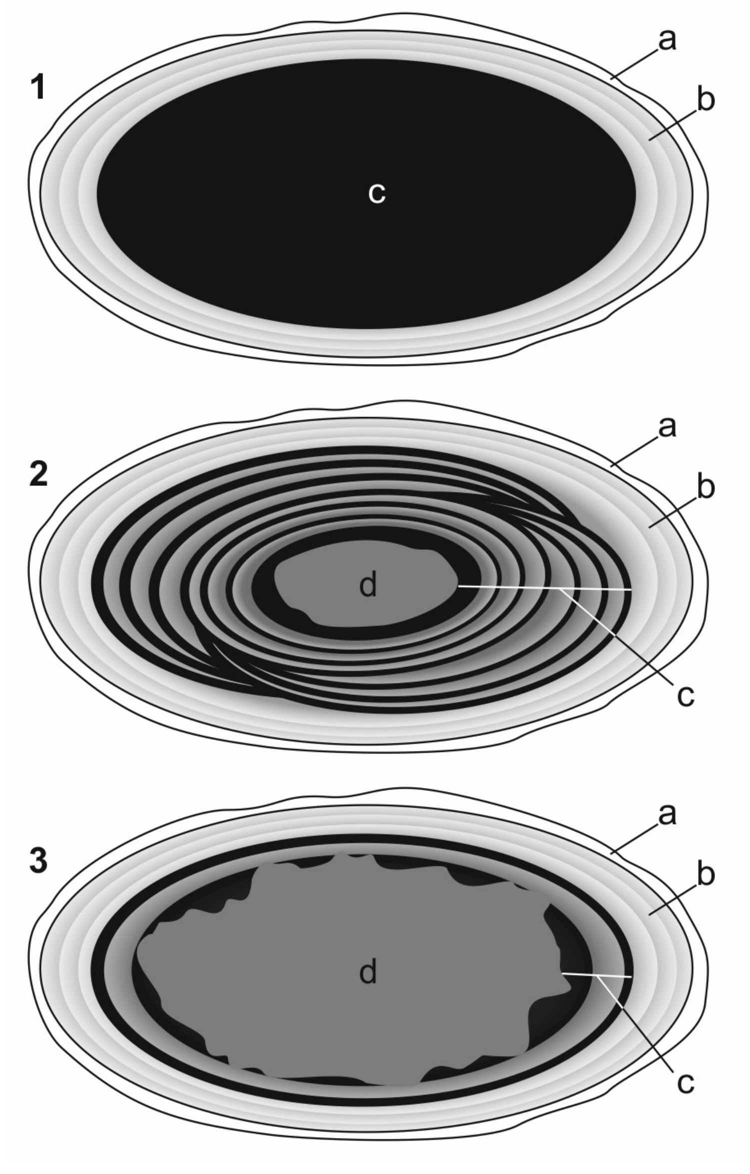

Fig. 3. Schematic internal structure of striped flint from Ryczów Upland (based on the collection from the ski slope in Cisowa): 1 – dark not-banded type; 2 – "typical" banded type with a nucleus; 3 – large nucleus type. Nodule components: a – cortex; b – sub-cortex smooth whitish silica band, usually internally banded; c – fine-crystalline smooth silica mass, dark or alternately dark-light banded; d – coarse-crystalline grey nucleus. Drawning: M. T. Krajcarz.

MATERIALS AND METHODS

Observations on the occurrence of the Kraków-Częstochowa striped chert within archaeological sites were collected in two ways:

1) Studies of lithic collections from known archaeological sites situated in the Ryczów Upland, stored in the Institute of Archaeology, Nicolaus Copernicus University in Toruń (Toruń, Poland) and the Archaeological and Ethnographic Museum in Łódź (Łódź, Poland).
2) Survey in the Ryczów Upland, in the vicinity of the outcrops.

The studied collections included the archaeological sites: Biśnik Cave; Jasna Strzegowska Cave; Shelter above the Zegar Cave; Jasna Smoleńska Cave; Perspektywiczna Cave; Shelter in Udórz II; Kleszczowa site without an assigned number; Poręba Dzierżna site 24; Deszczowa Cave; Krucza Skała Rockshelter; Kroczycka Cave; Cave IV in Birów Mt. and the Okiennik Wielki Cave. The survey was conducted during 2007–2022 and covered the area marked in Fig. 2.

Within lithic collections from the known archaeological sites and from the survey, we identified the raw material types, with a special focus on the striped flint. For an identification of raw materials, we used comparative collections of the Kraków-Częstochowa striped chert coming from the type locality at the ski slope in Cisowa. The comparative analysis included several basic criteria: the colour, lustre and transparency of the silica body; banding within the silica body; presence of intraclasts, fossils and other intercalations within the silica body; presence of inner nucleus (see Fig. 3); presence of whitish sub-cortex band (see Fig. 3); presence, smoothness, thickness and colour of cortex; separation of the cortex from the inner silica body and from the outer rock. In many cases, the identification was limited or even impossible, due to the varying preservation state of the artefacts, which included: fresh fractures (non-patinated), patinated (with different intensity of patina, from light grey until completely white), eolized, and discoloured, e.g., due to activity of water and soil.

Identified archaeological assemblages with the striped flint were studied in terms of their cultural and chronological affiliation as well as spatial distribution, which is expected to display the potential of the microregion in terms of its importance for ancient mineral procurement, processing and distribution.

STRIPED FLINT AT ARCHAEOLOGICAL SITES IN THE RYCZÓW UPLAND

It is noteworthy that the archaeological sites in the Ryczów Upland with striped flint artefacts are concentrated within no great distance from the recorded outcrops of the

Kraków-Częstochowa striped chert variety (Fig. 2). Amongst those sites there are a few distinctive locations, in the direct vicinity of flint outcrops that can be most likely identified as the extraction points, as well as caves and open sites with assemblages typical of both contemporary campsites and flint processing workshops (Sudoł-Procyk and Krajcarz 2021).

Until present in the south-eastern part of the Ryczów Upland, there have been recognised two zones that can be interpreted as flint acquisition points. One of them, well known thanks to the research currently being conducted there, is situated in the Udorka Valley (the region of Poręba Dzierżna village, Wolbrom commune, Lesser Poland Voivodeship), within the extent of the chocolate flint outcrops (Sudoł-Procyk and Krajcarz 2021; Sudoł-Procyk *et al.*, 2021a; 2021b). Another one, significant in respect of the presented topic, is located exactly in the region of occurrence of the striped flint outcrops, in the south-western part of the Barańskie Mountains, in the region of Cisowa and Kleszczowa villages, Pilica commune, Silesian voivodeship (Krajcarz *et al.*, 2014; Sudoł-Procyk and Krajcarz 2021). Here, LiDAR analysis has revealed several zones with a surface relief analogical to the chocolate flint mining fields confirmed by excavations. Although these zones have not yet been verified through excavations, there are certain premises which allow us to believe that these were the raw material acquisition points. First, the relief anomalies resemble pits analogical to e.g., chocolate flint mining pits from Udorka Valley (Sudoł-Procyk *et al.*, 2018). Here, the relief occurs in the closest surroundings of the striped flint outcrops. Secondly, most of striped flint nodules found nearby bear traces of testing and initial preparation (Fig. 4). Thirdly, the close proximity of flint exploitation points may also be indirectly suggested by a cluster of workshops concentrating along the edge of the plateau, directly above the Cisowa ski slope (Fig. 2).

This area must have been favourable in many aspects that were appreciated by prehistoric communities: proximity of the high-quality flint outcrops, a great observation point, and a well-situated communication hub, with gullies allowing easy routes up and down the slopes in many directions. Until now, direct evidence of exploitation consists of two pit-like features clearly visible in the artificial profile cutting through the lower portion of a slope, near the Cisowa ski slope management building (Fig. 5:1). This profile was recorded during one of the field surveys (in 2014), and was associated with construction work at the ski slope. Unfortunately, it is now inaccessible due to further construction works. The features were cut into the soil and limestone regolith and backfilled with limestone debris containing a large number of flint nodules (Fig. 5:2). Numerous flakes have been documented in their vicinity (Fig. 5:3). These features were probably the remains of exploitation pits.

Most of the excavated sites with numerous artefacts made of striped flint in the region are cave sites. Cultural levels recorded there confirmed that striped flint had been known from the Middle Palaeolithic until the Bronze Age. The oldest specimens made of this raw material come from the Biśnik Cave (Fig. 2) and occur within almost all of the Middle Palaeolithic cultural levels at this site (Krajcarz *et al.*, 2014; Sudoł-Procyk and Cyrek in press). The most representative, in terms of local utilisation of striped flint, are mainly younger, post-Vistulian cultural levels within layers 7–5, dated to OIS 4–3 (Early to Middle Plenivistulian). The flint materials found within these levels were characterised by concretions with test flakes, a high share of Levallois cores in various stages of exploitation, Levallois flake semi-products, and few tools, mostly sidescrapers (Fig. 6:1–3). Utilisation of local striped flint for production of blanks using the Levallois techniques confirms its excellent technical values, while the large amount of raw material at the site suggests undertaking of intentional provisioning episodes. The closest outcrops are within a distance of about 5 km from the cave. When compared with the older, significantly less numerous assemblages, the artefacts in question are covered with patina to much lesser extent, and many specimens are completely non-patinated. This may be explained by different lithological contexts: the older levels were deposited within loamy sediments with limestone clasts, while the younger were deposited in sands (Cyrek *et al.*, 2014; Krajcarz *et al.*, 2014).

Utilisation of local striped flint in the Middle Palaeolithic is also evident for the oldest Middle Palaeolithic cultural horizon in the Jasna Strzegowska Cave (Sudoł-Procyk and Cyrek in press), situated within a distance of *c.* 5 km from the Biśnik Cave (Fig. 2). There the striped flint is represented by a bifacial knife made on a Levallois flake (Fig. 6:4).

A few artefacts made of striped flint are also known from another Middle Palaeolithic site in the Ryczów Upland, the Okiennik Wielki Cave (Sudoł-Procyk and Cyrek in press), situated within a distance of c. 20 km to the north of the known striped flint outcrops. Amongst the tools found at this site especially noteworthy are bifaces and one circular sidescraper (*groshak*; Fig. 6:5–6).

Another trace of utilisation of this raw material in the Late Palaeolithic is represented by a few flint artefacts coming from the Perspektywiczna Cave (Fig. 2) in the Udorka Valley (Krajcarz *et al.*, 2014). Partly cortical blanks and flake semi-products discovered there are covered with an intense white patina and constitute a supplementary component of a larger assemblage dominated by another local raw material, namely chocolate flint (Krajcarz *et al.*, 2014; Sudoł-Procyk 2020). A significant analogue, in terms of raw materials used, is another, more numerous assemblage from an open-air site in Kleszczowa (Fig. 2), associated with the Magdalenian (Krajcarz *et al.*, 2014; Sudoł-Procyk 2020). The assemblage encountered at this site included

Fig. 4. Examples of nodules of striped flint with primary working: 1 – Cisowa (No. 7 in Fig. 2); 2 – Kleszczowa (No. 13 in Fig. 2); 3 – Kleszczowa (No. 17 in Fig. 2). Photo: W. Ochotny.

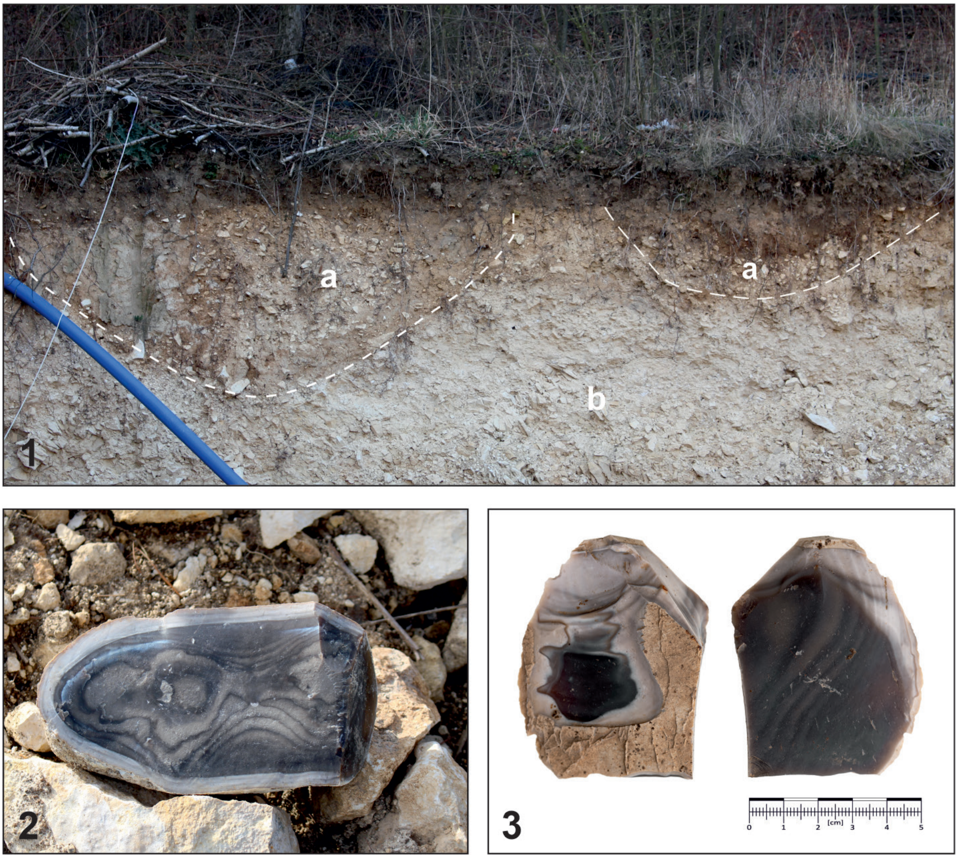

Fig. 5. Feature dug into weathered clay with concretions of the raw material. Key: 1 – the outline of the features; 2 – concretion of striped flint derived from weathered clay; 3 – flake. Photo: M. Sudoł-Procyk.

several dozen cores for blades, blades and tools, mainly endscrapers, made of striped flint (Fig. 7:1–6).

Striped flint is common at younger sites dated to the Neolithic and the Early Bronze Age. Sites from these periods are associated with production of dihedral and tetrahedral flint axes, and were recorded mostly in the region of the Wodąca Valley (Fig. 2), namely in the Biśnik Cave (Cyrek 2002), the Shelter above the Zegar Cave (Krajcarz *et al.*, 2012c), the Jasna Smoleńska and Jasna Strzegowska Caves (Stefaniak *et al.*, 2009), as well as in the surroundings of Strzegowa village (Pelisiak 2006). Flint assemblages coming from these sites are characterised by a very similar state of preservation, like the materials collected from the surface around the striped flint outcrops in Cisowa and Kleszczowa villages, which has an intense, light grey or white patina (Krajcarz *et al.*, 2014). A great number of artefacts evidence an intentional acquisition of striped flints on a large scale, which were then brought to the region of the Wodąca Valley, and their intense utilisation at the turn of the Neolithic and the Bronze Age.

Interesting results were delivered by a preliminary field survey carried out in the south-eastern region of the Ryczów Upland. Although the investigations are still in progress and some parts of the research area have not been verified yet, there is a clear concentration of sites around the striped flint outcrops near Cisowa village (Fig. 2). The concentration of sites along the slope is the result of mechanical levelling associated with the current utilisation of this area as a ski slope, but also agriculture and road maintenance. It is very likely that the artefacts found along the slope were artificially relocated, and their primary deposition spots should be sought somewhere on the slope, most likely on its higher parts. All sites in this zone are workshops, with a significant number of cores for blades (Fig. 8:2–5), mostly in their initial stage of exploitation. Amongst the tools the most distinctive are burins, sidescrapers and retouched blades (Fig. 9:1–4). Flakes represent all stages of core processing (Fig. 9:5–8, 10:1–6). We must consider the fact that the assemblages found in this zone are of various chronology, most likely starting from the Mesolithic until the Bronze Age. The earlier epoch may be evidenced, among other things, by the presence of a splintered piece (core; Fig. 8:1).

Scarce finds made of striped flint, gathered from the area located to the south of the outcrops, near Kąpiele Wielkie and Łobzów villages (Fig. 2), in general are not characteristic (Fig. 11:1–2). Attempts to more accurately determine their cultural and chronological affiliation will be the subject of further studies. Some of these artefacts were small single-platform cores for blades, usually with changed orientation, which certainly can be linked with the Mesolithic (Fig. 11:3–4).

CONCLUSIONS

Systematic studies of siliceous raw materials in the central part of the Kraków-Częstochowa Upland have revealed the presence of many variants of flints in this region. Among them, apart from chocolate flint (Sudoł-Procyk *et al.*, 2021a; 2021b), a local variety of the striped flint was identified. The micro- and macroscopic features of this chert resemble the classic striped flint from the Holy Cross Mountains.

Fig. 6. Examples of Middle Palaeolithic artefacts made of striped flint. 1–3 – Biśnik Cave (No. 1 in Fig. 2), 4 – Jasna Strzegowska Cave (No. 4 in Fig. 2), 5–6 – Okiennik Wielki Cave. Photo: M. Sudoł-Procyk.

Fig. 7. Examples of Final Palaeolithic artifacts made of striped flint from the Kleszczowa open-air site (No. 6 in Fig. 2). Key: 1–3, 5 – blades; 4 – endscraper, 6 – core. Photo by W. Ochotny.

Fig. 8. Selection of cores made of striped flint. 1 – Kleszczowa (No. 12 in Fig. 2); 2 – Kleszczowa (No. 15 in Fig. 2); 3 – Kleszczowa (No. 19 in Fig. 2); 4 – Kleszczowa (No. 18 in Fig. 2); 5 – Kleszczowa (No. 20 in Fig. 2). Photo: W. Ochotny.

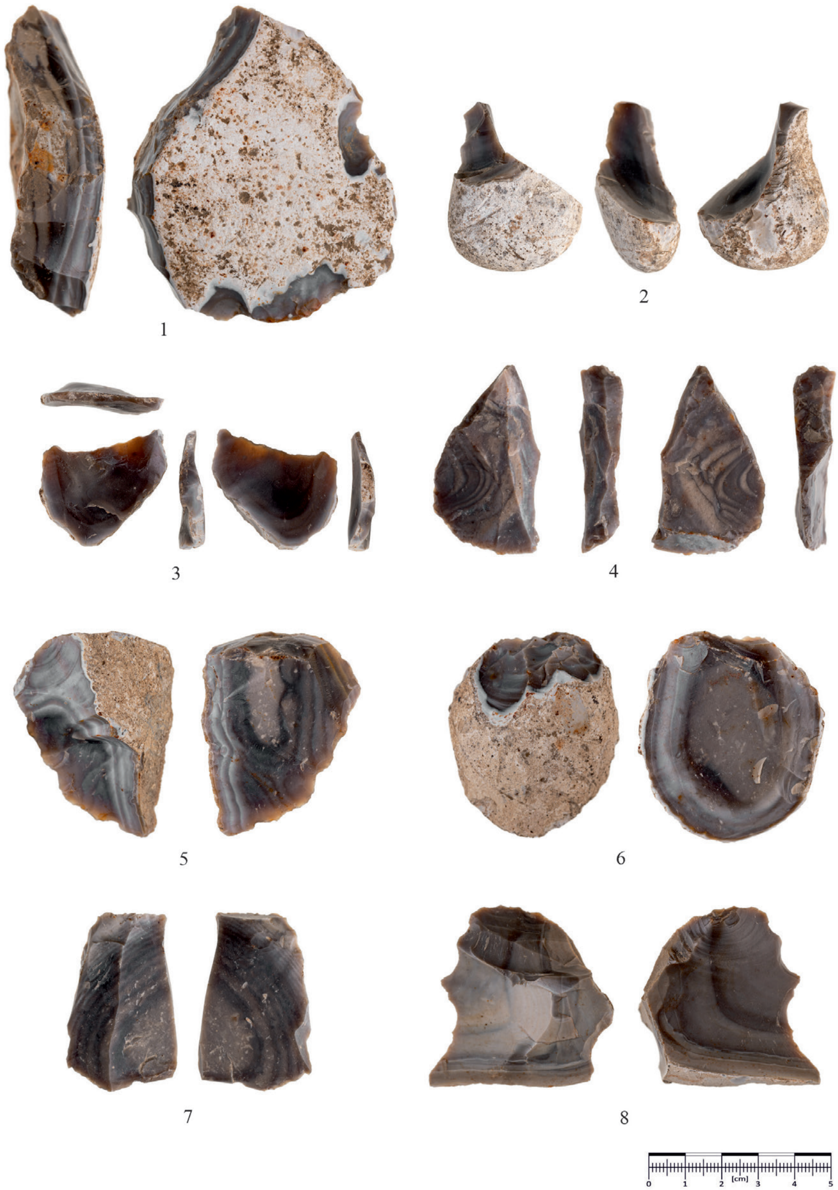

Fig. 9. Striped flint tools and flakes: 1 – sidescraper from Kleszczowa (No. 15 in Fig. 2); 3 – double perforator on rejuvenation flake from Kleszczowa (No. 18 in Fig. 2); 4 – dihedral burin from Kleszczowa (No. 16 in Fig. 2); flakes: 2, 7 – Kleszczowa (No. 16 in Fig. 2); 5, 6, 8 – Kleszczowa (No. 17 in Fig. 2). Photo: W. Ochotny.

Fig. 10. Examples of striped flint flakes: 1–4 – Kleszczowa (No. 18 in Fig. 2); 5–6 – Kleszczowa (No. 13 in Fig. 2). Photo: W. Ochotny.

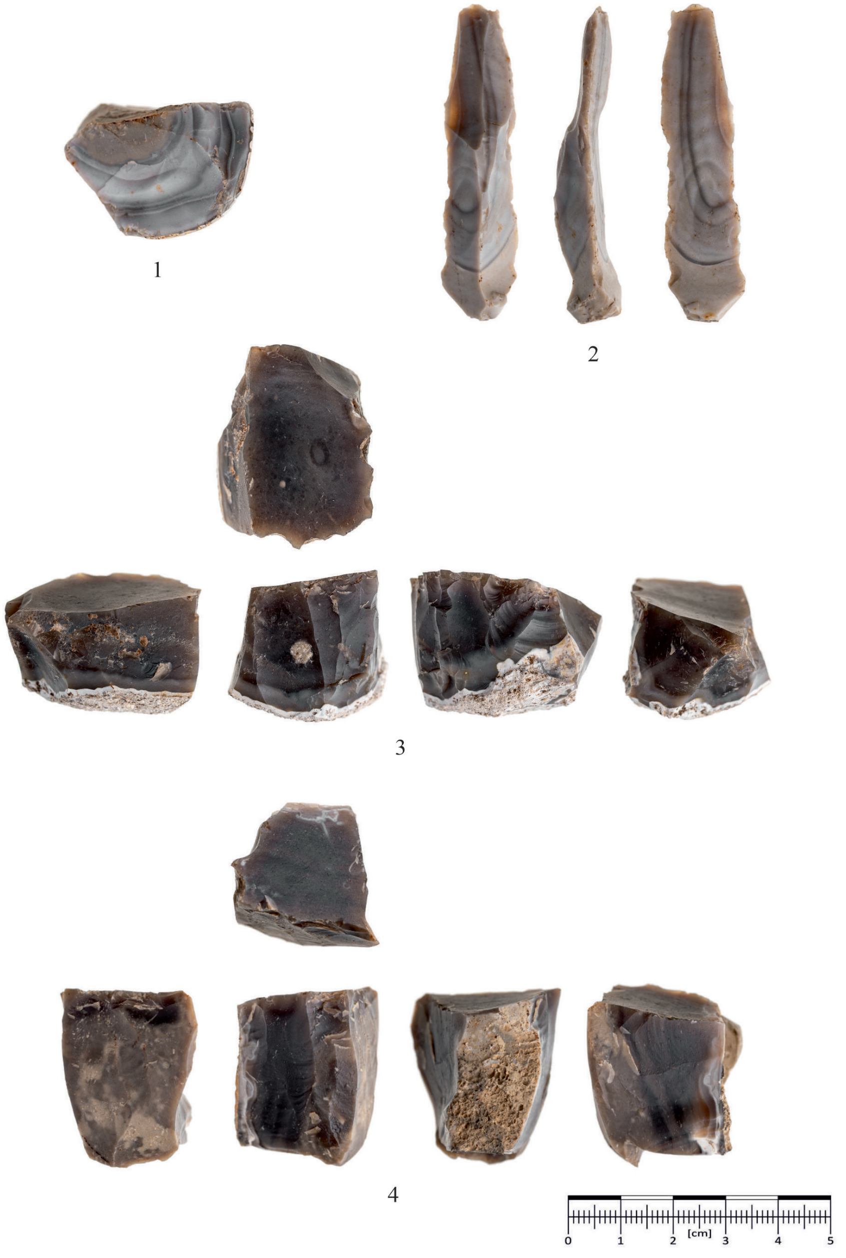

Fig. 11. Selection of striped flint artifacts: 1, 4 – Kąpiele Wielkie (No. 22 in Fig. 2); 2–3 – Kąpiele Wielkie (No. 21 in Fig. 2). Photo: W. Ochotny.

The material from the outcrops of striped flint in the central part of the Kraków-Częstochowa Upland discussed in this paper was undoubtedly of great economic significance in prehistoric times. Taking all the mentioned sites into consideration, we can see the broad picture of the local striped flint being a constant component of the assemblages in the microregion dated to various periods of the Stone Age. Exploitation of outcrops of this raw material is evidenced by numerous archaeological sites of workshop type, situated near these outcrops. Flint artefacts collected during excavations and those coming from field surveys, confirm that this raw material was used constantly, starting from the Middle Palaeolithic until the Early Bronze Age (Krajcarz *et al.*, 2014). Lithic artefacts made of local striped flint prove that even the Neanderthals appreciated its excellent utilitarian valour, although other raw materials were equally accessible (Krajcarz *et al.*, 2012b).

In the successive periods, particularly in the Late Palaeolithic and Mesolithic, the use of an increasing amount of the striped flint among the raw materials is clearly legible. At the Magdalenian site in Kleszczowa, the raw material analysis revealed that the contribution of striped flint reaches nearly 25% of the entire assemblage (Sudoł-Procyk 2020). We cannot also exclude that among the numerous initial cores for blades coming from workshops in the Barańskie Hills, there are specimens of the Late Palaeolithic and Neolithic periods. It is highly probable that this raw material had been known and utilised in the Mesolithic as well. Small single-platform cores for blades, mostly conical in shape, coming mainly from field surveys, were present over nearly the entire region under study. Although only some of them were made of striped flint, they were usually accompanied, in the very same stratigraphic context, by flakes, blades and pieces with test flaking made of striped flint.

Until the present, it has been impossible to determine univocally whether the materials made of striped flint found during field surveys contain forms classified as dating to the Neolithic. Nevertheless, it seems significant that the finds of flints of this material were lacking Neolithic pottery in their direct contexts. On the other hand, it is noteworthy that striped flint was the major raw material for production of Neolithic-Bronze Age axes. In the area of Udorka Valley a few workshops dated to the Early Bronze Age are known with numerous semi-products, mostly flakes, being waste from axe production (Krajcarz *et al.*, 2012b; 2014). Such mass production required high-quality raw material and must have engaged advanced methods of exploitation. The answer to the question whether the raw material used by the Early Bronze Age communities was extracted in the region of the Barańskie Hills remains open, and must be verified in the course of further studies.

New findings in this respect are extremely important from the viewpoint of the acquisition and distribution of siliceous materials, with regard to the Middle and

Upper Pleistocene, as well as the Holocene, since not only do they complement the current state of knowledge, but they also significantly change it. The discovery of an additional region, apart from the Holy Cross Mountains, where striped flint was acquired and processed, sheds a new light on the issue of importation and distribution of this raw material in the Stone Age. It was undoubtedly used on the scale of the microregion, but its inter-regional importance cannot be excluded and needs further studies.

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Prehistoric Stone Raw Materials from the Bükk Mountains in Northeastern Hungary

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From the period of the Neanderthals to those of the Late Neolithic populations, the Bükk Mountains region played an important part in the lives of various prehistoric societies, and the varied geological history of this territory provided distinct circumstances for the production of stone implements. The major goal of our research is to outline the current state of information concerning the prehistoric use of the diverse silicified source materials of the Bükk mountains. The results of these studies are presented concerning four selected local rock types, cited in the archaeological literature as the silicified sandstone of Egerbakta, the radiolarite and hornstone (black chert), the silicified marlstone and the quartz-porphyry (metarhyolite). Except for the latter, little attention has previously been paid to studying them in detail. Our new petrographic analyses revealed two variants of the raw material from Egerbakta: a silicified sandstone and a diatomaceous detrital chert. The other samples turned out to be radiolarites. This result confirmed what was already suggested for the hornstones (black cherts), however, it has new consequences for the "silicified marlstone". Regarding the prehistoric use of the selected raw materials, archaeological data show interesting dynamics through time. The Mousterian groups of the region used a large spectrum of rocks for lithic tools with a preference for hornstone (black cherts) and radiolarite in the southern part, and the quartz-porphyry (metarhyolite) in the northeastern part. The Bábonyian/Micoquian assemblages are characterized by a bifacial toolkit and an apparent preference for quartz-porphyry (metarhyolite). At the beginning of the Upper Palaeolithic, a new attitude appears in the region: the Aurignacian

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groups almost completely ignored local sources. During the Neolithization of the Carpathian Basin, the lithic assemblages of the Alföld Linear Pottery culture became more and more habituated to the locally available rock types, albeit their raw material economy was based on limnosilicites and obsidian. Another change took place during the Late Neolithic when supra-regional sources became dominant over local or regional sources.

KEY-WORDS: petrography, raw material economy, quartz-porphyry (metarhyolite), silicified sandstone, radiolarite, Palaeolithic, Neolithic

INTRODUCTION

The region of the Bükk Mountains has an extraordinary place in the history of Hungarian prehistoric archaeology and is of special interest in the study of the Stone Age of Hungary. The first evidence of "Diluvial Man" in the territory of Hungary, the so-called "handaxes of Bársony's house" were found in 1891 here in Miskolc (Herman 1893). As a consequence, systematic excavations have been carried out in the caves of the Bükk Mountains from 1906 onward, yielding archaeological material from Palaeolithic and Neolithic times (Kadić 1934). The intensive archaeological research in the region has resulted in important assemblages which have constituted the basis for defining cultural units, like the Middle Palaeolithic Bábonyian (Ringer 1983), the Szeletian of the Middle to Upper Palaeolithic transition (Prošek 1953) and the Middle Neolithic Bükk culture (Lichardus 1974). The special interest is because the region is rich in various siliceous rocks of different geological origins that were used by prehistoric people as raw materials for their knapped stone tools (Biró and Pálosi 1985; Pelikán 2005).

Early on, petrographic characterization of the raw materials of the unearthed lithic industries was carried out for the publication of site monographs, like that of the Szeleta and Subalyuk caves (Vendl in Kadić 1916: 231–235; Vendl 1940). However, these were only suggestions concerning the sources of these siliceous rocks because the comprehensive study of the geology of the Bükk Mountains was conducted later (Balogh 1964; Pelikán 2005). Another problem with these former petrographic identifications is using varied rock names in archaeological studies (Biró 2010). Systematic study of rocks of archaeological interest in Hungary started in the 1970s at the Hungarian Geological Institute following the initiative of geologist József Fülöp, director of the institute, after the discovery of a prehistoric radiolarite mine at Tata (Fülöp 1973). The intensified investigations in this field were crowned with an international conference on flint mining and lithic raw material identification (Biró 1986; 1987a) and the establishment of the Lithotheca comparative raw material collection at the

Hungarian National Museum in Budapest (Biró and Dobosi 1991; Biró *et al.*, 2000). The siliceous rocks of the Bükk Mountains were only marginally covered by these investigations, only three of them have been analyzed in thin sections and by geochemistry and spectrometry (Biró *et al.*, 2000: 214–275). The reason is probably that the international research was mostly interested in the detailed study of more recognizable raw material types, such as Carpathian obsidians and Transdanubian radiolarites which were recorded on archaeological sites from Germany to the Balkans proving long-distance contacts of Neolithic communities (Mateiciucová 2007). Among the raw materials of the Bükk Mountains is one lithic source of interest for that reason, the quartz-porphyry (metarhyolite), which is recognized in some archaeological assemblages of neighbouring countries (Markó *et al.*, 2003).

During the 1980s and 1990s, the fieldwork and analytical studies related to siliceous rocks in Hungary were based on the "provenience approach" which generally compares raw materials found at the archaeological sites with rock samples of the known origin of already existing databases and lithothecas. This approach, completed by the geochemical fingerprinting methods, provided a considerable amount of knowledge about raw material sourcing, however, it also showed its limits too (Biró 2004; 2009). The distances calculated between archaeological sites and geological sources were interpreted as the "action radius" of a given human group or in terms of raw material circulation (Simán 1991; Dobosi 2009; Biró 2004; 2009; Markó 2009). However, a series of problems arise from both geological and archaeological points of view. The different silicification processes that happened under varied conditions could result in great variability in the same geological formation. This variability either allows us to differentiate raw material sources (e.g., obsidian, Williams-Thorpe *et al.*, 1984; Kasztovszky and Biró 2006) or prevents us from distinguishing between sources in a wider area (e.g., radiolarite, Biró *et al.*, 2009; Szilágyi *et al.*, 2020). In the case of post-volcanic (metasomatic) silicification, the characteristics of the original sediment could result in high variability even within one source (e.g., limnosilicites, Szekszárdi *et al.*, 2010; Mester and Faragó 2016). For a better archaeological interpretation, it is important to take into consideration the different ways in which a lithic raw material could arrive at the site through human activities, including mobility, network, exchange and supply (Renfrew 1984; Féblot-Augustins 1999; Gamble 1999; Lech 2003; Whallon 2006). Moreover, the organization of the raw material economy in time and space resulted in differences in the presence of raw materials on the site according to stages of lithic production (Geneste 1988; Otte *et al.*, 2001; Bonjean and Otte 2004). The "palaeoethnological approach" leads us to study these archaeological–anthropological problems through the pieces of evidence of the prehistoric human activities in a social context. All the activities of a human group form its technical system which is reflected in their technical behaviour during raw material procurement and stone tool production (Lemonnier 1986; Geneste 1991).

Applying the palaeoethnological approach, we started to study the technical behaviour of Stone Age human groups regarding the raw material sources in the northern part of the Carpathian basin (Mester *et al.*, 2012; Mester 2013; Mester and Faragó 2013). In the first stage of this research, we focused on two selected areas, the Mátra and Bükk mountains, in a diachronic approach, from Middle Palaeolithic to Middle Neolithic (Mester 2019). Based on the assumption that environmental and cultural changes were taking place over this long period, our research aims at reconstructing the potential natural lithic resources available for prehistoric people and recognizing the human choice among them with their behavioural background. For describing the interactions between lithic resources and human groups, we developed the Occurrence–Source–Archaeological site (OSA) model (Mester and Faragó in press). Each siliceous rock occurrence mapped in the region, available in a given period, is an Occurrence in the model. If the lithic analysis demonstrates that a variety of siliceous rocks was used for tool production by a human group in the period, the related occurrences become Sources in the model. If there is any archaeological evidence of human activity related to the siliceous rock at the source (exploitation, workshop), it becomes an Archaeological site in the model. In the archaeological and palaeohistorical interpretation, the OSA model allows us to manage the abovementioned problems originating from the variability or the weakness of our actual knowledge (e.g., wider distribution of variants in the geological formations, uncertainties in the petrographic identification and source location). Taking into account the consequences of the possibilities given by the model, we can formulate options in our interpretation and evaluate their probabilities and the resulting questions. Moreover, the OSA model allows us to study the dynamism of the region's human–lithic resource interaction through the changes in attributions of documented lithic resources.

METHODS AND MATERIALS

The application of the OSA model for human–lithic resource interaction requires a twofold study. The first one is the reconstruction of the locations of potential natural lithic resources in the region. It needs a comprehensive inventory of all kinds of occurrences of siliceous rocks. The basic methodology is well-known and widely used: field prospection and rock sampling of the outcrops of the geological formations which potentially contain siliceous rocks according to the geological map and its explanation (e.g., Turq 2000: 33–35; Féblot-Augustins 2009: 170–171). Observations gathered during archaeological field surveys about the presence of blocks of siliceous rock round out the picture (Faragó *et al.*, 2018: 117–119). To understand the occurrences within the framework of landscape history, the geomorphological and pedological characteristics of the region (Dövényi 2010) had been overlapped with the geological map of the Mining and Geological Survey of Hungary in a GIS-based database (Gyalog 2005). The data about the locations have to be checked in the field. Each occurrence is characterized according to source types (Turq 2000; 2005) and sampled for siliceous rock diversity. The samples are stored in the reference collection, established in 2011 at the Institute of Archaeological Sciences of the Eötvös Loránd University in Budapest (Mester *et al.*, 2012). The basic petrographic characterization of the samples is usually done at a macroscopic and microscopic level (water immersion; e.g., Turq 2000: 35–36; Féblot-Augustins 2009: 167–168; Přichystal 2013: 43–45; Brandl 2014: 39–40). Analysis by thin sections and by geochemical analytical methods (e.g., Brandl 2014: 40) are in progress or planned for the future.

The second required study is to reconstruct and understand how humans chose raw materials from available siliceous rocks. For this, a techno-economic analysis based on the technical reading method (Inizan *et al.*, 1999; Tixier 2012) is applied to the lithic assemblages of archaeological sites (Geneste 1988; Turq 2000: 39–43). The key concept behind this reconstruction is the notion of operational chain or *chaîne opératoire* (Pelegrin *et al.*, 1988; Karlin *et al.*, 1991; Sellet 1993; Audouze and Karlin 2017). The reference collection of the Institute of Archaeological Sciences Eötvös Loránd University, Budapest, aids in the identification of the used raw material and source type.

In this paper, we deal with the region of the Bükk Mountains (Fig. 1). Concerning the potential raw material sources, the study area is constituted by the mountains and their foothills (named Bükkalja), which together have a complex geological history (Pelikán 2005; Szederkényi *et al.*, 2012). From a structural point of view, the Bükk Mountains are a part of the ALCAPA Mega-unit which belongs to the African plate. The Mesozoic rocks of the mountains were formed in the western basin of the Tethys ocean (sited where now is currently the western basin of the Mediterranean Sea). They were moved to their present place through the process of the collision of the African and the Eurasian plates that lasted up to the Lower Miocene.

Regarding possible raw materials, these rock formations contain siliceous rocks of volcanic and sedimentary origins. The Bagolyhegy Metarhyolite Formation's grey "quartz-porphyry", which dates to the most likely Early Carnian era, is the one that is most well-known archaeologically (Pelikán 2005: 191–192). Because the "hand-axes of Bársony's house" as well as the majority of the "laurel leaf points", found at Szeleta Cave at the beginning of the Palaeolithic research in Hungary, were knapped from this raw material, it became well-known and studied several times. In the case

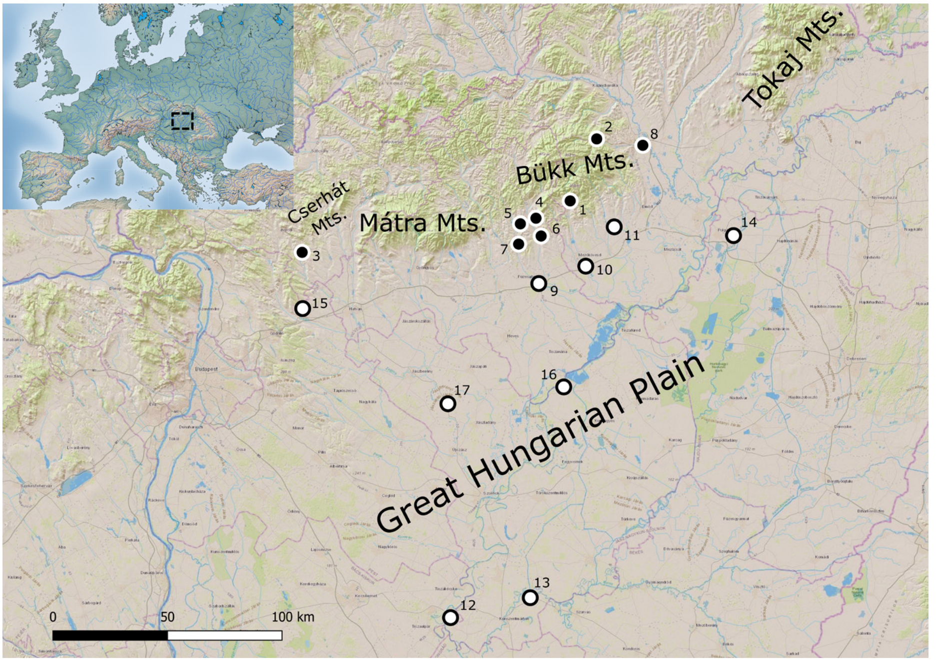

Fig. 1. Location of the Bükk Mountains in Northern Hungary with the archaeological sites mentioned in the text. Archaeological sites: 1 – Subalyuk Cave; 2 – Büdöspest Cave; 3 – Vanyarc-Szlovácka-dolina; 4 – Eger-Kőporos; 5 – Egerszalók-Kővágó; 6 – Andornaktálya-Gyilkos, Andornaktálya-Zúgó; 7 – Demjén-Szőlő-hegy III; 8 – Miskolc-Molotov Street; 9 – Füzesabony-Gubakút; 10 – Mezőkövesd-Mocsolyás; 11 – Bükkábrány-Bánya VII; 12 – Tiszaug-Vasútállomás; 13 – Öcsöd-Kováshalom; 14 – Polgár-Csőszhalom; 15 – Aszód-Papi földek; 16 – Pusztataskony-Ledence; 17 – Alattyán-Vízköz. CAD by N. Faragó.

of the tools of Szeleta Cave, A. Vendl considered that it was "ash-grey chalcedony" (Kadić 1916). Using spectroscopic analysis, L. Vértes and L. Tóth (1963) renamed it "vitreous quartz-porphyry". After new petrographic data, K. Simán (1986) used the name "felsitic porphyry" which was modified later to "Szeletian felsitic porphyry" (Biró and Dobosi 1991; Markó *et al.*, 2003). During the revision of the geology of the mountains, this rock was revealed to be a slightly silicified metarhyolite (Pelikán 2005). Using different names for the same raw material type introduces confusion. The term "Szeletian felsitic porphyry" is a wrong denomination because it has neither geologic nor petrographic meaning. The Szeletian is an archaeological cultural unit that used local and regional raw materials: in Northern Hungary this metarhyolite, in Moravia the Krumlovský les type chert, in Western Slovakia the Carpathian radiolarite

(Kaminská *et al.*, 2011; Mester 2014). Moreover, this metarhyolite was used by other Middle and Upper Palaeolithic industries in Northern Hungary: Mousterians, and Micoquians (Ringer 1983; Mester 2004; Markó 2009). For this reason, we propose to name this raw material in the publications by the combination of its archaeological and petrographic names: "quartz-porphyry (metarhyolite)". The sedimentary siliceous rocks in the Mesozoic formations are radiolarites and radiolarian cherts of Middle and Upper Jurassic age: Csipkéstető and Bányahegy Radiolarite formations, Bükkzsérc Formation (Pelikán 2005: 198–199, 201–202). The colour of these radiolarites varies from red to grey. The Bükkzsérc Formation contains black chert which is usually named in the archaeological literature as hornstone (Pelikán 1986; Biró 2010). By the former suggestion, we propose to use also the combination of archaeological and petrographical names in this paper: "hornstone (black chert)".

During the Palaeogene period, the mountains ascended and descended several times (Pelikán 2005; Szederkényi *et al.*, 2012). As a result, while these formations were covered by the Pannonian Sea, shallow marine sediments (marl, clay, sand) were deposited, and extensive erosional processes took place, resulting in denudation when they were raised. During the Neogene period, intensive volcanic activities took place on the border of the Pannonian Sea. Other members of the North Hungarian Range (Börzsöny, Mátra, Tokaj mountains) were formed by this volcanism (Harangi 2001; Seghedi *et al.*, 2005; Harangi and Lenkey 2007). On the foothills of the mountains, extended rhyolite tuff bodies were deposited in this period (Felnémet, Gyulakeszi, Harsány Rhyolite Tuff formations). Silica-containing hot water erupted during linked post-volcanic processes, causing metasomatic silicification in the lake and lagoon strata. These processes formed a high variety of siliceous rocks: silicified sandstone, silicified marlstone, silicified tuff, geyserite, limnic quartzite/chalcedony/opal (Szekszárdi *et al.*, 2010; Přichystal 2013; Mester and Faragó 2016). Because of the difficulties in determining exactly the petrographic characteristics of these latter rocks without detailed analyses, we use the term "limnosilicites" for them, following A. Přichystal's (2010) proposition (Mester and Faragó 2016). Several raw material types in the Bükkalja region belong to this group of rocks. The sources of silicified sandstone which are known at Egerbakta is also named "Mátraháza–Felnémet type opal" (Biró and Pálosi 1985). The so-called "silicified marlstone" was identified by Vendl (1940), however, its sources have not been located yet within the territory of Bükkalja (Kozłowski and Mester 2003–2004). The limnosilicites that come from the known source near Kács (Schréter 1916; Biró and Dobosi 1991: 39, 121) are very varied in terms of colour and texture.

In this paper, we deal only with selected raw materials for which we have new petrographic data, field observations concerning occurrences and archaeological data of prehistoric use: the silicified sandstone of Egerbakta, the radiolarite and hornstone (black chert), the silicified marlstone and the quartz-porphyry (metarhyolite). The new petrographic data for these raw materials have been obtained by thin section analysis at the Laboratory for Applied Research of the Hungarian National Museum. The samples were collected during fieldwork in the framework of the ongoing research project (NRDI Fund grant no. K 124334). Archaeological data of published sites concerning the prehistoric use of these raw materials come from our direct lithic analyses or literature.

RESULTS

Field observations

In the framework of the ongoing research project, field surveys have been undertaken for verifying already known siliceous rock occurrences and looking for new ones (Mester and Faragó 2013). The documented occurrences were categorized according to Turq's source types (Turq 2000; 2005). Until now, we have not observed the primary autochthonous type of source of radiolarite in the mountains. However, an outcrop with red radiolarite lenses embedded in limestone was observed at Bánya-hegy hill near Répáshuta (Bányahegy Radiolarite Formation; Fig. 2:1). But the lenses were compressed by metamorphic processes (Pelikán 2005: 199) and, thus, were not suitable for knapping (Fig. 3). Similarly, black cherty layers were documented in limestone at Hódos-hegy hill beneath Patkó-sziklák cliffs near Bükkzsérc (Bükkzsérc Formation) in an abandoned modern quarry (Fig. 2:2). The layers showed a huge amount of cracks inside which makes the material from it unfavourable for knapping (Fig. 4). Macroscopically similar black chert blocks were picked up from a nearby modern dirt road which could represent a secondary autochthonous source type as eroded slope sediments, but the blocks are dispersed (Fig. 2:3). Small grey and greenish-grey blocks of siliceous rock were sampled from slope sediments on the territory of the Csipkéstető Radiolarite Formation near Felsőtárkány (Fig. 2:4). Thus, the possibility of secondary autochthonous sources arose for this raw material too. On the contrary, outcrops of the silicified sandy and tuffic sediments were documented on the top of Tó-hegy hill near the village of Egerbakta (Felnémet Rhyolite Tuff Formation; Pelikán 2005: 216; Fig. 2:5). Blocks outcropping on the surface could be exploited, even knapped flakes were recorded at the source (Fig. 5). Some of them are of Middle Palaeolithic character at first appearance. The same concerns the outcrops of the quartz-porphyry (metarhyolite) in the eastern part of the mountains between Bükkszentkereszt and Bükkszentlászló villages (Bagolyhegy Metarhyolite Formation; Fig. 2:6). Large blocks outcrop on the slope of Bagoly-hegy hill, as well as fragments of different sizes, can be found on the surface (Fig. 6:A) and in the streambed in the nearby valley (Fig. 6:B).

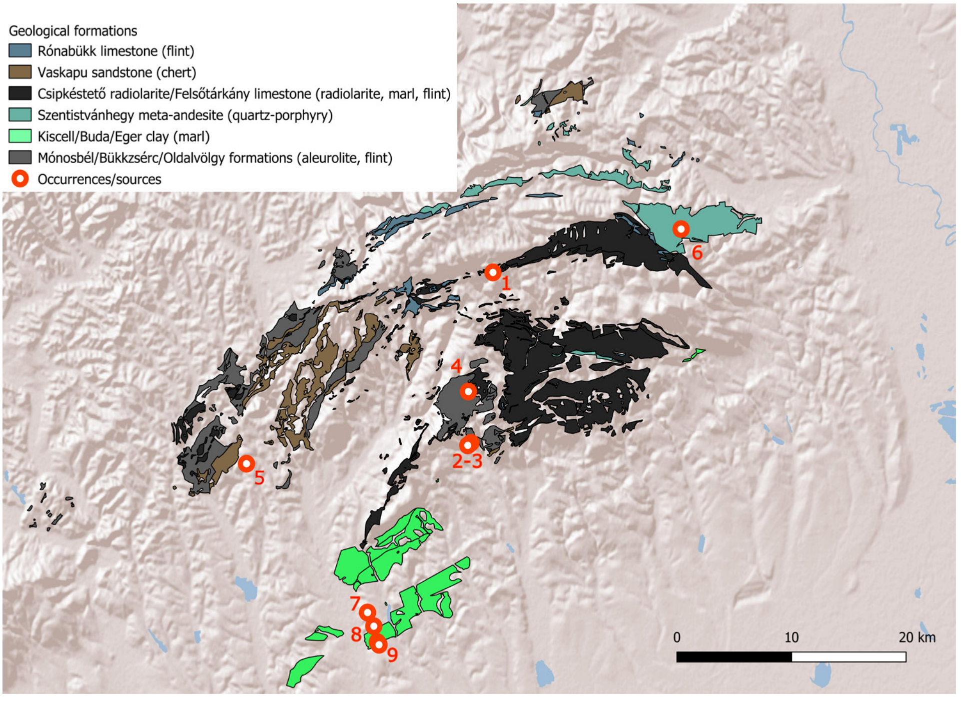

Fig. 2. Geological formations in the Bükk Mountains with siliceous rocks according to the geological map of the Mining and Geological Survey of Hungary 1: 100 000 (https://map.mbfsz.gov.hu/fdt100/). In this scale, the Szentistvánhegy Metaandesite Formation contains the Bagolyhegy Metarhyolite Formation, as well as the Felsőtárkány Limestone Formation, contains the Bányahegy Radiolarite Formation, distinguished in scale 1: 50,000. Sampled localities: 1 – Bánya-hegy hill; 2 – Hódos-hegy hill, quarry; 3 – Hódos-hegy hill, dirt road; 4 – Csipkés-tető hill; 5 – Tó-hegy hill; 6 – Bagoly-hegy hill; 7 – Kőporos-tető hill; 8 and 9 – dirt road and wineyard near Ostoros. CAD by N. Faragó.

During the fieldwork, we regularly observed smaller or bigger blocks or pebbles of different siliceous rocks, including radiolarite, silicified marlstone and limnosilicites, on the dirt roads (Fig. 7:A) and in the vineyards (Fig. 7:B) of the Bükkalja foothill area (Fig. 2:7–9). Their presence should be related to the erosional and planation processes of the formation of the foothill region during the Pliocene and Pleistocene (Pinczés 1980; Pinczés *et al.*, 1993; Karátson 2006). Along the North Hungarian Range, this formation is due to the continuous uplift of the mountainous area parallel to the subsidence of the basin (Great Hungarian Plain). As a consequence, these occurrences could be considered sub-allochthonous sources in Turq's categorization.

Fig. 3. Radiolarite lenses in limestone at Bánya-hegy hill near Répáshuta. Photo: N. Faragó.

Fig. 4. Black cherty layers in limestone at Hódos-hegy hill near Bükkzsérc. Photo: N. Faragó.

Fig. 5. Outcrop of silicified sandstone at Tó-hegy hill near Egerbakta. Photo: N. Faragó.

Petrography

During the study of archaeological and unworked materials, we observed a certain variability within rock types. In particular, the silicified sandstone of Egerbakta has varieties by the grain size of the silicified sediment suggesting different conditions of formation (sand or tuff). In the case of the silicified marlstone, there are two variants: one with black veins in the matrix, and another with patches (MP13 and MP14 in Mester 2004). Pelikán (1986) pointed out that the samples examined by Vendl (1940) in thin sections and classified as hornstone (chert) or chalcedony can be reinterpreted partly as radiolarite. Regarding these problems, we decided to carry out detailed petrographic analyses. The first examinations concerned the four macroscopic variants of the silicified sandstone of Egerbakta, the radiolarite of the Bükk Mountains, the local black chert (hornstone) and the silicified marlstone.

Fifteen rock samples from nine sites in the Bükkalja region have been selected for petrographic study. All but two were collected during field surveys, the two others were chosen from the unworked flakes of the surface material of the Andornaktálya--Gyilkos open-air site (Table 1). The samples were subjected to macroscopic examination, thin section analysis, rock identification, fabric description, and compositional analysis. Following the Prehistoric Ceramic Research Group criteria (PCRG 2010),

Table 1. Raw material samples selected for petrography.

Sample	Locality	Archaeological name	Petrographic name
1	Bükkzsérc-Csipkés-tető hill	hornstone	radiolarite
2	Bükkzsérc-Csipkés-tető hill	radiolarite	silicified aleurolite
3	Bükkzsérc-Hódos-hegy hill, from dirt road	hornstone	radiolarite or radiolarian chert
4	Bükkzsérc-Hódos-hegy hill, from dirt road	hornstone	partially transformed radiolarite
5	Bükkzsérc-Hódos-hegy hill, quarry beneath Patkó-cliffs	black chert	silicified limestone
6	Bükkzsérc-Hódos-hegy hill, quarry beneath Patkó-cliffs	black chert	silicified limestone
7	Egerbakta-Tó-hegy hill	silicified sandstone,variant 3	diatomaceous detritic chert
8	Egerbakta-Tó-hegy hill	silicified sandstone,variant 4	silicified sandstone
9	Egerbakta-Tó-hegy hill	silicified sandstone,variant 4	silicified sandstone
10	Egerbakta-Tó-hegy hill	silicified sandstone,variant 1	diatomaceous detritic chert
11	Egerbakta-Tó-hegy hill	silicified sandstone,variant 1	silicified sandstone
12	Egerbakta-Tó-hegy hill	silicified sandstone,variant 2	silicified sandstone
13	Eger-Kőporos-tető hill, southern slope	silicified marl	silicified aleurolite with radiolarite lenses, bands
14	Andornaktálya-Gyilkos site	silicified marl	radiolarite
15	Andornaktálya-Gyilkos site	silicified marl	radiolarite

a petrographic examination was performed to identify the volume-percentage ratio of the components, their size categories, grading, and roundness. Percentage by volume ratios: dispersed (less than 3%), few (3–9%), medium (10–19%), many (20–29%), very many (30–39%), abundant (more than 40%). Extremely fine (<0.1 mm), fine (0.1–0.25 mm), medium (0.25–1 mm), coarse (1–3 mm), and very coarse (>3 mm) are the size categories. Components are classified according to their size: badly graded, medium graded, well-graded, and very well graded. Aggregate roundness can be angular, slightly angular, somewhat rounded, rounded, and well rounded.

The full rock analysis report is published on the Archaeology Database of the Hungarian National Museum (https://archeodatabase.hnm.hu/en/node/62012), here we describe the macroscopic and microscopic study of the rock samples previously assumed to be hornstone and silicified sandstone.

Fig. 6. Blocks of quartz-porphyry (metarhyolite) at an outcrop (A) and in the streambed (B) near Bükkszentlászló. Photo: Zs. Mester and N. Faragó.

Fig. 7. Blocks and pebbles of different siliceous rocks found on the dirt road (A) and in the vineyard (B) near Ostoros. Photo: Zs. Mester.

Sample 1: radiolarite (Fig. 8:A)

The sample was collected at Csipkés-tető hill in the slope sediment of the road cut between Felsőtárkány and Bükkzsérc villages.

Macroscopically, it is a large rock that fractures in a clam-shell or splintery way, with a dull sheen on the fracture surface, and dark greenish-grey on the unaltered surface. The worn surface has a yellowish-brown, somewhat reddish hue, and a limonitic crust with a greasy-greenish feel, the crust is not separated from the rock body. The rock is punctured by cracks, with limonitic-coloured surfaces along the crevices. The rock has a subtle banding pattern.

By microscopic examination, it is a very fine-grained clayey-aleuritic clastic sedimentary rock with more than 50% radiolarian remnants (predominant grain size 0.03 mm). The majority of the rock is made up of radiolarian bands, with patches or distinct bands of more clayey-aleuritic material interspersed throughout. The amount of radiolarian remnants is low in clay-aleuritic locations, and the parent material is less recrystallized. The radiolarian remains (0.05–0.14 mm) are primarily circular or

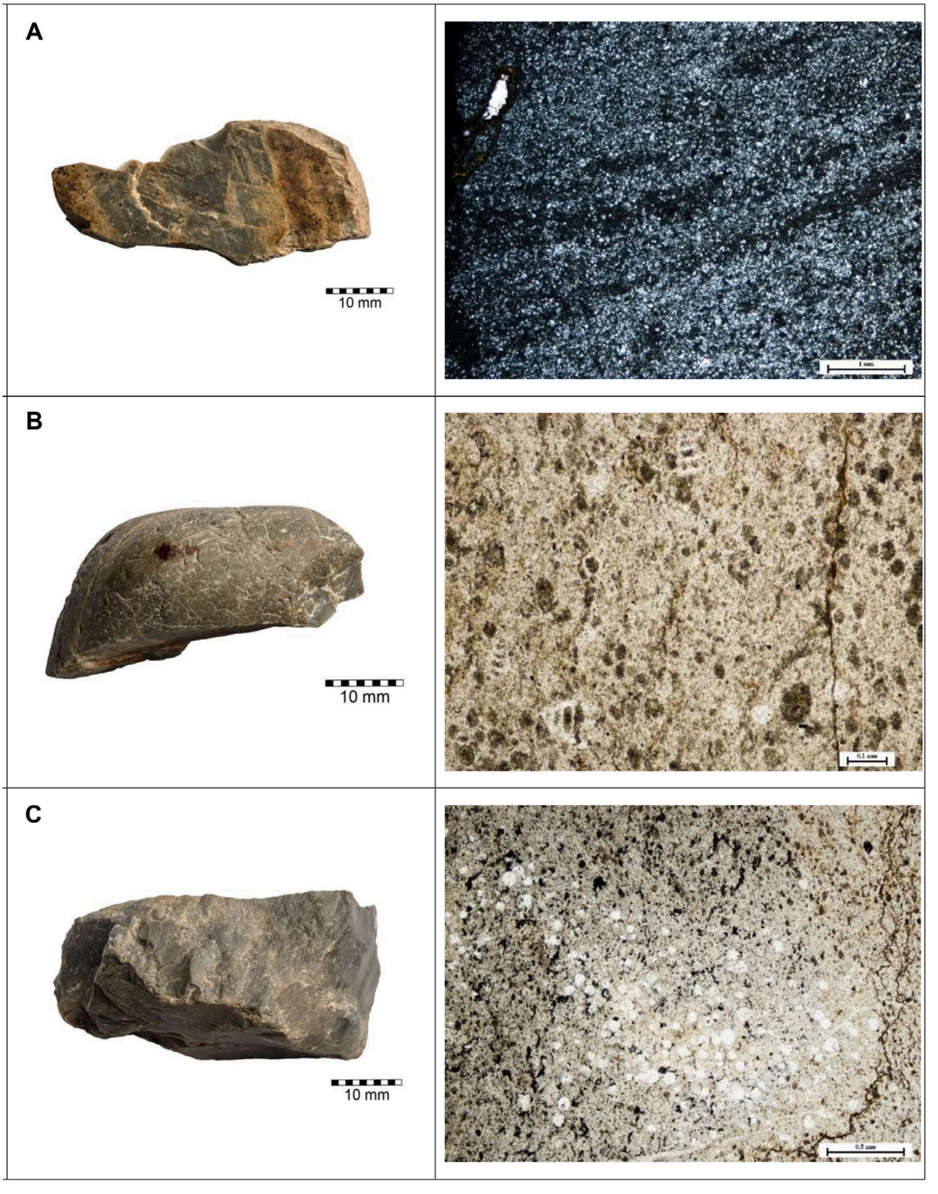

Fig. 8. Raw materials analyzed macroscopically and in thin section (see Table 1). A – Sample 1; B – Sample 3; C – Sample 4. Photos: R. K. Péter, O. Viktorik and L. Máté.

irregularly shaped portions of chalcedony or microcrystalline silica material, which are entirely in the clay-aleuritic areas but more fractured in the radiolarian-rich parts. A radiolarian skeleton piece has also been discovered.

The matrix is mostly made up of micro- and cryptocrystalline silica and clay minerals, with some chlorite thrown in for good measure. It contains a fewer amount of clay minerals than Sample 2 which was collected likewise at the same location. Monocrystalline quartz, mica flakes (sericite, muscovite, 1 discoloured), chlorite flakes, rutile (max. 0.09 mm), tourmaline (greenish-brown, greenish-yellow, 0.03–0.04 mm), opaque minerals (3%, locally limonitised/hematitised), unrelated feldspar carbonate single crystals and mineral clusters, organic matter (1N: opaque or brownish dark grey, irregularly shaped, diffuse-edged clusters, patches).

Limonitic, chloritic, and clayey post fractures have a directional angle of around 40° to the layers. Green chlorite formations can be found in cracks surrounding radiolarian relics in one location. The material is saturated in the vicinity of another limonitic-chlorite vein, and the radiolarian remains are saturated to varying degrees: some are merely coated on the outside, while others are filled on the interior. Fractures were found to be related to feldspar carbonate mineral clusters and solitary crystals (0.02–0.2 mm). The feldspar clasts' crystals sometimes exhibit an abraded outline, which could indicate disintegration. In addition, the sample has a feldspar inclusion around which numerous minerals have precipitated: limonite, chlorite, siderite, and zeolite.

Sample 3: radiolarite or radiolarian chert (Fig. 8:B)
The sample was collected on a dirt road under the Hódos-hegy hill near Bükkzsérc village.

Macroscopically, it is a large rock that fractures in a splintery, slightly fragmented manner with slightly oily fracture surfaces, dark greenish-grey on the unaltered surface. The worn surface is yellowish greyish-green in colour, somewhat glazed, oily, and only mildly earthy to the touch, and it is not separated from the pure rock surface. The rock is laced with cracks, the surfaces of which are limonitic in colour.

By microscopic examination, it is a very fine-grained clayey-aleuritic clastic sedimentary rock (predominant grain size <0.03 mm) containing more than 50% of radiolarian remnants in various states of preservation. Lenses with significantly weaker clay mineralization and chalcedonic radiolarian remnants are observed in addition to the more clayey section of the rock.

The radiolarian remnants are predominantly chloritic-sericitic internal fillings with no external cortical skeletal remains and range in size from 0.05 to 0.16 mm.

Those with exterior cortical skeletal remains of chalcedony material, the bulk of which are chloritic-sericitic and some with micro-cryptocrystalline silica interiors, are far less common. Only chalcedony radiolarian remnants, the majority of which are not intact, are found in a 1.3 mm long lens, which is poorer in clay fossils. Even if entire, chalcedonized radiolarian remains are rare in the clayey sections of the chloritic-sericitic remains. The chloritic-sericitic radiolarian remnants are also penetrated with limonite near the limonitic veins.

Micro- and cryptocrystalline silica, as well as clay minerals, make up the substance. Monocrystalline quartz, mica flakes (muscovite, sericite), chlorite, rutile, titanite, leucoxene, hematite, tourmaline (greenish-yellow to brownish-yellow 0.02–0.05 mm), zircon, opaque minerals (<1%; locally limonitised/hematitised, sometimes leucoxene?), and organic materials are also found (1N: opaque or brownish dark grey, irregularly shaped, diffuse-edged clumps, patches). The sericites in the clay-aleurithic matrix are arranged in a directed pattern, and the matrix brightens in specific directions as the slide is turned. (Note that this is not the case for samples 1 and 4, and only to a lesser extent for sample 2.)

The rock body is littered with stylolites containing limonite, chlorite, and sericite, as well as limonitic fissures and quartz-filled fissures. Limonitic veins go through quartz-filled fissures, forming ridges. Quartz is the first mineral to be deposited on the vein wall in the quartz vein, and the inner half of the vein is covered in limonitised mica and chlorite. Patches of pale brownish residues of once biotitic clay that afterwards became chloridized can be seen near the quartz grains, but also elsewhere in the matrix.

Sample 4: partially transformed radiolarite (Fig. 8:C)

The sample was collected on a dirt road under the Hódos-hegy hill near Bükkzsérc village.

Macroscopically, it is a large rock with a greenish tint to dark grey on a unaltered surface, with a clam-shell, flaked fracture, dull, slightly oily fracture surfaces. The aged surface is brownish grey with a reddish tinge and a greasy, glaze-like texture that does not separate from the unaltered stone. Darker grey patches and streaks punctuate the slightly worn, brownish-grey surface. Cracks in the rock can also be noticed, some of which have limonitic staining along the surface and others that have small cavities.

By microscopic examination, it is a very fine-grained clayey-aleuritic clastic sedimentary rock (predominant grain size <0.03 mm), including more than 50% of radiolarian remnants preserved in diverse forms (0.04–0.13 mm). Lenses with significantly weaker clay mineralization and chalcedonic radiolarian remnants are observed in addition to the more clayey section of the rock.

The majority of the rock is brownish-greenish in colour, with irregular patches of lighter grey (1N) material. Two varieties have been identified. One is enriched in chalcedony-filled radiolarians (chalcedony radiolarian lenses), and it is surrounded by the other development, in which greyish brown (1N) clumps of microcrystalline and cryptocrystalline silica (XN) filling the interiors of former radiolarian skeletons become dominant, black-coloured, tufted, or mossy or mottled organic matter, as well as sporadic amounts of chalcedony-filled radiolarians. In the grey areas, there is less sericite.

Clumps of what used to be/are filling the inside of previous radiolarian skeletons can also be seen in places with a brownish-greenish tint (1N), but they are red, reddish-brown, or greenish-brown (limonitic-chloritic). Chalcedony-filled radiolarians can also be found here, but only in irregular clusters. Limonitic veins pervade these brownish-green sections, which may be responsible for the brownish-green colouration of this section of the rock.

Due to the greater organic matter concentration, there are lenses and patches of slightly darker-coloured (1N) material in both the brownish-green and grey sections, primarily in the form of deeper staining.

Microcrystalline and cryptocrystalline silica, as well as clay particles, make up the matrix. Monocrystalline quartz, mica flakes (muscovite, sericite), chlorite, hematite, zircon, rutile, titanite, tourmaline (yellowish-green, greenish-yellow, brownish yellow, bluish greenish-yellow, 0.03–0.04 mm), opaque minerals (3–5 percent, often limonitised/hematitised), organic matter (1N: opaque or brownish dark grey, irregularly shaped, diffuse, non-radiolarian in origin).

The chalcedony-filled radiolarians' placement reveals a sense of directionality, with the limonite vessels' and the coarctation's directions running at distinct angles. The coarsening veins divide the orientation at 60°, but the limonitic fissures are mostly perpendicular to it. The earlier styolitic surfaces, running roughly perpendicular to the original stratigraphy, were subsequently infiltrated with limonite.

Samples 14 and 15: radiolarite (Fig. 9:A)

The samples were selected from the unworked lithic material of Andornaktálya--Gyilkos open-air archaeological site.

Macroscopically, it is a huge boulder with a shelly to splintery fracture, greenish-grey on the unaltered surface. The worn crust is reddish-brown in colour, glaze-like, and oily to the touch, and is not separated from the pure rock surface. The fissures in the rocks are limonitic in hue, and they cleave the rocks. Small voids can also be visible along some of the fissures.

By microscopic examination, it is a very fine-grained clayey-aleuritic clastic sedimentary rock (predominant grain size <0.03 mm) with radiolarian bands and lenses,

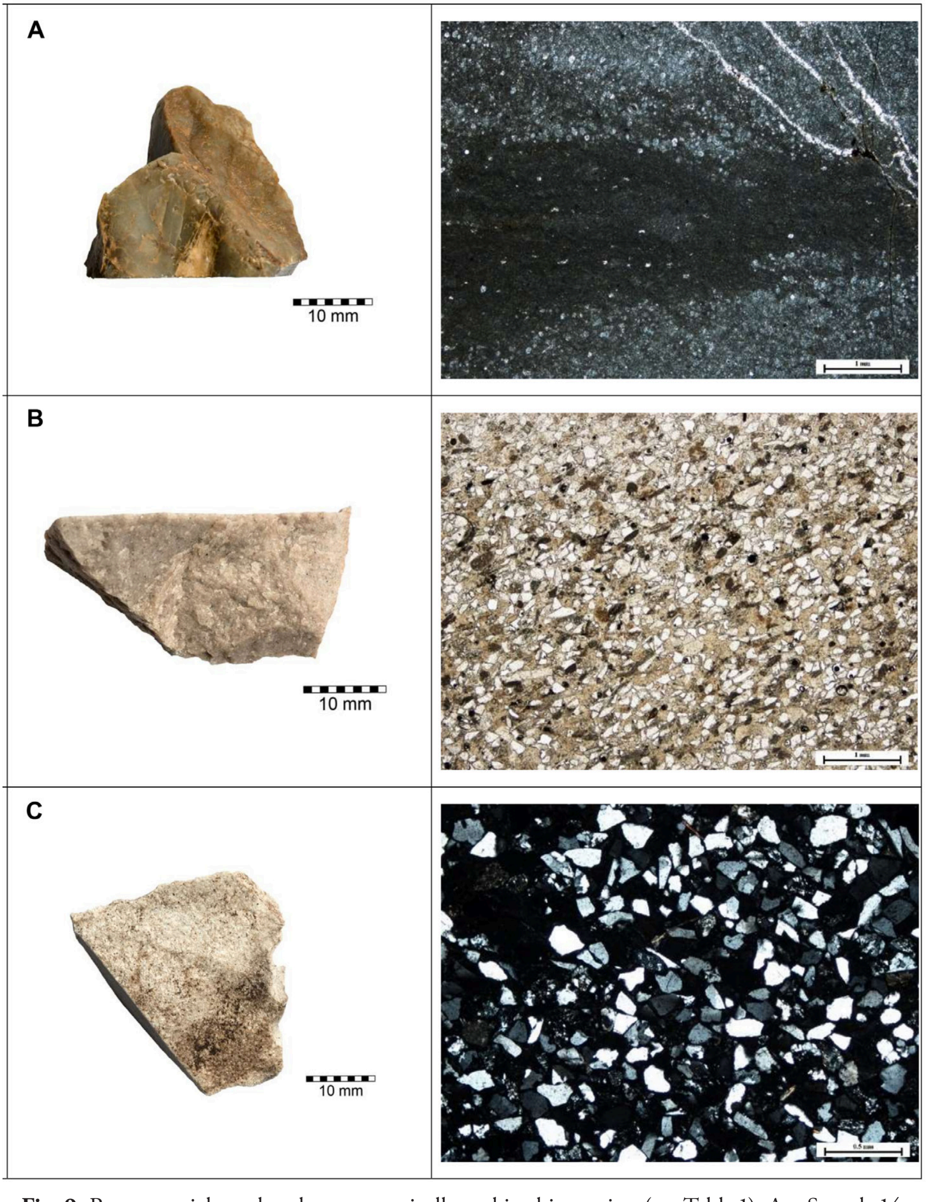

Fig. 9. Raw materials analyzed macroscopically and in thin section (see Table 1). A – Sample 14; B – Sample 9; C – Sample 11. Photos: R. K. Péter, O. Viktorik and L. Máté.

containing more than 50% radiolarian remains. A smaller region of a more clayey--aleuritic layer with sporadic to low levels of radiolarian remnants may be found in Sample 14. The radiolarian remnants (0.04–0.11 mm) are made of chalcedony and have circular to largely elliptical sections, with some radiolarians' cortical skeletons intact. The ellipses' longitudinal axis defines a direction that is at a 55° angle to the initial stratification. The ellipsoidal sections indicate that they were bent by pressure, which is most likely why the rock fabric looks to be a little blurry. Only minor patches of cryptocrystalline silica and clay fossils are found in Sample 15, which is predominantly microcrystalline silica.

Microcrystalline and cryptocrystalline silica, as well as clay particles, make up Sample 14. Monocrystalline quartz, mica flakes (muscovite, sericite), chlorite, tourmaline, rutile, zircon, and zoisite/clinozoisite have also been discovered, as well as opaque minerals (<1% outside the veins, also occur in small nests, possibly limonitised/hematitised), carbonate feldspars (calcite?, also in the parent material and quartz, single crystal along with quartz, small nests), organic matter (1N: brownish dark grey, irregularly shaped, diffuse-edged clusters, patches, locally carbonated or clay mineralized). As accessories, tourmaline, rutile, zircon, titanite, hematite, and carbonate minerals are found in Sample 15.

The rock body is laced with limonitic and opaque mineralization, as well as siliceous fissures. The amount of limonite in the limonite and opaque mineral veining is various. The silicic veins are nearly parallel to one another, forming a 45° angle with the initial layers. Some limonitic veins run parallel to the siliceous veins, whereas others run perpendicular to the siliceous veins. Smaller styrolitic surfaces can be seen running nearly parallel to the initial layering, where limonite was deposited.

Samples 8, 9, 11 and 12: silicified sandstone (Fig. 9:B and C)

The samples were collected on the hilltop of Tó-hegy hill near Egerbakta village.

Macroscopically, the unaltered surface of the rock is somewhat yellowish to whitish-yellowish shades of light grey, with a flaky, shell-like fracture. Except for Sample 12, where the fracture surfaces are dull, earthy, slightly gritty to the touch, and occasionally crumbly, the fracture surfaces are oily. On the dazzling surface, tiny sheets of colourless crystals shine through, along with a few black crystals and a narrow band of greyish colour. The aged surface feels slightly abrasive to the touch, not lustrous, and has the same colour as the unaltered surface, with some blackish discolourations. The aged surface of Sample 12 is slightly darker in colour, gritty to the touch, earthy in texture, crumbly at times, and has blackish-brownish discolourations.

By microscopic examination, there are certain areas where grain orientation is weak, and grains are not evenly dispersed throughout the material in Sample 8. The arrangement of elongated and platy minerals in sample 9 indicates irregular orientation. Sample 11 seems to have "layers". The components are more densely arranged in one layer of the rock, and the rock is more granular here, in other layers, they are more sparsely arranged, there is more volcanic sediment, and the mica appears to be aligned.

With scattered fossils (siliceous sponge, diatomite), quartz, and muscovite, the matrix is isotropic, opalized, and silicified. Samples 8 and 9 have fewer fossils than Samples 7 and 10. Siliceous sponges are the most common fossils, but radiolarians and diatoms have also been discovered. Opal/chalcedony grain inclusions can be seen in some instances.

Angular, splintery, infrequently abraded debris grains with a predominant grain size of 0.1–0.3 mm (max. 0.7 mm) are seen in the material. Debris grains make up around 50–60% of the total, with thinner and denser sections, due to their unequal distribution. Metamorphic rocks make up the majority of the abraded grains. Quartz (volcanic origin, siliceous, spheroidal, and deep-formed with a more isometric appearance), transformed, faded biotite, muscovite, fine crystalline silica, microcrystalline silica, chalcedony, polycrystalline quartz, altered rock fragments, rock fragments with equilibrium crystallization, quartzite, metagranitoid, muscovite can be observed among the clastic components. Rutile, zircon, tourmaline, and opaque minerals occur as accessories.

The deteriorated grains have undergone severe alteration and have consequently been assimilated (alteration) into the sandstone, as indicated by of altered biotite. The most common mineral found in the rock is quartz, while feldspars are rare.

Samples 7 and 10: diatomaceous detrital chert (Fig. 10:A and B)
The samples were collected on the hilltop of Tó-hegy hill near Egerbakta village.

Macroscopically, the rocks have a subtle greenish-yellowish tinge to light grey on the unaltered surface, and a flaky, shelly fracture, and greasy fracture surfaces. Sheets of very small, colourless crystals glitter on the unaltered surface, together with a few black crystals. In Sample 7, there is no worn surface or cracking visible. On the unaltered surfaces of Sample 10, a faint or somewhat darker reddish-brown staining may be seen. The worn surface – which may have been a crack – is only slightly rougher to the touch than the unaltered surface, not lustrous but matching or slightly darker in colour, with blackish discolouration, more microscopic black crystals, and slightly larger than the unaltered surface. The worn surface is not separated from the pure rock body. In Sample 7, a small band of off-white to brown "interlayer" may be seen.

By microscopic examination, the rock has a weak orientation due to the matrix's distinct colouration (1N). Local orientation is widespread in platy minerals (mica), but not in the rock fabric. In comparison to Sample 7, Sample 10 is more directed. It's

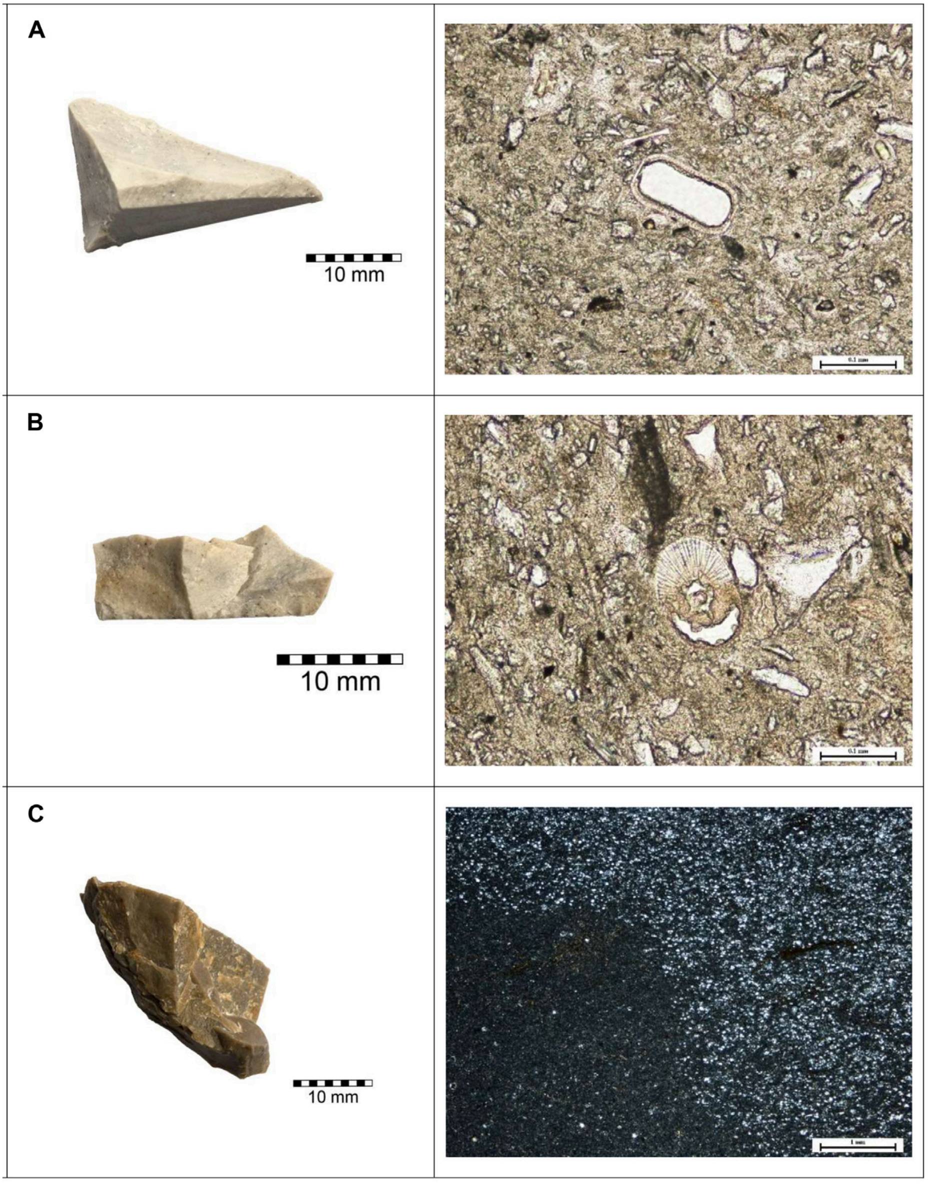

Fig. 10. Raw materials analyzed macroscopically and in thin section (see Table 1). A – Sample 7; B – Sample 10; C – Sample 13. Photos: R. K. Péter, O. Viktorik and L. Máté.

very fine-grained (<0.03 mm), isotropic, opalized, silicified, matrix-rich, and contains quartz and muscovite. The source material contains angular, siliceous debris grains, as well as fossils (a few radiolaria, siliceous sponge, and diatoms), all of which could be lens enriched. The majority of the debris is 0.07–0.3 mm in size (max. 0.6 mm). Quartz (volcanic, splintery, flaked), polycrystalline quartz, muscovite, microcrystalline silica, chalcedony, volcanic glass, quartzite, micritic limestone pieces, opaline-edged shards, faded biotite, and hematite inclusions make up the debris grains, which range from 5% to 7%. More fine crystalline rocks can be found in Sample 7. Tourmaline, rutile, titanite, zircon, and opaque are examples of accessory minerals.

This rock could be limnic-lagoonal silt with tuffaceous debris deposited in it, as well as a calm aquatic environment where muscovites could have settled.

Sample 13: silicified siltstone with radiolite lenses, bands (Fig. 10:C)
The sample was collected on the dirt road on the southern slope of Kőporos-tető hill, near Eger-Kőporos's open-air archaeological site.

Macroscopically, it is a massive rock with a shell-like, slightly splintered-particular fracture. Fracture surfaces are dull, slightly greasy, greenish tinted grey to dark grey on the unaltered surface. The aged surface is brownish grey-brown and has a greasy, glaze-like feel to it that does not separate from the pure rock body. Darker grey patches and streaks punctuate the slightly worn, brownish-grey surface. The rock has a slight banding that can be seen. Cracks in the rock may also be seen, some of which have limonite staining on the surface and others that are filled with white-coloured material.

By microscopic examination, there are radiolarian bands and lenses in very fine-grained clayey-aleuritic clastic sedimentary rocks (predominant grain size <0.03 mm). The presence of radiolarians in the clay-aleuritic region is sporadic. The clay-aleuritic sections and radiolarian-rich parts are similar to those in Samples 1, 2, 3 and 4. The radiolarian remains (0.06–0.11 mm) are round chalcedony sections that are entire in clay-aleuritic areas but fractured in radiolarian-rich areas. Some radiolarians have retained cortical skeletons, while others do not. Limonitic-chloritic-sericitic fill is used to fill the inner half of some radiolarian remnants along with fractures. The clay-aleuritic section also has chloritic-sericitic interiors (radiolarian remnants).

Micro- and cryptocrystalline silica, as well as clay minerals, make up the parent material. Monocrystalline quartz, mica flakes (muscovite, sericite), chlorite, rutile, titanite, leucoxene, tourmaline, epidote? metamorphic or granitoid lithic pieces (0.04 mm), opaque minerals (3–5%, locally limonitised/hematitised), organic matter (1N: brownish dark grey, irregularly shaped, diffuse-edged clasts, patches, locally carbonated or clay mineralised). Parallel and perpendicular to the banding, fissures permeate the rock. Limonite or sericite fills the cracks.

Concluding remarks of the petrographic analysis

Microscopic examination of three samples thought to be hornstones (black cherts) revealed that they are radiolarites. The two samples from the Andornaktálya-Gyilkos archaeological site, originally assumed to be silicified marlstones, were revealed to be also radiolarites. Among six samples thought to be silicified sandstones, two were discovered to be diatomaceous detrital chert. These results indicate that the identification of the varied local raw materials of the Bükkalja foothill region needs thorough petrographic analysis. It is impossible to carry out this analysis for all artefacts collected at archaeological sites. However, establishing a reference collection of identified variants is useful for archaeological investigations.

Taking into account the location where the analysed samples were collected, their geological context can be evaluated. The Hódos-hegy hill belongs to the Bükkzsérc Limestone Formation of Dogger–Early Malm age. The formation is composed of limestone with black chert nodules, and its body is dissected by aleurite-clay layers. It was formed by the partial sorting of flow-off silt so that the formation has a transition to the Oldalvölgy and the Mónosbél Formation. Its key section is located in an abandoned quarry beneath the Patkó-sziklák cliffs (Pelikán 2005: 202). The Csipkés-tető hill belongs to the Csipkéstető Radiolarite Formation. Based on the radiolarian fauna, its age may encompass the interval from the Late Bajocian to the Early Callovian. Two variations of this formation are known, one finely laminated, the other with fragments of varying size scattered or stratified. In the finer areas, shale is characteristic. Its key section is located in the road cut at Csipkés-tető (Pelikán 2005: 201). According to the location of the samples collected at Tó-hegy hill near Egerbakta, the geological context would be the Harsány Rhyolite Tuff Formation, related to the volcanism that took place between Late Badenian and the beginning of the Pannonian of the Miocene (Pelikán 2005: 214). However, the petrographic description of samples 8–12 suggests the Vaskapu Sandstone Formation of Dogger–Malm age (Pelikán 2005: 201). The key section of this latter is located in an abandoned quarry in the valley of the Eger stream. The Kőporos-tető hill in the southeastern part of Eger town belongs to the Gyulakeszi Rhyolite Tuff Formation of the Miocene age (Pelikán 2005: 212), but the sampled rocks can be related much more to the Kiscell Clay Formation of Oligocene age (Pelikán 2005: 207). Of course, the rocks may have been transported to their present position due to an erosional process.

Use at Palaeolithic sites

As already mentioned, research on the Palaeolithic in Hungary started in the Bükk Mountains in the early 20th century. After the evidence for Palaeolithic use had been found at Szeleta Cave (Kadić 1916), systematic excavations were carried out in all of the known cavities of the mountains until the Second World War (Kadić 1934; 1940; 1944; Kadić and Mottl 1938). The archaeological investigations on the foothills started after the War through some excavations (Vértes 1951; Dobosi 1976) and mainly by field survey (Ringer 1983; Fodor 1984). From 2000 onward, this intensified research has been yielding a considerable amount of open-air sites (Zandler 2012). Despite the increasing body of evidence, we can use the data of only a limited number of assemblages because of the uncertainties in chronological and cultural attribution (e.g., Zandler 2012) or the lack of detailed analyses (e.g., Ringer and Mester 2000; Markó 2015; Table 2, Fig. 1).

There is no clear evidence of human occupation from the Lower Palaeolithic in the region. The famous "handaxes of Bársony's house" are big bifacial leaf-shaped tools (Kadić 1934: 17). Both their cultural attribution and chronological position are uncertain (Szolyák and Lengyel 2014). The earliest inhabitants of the region were Neanderthals in the Middle Palaeolithic (Kozłowski 2006), documented in the stratigraphic sequence of Subalyuk Cave, with bone remains of two individuals (Bartucz *et al.*, 1940; Mester and Patou-Mathis 2016). Layers 1 to 6 (from bottom to top) represent the whole stage MIS 5 (Eemian and Early Weichselian, 130–71 ka BP), and layers 7 to 13 correspond to the stage MIS 4 (Lower Pleniglacial of the Weichselian, 71–57 ka BP), while layer 14 to the beginning of MIS 3 (Interpleniglacial of the Weichselian, 57–29 ka BP). In layers 1–7, occupations of human groups belonging to the Typical Mousterian were recorded, while archaeological materials from layers 7–14 are attributed to Quina type Mousterian (Mester 1990). The richest assemblages, respectively from layers 3 and 11, demonstrate their differences in the raw material economy (Mester 2004). The most common rock type used by both industries is the local hornstone (black cherts)/radiolarite, acquired probably in nearby sources. Although no blocks of this raw material have been found in either group of layers, flakes and tools with cortical surfaces suggest big pebbles as the original form of acquisition. The relatively small number of cores can indicate a production mainly off-site. The quartz-porphyry (metarhyolite) was also common for the two Mousterians, however, it was treated differently: the Typical Mousterian users of the site brought debitage products and tools to the cave, while the Quina type Mousterian community produced blanks at the site according to the presence of cores and flakes with natural surface of the block. The only source area of this rock is located about 20 km distance from the cave. The silicified sandstone of Egerbakta was the preferred raw material for the knappers of the Typical Mousterian, they made nice points and side scrapers of it, while those of the Quina type Mousterian did not use it at all, however, they knew this rock according to the presence of some flakes. During fieldwork, we also observed flakes of Middle Palaeolithic character with a patinated/eroded surface at the source lying about 20 km from the site.

Based on typological arguments (Mester 1995), these two facies of the Mousterian had short occupations at Büdöspest Cave also during the accumulation of layer 4 (probably MIS 4). The lithic assemblage unearthed from the layer is largely dominated (86.4%) by the quartz-porphyry (metarhyolite), the sources of which are located about 5 km from the cave. The whole sequence of the stone tool production process is represented, including raw material blocks, cores, blanks and retouched tools. The toolkit contains 20.5% of retouched tools made of other raw materials: half of it is of quartz and quartzite, but it includes a few hornstone (black chert)/radiolarite artefacts too. The cave site probably had a special function.

Among the tools found in layer 4 at Büdöspest Cave, there is an elongated asymmetrical bifacial artefact made of quartz-porphyry (metarhyolite; Kadić 1934: fig. 28). It resembles a *Keilmesser* and seems to be intrusive in the assemblage. It is worth mentioning that this tool fits into the Micoquian-like local Bábonyian industry not only typologically but by its raw material too. Quartz-porphyry (metarhyolite) is a preferred raw material on the open-air sites of this culture (Ringer 1983; Adams 2000). Moreover, this rock type constitutes one of the main raw materials of the Middle Palaeolithic bifacial industries in the Cserhát Mountains, a hundred kilometres from the Bükk Mountains to the west (Markó 2009). At Vanyarc-Szlovácka dolina open-air site, this rock type represents 23.8% of the lithic assemblage (Markó 2007). Although cores have not been found, on-site processing is demonstrated by refitted pieces.

During the Late Middle Palaeolithic and the Early Upper Palaeolithic, the region of the Bükk Mountains seems to have been a very populated area. Several cave sites yielded small assemblages with ambiguous cultural attribution (e.g., Mester 2000a; 2000b). Numerous open-air sites have also been identified in the territory of the foothills, especially in the western part near the modern town Eger, due to intensive field surveys (Zandler 2012). Carrying out archaeological investigations on these sites is difficult because the area belongs to one of the famous wine regions of Hungary. Four sites were excavated by a Polish-Hungarian collaboration project: Andornaktálya-Zúgó, Egerszalók-Kővágó, Eger-Kőporos and Andornaktálya-Gyilkos (Kozłowski and Mester 2003–2004; Kozłowski *et al.*, 2009; 2012; Mester *et al.*, 2021). They are located on hilltops on both sides of the valley of Eger stream. The hilltops were affected by erosional processes during the Upper Pleistocene. The sedimentological analyses of the stratigraphic sequences of Egerszalók-Kővágó and Eger-Kőporos revealed colluvium containing the archaeological material. According to the obtained radiocarbon and OSL dates, the redeposition of the sediments took place at approximately 28–30 ka BP (Kozłowski *et al.*, 2009: 416; 2012: 420).

Table 2. Distribution of selected raw materials from the Bükk Mountains in Palaeolithic and Neolithic assemblages.

Number on the map	Site	Age	Sum of assemblage (pc.)	silicified sandstone of Egerbakta				quartz-porphyry (metarhyolite)				Bükk radiolarite/hornstone			
				raw material	core	debitage product	tool	raw material	core	debitage product	tool	raw material	core	debitage product	tool
1	Subalyuk Cave layer 3	Middle Palaeolithic	758	-	-	9	7	-	-	30	14	-	2	201	27
1	Subalyuk Cave layer 11	Middle Palaeolithic	4328	-	-	3	-	-	45	684	58	-	2	2023	59
2	Büdöspest Cave layer 4	Middle Palaeolithic	697	-	-	-	-	1	21	518	62	-	-	6	4
3	Vanyarc-Szlo-vácka-dolina	Middle Palaeolithic	1368	-	-	-	-	-	-	351	11	-	-	-	-
4	Eger-Kőporos	Middle & Upper Palaeolithic	2208	8	3	136	17	-	1	374	73	11	4	183	20
5	Egerszalók--Kővágó	Middle & Upper Palaeolithic	681	5	3	231	31	3	1	52	30	6	1	22	3
6	Andornak-tálya-Gyilkos	Upper Palaeolithic	1156	-	2	30	1	-	3	30	3	5	7	53	5
6	Andornak-tálya-Zúgó	Upper Palaeolithic	1380	2	-	38	3	-	1	17	2	9	15	11	9
7	Demjén--Szőlő-hegy III	Upper Palaeolithic	81	-	-	1	-	-	-	-	-	-	-	1	-
8	Miskolc--Molotov St.	Upper Palaeolithic	142	-	-	-	-	-	5	8	1	-	-	-	-
9	Füzesabony--Gubakút	Middle Neolithic	942	-	3	6	2	-	-	-	-	-	-	-	-

Number on the map	Site	Age	Sum of assemblage (pc.)	silicified sandstone of Egerbakta				quartz-porphyry (metarhyolite)				Bükk radiolarite/hornstone			
				raw material	core	debitage product	tool	raw material	core	debitage product	tool	raw material	core	debitage product	tool
10	Mezőkövesd--Mocsolyás	Middle Neolithic	1398	-	-	3	2	-	-	2	1	-	-	2	-
11	Bükkábrány--Bánya VII	Middle Neolithic	2350	-	-	1	-	2	1	7	-	3	-	6	-
12	Tiszaug--Vasútállomás	Middle Neolithic	26	-	-	-	3	-	-	-	-	-	-	-	-
13	Öcsöd-Kováshalom	Late Neolithic	910	-	-	1	-	-	-	-	-	-	-	-	-
14	Polgár--Csőszhalom (horizontal)	Late Neolithic	12276	-	-	-	-	2	1	4	2	-	-	-	-
14	Polgár--Csőszhalom (tell)	Late Neolithic	6650	-	-	-	-	-	-	3	-	-	-	-	-
15	Aszód-Papi földek	Late Neolithic	3794	-	-	3	-	-	-	-	-	-	-	-	-
16	Pusztataskony--Ledence	Late Neolithic	449	-	-	10		-	-	-	-	-	-	-	-
17	Alattyán--Vízköz	Late Neolithic	40	-	-	2	-	-	-	-	-	-	-	-	-

As a result, the archaeological materials of both sites contain Middle Palaeolithic and Early Upper Palaeolithic components. Based on the technological and typological characteristics, the Middle Palaeolithic is represented by Mousterian, Bábonyian/Micoquian and Jankovichian elements, as well as elements of macroblade industry, and Early Upper Palaeolithic by Szeletian and Aurignacian ones. Although limnosilicite (partly from the Tokaj Mountains) was the most common raw material of the Middle Palaeolithic groups at the sites, the three rock types chosen for this study were used because we were unable to distinguish preferences based on cultural attribution. On the contrary, the macroblade industry of the Initial Upper Palaeolithic preferred the different limnosilicites that originated mainly from the Tokaj Mountains to the east of the sites. They used local rock types such as the silicified sandstone of Egerbakta also. The Szeletian component is dominated by the quartz-porphyry (metarhyolite), not only the bifacial tools but endscrapers were made of it. The Aurignacian knappers made endscrapers and burins at the two sites from limnosilicites and some local raw materials, but they used radiolarite too. At Egerszalók-Kővágó, even long-distance raw materials are present in the Aurignacian component of the assemblage, like Carpathian radiolarite from western Slovakia and flints from southern Poland (Kozłowski *et al.*, 2009: 447).

The dominance of long-distance raw materials is an apparent characteristic of the neighbouring Demjén-Szőlő-hegy III site too (Béres and Kerekes 2021). In this case, 68% of the lithic assemblage (72% of the retouched tools) is made of Carpathian radiolarite. Besides this, local limnosilicites (15%) and silicified marlstone (11%) constitute the basic raw materials of the assemblage. Other rocks, like obsidian, Volhynian flint, silicified sandstone of Egerbakta and radiolarite of the Bükk Mountain are represented by one or two flakes. The industry of the site can be attributed to the Early Aurignacian based on typological arguments.

Similarly, extralocal raw materials dominate the lithic material of the Late Aurignacian site at Andornaktálya-Zúgó (Kozłowski and Mester 2003–2004; Mester and Kozłowski 2014). The "erratic" flint from Silesia (southern Poland) and the Carpathian 1 type obsidian from eastern Slovakia each constitute almost one-quarter of the lithic finds, while local rock types do not reach ten percent each. The most interesting characteristic of this assemblage is that the Silesian flint and the obsidian had been treated by the knappers like local rocks from an economical point of view: all phases of the lithic tool production are present in the archaeological material from cortical flakes of the core preparation to retouched tools as endproducts. On the neighbouring hilltop at the Andornaktálya-Gyilkos site, two occupations of the Early Upper Palaeolithic can be distinguished in the assemblage: a macroblade industry like that at Eger-Kőporos and an Aurignacian one. These units differ from each other in the raw material economy too. The most common raw material was limnosilicite for both, respectively 32.1% and 48.5% for cores, 55.3% and 58.1% for tools (Mester *et al.*, 2021). However, the macroblade industry preferred the Mád-Mezőzombor type, of beige colour and banded pattern, originating from the southern part of the Tokaj Mountains about 75 km to the east, which was unknown to the Aurignacians. This latter used mostly local variants of limnosilicite. The second most frequent raw material of cores of the macroblade industry is the local silicified marlstone (25.4%), while this rock is rare among the cores of the Aurignacian (7.6%). On the other hand, the number of radiolarites and extracarpathian flints increases in the Aurignacian assemblage.

Unfortunately, the archaeological observations and documentation collected during the Miskolc-Molotov Street site rescue excavation in 1959 are insufficient to resolve the many concerns highlighted by this particular lithic assemblage. However, a probably Early Upper Palaeolithic workshop can be reconstructed thanks to the thorough technological and typological analysis that has been carried out recently (Szolyák 2019–2020). The site is located in Miskolc at the foot of Avas hill, situated in the very close vicinity of a limnosilicite source (Hartai and Szakáll 2005). The overwhelming majority of the archaeological material is of local limnosilicite (85.92%). However, the quartz-porphyry (metarhyolite) is also represented by cores, blades and core trimming removals. Moreover, a bifacial leaf-shaped tool was made from this raw material (Szolyák 2019–2020: fig. 16.3). A very similar artefact is published from layer 6 of the Nietoperzowa Cave in Poland attributed to the Jerzmanowician (Chmielewski 1961). The sources of quartz-porphyry (metarhyolite) are located about 10 km from the workshop site.

Use at Neolithic sites

The beginnings of the research on Neolithic knapped assemblages coincided with the intensive research and organised collection of siliceous raw materials in Hungary (Biró 1986; 1987a; 1987b; Bácskay and Simán 1987). It is interesting to note, however, that although the Neolithic assemblages are much more numerous and cover the territory of Hungary more evenly, they do not contain the same raw materials in the same ratio. Individual Palaeolithic assemblages were frequently dominated by raw materials found in the Bükk Mountains, such as quartz-porphyry (metarhyolite), silicified sandstone of Egerbakta, and Bükk radiolarite. During the Neolithic, however, they had a significantly less important role, at least east of the Danube, and were supplanted by various regional and distant raw materials (Biró 1998). So it is perhaps not surprising that systematic research on the raw materials of the Bükk Mountains, except for quartz-porphyry (metarhyolite), has of course been somewhat overshadowed by the radiolarites of the Transdanubian region (Szilasi 2017; Szilágyi 2018) or obsidian (Kasztovszky and Přichystal 2018; Szepesi *et al.*, 2018). However, if we want a more detailed picture of the paleoethnological behaviour of Neolithic raw material procurement, we need to go beyond the dominance of diverse limnosilicite and obsidian varieties, as well as rocks from outside the Carpathians (Table 2, Fig. 1).

From the context of the earliest Neolithic culture, the Körös culture (approximately 6000–5400 BC), we do not know of any assemblages containing lithic artefacts made of raw materials from the Bükk Mountains. However, from the emerging phase of the Alföld Linear Pottery culture, the Szatmár group (approximately 5500–5300 BC), we know of several sites where such stone tools have been found. One of the first sites of this age was excavated at Füzesabony-Gubakút, in 1995 and 1996, on the route of the construction of the M3 motorway (Domboróczki 2003; 2009). It was the first time that the world of longhouses and settlement structures of the emerging Alföld Linear Pottery culture could be explored over such a large area. Many of the settlement phenomena and finds are still awaiting a complete evaluation, but in any case, some preliminary reports on the stone tools that were found have been published (Biró 2002). From there, we know that, in addition to the limnosilicite variants and obsidian associated with the Tokaj Mountains, 11 of the 942 stone tools reported were of the silicified sandstone of Egerbakta. These were practically representative of the whole range of *chaîne opératoire*, as they included cores (three pieces), debitage products (six pieces), and finished tools (two pieces).

The second site of similar age from the Bükkalja region is Mezőkövesd-Mocsolyás, which, like Füzesabony-Gubakút, was also discovered in the 1990s during the construction works of the same motorway, and where we also have published data on the use of the selected raw materials (Kalicz and Koós 2014). Compared to the size of the excavated area and the number of excavated settlement features – five houses and their associated pits and graves – a large amount of knapped artefacts were found (Biró 2014). Of the 1398 finds, ten could be classified as raw materials from the Bükk Mountains. Besides the lack of cores, silicified sandstone of Egerbakta and quartz-porphyry (metarhyolite) tools were also found, three pieces in total, and all the other finds could be classified as debitage products. The other characteristics of the assemblage are identical to those of the two sites mentioned above, such as the dominance of obsidian and limnosilicites from the Tokaj Mountains, and a varied set of blade tools.

In 2011 and 2012, at Bükkábrány-Bánya VII salvage excavations in a lignite mine revealed an early Alföld Linear Pottery settlement. Here also a large area of 3 ha was excavated and numerous buildings, longitudinal pits, and burials were found (Faragó *et al.*, 2015; Füzesi *et al.*, 2021). The associated knapped lithic assemblage consisted of a total of 2350 finds, most of which were made of limnosilicite and obsidian.

The majority of these raw materials originated from the Tokaj Mountains, but several specimens represented the limnosilicite of the Avas hill at Miskolc, the eastern part of the Bükk Mountains. The seven pieces of quartz-porphyry (metarhyolite), nine pieces of Bükk radiolarite, and one piece of silicified sandstone of Egerbakta add to the extensive prehistoric knowledge of the region concerned. These raw materials could not only have had an occasional role, as all three varieties are associated with debitage products, and even a beautifully formed prismatic core of quartz-porphyry (metarhyolite) was found. However, no tools survive from any of the raw materials, only unworked pieces.

We do not have information on the further phases of the Alföld Linear Pottery culture, but an interesting assemblage from the late period, the Szakálhát culture, has been found at Tiszaug-Vasútállomás (Füzesi *et al.*, 2017). Salvage excavations were carried out at the relevant site in 1980, during work on a railway embankment damaged after a flood, and six pits containing pottery and stone tools were recovered from a 100×50 m area. The lithic finds are not very numerous, but they show a more pronounced connection with Transdanubia, the Tokaj, and the Bükk mountains. The raw material of the three tools was also associated with the latter region, all three were of the silicified sandstone of Egerbakta and all three were laterally retouched blades. Evidence of their intensive use was shown by one of the pieces, as it bears sickle-gloss. The dating of the site has raised further interesting questions, as the radiocarbon dates suggest that it is a very late site, partly coeval with the emerging and succeeding Tisza culture (4950–4841 calBC; 5023–4909 calBC).

Moving on to the Late Neolithic, and the Lengyel culture, we have extensive information on the knapped assemblage of Aszód-Papi földek, an iconic site east of the Danube. The half-hectare area, excavated for more than 20 years, has provided a wealth of new information on the spatial distribution, connection, and chronology of Late Neolithic cultures (Kalicz 2008), as well as on many specific details of contemporary life and material culture, including the stone tools used (Kaczanowska 1985; Biró 1998). Although the raw material of the 3794 pieces of knapped stone recovered from the site is very diverse and therefore seemed to be a solid basis for broad research on flint knapping in Hungary and the Carpathian Basin, information is only available on three pieces of raw material from the Bükk Mountains. All three are related to the silicified sandstone of Egerbakta, and all three are unretouched debitage products.

More south of the foothills of the North Hungarian Range, in the Jászság, there is reported information about a surface collection from which similar raw material has been found. Thanks to the fieldwork of Gyula Kerékgyártó in Alattyán-Vízköz, about 40 pieces of knapped stones were collected together with pottery from the Tisza and

Szakálhát cultures (Biró 1998). In addition to the dominance of limnosilicites from the Mátra, two finds made of silicified sandstone of Egerbakta were also recovered from the assemblage, both of which were defined as debitage products according to the technological classification.

The site of Pusztataskony-Ledence also dates to the Late Neolithic, and a large excavation of a Tisza culture settlement of about 5 hectares was found here, also linked to a large development (Sebők and Faragó 2018). The site is unique not only because of the relative size of the excavated area and the lack of a tell but also because of the high proportion of knapped raw materials from outside the Carpathians (Faragó 2021). A further indication of the intensive contact by the community living here over a large area is the ten finds of silicified sandstone of Egerbakta. None of these could be classified as a raw material fragment, core, or tool, yet the debitage products generally indicate the use of raw material.

Only two of the numerous Late Neolithic tell settlements in the Great Hungarian Plain have produced knapped raw materials from the Bükk area. In the first case, an excavation at Öcsöd-Kováshalom in the early 1980s revealed a multi-layered Middle Tisza settlement of outstanding importance, associated with the Tisza culture (Raczky 2009; Füzesi and Raczky 2018). Several studies on the knapped stone tools have been published (Kaczanowska *et al.*, 2009; Kaczanowska and Kozłowski 2015), so the assemblage can be considered relatively well processed, yet only one single piece of debitage product is known from the silicified sandstone of Egerbakta as raw material (Biró 1998). The relevant tell settlement is also interesting because it is relatively close to the previously mentioned Tiszaug-Vasútállomás site, and in addition, they can be considered to be partly contemporaneous.

The second site is Polgár-Csőszhalom, where only the tell settlement and its artefacts were known until the 1980s (Bánffy and Bognár-Kutzián 2007). Thanks to field research and preliminary studies, which can be considered as a fairly continuous process since the 1990s, not only the outer settlement surrounding the tell but practically the whole micro-region have become well researched (Raczky *et al.*, 2015). Several studies have been published in recent years on the knapped stones, providing insights into the highly diverse spatial and temporal behavioural patterns of the former community and the cognitive system behind them (Faragó 2017; 2019). The two parts of the settlement, the tell and the outer settlement, had fundamentally different raw material preferences, but from our point of view, it is the quartz-porphyry (metarhyolite) that is important. Out of more than 12,000 lithic artefacts in the outer settlement, only nine pieces belonged to this category, but they represented all elements of the sequence of the knapping operation (two raw material pieces, one core, four debitage products, and two tools). The picture was not so clear in the tell, but the three debitage products of quartz-porphyry (metarhyolite) proved that the presence of raw material on the site was not accidental.

CONCLUSIONS

The region of the Bükk Mountains is one of the most important regions in Hungary for the study of the life of the Stone Age population. Due to its complex geological history, the mountains and their foothills are rich in different siliceous rocks, including those of Mesozoic sedimentary and Tertiary metasomatic origin, used by prehistoric knappers for lithic tool production (Pelikán 2005). Although the petrographic determination of the raw materials of the archaeological assemblages of some important Palaeolithic sites has been published since the beginning of the research in the region, many questions concerning the petrographic identification and origin of the local siliceous rock types remained open or raised until now.

In the framework of an ongoing project, we are studying the human–lithic resources interaction in northern Hungary, including in the region of the Bükk Mountains (Mester and Faragó in press). For this study, a palaeoethnological approach is applied that encompasses field surveys for mapping siliceous rock occurrences, petrographic analyses for rock identification and study of archaeological lithic assemblages for reconstructing human technical behaviour and raw material economy. In this paper, the results of these studies are presented concerning four selected local rock types: the silicified sandstone of Egerbakta, the radiolarite and hornstone (black chert), the silicified marlstone and the quartz-porphyry (metarhyolite). Except for this latter, little attention has been paid to studying them in detail. The new petrographic analyses have revealed two variants of the raw material from Egerbakta: a silicified sandstone and a diatomaceous detrital chert. This result suggests that they had formed in different conditions. Further field surveys are needed to verify whether their occurrences are separate in the area where small lakes are located too. The other samples turned out to be radiolarites or radiolarian rocks. This work has confirmed what had already been suggested for the hornstones (black cherts), however, it has new consequences for the "silicified marlstone" because of the differences in formation processes. Moreover, the origin and connection of this raw material to a certain geological formation need reconsideration, taking into account that we found blocks of this kind of rock dispersed in the foothill area which suggests the sub-allochthonous source type.

Regarding the prehistoric use of the selected raw materials, archaeological data show some interesting dynamics through the periods of the Stone Age. The OSA model allows us to interpret the data for the palaeohistory of the Carpathian Basin. It is important to note that we use the archaeological denominations of the raw materials for this study because the data are recorded in this conceptual framework. After the new petrographic results, a re-analysis of the lithic assemblages will be necessary.

During the Middle Palaeolithic (MIS 5 to 3), groups of three cultural traditions inhabited the region. All of them had in-depth knowledge about available local siliceous rock occurrences but they had different raw material economies based on different technical behaviour. Both Typical and Quina type Mousterian groups used the large spectrum of rocks for lithic tool production with a preference for the most easily procurable ones: the hornstone (black chert)/radiolarite in the southern part, the quartz-porphyry (metarhyolite) in the northeastern part of the region. Aside from that, they exhibited behavioural differences in approach to some rock types that were recognised but not used (Occurrence in the model), such as silicified sandstone and silicified marlstone for the Quina type Mousterian, and local limnosilicite and porphyric tuff for the Typical Mousterian. This technical behaviour suggests a kind of limited mobility or a less extended territory. On the contrary, the groups of the Bábonyian/Micoquian, characterized by a bifacial toolkit, seem to be much more mobile. Their lithic assemblages testify to an apparent preference for the use of quartz-porphyry (metarhyolite) and certain types of limnosilicites. They obtained these raw materials from larger distances (from Bükk to Cserhát and from Tokaj to Bükk Mountains), up to a hundred kilometres away. Eventually, they had extracarpathian contacts too.

At the beginning of the Upper Palaeolithic, a new attitude appears in the region that is expressed in the increased role of long-distance raw materials. It is likely that the groups of anatomically modern humans (AMH), arriving in the Carpathian basin, had not enough knowledge about local siliceous rock occurrences, on the contrary, they probably had extended network contacts with other AMH groups. The Aurignacian groups in the region almost completely ignored the local sources. Instead, their raw material economy was largely based on extra local rocks, like obsidian, Carpathian radiolarite and extracarpathian flints. The interesting question is the raw material economy of the macroblade industry of the Initial Upper Palaeolithic, preferring selected local and regional raw material types, like the silicified sandstone and the silicified marlstone from the Bükkalja, as well as the Rátka and Mád-Mezőzombor type limnosilicites from the southern part of the Tokaj Mountains. Hunters of the Gravettian and Epigravettian lived farther from the mountainous area. Their sites are located mainly in the river valleys in the basin. However, they knew some sources of better quality raw materials convenient for blade production, like the limnosilicite of the Avas hill in Miskolc.

During the Neolithization of the Carpathian basin, new populations arrived from the Balkans. The Starčevo and Körös groups partly relied on the well-known lithic sources of the southern flint and chert types. In the meantime, they approached the source area of the Carpathian obsidian and started to change their raw material procurement strategies. It seems from the lithic assemblages of the settlements of the Alföld Linear Pottery culture that they became increasingly familiar with the locally available rock types over time. Their raw material economy was based on these limnosilicites and obsidian. Another change in technical behaviour took place during the Late Neolithic when extra local raw material had a more important role, but more in a social than economic sense.

To sum up the above palaeohistory, it is difficult to describe these selected raw materials of the Bükk Mountains as "Palaeolithic only", as was earlier thought. Two of them occur sporadically throughout the Neolithic period. The emergent phase of the Alföld Linear Pottery culture period is indicative of the journey that the forming community may have been going through as it tried to find its place in the landscape (Kozłowski 2009). The dominance of different limnosilicite variants, obsidian, and then long-distance raw materials could not make completely superfluous the experimentation with that of Egerbakta. Although the use of Bükk hornstone (black chert)/radiolarite has disappeared completely over time, the rediscovery of quartz-porphyry (metarhyolite) at Polgár-Csőszhalom means that Neolithic communities were an integral part of their immediate and wider environment (Füzesi 2019). Therefore, the outcrops of raw materials that we have recorded in the Bükk Mountains can be interpreted as true sources of this period too (Mester and Faragó in press).

This is precisely the important lesson of the palaeoethnological approach we promote, as opposed to the provenance approach: to reach prehistoric human behaviour in its totality. From this point of view, it is worth dealing not only with the dominant phenomena that are tangible but also with what is barely detectable or even absent.

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BOOK REVIEWS

Wojciech Brzeziński (ed.), *Kopalnie krzemienia na stanowisku „Za garncarzami" w Ożarowie* [Flint mines at the "Za garncarzami" site in Ożarów], Warsaw 2020, Państwowe Muzeum Archeologiczne w Warszawie, Wydawnictwo Naukowe – Uniwersytet Kardynała Stefana Wyszyńskiego, pp. 280 + CD; 108 illustrations; 28 tables; 60 plates

Reviewed by Hubert Binnebesel[a]

In 2020, the Publishing House of the Cardinal Stefan Wyszyński University in Warsaw and the State Archaeological Museum in Warsaw released a monograph dedicated to a mine site named "Za garncarzami" in Ożarów (Opatów distr., Świętokrzyskie voivodeship). This publication was an outcome of the project aimed at summarising the results of studies carried out in the mining field in Ożarów in the years 1979–1991. It was also an attempt to interpret these results employing modern metholology and available techniques. This publication has filled up the gap in our knowledge of this site, since before its release the results of such research had been announced only as short articles (e.g., Budziszewski 1986; 1997; Budziszewski and Grużdź 2014). As a result, a modern monograph of the site was created, presenting the outcomes of studies in a comprehensive and multi-aspect manner. The research project and releasing of the publication in question were co-financed by the Ministry of Culture and National Heritage, National Institute of Cultural Heritage, and the Local Government of the Masovian Voivodeship.

The monograph starts with a short introduction by Wojciech Brzeziński and Witold Grużdź, where the scholars present the goal that lead them to create this work, and a brief summary of what is to be expected in the following chapters.

The chapter I, entitled "Krzemień ożarowski [Ożarów flint]" is divided into two sections written by Janusz Budziszewski, W. Grużdź and Miłosz Huber. In this part, the authors focus on the question of what the Ożarów flint actually is. They also draw the reader's attention to the issue of the ambiguous meaning of the term "flint". The problem is that most of archaeologists use this term for any sorts of siliceous

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rocks, while researchers specialising in natural sciences distinguish cherts and hornstones, apart from flints. With regard to Ożarów flint, this issue is particularly important, since it is a much diversified raw material. Petrographic analyses revealed that most of the "Ożarów flints" should be called "Ożarów chert". However, in order to avoid unnecessary misunderstandings referring to the proper nomenclature, the authors suggest staying with the traditional name, but at all times keeping in mind that this is only a conventional term.

The following chapter II, entitled "Badania na stanowisku – lokalizacja, budowa geologiczna, zasięg stanowiska oraz stratygrafia obiektów [Research at the site – the location, geologic structure, the site extent and stratigraphy of features]", is divided into three sections written by Maciej T. Krajcarz, J. Budziszewski and Tomasz Herbich. This part is quite varied in terms of its content. The first section (II.1.) by M. T. Krajcarz describes the stratigraphy, geology and geological history of the site in the context of archival studies. These considerations are complemented with the most recent information obtained during a field survey conducted in 2019. An extremely interesting fragment of the chapter is dedicated to the analyses of fillings of shafts based on the drawn documentation from the excavations. Thanks to these studies it was possible to reconstruct the sequence of filling of extraction holes, and establish to which degree the features were backfilled intentionally. In the two following sections, the authors (J. Budziszewski and T. Herbich) present the history of archaeological research (field surveys and excavations) carried out at the site, and their outcomes. A significant fragment dedicated to electrical resistivity tomography analysis sheds a whole new light on the possibilities of application of this research technique. The first investigations in the respect, conducted in the 1980s and 1990s, delivered rather inaccurate results. They were subject to analysis once more in 2019, this time using the archival data combined with the most recent IT and analytical techniques. The results turned out to be much more than satisfactory and allowed establishing the extent of the mining field more accurately, on one hand. On the other, they displayed the possibilities of creating such new models using archival materials.

Chapter III, "Materiał krzemienny [Flint material]" is divided into 7 sections, the authors of which are W. Grużdź, Witold Migal and Katarzyna Pyżewicz. This chapter is the longest in the entire monograph, since it comprises nearly 100 pages. It contains detailed analyses of flint materials, such as cores, blanks, and refittings. Noteworthy is the approach of the authors to the issues discussed there. Instead of employing a classical analytical technique focused on the technology of core preparation and blank production, the scholars rather paid their attention to the reconstruction of the operational chain in order to associate particular artefacts with the flint processing stage they came from, and determine the type of waste products and blanks that were expected to be the result of this processing stage. A significant element of this chapter is also the microscopic analysis of traces left on the artefact surfaces, which provided the grounds for confirmation of macroscopic observations with regard to the application of hard hammerstones for initial preparation of flint and organic tools (retouchers) for more advanced and precise working. Moreover, the scholars succeeded in confirming reliably the purpose for obtaining flint material in Ożarów, indicating that it was to be used for the production of flint sickles.

Chapter IV, "Materiały ze skał niekrzemionkowych [Non siliceous materials]" is relatively short, only 9 pages long. It is divided into two sections written by M. Huber, W. Migal and W. Grużdź. In the course of the studies there were distinguished almost 1,000 specimens of non siliceous rocks, which according to the analysis performed in the field, could have been used by humans, or they might have been a foreign element, not occurring at the site naturally. Ultimately, 93–94% of this collection turned out to be geofacts. The scholars analysed this collection using laboratory techniques to identify the exact raw material they represented. Thanks to this analysis, it was possible to determine that these materials were most likely transported to the site by the continental glacier from Scandinavia. The investigations revealed that most of these specimens were used as hammerstones for flint processing. There is still an unsolved issue of the sandstone slabs found, the function of which has not been discovered until present. They could have been unfinished hammerstones or polishing stones.

The following chapter V is entitled "Fragmenty naczyń ceramicznych z terenu pola górniczego w Ożarowie [Fragments of ceramic vessels from the mine field in Ożarów]". In this chapter its author, Piotr Włodarczak, describes the analysis of all, namely three, pottery fragments found in the mining field in Ożarów. This collection, though very small, turned out to be very useful. One of the fragments was assigned to the older phase of the Corded Ware Culture, which until now had not been associated with the utilisation of Ożarów flint. The other two were linked with the Mierzanowice Culture, for which the utilisation of this raw material had been already confirmed.

Chapter VI, consisting of three sections, is entitled "Analizy środowiskowe [Environmental analyses]". It was written by J. Budziszewski, Alicja Lasota-Moskalewska, Joanna Piątkowska-Małecka, Marcin Szymanek and Magdalena Moskal-del Hoyo. In this chapter one can find information on two artefacts made of deer antler, the function of which has not been established until present. They could have played a role of a lever, retoucher, punch or simply they might have been post consumption waste. This part of the monograph also contains a description of the malacological analysis. Shells of snails recorded at the site indicated a deforested environment covered with bushes. This finding may evidence a landscape typical of mining fields, which confirms, once again, the effectiveness of applying this research method for reconstruction of archaeological sites. In addition, the chapter encloses a section on fragments of charcoal found. Due to the fact that only two fragments in poor condition were found, their contribution to our knowledge about the site must, however, be considered irrelevant.

Chapter VII, "Analiza geometryczno-morfologiczna sierpów z krzemienia ożarowskiego [Geometrical and morphological analysis of sickles made of Ożarów flint]" was written by Kamil Serwatka. The author presents a less popular method used for description of bifacial tools, namely employing the allometric index. This research method revealed that the main criterion that diversified the appearance of sickles is the degree of exploitation of their cutting edges. The analysis covered artefacts coming from five sites. In total, 31 specimens were examined, most of which (as many as 25 pieces) were found at the site Mierzanowice 1 (Bąbel 2013).

Chapter VIII, "Badania eksperymentalne związane z wytwarzaniem sierpów z krzemienia ożarowskiego [Experimental studies associated with production of sickles made of Ożarów flint]" by W. Migal was dedicated, as indicated by the title itself, to the analysis of experiments aimed at producing flint sickles and then, investigating the traces left on the surfaces of these tools and the waste products coming from their elaboration. This experiment was based on the assumption that only mineral hammerstones were used for flint processing, and it aimed at verifying whether it is possible to make a thin bifacial tool without using organic or metal tools, in contradiction to commonly accepted opinions. The experiment was successful and the scholar managed to produce knives/sickles of desired parameters only with the usage of mineral hammerstones (both, hard and soft ones). Moreover, the author confronts, among other things, the statistical amount and weight of flakes and waste products that was left after the flint processing with the results of excavation studies. He also notices that at the site in Ożarów only semi-products of sickles were made since no artefacts associated with the final stage of the sickle production were found there; therefore, their final preparation must have been performed elsewhere, in the nearby workshop or at a settlement. A significant outcome of the experiment was to obtain flakes bearing morphological traces linked with soft organic hammers, e.g. made of antler, while they were actually detached with the use of a mineral hammerstone.

The ninth chapter, "Datowania absolutne i ich prahistoryczny kontekst [Absolute datings and their prehistoric context]" written by J. Budziszewski, W. Grużdź and P. Włodarczak presents the radiocarbon dates obtained, and investigates them in terms of their location and the layers they were found in. These datings confirmed the conclusions drawn from the analysis of ceramic materials, evidencing that the mining field was used in three periods, namely by the communities of the Corded

Ware and the Mierzanowice Cultures. The authors also quote similar datings from the neighbouring mine sites, such as Polany site II, Polany Kolonie site II, Wierzbica "Zele", Radom distr., Borownia, Ostrowiec Świętokrzyski distr. (Schild 1995; Lech *et al*., 2019; Lech and Werra 2019). Furthermore, an attempt was made to correlate the datings from the mine in question with dates obtained from settlements. However, it turned out to be very difficult due to the poor degree of knowledge of settlements of the Mierzanowice Culture.

Chapter X, "Koncepcja czasu i przestrzeni w kulturze mierzanowickiej a Ożarów [The concept of time and space in the Mierzanowice Culture against the background of Ożarów]" by Stanisław Iwaniszewski is an interesting proposition of a wider perspective to investigate the issue of human settlement and a role of mining activity within it. The author made an attempt to reconstruct the microregion inhabited by the communities of the Mierzanowice Culture, employing, among other things, the possible visibility of crucial points in the ancient landscape, as well as the possibility to relocate of human groups in the Neolithic and the Bronze Age. S. Iwaniszewski suggests that the localisation of the mining field could have excluded, to some extent, prehistoric miners from everyday activity of the microregion, since only a small part of population living there could have seen this spot.

The final chapter (XI) is entitled "Wykorzystanie krzemienia ożarowskiego w świetle materiałów osadniczych [Utilisation of Ożarów flint in the light of settlement material]". The author of this part of the monograph is J. Budziszewski. The chapter starts with a short introduction outlining the issue of identification of the raw material from Ożarów. Then, the scholar analyses particular epochs and cultural units in respect of utilisation of Ożarów flints. He notices that until the times of the Corded Ware Culture, this raw material was used only occasionally, since in the closest surroundings of the site there were available Jurassic flints of better quality. A noteworthy part of this text is that discussing the manners of utilisation of Ożarów flint, where the author made an attempt to reconstruct its role in the activity of the community of the Mierzanowice Culture.

The monograph ends with a summary written by W. Grużdź. The scholar briefly summarises the most significant results of studies and analyses, based on which he creates a coherent picture of the prehistoric mine in Ożarów, however, he stresses the fact that there are still many gaps in our knowledge about this site. One of the unsolved issues is the identification of the oldest episode of the mining field exploitation.

The monograph is complemented with a CD containing a digital version of the book and a catalogue enclosing all of the artefacts obtained from the site. A great value of the monograph is the large fragments translated into English and English captions added for all illustrations.

In terms of content, my evaluation of the monograph is very high. As was mentioned at the beginning of this review, this work presents a very comprehensive and innovative approach to the studies upon the prehistoric mining. It is difficult to find methods for analysing artefacts coming from prehistoric mines available in Poland that were not employed in the investigations carried out in Ożarów. One cannot neglect how much attention was paid to the methodology of the studies conducted. Nevertheless, each of the methods is discussed very critically, outlining the drawbacks of its application. My only reservation refers to the specific wording used by the authors, which at some points may seem hermetic and difficult to understand. For instance, in the third chapter, an expression *zgrubne* (in English: *coarse, rough*) is used multiple times with reference to the working of tools or flakes. By intuition, the reader can guess the meaning of this term; however, the authors have defined neither the word itself, nor the source literature where such definition could be found.

In technical terms, the monograph was prepared very nicely, aesthetically and conveniently. A hard cover with a minimalist graphic design immediately gives the impression of a scientific elegance. The large and very readable illustrations and figures help a better perception of the issues discussed. Nevertheless, in this regard, apart from my general very positive reception, I can formulate a few small reservations of editorial nature. Firstly, the great majority of the illustrations are provided with thoroughly prepared and informative captions, containing the description of the specimen presented and its provenance, except for the section III.3, where the captions inform only about the provenance of artefacts, though in great detail. I can understand the concept of demonstration of artefacts coming from particular features, however, in my opinion, these captions lack information on the specific type of the artefact (flake, blade, waste product, etc.). I particularly enjoyed the manner of employing archival drawings, onto which readable boundaries were superimposed (e.g., fig. 3, section II.3), or supplementing them with modern, digital re-drawings placed right below the original, archival sketch (e.g., fig. 10, section II.1.). My next comment is of strictly subjective nature: if the authors decided to make such effort to present most of the drawn documentation in the above-mentioned manner, very legibly and aesthetically, it is incomprehensible, in my opinion, that in some sections the drawings lack any elaboration or they only contain markings of the features, which makes them significantly less readable (e.g., fig. 10, section II.3). It is a bit striking and disappointing that both of these manners of presentation can be found in one chapter, within the same section even. My last remark concerns chapter X. While reading it, I was very surprised not to find an illustrative map, which could help in understanding the perception of the region in question, with the spatial relationships between the sites. Instead, the author attached only a picture with the line of the horizon. Adding a plan of the region under study would be very helpful in better understanding of this very interesting discussion.

In my opinion, this monograph is a very valuable contribution which I sincerely recommend to all archaeologists, not only those interested in the issues of prehistoric mining or the Mierzanowice Culture. Every scholar, especially those engaged in prehistoric studies, can take advantage of reading this publication, mainly thanks to the holistic approach to the issues discussed in it, which includes a very wide range of various analyses and critical viewpoints on the research methods employed. There is one other reason why this work has high value. It proves how comprehensive studies can be conducted if they engage modern and innovative techniques and technologies when almost only archival documentation is available. Last but not least, I would like to note the fact that the book under review aligns well with a certain trend developing presently in Polish archaeology. For a few years we can observe the revival of studies on prehistoric mining. There are new investigations carried out at many sites, including both those previously known, as well as recently discovered ones. Amongst those, one can name the studies in Borownia (Lech 2020), Orońsko site II, Szydłowiec distr. (Osipowicz *et al.*, 2019), or Poręba Dzierżna site 24, Olkusz distr. (Sudoł-Procyk *et al.*, 2021). At the same time, studies on archival materials are carried out, or examining sites using non-invasive methods, such as those in Bębło, Cracow distr. (Trela-Kieferling 2021). To summarise, the monograph under review is a very valuable contribution, and its authors deserve the highest appreciation for their tedious work on almost exclusively archival material.

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Elżbieta Trela-Kieferling (ed.), *Nakopalniane pracownie krzemieniarskie z okresu neolitu w Bęble, stan. 4, woj. małopolskie* [*Neolithic Flint Workshops at the Mine in Bębło, Site 4, Małopolska*]. Kraków 2021, Muzeum Archeologiczne w Krakowie. Biblioteka Muzeum Archeologicznego w Krakowie vol. X, pp. 204, 68 illustrations (57 colour, 11 black-white), 72 plates and 37 tables

Reviewed by Dagmara H. Werra[a]

This monograph on the Neolithic flint workshops of the Bębło mining complex (Cracow district, Lesser Poland Voivodeship) appeared in 2021, published by the Archaeological Museum in Kraków with financial aid from the Ministry of Cultural and National Heritage, National Heritage Board of Poland and the Marshal's Office of the Małopolska Region. The editor of the publication is Elżbieta Trela-Kieferling. The book appeared in the series „Biblioteka Muzeum Archeologicznego w Krakowie" [The Library of the Archaeological Museum in Kraków], edited by Dr hab. Jacek Górski. It is the tenth volume in the series, which has appeared since 2006, and is a commemorative volume, dedicated to the initiator of the series, Dr. Jacek Rydzewski.

The work consists of eight chapters, preceded by an introduction written by the editor of the series, J. Górski, Director of the Archaeologial Museum in Kraków. The entire study is published in Polish and English. The English version is at the end of each chapter, after the list of references, the captions for the figures and tables are also in two language versions.

The first chapter, "Site 4 in Bębło, Kraków district: its location and history, and the present state of research" [in Polish: Lokalizacja, historia i stan badań stanowiska 4 w Bęble, pow. Kraków], is written by the editor of the volume, E. Trela-Kieferling (curator at the Department of Archaeological Education and Exhibitions at the Museum). Within, the reader is introduced to the history of research on the site and its geographical location. The material presented in the following chapters come from the research of Albin Jura (1873–1958), the discoverer and the first researcher of the site, in 1935–1936, and the research by Stanisław Kowalski and Janusz Krzysztof Kozłowski from 1954. The site was later excavated by Jacek Lech in 1973, and was verified by this researcher in the years 1976–1980, as well as in 1990 as part of the "Polish Archaeologial Record" survey [in Polish: Archeologiczne Zdjęcie Polski]. During the preparation of this study, no new excavations were undertaken, but non-invasive magnetic and electroresistivity surveys (chapter 2) and analysis of airborne laser scanning data of the site (chapter 3).

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The results of the aforementioned non-invasive studies are presented in chapter 2: "Magnetic survey and electrical resistivity tomography at the flint mine in Bębło, site 4, Kraków district" [in Polish: Badania magnetyczne i elekrooporowe na terenie kopalni krzemienia w Bęble, stan. 4, pow. krakowski]. The authors of the chapter are Marcin M. Przybyła, Michał Podsiadło and Piotr Gruba. They begin from presenting the methodology and the history of this type of research carried out so far in the sites related to flint mining. The geophysical investigations conducted at Bębło confirmed the prevailing opinion about exploitation of the site by simple open pits. Unfortunately, the applied methods are of limited usefullness for examining a mining site with remains of shallow exploitation. This is due to the fact that the fills of mining pits and their surroundings are very similar in structure, which does not favour obtaining a contrast between them. During these studies, a detailed surface prospection of the site was also carried out. It consisted of plotting, using a GPS locator, the distribution of flint items and workshop waste exposed on the surface. The material itself was not collected but the material was left in situ. As a result of this survey, it was found that the workshop waste was absent from the area revealed by the electroresistivity survey (as a zone of homogeneous reduced resistance) that is inferred was related to the presence of features related to intensive mining activities. However, this interpretation requires verification using excavation methods.

In the next chapter, by Michał Kasiński – "Site 4 in Bębło, Kraków district: analysis of data from airbone laser scanning (ALS)" [in Polish: Stanowisko 4 w Bęble, pow. krakowski, w świetle analizy danych lotniczego skanowania laserowego (ALS)], the results of the attempt to apply the ALS technique on the site are presented, together with a discussion of the factors influencing the effectiveness of this analysis in research on prehistoric mining on the site. Unfortunately, in the case of Site 4 at Bębło, this method did not allow for the presence of traces of the activity of prehistoric miners to be found The reason for this can be sought in the fact that the area of the site is currently used for agriculture. Nevertheless, there is an interesting presentation in this chapter introducing the reader to the secrets of ALS analysis, outlining various methods and useful tools in this type of research. The great advantage of this part of the book is the presentation of the results of the ALS analysis in the area of the southern zone of the Olkusz Upland around the site at Bębło. The author presents potential places the surface relief of which may represent traces of mining activities of past prehistoric communities. Unfortunately, these sites have not yet been verified in the field.

Chapter 4, "Technological classification of flint artefacts from Site 4 in Bębło, Kraków district" [in Polish: Klasyfikacja technologiczna wyrobów krzemiennych ze stanowiska 4 w Bęble, pow. krakowski] by Trela-Kieferling is the most extensive portion of the volume. The author analysed the collection of 8,800 flint products stored at the Museum, including all the flakes, cores, technical waste, tools and blades. On the other hand, she decided against giving a detailed description of all 6,672 flakes and splinters, and only analyzed 1015 specimens selected at random from the latter group of material. When working on this assemblage, Trela-Kierferling used the *chaîne opératoire* inference method. She also presented a detailed description of the raw material obtained by prehistoric communities in Bębło, at the same time denying the sense of introducing petrographic divisions based solely on macroscopic features.

In the chapter, the reader is introduced to the details of the methodology adopted for the study and the results obtained from its application. The author analyzed the collection divided into three technological groups in order to recreate the production chain: the first consisted of items related to core preparation and repair, the second group consisted of the products of core exploitation, and the third group comprised tools.

As a result of the analysis, it was shown that the purpose of the activity of the prehistoric communities in Bębło was twofold: the production of flakes (micro- and mediolithic) and cores, mainly for blades. The description of the cores was carried out taking into account the operating phases (initial operation, advanced operation, rudimentary cores and transformations of cores).

The collection also includes five core forms related to the acquisition of semi-raw material for the production of gunflints. The modern activity in the area of the flint mine in Bębło has not been discussed in detail in the study.

The blades (729 items) were analyzed in detail in terms of the condition, dimensions, presence of cortex, the nature of the striking platform (size, shape, number of flake scars), the characteristics of the bulb of percussion, the features of the negative side and the tip, and the raw material from which they were made. On the other hand, the described flakes (1015 specimens, see above) were characterised taking into account the following features: dimensions, outer surface, striking platform, bulb of percussion, profile of the sides in relation to the longitudinal axis, bends or twists, and the shape of the tip.

The last technological group discussed are the tools (389 specimens). They were dominated by scrapers piercers and drills, moreover there were also some truncations, burins, combination tools, notched and toothed and other retouched tools as well as retouched tools. The seven backed knives that were also recognised deserve attention, they may indicate that the Bębło mine was also used by later communities of the Early Bronze Age. In addition, 37 mining tools were identified, they were picks, forms with straight or incurved sides and retouched edges (resembling two-horned types, the cordiform type or waisted hammers). There were also mauls (19 examples).

Additionally, the collection includes specimens with a much later chronology (e.g., tetrahedral smooth forms). As in the case of gunflint production cores, these specimens were not included in the study.

The text of this chapter is complemented by detailed tables, charts and very high-quality drawings of these forms.

The next chapter presented by Trela-Kieferling refers directly to the analysis of the flint products. These are the results of microwear analysis carried out by Katarzyna Pyżewicz (chapter 5, "Site 4 in Bębło, Kraków district: microwear analysis of the flint material" [in Polish: Bębło, stan. 5, pow. krakowski. Badania traseologiczne materiałów krzemiennych]). Trasological studies of flint materials from flint mines are complex and difficult. This is due to the fact that they are particularly exposed to postdepositional processes (as a result of both human and natural activities; cf. Małecka-Kukawka 2011; Małecka-Kukawka and Werra 2011). As a result of the research, it was found that most of the microscopically examined formal tools did not have traces related to their use. There were traces of use only on a few individual flint specimens, for example as a fire-striker, for intensive processing of other stone materials (grinders? hammers?), others showed traces of contact with antlers / bone. Single flakes showed traces resulting from plant and leather processing. Additionally, Pyżewicz noticed traces related to the flint processing techniques used (visible on the striking platforms and on the flake scars of the retouch). The recorded traces indicate the use of a direct blow with a hard hammerstone. The obtained results are in line with the current knowledge on the traseological analyzes of flint finds from flint mines, which in recent years have shown that these materials have a very high research potential. The negligible results obtained for Bębło could largely be the result of the selection of forms intended for analysis.

Chapter 6, "Bębło, Site 4, Kraków district: the refitting of the material excavated by Stanisław Kowalski and Janusz Krzysztof Kozłowski" [in Polish: Bębło, stan. 4, pow. krakowski. Materiały z badań Stanisława Kowalskiego i Janusza Krzysztofa Kozłowskiego – składanki] written by Justyna Zakrzewska presents the results of the results of an attempt to refit the flints. The author presents the methodology of work and the stages of the analysis. Disappointingly, as a result of the work undertaken, only three two-piece compilations were obtained. The reasons for this result are due to a number of factors above all the very intense flint-making activity on the site which produced a high volume of material, then its subsequent mixing and scattering due to the very intensive agricultural exploitation of the site. This was compounded by the material being studied having been derived from a surface survey and undertaking the analysis of only a part of the collection.

In the penultimate chapter, the editor of the monograph undertakes a description the flint-working strategy of prehistoric communities and the dating of the mining workshops in Bębło (chapter 7, "Strategies in flint knapping and the dating of workshops at the flint mine in Bębło, site 4, Kraków district" [in Polish: Strategie krzemieniarskie i datowanie pracowni nakopalnianych na stanowisku 4 w Będle, pow. krakowski]). Through the analysis of the flint material, the technological sequence was reconstructed. On the basis of the results of a comparative analysis, it is stated that these materials are similar to those known from the flint mine in Sąspów, Cracow area. Therefore, despite the lack of radiocarbon dates, in the light of typological and comparative results, the author links the functioning of the mine with the activities of the so-called "early metric change" communities of the Lengyel culture group. Thus, she discusses the change in dating of the Sąspów mine, which is currently associated with the middle phase of the Lengyel-Polish cycle (Lech 2011). The author points to the possibility of linking the beginning of technological change (the production of medio- and macrolithic products from concretions obtained by mining methods) with the environment of the Wyciąże-Złotniki group, and therefore she also postulates such chronology of both mines and workshops. It seems, however, that this hypothesis has not yet been sufficiently argued through.

The monograph is closed by chapter 8 ("Conclusions"), also by the editor. This short summary, where we find the most important conclusions presented in the monograph, is complemented by very elegant and interesting visualizations of the mine and the studio in Bębło by M. Podsiadło.

The issue of prehistoric flint mining stands out clearly in the context of European archaeology. The first traces of systematic extraction of this raw material date back to the Middle Palaeolithic, but there was increased exploitation of silicates among Late Palaeolithic communities and this was continued by Mesolithic communities, albeit in a more modest form. Nevertheless, the most advanced examples of flint exploitation date back to the Neolithic and Eneolithic times and are related to the activities of agricultural communities. In the mining fields, apart from spectacular forms of prehistoric underground mining, there are examples of parallel exploitation with simpler forms of mining. In a number of cases, a variety of mining forms is observed within one mining field (e.g., Spiennes, Grimes Graves; see Lech 2012).

After many years when it was permanently present in the literature of the subject, the prehistoric flint mine in Bębło, which is an example of a mine with simple forms of mining, has at last become the subject of a monographic study (see also Brzeziński 2020). The editor of the study undertook not only the difficult task of researching the remains of the activities of prehistoric flint miners in the field, but also the analysis of archival collections, that is the study of material from the Museum's resources. Unfortunately, no new excavations were carried out as part of the work, and no results from the research by Jacek Lech from 1973 were included in the study (Lech 1981). As a result, some of the issues raised remain open. This is especially true in the case of the chronology. Unfortunately, no material that could have been used to resolve that issue has survived in the Museum's resources. When preparing the work, no new research was carried out that could provide new artefactual material for study, or to use for closer dating of activities on the site. The study also lacks wider information about the mining facilities of prehistoric communities, the description of which can be found in the study by J. Lech (cf. 1981: 64–67). There is also a certain lack of satisfaction after reading the chapter on airborne laser scanning (ALS) data. Unfortunately, the results shown that detected to traces of potential mining fields in the vicinity of the site have not been verified in the field. As a result, this prevented the author of the chapter, as well as the editor of the monograph, from drawing broader conclusions about prehistoric mining in the southern zone of the Olkusz Upland and the site in Bębło against the wider background of flint mining in Neolithic communities in the region.

However, these comments do not affect the overall positive assessment of the monograph. The analytical study was conducted at a high level of competence and was carefully prepared. The processing of the collection of several thousand flint materials from site 4 in Bębło is a valuable contribution to expanding our knowledge about the mining activities of Neolithic communities, as well as their flint processing. It is worth emphasizing that there is a significant discussion of the creation and assessment of research postulates concerning the verification of the dating of the dating of Lesser Poland region flint mines.

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