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Editorial

The first scientific investigations of the sources of flint in Poland were undertaken by archaeologist Stefan Krukowski and geologist Jan Samsonowicz in the early 20th century. Krukowski used archaeological materials to identify the macroscopic characteristics of 'chocolate' flints, described their differences, and showed the potential location of the deposits (Krukowski 1920: 189–195; Budziszewski 2008: 33). In the search for deposits of flint, their outcrops, and prehistoric mines, Krukowski was accompanied by young geologist Jan Samsonowicz. The result of their cooperation was the discovery in 1921 of *in situ* deposits and surface accumulations of limestones containing fragments of flint and, in 1922, the identification of a prehistoric mine at Krzemionki Opatowskie (Krukowski 1923; Samsonowicz 1923; Bąbel 2014).

This long tradition of studying siliceous rocks has continued at the Institute of Archaeology and Ethnology, Polish Academy of Science. In 1965 Zygmunt Krzak published the first characterization of gray white-spotted (świeciechów) flint (Krzak 1965) and five years later he described Turonian flint from Ożarów (Krzak 1970). In 1971 Romuald Schild devised a classification of 'chocolate' flint from the north-east margin of the Holy Cross (Świątokrzyskie) Mountains (Schild 1971, 1976) and Bogdan Balcer investigated a flint mine in Świeciechów, Kraśnik district, and the use of gray white-spotted (świeciechów) flint during the Neolithic (Balcer 1975, 1976). In 1980 Jacek Lech discussed the geology of Jurassic-Cracow flint and showed its relevance to archaeology (Lech 1980). Since that time Polish archeologists have carried out many investigations on different types of flint (e.g., Budziszewski and Michniak 1983/1989; Pawlikowski 1989; Budziszewski and Michinak eds 1995; Schild and Sulgostowska eds 1997; Matraszek and Sałaciński eds 2002; Gutowski 2004; Borkowski *et al.*, 2008; Migaszewski *et al.*, 2006, Krajcarz *et al.*, 2014).

In addition to ongoing investigations describing the occurrence and geological nature of the raw material, determination of the number of levels at which the raw material occurs in the limestone, and the stratigraphic context and geological dating of the layers, a principal goal is to identify instrumental method/methods for accurately distinguishing siliceous rocks and applying the results in archeological studies. The cooperation between archeologists and geologists started by Krukowski and Samsonowicz continues and the collection of studies presented here are the latest results of those cross-disciplinary cooperative efforts directed to understanding the origin, occurrence and characteristics of siliceous rocks, and their exploitation and conveyance by prehistoric communities.

Ten years ago Zofia Sulgostowska and Andrzej Jacek Tomaszewski edited a volume celebrating Romuald Schild's 70th birthday (Sulgostowska and Tomaszewski 2008) and, one decade later, we would like to dedicate this volume to him in celebration of his 80th birthday. The summary of Schild's extensive scientific work appears in Zofia Sulgostowska and Andrzej Jacek Tomaszewski's – *On the 80th birthday of Professor Romuald Schild* (pp. 11–13). The bibliography of Professor Schild was assembled and prepared by Katarzyna Kerneder-Gubała (pp. 15–19).

Most of the papers published here were presented in preliminary form at a conference held in the Institute of Archaeology and Ethnology Polish Academy of Science in Warsaw on May 12, 2015, entitled: *Flint in time and space – Time and space in flint: Use of geochemical and petrographical methods in archaeology*. The meeting was supported by Polish Academy of Science and the Institute of Archaeology and Ethnology PAS with the aim of fostering cooperation and communication between scientists from different fields (Fig. 1).

The first three papers in the volume provide information on new flint sources, new deposits, and outcrops. In *Siliceous raw material from Bieszczady Mountains: Sources and use* (pp. 21–31) Andrzej Pelisiak presents the results of his latest research connected with Late Neolithic and Early Bronze Age human occupation in the Bieszczday Mountains. Two researchers (Zsolt Mester and Norbert Faragó) present new information on Hungarian limnosilicites in *Prehistoric exploitations of limnosilicites in Northern Hungary: problems and perspectives* (pp. 33–50). The last paper in this group, by Jacek Kabaciński and Iwona Sobkowiak-Tabaka, *A newly discovered source of 'banded flint' in the Polish lowlands* (pp. 51–65), illustrates an important first step to distinguish a new

Fig. 1. Professor Romuald Schild concludes the conference *Flint in time and space – Time and space in flint: Use of geochemical and petrographical methods in archaeology* at the Institute of Archaeology and Ethnology PAS, Warszawa. 12 May 2015. Photo D.H. Werra.

type of flint – Pęgów flint – by conducting instrumental neutron activation analysis (INAA). These four articles address the first step of work with siliceous rocks – field investigations and initial, mostly macroscopic, differentiation.

The next group of papers feature collaborations between archaeologists and geologists, petrologists, and geochemists. In *Erratic flint from Poland: Preliminary results of petrographic and geochemical analyses* (pp. 67–82) Iwona Sobkowiak-Tabaka and colleagues present the results of petrographic and geochemical analyses of the erratic flint from present-day Poland using electron probe micro analysis (EPMA), scanning electron method (SEM) and energy-dispersive x-ray fluorescence (EDXRF) spectrometry. Next, Marcin Szeliga and Miłosz Huber, in *Mineralogical and petrographic characteristic of basic types of Turonian flints from the north–eastern margin of the Holy Cross Mountains: a preliminary report* (pp. 83–97) provide descriptions of the mineralogical-petrographical characteristics of Turonian flints from the Holy Cross (Świętokrzyskie) Mountains. In the following article *On the chemical composition of 'chocolate' flint from central Poland* (pp. 99–114) the editors of this volume and Rafał Siuda present the initial results of EDXRF spectrometric analysis of 'chocolate' flint from outcrops located on the northeastern slopes of the Świętokrzyskie (Holy Cross) Mountains. These three papers on employing instrumental methods are promising, while emphasizing that there is still much progress to be made along these lines. The last paper in this group *Reflectance spectroscopy as a chert sourcing method* (pp. 115–128) by Ryan Parish presents the results of analysis of a large number of chert artifacts from different geological formations to support his position that reflectance spectroscopy is a viable methodology for chert provenance research.

The next five articles are devoted mainly to archeological data. The first of these, Henrik Zoltán Tóth's *Palaeolithic heat treating in Northeastern Hungary?: An archaeometric examination of the possible use of fire-setting in Stone Age quarries in the Bükk area* (pp. 129–135) discusses signs of thermal alternations supported by laboratory testing, concluding that the Paleolithic use of fire-setting to extract lithic raw material cannot be excluded. Next, in *Archaeometric study of some functional tools from the Sąspów and Wierzbica 'Zele' flint mines sites* (pp. 137–150), Jolanta Małecka-Kukawka and colleagues employ use-wear analysis, laser ablation, and SEM-EDS to examine red marks on the surface of flint tools, identifying the material traces as indicative of evidence for human processing of ochre. Next, in *The Lublin-Volhynian culture retouched blade daggers in light of usewear analysis of artefacts from burials at site 2 in Książnice, Poland* (pp. 151–165), Stanisław Wilk and Bernadeta Kufel-Diakowska present the results of use-wear analysis made on flint daggers to evaluate the suggestion that those artifacts signified social prestige in Lublin-Volhynian culture communities. They conclude that important social roles in Lublin-Volhynian culture may not have been determined exclusively on the basis of wealth. In *Early Neolithic flint mining at Södra Sallerup, Scania, Sweden*, Åsa Berggren and colleagues (pp. 167–180) describe the history of research at the mine and the most recent excavation, conducted in

2014. This article presents important facts about the mine (its geology, mining methods and tools, chronology, production and mining activity) as well as the social and cultural context of mining undertaken there. Finally, in *The use of erratic stone by the communities of the Linear Pottery culture: a view from the excavations in Kostomłoty, site 27, province of Lower Silesia*, Mirosław Furmanek and Mirosław Masojć (pp. 181–200) examine the differences in flintworking in the settlement at Kostomłoty, suggesting that observed differences were not related so much to the location of the site on the marginal of the centre of Linear Pottery culture settlement, as they were to the settlement reorganization and diminution of long-distance contacts characteristic of post-Linear Pottery culture groups.

Taken together, we hope that the chapters in this volume will contribute to, and advance, the research pioneered by Krukowski and Samsonowicz emphasizing interdisciplinary analysis and the contributions it can make to understanding the archaeological past.

Finally, we extend special thanks to all the reviewers of these chapters for their time and commitment; the volume could not have been completed without their cooperation and assistance. These individuals include: Katalin Biró (Budapeszt), Michael Brandl (Vienna), Ivan Cheben (Nitra), Jacek Lech (Warszawa), Jolanta Małecka-Kukawka (Toruń), András Markó (Budapeszt), Miroslaw Masojć (Wrocław), Zdeňka Nerudová (Brno), Ryan Parish (University of Memphis, USA), Andrzej Pelisiak (Rzeszów), Antonín Přichystal (Brno), Joanna Pyzel (Gdańsk), Katarzyna Pyżewicz (Poznań), Romuald Schild (Warszawa), Rafal Siuda (Warsaw), Iwona Sobkowiak-Tabaka (Poznań), Christoper Stevenson (Virginia Commonwealth University, Richmond, USA), Zofia Sulgostowska (Warsaw), Marcin Szeliga (Lublin), Paweł Valde-Nowak (Kraków), and Anna Zakościelna (Lublin). The English language translation of some articles was done in consultation between both volume editors, which hopefully allowed us to avoid substantive errors. Nonetheless, we take responsibility for errors that remain.

Dagmara H. Werra
Richard E. Hughes

REFERENCES

Balcer, B. 1975. *Krzemień świeciechowski w kulturze pucharów lejkowatych. Eksploatacja, obróbka i rozprzestrzenienie*. Wrocław–Warszawa–Kraków–Gdańsk.

Balcer, B. 1976. Position and stratigraphy of flint deposits, development of exploitation and importance of the Świeciechów Flint in prehistory. *Acta Archaeologica Carpathica* 16: 179–199.

Bąbel, J.T. 2014. „Krzemionki Opatowskie", najważniejszy zabytek górnictwa pradziejowego w Polsce. In D. Piotrowska, W. Piotrowski, K. Kaptur and A. Jedynak (eds), *Górnictwo z epoki kamienia: Krzemionk–Polska–Europa. W 90. Rocznicę odkrycia kopalni w Krzemionkach*, 53–121. Ostrowiec Świętokrzyskie, Silex et Ferrum I.

Borkowski, W., Libera, J., Sałacińska, B. and Sałaciński, S. (eds.) 2008. *Krzemień czekoladowy w pradziejach. Materiały z konferencji w Orońsku 8–10 X 2003*. Warszawa-Lublin.

Budziszewski, J. 2008. Stan badań nad występowaniem i pradziejową eksploatacją krzemieni czekoladowych. In W. Borkowski, J. Libera, B. Sałacińska and S. Sałaciński (eds.), *Krzemień czekoladowy w pradziejach. Materiały z konferencji w Orońsku 8–10 X 2003*, 33–106. Warszawa-Lublin.

Budziszewski, J. and Michniak, R. 1983/1989. Z badań nad występowaniem, petrograficzną naturą oraz prahistoryczną eksploatacją krzemieni pasiastych w południowym skrzydle niecki Magoń-Folwarczyska. *Wiadomości Archeologiczne* 49: 151–190.

Budziszewski, J. and Michniak, R. (eds) 1995. *Guide-Book of excursion 2: northern footslopes of Holy Cross Mountains VIIth International Flint Symposium. Warszawa-Ostrowiec Świętokrzyski. 4–8 September 1995*. Warszawa.

Gutowski, J. 2004. Oolitowy cykl sedymentacyjny wczesnego kimerydu w profilu Wierzbicy koło Radomia. *Volumina Jurassica* 2 (2): 37–48.

Krajcarz, M.T., Sudoł, M., Krajcarz, M. and Cyrek, K. 2014. Wychodnie krzemienia pasiatego na Wyżynie Ryczowskiej (Wyżyna Krakowsko-Częstochowska). In D. Piotrowska, W. Piotrowski, K. Kaptur and A. Jedynak (eds), *Górnictwo z epoki kamienia: Krzemionk–Polska–Europa. W 90. Rocznicę odkrycia kopalni w Krzemionkach*, 53–121. Ostrowiec Świętokrzyskie, Silex et Ferrum I.

Krukowski, S. 1920. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski. Wnioski z właściwości surowców i wyrobów. *Wiadomości Archeologiczne* 5: 185–206.

Krukowski, S. 1923. Sprawozdanie z działalności państwowego konserwatora zabytków prehistorycznych na okrąg kielecki w r. 1922. *Wiadomości Archeologiczne* 8: 64–84.

Samsonowicz, J. 1923. O złożach krzemieni w utworach jurajskich północno-wschodniego zbocza Gór Świętokrzyskich. *Wiadomości Archeologiczne* 8: 17–24.

Krzak, Z. 1965. Tymczasowa charakterystyka kopalni krzemienia w Świeciechowie. *Archeologia Polski* 10: 217–233.

Krzak, Z. 1970. Wstępna charakterystyka kopalni krzemienia w Ożarowie Opatowskim. *Archeologia Polski* 15: 291–303.

Lech, J. 1980. Geologia krzemienia jurajskiego-podkrakowskiego na tle innych skał krzemionkowych. Wprowadzenie do badań z perspektywy archeologicznej. *Acta Archaeologica Carpathica*, 20: 163–228.

Matraszek, B. and Sałaciński, S. (eds) 2002. *Krzemień świeciechowski w pradziejach*. Warszawa.

Migaszewski, Z.M., Galuszka, A., Durakiewicz, T. and Starnawska, E. 2006. Middle Oxfordian–Lower Kimmeridgian chert nodules in the Holy Cross Mountains, south-central Poland. *Sedimentary Geology* 187: 11–28.

Pawlikowski, M. 1989. On the necessity of standarization of petrological investigations in archaeology. In J.K. Kozłowski (ed.), '*Northern' (Erratic and Jurassic) flint of southern Polish origin in the Upper Palaeolithic of Central Europe*, 7–15. Kraków.

Schild, R. 1971. Lokalizacja prahistorycznych punktów eksploatacji krzemienia czekoladowego na północnowschodnim obrzeżeniu Gór Świętokrzyskich. *Folia Quaternaria* 39: 1–61.

Schild, R. 1976. Flint mining and trade in Polish prehistory as seen from the perspective of the chocolate flint of central Poland. A second approach. *Acta Archaeologica Carpathica* 16: 147–177.

Schild, R. and Sulgostowska, Z. (eds) 1997. *Man and Flint. Proceedings of the VIIth International Flint Symposium, Warszawa–Ostrowiec Świętokrzyski, September 1995*. Warszawa.

Sulgostowska, Z. and Tomaszewski, A.J. (eds) 2008. *Man–Millennia–Environment. Studies in honour of Romuald Schild*. Warsaw.

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Photo: H. Królik

Profesor Romuald Schild
at Nabta Playa (Western Desert, Egypt, 2005)
at the quarry of quartzite sandstones used for steles

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On the 80th birthday of Professor Romuald Schild

Zofia Sulgostowska[a] and Andrzej J. Tomaszewski[b]

Liberation from organizational duties as the Director of the Institute of Archaeology and Ethnology of the Polish Academy of Sciences (further: IAE PAS), which Professor Romuald Schild performed from 1990 to 2007, unlocked new energy in him. The professional profile and scientific achievements of the Jubilarian, including the list of 240 books and articles authored or co-authored by him though 2006, have been presented earlier by his friends and pupils on the occasion of his 70th birthday[1].

Professor Schild's activity in the last decade brought many new achievements in different fields. Among the most important ones were his publishing of 40 edited papers, among them three substantial monographs dealing with key European sites (Rydno [2011], Całowanie [2014] and Wilczyce [2014]) explored under his leadership through many excavation seasons (see the list below). All these works, edited by the Jubilarian and published in English, include contributions of numerous co-authors, mainly experts in natural sciences.

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[1] Kozłowski, J.K. and Machnik, J. 2006. Kilka słów o Profesorze Romualdzie Schildzie [About Professor Romuald Schild]. *Archeologia Polski* 50: 7–12.
Ginter, B. and Kobusiewicz, M. 2008, Our Friend. In Z. Sulgostowska and A.J. Tomaszewski (eds), *Man–Millennia–Environment. Studies in honour of Romuald Schild*, 13–14. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.
Balcer, B. 2008. O Profesorze dr. hab. Romualdzie Schildzie [About Professor Romuald Schild]. In W. Borkowski, J. Libera, B. Sałacińska and S. Sałaciński (eds), *Krzemień czekoladowy w pradziejach*. Studia nad gospodarką surowcami krzemiennymi w pradziejach 7, 13–16. Warszawa–Lublin: Państwowe Muzeum Archeologiczne w Warszawie; Instytut Archeologii Uniwersytetu Marii Curie-Skłodowskiej w Lublinie; Stowarzyszenie Naukowe Archeologów Polskich, Oddział w Warszawie.
Sulgostowska, Z. and Tomaszewski, A.J. 2008. Profesor Romuald Schild – zarys portretu w ruchu [Professor Romuald Schild – sketching a portrait in motion]. In W. Borkowski, J. Libera, B. Sałacińska and S. Sałaciński (eds), *Krzemień czekoladowy w pradziejach*. Studia nad gospodarką surowcami krzemiennymi w pradziejach 7, 17–23. Warszawa–Lublin: Państwowe Muzeum Archeologiczne w Warszawie; Instytut Archeologii Uniwersytetu Marii Curie-Skłodowskiej w Lublinie; Stowarzyszenie Naukowe Archeologów Polskich, Oddział w Warszawie.

Due to the damage to megaliths resulting from increased tourism, Professor Schild initiated moving the megaliths discovered in the Western Desert in Egypt from the Nabta Playa site to the Nubian Museum in Aswan. This action, preceded by detailed recording and mapping of all steles, was completed in 2009. Subsequently, the presumable solar calendar and the seven stone steles, along with a crude sculpture reminiscent of a cow (all made of Nubian sandstone) were placed in the Western Garden of the Museum at Aswan.

Until 2010, he lead archaeological excavations at Wilczyce, near Sandomierz, and participated in the geoarchaeological work at the Mesolithic sites at Dąbki in Western Pomerania and at Krzyż Wielkopolski in Greater Poland, excavated by Jacek Kabaciński from IAE PAS in Poznań.

Professor Schild was a precious mentor to young archaeologists, employees at IAE PAS, and at other scientific institutions. He supervised scientific projects financed by the National Science Centre (further: NSC), reviewed doctoral theses, served as a member of commissions for the review and acceptance of PhD theses and habilitations, and evaluated candidates for the title of a full professor.

In addition to academic duties, he served archaeology more broadly as an elected member of the Scientific Council of the IAE PAS (always at the top of the elected list), as a member of the Committee of Pre- and Protohistoric Sciences of the Polish Academy of Sciences, and a member of the Polish Academy of Arts and Sciences, Section History and Philosophy.

Professor Schild also has been active in the public sector of archaeology, particularly in public interpretation of the sites he personally examined. In 2015 he led a scientific conference titled 'Rydno – places and people' at the District Museum in Radom and guided field trips to the sites at Rydno and Całowanie. The session was attended by no fewer than a hundred people specializing in the Stone Age from many scientific centers throughout Poland. In 2011, the unusual finds from Wilczyce became a centerpiece of the Polish-German-French exposition on display in Musée National de Préhistoire at Les Eyzies-de-Tayac, titled: 'Mille et une femmes de la fin des temps glaciares'. The text accompanying the exposition catalogue, written by Professor Schild, brought to the demanding French audience a vivid picture of the eastern frontiers of Magdalenian culture.

Together with his wife Krystyna, they continue to hold elegant parties at their home, attended by specialists from Warsaw, outstanding foreign scientists, and others conducting research on the Stone Age.

The stereotype of a once-active professional resting on his laurels certainly does not apply to Professor Schild! The Jubilarian personifies the exact opposite; his great physical condition and physical activity doubtless contribute to his continuing intellectual writing as well as in all previously mentioned duties.

The only real change we are aware of in Professor Schild's habits are his more frequent outings to his country retreat in the area of Grudziądz, where he devotes himself to scientific work and prepares his next monograph summing up his multi-year research projects in the western desert in Egypt, which he led for over 50 years with the Combined Prehistoric Expedition (together with Prof. Fred Wendorf of Southern Methodist University in Dallas, USA, who died in 2015). Professor Schild is planning further projects with the financial support of NSC.

Finally, we hope that we have not omitted any of the Jubilarian's important achievements. If so, we will happily contribute corrections and additions at his next round birthday anniversary. We are convinced that the coming decade will find Professor Romuald Schild in good health and still active in the field of prehistory. There is still so much to be done.

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PL ISSN 0066-5924

Bibliography of Romuald Schild – from 2005–2016[1]

Katarzyna Kerneder-Gubała[a]

2005

- Are the Early Holocene cattle in the Eastern Sahara domestic or wild?. *Evolutionary Anthropology* 3 (4): 118–128 [together with F. Wendorf].
- Short communication: Two additional Egyptian Neolithic burials exhibiting unusual mortuary treatment of teeth. *International Journal of Osteoarchaeology* 15 (2): 136–139 [together with J.D. Irish, M. Kobusiewicz and J. Kabaciński].

2007

- Middle Holocene environments of North and East Africa, with special emphasis on the African Sahara. In D.G. Anderson, K. Maasch and D.H. Sandweiss (eds), *Climate change and cultural dynamics: A global perspective on Mid-Holocene transitions*, 189–227. London: Academic Press/ Elsevier [together with F. Wendorf and W. Karlén].

2008

- Rozkopując otwarte kopalnie krzemienia czekoladowego. In W. Borkowski, J. Libra, B. Sałacińska and S. Sałaciński (eds), *Krzemień czekoladowy w pradziejach, materiały z konferencji w Orońsku, 08-10.10.2003*, 105–133. Lublin-Warszawa: State Archeological Museum in Warsaw, Intitute of Archaeology Maria Curie-Skłodowska University of Lublin. 'Studia nad gospodarką surowcami krzemiennymi w pradziejach' 7.
- A Late Magdalenian perinatal human skeleton from Wilczyce, Poland. *Journal of Human Evolution* 55: 736–740 [together with J.D. Irish, B. Bratlund, E. Kolstrup, H. Królik, D. Mańka and T. Boroń].

[1] The present bibliography supplements an earlier list of Professor Romuald Schild's publications prepared by Tomasz Boroń, Zofia Sulgostowska and Andrzej J. Tomaszewski in: Z. Sulgostowska and A.J. Tomaszewski (eds), *Man–Millenia–Environment. Studies in honour of Romuald Schild.* Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences, 2008.

[a] Institute of Archeology and Ethnology Polish Academy of Sciences, Al. Solidarności 105, PL 00-140 Warsaw
e-mail: gubala@iaepan.edu.pl

– Astronomy of Nabta Playa. In J.C. Holbrook, R. Thebe Medupe and J.O. Urama (eds), *African cultural astronomy – Current archaeo-astronomy and ethnoastronomy research in Africa*, 131–143. Berlin Springer [together with J. Mc Kim Malville, F. Wendorf and F. Brenmer].

2009

– Possible Oldowan traces in the Gebel Nabta area, Egypt. In J.M. Burdukiewicz, K. Cyrek, P. Dyczek and K. Szymczak (eds), *Understanding the past. Papers offered to Stefan K. Kozłowski*, 315–320. Warszawa: Center for Research on the Antiquity of Southeastern Europe, University of Warsaw.

2010

– The Combined Prehistoric Expedition in Nubia, 2003–2008. *Gdańsk Archaeological Museum African Reports* 6: 15–30 [together with P. Bobrowski, M. Jórdeczka, D. Mańka, H. Królik and F. Wendorf].
– *Gebel Ramlah. Final Neolithic cemeteries from the western desert of Egypt*. Poznań: Institute of Archaeology and Etnology Polish Academy of Sciences, Poznań Branch, pp. 276 [together with M. Kobusiewicz, J. Kabaciński, J.D. Irish, M.C. Gatto and F. Wendorf].
– Late Palaeolithic hunter-gatherers in the Nile Valley of Nubia and Upper Egypt. In E.E.A. Garcea (ed.), *South-eastern Mediterranean peoples between 130,000 and 10,000 years ago*, 89–125. Oxford: Oxbow, [together with F. Wendorf].
– Geomorphology, lithostratigraphic environment and paleoecology of Neolithic camps and cemeteries at Gebel Ramlah Playa. In M. Kobusiewicz, J. Kabaciński, R. Schild, J.D. Irish, M.C. Gatto and F. Wendorf (eds), *Gebel Ramlah. Final Neolihic cemeteries from the western desert of Egypt*, 159–88. Poznań: Institute of Archaeology and Ethnology Polish Academy of Sciences, Poznań Branch [together with F. Wendorf].

2011

– *Rydno. A Stone Age red ochre quarry and socioeconomic center* edited by R. Schild, H. Królik, A.J. Tomaszewski and E. Ciepielewska. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences, pp. 467.
– Rydno – kopalnia odkrywkowa ochry z epoki kamienia i prehistoryczne centrum społeczno-gospodarcze. In. *Skarżysko-Kamienna. Panorama dziejów miasta*, 9–22. Skarżysko-Kamienna: Stowarzyszenie Pra-Osada Rydno, Polskie Towarzystwo Historyczne, Oddział w Skarżysku-Kamiennej.
– Najstarsze kurhany świata. Neolityczny kompleks ceremonialny z Nabta Playa na Pustyni Zachodniej w Egipcie. In H. Kowalewska-Marszałek and P. Włodarczak (eds), *Kurchany i obrządek pogrzebowy w IV-II tysiącleciu p.n.e.*, 77–90. Cracow-Warsaw:

Institute of Archaeology and Ethnology Polish Academy of Sciences, Institute of Archaeology University of Warsaw [together with P. Bobrowski, A. Czekaj-Zastawny and F. Wendorf].
– Early Holocene pottery in the western desert of Egypt: new data from Nabta Playa. *Antiquity* 85 (327): 99–115 [together with M. Jórdeczka, H. Królik and M. Masojć].

2012
– The Early Neolithic offering tumuli from Sacred Mountain (Site E–06–4) in Nabta (western desert of Egypt). *Studies in African Archaeology* 11: 410–20 [together with P. Bobrowski and A. Czekaj-Zastawny].
– Early Holocene pottery in the western desert of Egypt: new data from Nabta Playa. *Antiquity* 85: 99–115 [together with M. Jórdeczka, H. Królik and M. Masojć].
– Early Neolithic settlements of El Adam Type from Nabta Playa. Site E–06–1. *Studies in African Archaeology* 11: 365–407 [together with M. Jórdeczka, H. Królik and M. Masojć].
– Wilczyce, un campement de chasseurs du Magdalénien supérieur en Pologne centrale. In J.P. Cluzel, J.J. Cleyet-Merle (eds), *Mille et une femmes de la fin des temps glaciaires*, 121–130. Paris: Editions de la Réunion des musées nationaux – Grand Palais.
– The New Age reuse of Nabta Playa's Neolithic sanctuary. *Studies in African Archaeology* 11: 421–439 [together with F. Wendorf].

2013
– Hunter-gatherer cattle-keepers of early Neolithic El Adam type from Nabta Playa: Latest discoveries from Site E–06–1. *African Archaeologiva Revue* 30: 253–284 [together with M. Jórdeczka, H. Królik and M. Masojć].
– *Dictionary of Prehistoric Archaeology*. Cracow: Intitute of Archaeology and Ethnology Polish Academy of Sciences, pp. 684 [together with S. Milisauskas and J. Kruk].
– Early and Middle Holocene paleoclimates in the south western desert of Egypt – The world before unification. *Studia Quaternaria* 30 (2): 125–133 [together with F. Wendorf].

2014
– *Wilczyce. A Late Magdalenian winter hunting camp in central Poland* edited by R. Schild. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences. pp. 448.
– Introduction. In R. Schild (ed.), *Wilczyce. A Late Magdalenian winter hunting camp in central Poland*, 17–28.Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.

– Taphonomy and chronology of the settlement. In R. Schild (ed.), *Wilczyce. A Late Magdalenian winter hunting camp in central Poland*, 87–104. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.
– Wilczyce – A Late Magdalenian base camp. In R. Schild (ed.), *Wilczyce. A Late Magdalenian winter hunting camp in central Poland*, 381–400. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.
– *The Wilczyce ice wedge system.* In R. Schild (ed.), *Wilczyce. A Late Magdalenian winter hunting camp in central Poland*, 81–86. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences [together with E. Kolstrup].
– *Całowanie. A Final Paleolithic and Early Mesolithic site on an island in the ancient Vistula channel* edited by R. Schild, Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences, pp. 376.
– Preface. In R. Schild (ed.), *Całowanie. A Final Paleolithic and Early Mesolithic site on an island in the ancient Vistula channel*, 9–10. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.
– Introduction. In R. Schild (ed.), *Całowanie. A Final Paleolithic and Early Mesolithic site on an island in the ancient Vistula channel*, 11–15. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.
– Geomorpology, stratigraphy, paleoecology and radiochronology. In R. Schild (ed.), *Całowanie. A Final Paleolithic and Early Mesolithic site on an island in the ancient Vistula channel*, 17–58. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.
– Archaeological materials. In R. Schild (ed.), *Całowanie. A Final Paleolithic and Early Mesolithic site on an island in the ancient Vistula channel*, 59–253. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences [together with D. Mańka, H. Królik and M. Marczak].
– A synthesis. In R. Schild (ed.), *Całowanie. A Final Paleolithic and Early Mesolithic site on an island in the ancient Vistula channel*, 349–374. Warsaw: Institute of Archaeology and Ethnology Polish Academy of Sciences.
– Schyłkowo neolityczne megalityczne Pola Pamięci w Nabta Playa, południowa Pustynia Zachodnia w Egipcie. In A. Grossman and W. Potocki (eds), *Miejsca pamięci – pradzieje i współczesność*, 149–164. Biskupin-Wrocław.

2015

– Here comes the rain again… The early Holocene El Adam occupation of the Western Desert, Nabta Playa, Egypt: Site E–08–2. *Azania: Archaeological Research in Africa* 50(1): 1–24, http://dx.doi.org/10.1080/0067270X.2014.984969 [together with M. Jórdeczka, H. Królika and M. Masojć].
– Displaying the Nabta Playa Monuments in the Nubian Museum, Aswan, Egypt. *Studies in African Archaeology* 14: 351–376 [together with F. Wendorf].

– Denver Fred Wendorf, Jr. (1924–2015). A Very Busy Life of a Field Archaeologist. *Sudan and Nubia* 19: 181–184.

2016

– Comments on the sequence of biodeposits at Dąbki. In J. Kabaciński, S. Hartz, D.C.M. Raemaekers and T. Terberger (eds), *The Dąbki site in Pomerania and the neolithisation of the northern European lowlands (ca. 5000–3000 calBC)*, 25–30, 'Archaeology and History of the Baltic' 8. Rahden/Westphalia: Verlag Marie Leidorf GmbH.

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Siliceous raw material from Bieszczady Mountains: Sources and use

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Lithic chipped materials discovered in the course of research in the Polish High Bieszczady Mts. carried out from 2012 are dated to the Late Neolithic and the Early Bronze Age. They represent several raw material groups: menilite hornstones, siliceous sandstones, siliceous marl, and the so-called Bircza flint. Sources of these rocks are located either in the Bieszczady Mts. or in the nearby vicinity. Individual raw material groups are not homogenous; the same kind of rock can have different physical characteristics, depending on specific sources. Consequently, their effectiveness as tool production raw material is uneven. All raw materials were utilized mainly locally.

KEY-WORDS: siliceous raw material, Carpathians, Bieszczady Mountains, Late Neolithic, Bronze Age

INTRODUCTION

Archaeological research in the Polish High Bieszczady Mountains was initiated in 2012[1], inspired by analyses of pollen diagrams indicating palynological traces of human activities in this region from about 3200/3000 BC (Ralska-Jasiewiczowa 1980). These observations did not correspond with prehistoric evidences which had been until then totally unknown (Pelisiak 2013a, 2013b, 2014b; Parczewski *et al.*, 2013). Since 2012 research has been focused on palynological sites in Smerek and Wołosate, Bieszczady district and in the vicinity of Wetlina, Lesko district involving surface survey and analyses of LIDAR images which revealed the presence of a number of artifacts, including those from the Late Neolithic and the Early Bronze Age (Pelisiak and Maj 2013; Pelisiak 2014a; Pelisiak *et al.*, 2015). The varieties of raw materials used to manufacture these artifacts encouraged extending the scope of the research to include identification of the raw material sources to complement other studies on identification of Carpathian siliceous rocks and their use in the prehistoric times (Dagnan-Ginter and Parczewski 1976; Jarnot-Kozłowska 1988; Rydlewski 1989a, 1989b; Valde-Nowak 1991, 1995a, 1995b, 2009; Foltyn *et al.*, 1998, 2009;

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[1] Archaeological field work 2012–2015 in the Polish High Bieszczady Mountains were carried out by Andrzej Pelisiak, Institute of Archaeology, University of Rzeszów.

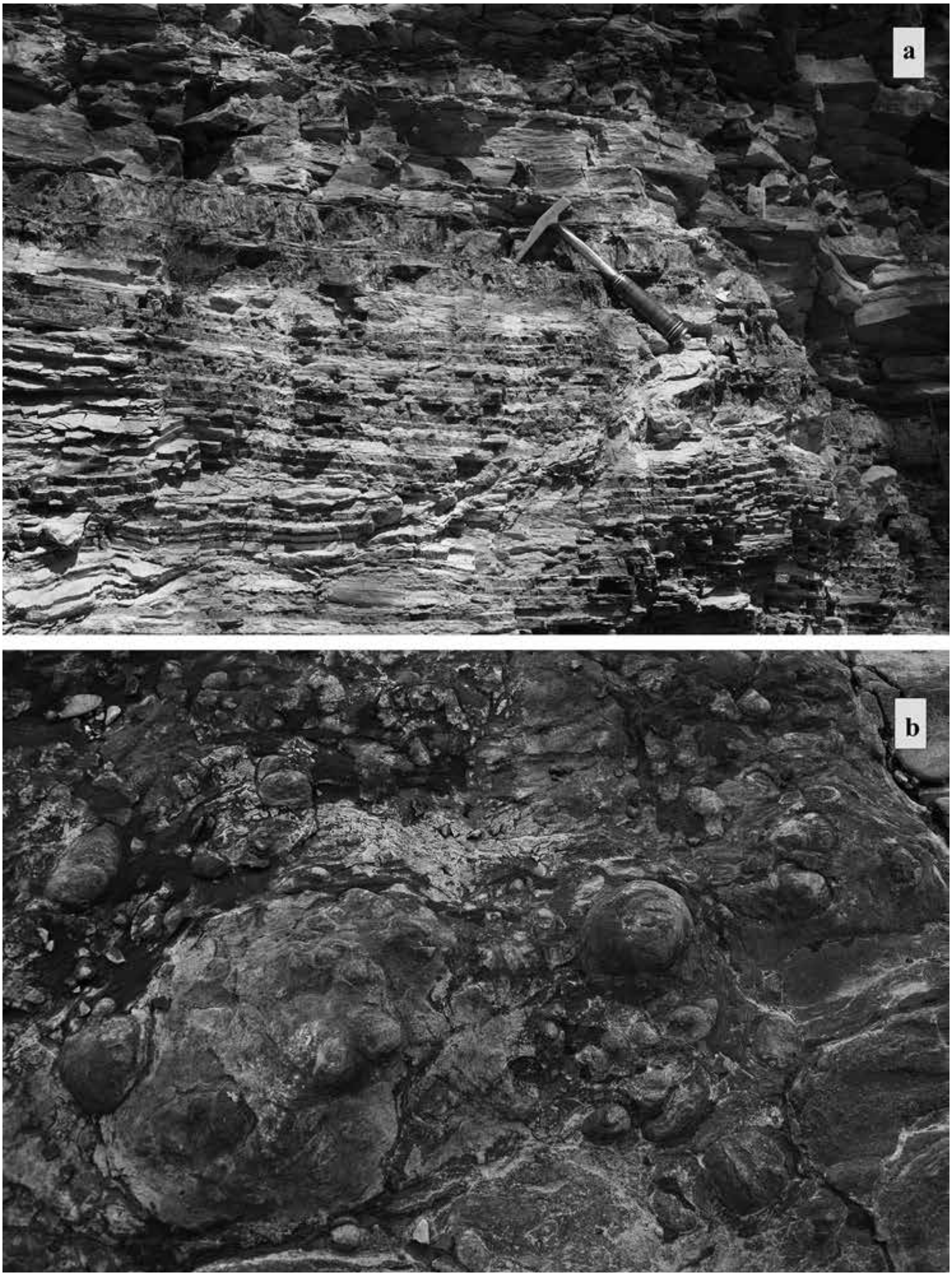

Fig. 1. Outcrop at Leszczawa Górna near Bircza, Przemyśl district, with black menilite hornstone and brown chert (a), and sources of mudstone at Wetlina, High Bieszczady Mountains (b). Photo: A. Pelisiak and Z. Maj.

Budziszewski and Skowronek 2001; Łoptaś *et al.*, 2002; Pawlikowski 2009; Přichystal 2009; Foltyn and Jochemczyk 2013). Field work was carried out in the area of Dynów, Rzeszów district, Bircza, Przemyśl district, Baligród, Lesko district, and in the Polish High Bieszczady Mts. In the area of the Ulanica near Dynów, in a small quarry, a small outcrop of siliceous Dynów marl was observed. In the Krępak preserved area (about 6 km to NEE from the center of Bircza) there were sources of melinite hornstones, light brown cherts and siliceous rocks with macroscopic characteristics similar to so-called Bircza flint. Moreover, there were discovered possible traces of mining of those rocks in the form of depressions (shafts?) and heaps, with rocky debris, rock chunks and artifacts on the surface. Outcrops of melinite hornstones, brown cherts and siliceous rocks of Bircza flint type were discovered also in Leszczawa Górna, Przemyśl district (about 7.5 km south of Bircza; Fig. 1). In the region of Baligród (Rabe, Bystre) there are outcrops of Lower Jurassic siliceous rocks. In the Bieszczady Mts. the research was focused in the vicinity of Cisna, Lesko district, and Wetlina. Melinite cherts were documented in Cisna (close to the newly-discovered late Paleolithic stone processing site) and in Wetlina, in denuded parts valleys of the Wetlinka and Solinka rivers. In Wetlina, in the same river valleys, there were outcrops of quartzite, melinite hornstones, mudstones (Fig. 1), and – in one place – of siliceous marl. In addition, in Moczarne (administrative part of Wetlina), outcrops of siliceous sandstone were identified to the south of the housing area in Wetlina.

CHIPPED ARTIFACTS

Lithic chipped artifacts appear in various landscape zones, from the low terrace of the Wetlinka River valley to elevations and tops of the nearby hills, up to about 1200 m a.s.l. (Fig. 3). From the Wetlinka valley there is a blade fragment of quartzite (Pelisiak and Maj 2013), discovered on the left-hand low terrace of that river (Wetlina, site 12; Fig 2: d). The most elevated sites are located on the Połonina Wetlińska, Podkarpackie Povince (Pelisiak *et al.*, 2015). Among artifacts discovered in this area is a heart-shaped arrowhead of the melinite hornstone (Wetlina, site 6; Fig. 2: a). Artifacts were also found in a depression called the Orłowicz Pass – an endscraper made on a blade (Wetlina, site 23; Fig. 2: b), a splintered piece (Wetlina, site 26; Fig. 2: c), and a tool on flake (Wetlina, site 22; Fig. 2: e), all of them made from melinite hornstones. The highest number of artifacts were found on the Solinka River and the Beskidnik Creek (Pelisiak and Maj 2013; Pelisiak 2014a). From the area of the former village of Moczarne[2], Lesko district, there is a splintered piece of melinite hornstone (Wetlina, site 15; Fig. 2: f), and single finds of cores of siliceous sandstone (Wetlina, sites 17, 18, 19, 20, and 21; Fig. 2: h). In addition, a blade fragment of Bircza flint was found on the Pod Czerteżem Pass in

[2] The village was abandoned in 17th century. Now it is a small settlement for mountain forest workers.

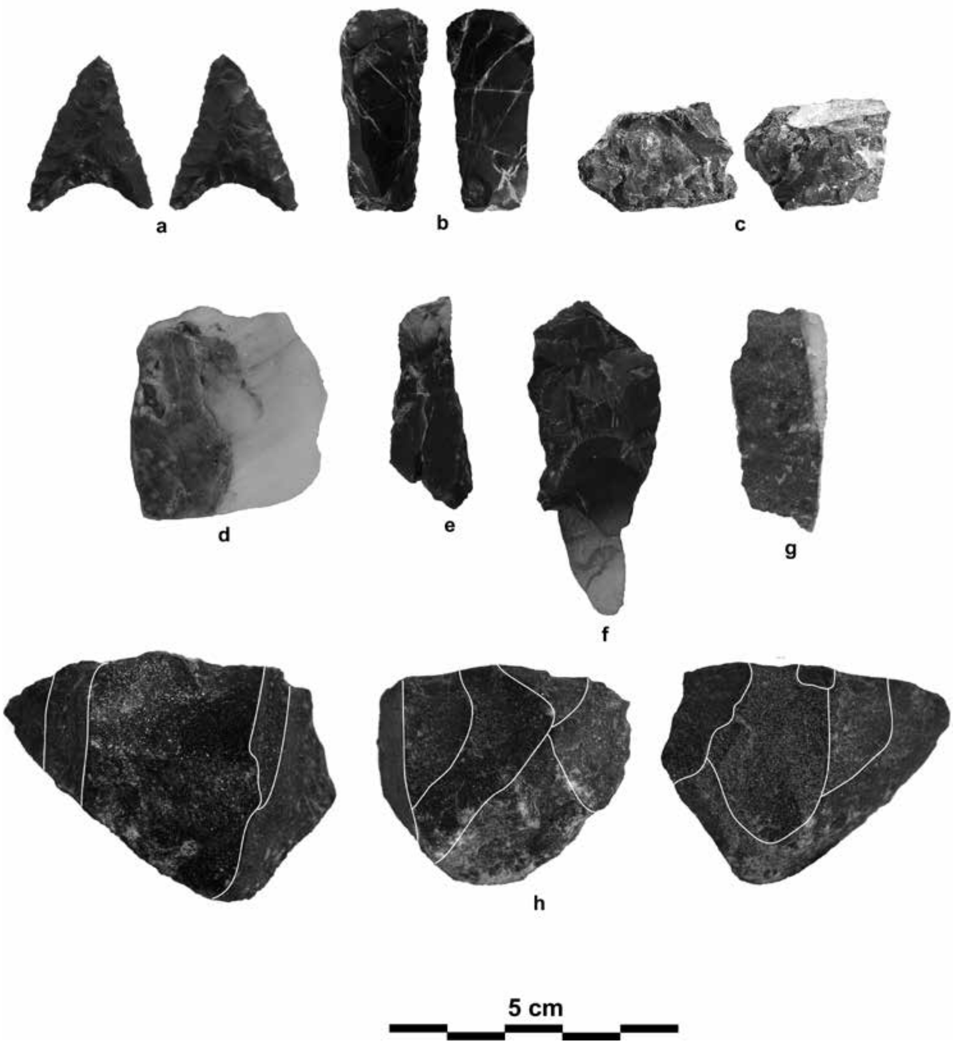

Fig. 2. Chipped artefacts from Wetlina village, Lesko district, and its surroundings (selected sites); a – arrowhead made of menilite hornstone from Wetlina, site 6 (Połonina Wetlińska); b – blade end-scraper made of menilite hornstone from Wetlina, site 23 (Orłowicz Pass); c – bipolar made of menilite hornstone from Wetlina, site 26 (Orłowicz Pass); d – fragment of blade made of quartzite from Wetlina, site 12; e – knife-like tool made menilite hornstone from Wetlina, site 22 (Orłowicz Pass); f – bipolar made of menilite hornstone from Wetlina, site 15 (Moczarne); g – fragment of blade made of Bircza flint from Wetlina, site 25 (Czerteż Pass); h – flake core made of siliceous sandstone from Wetlina, site 17 (Moczarne).

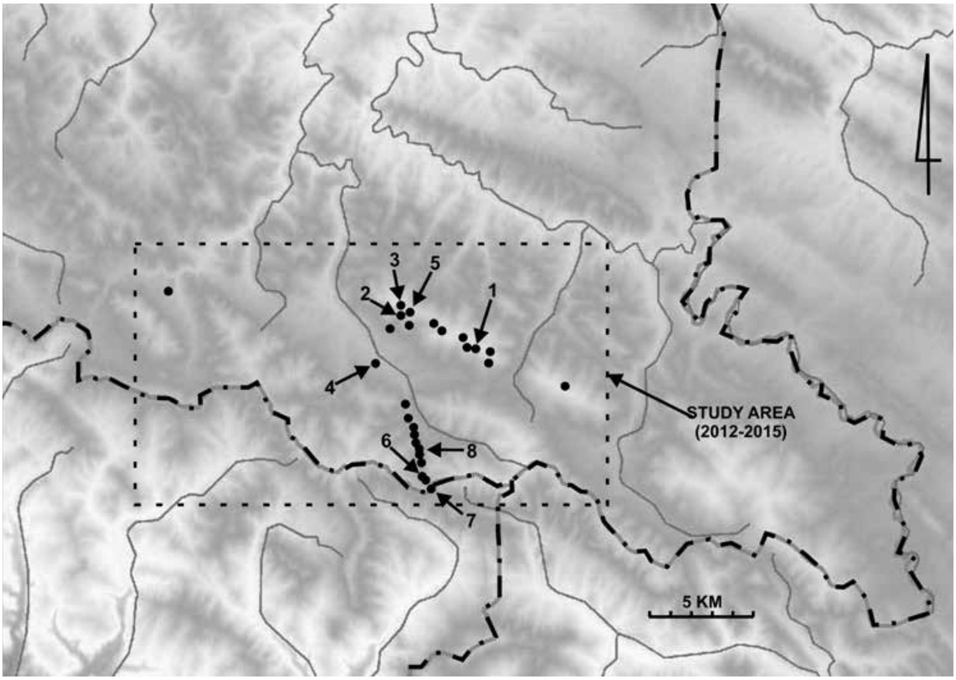

Fig. 3. Neolithic and Early Bronze Age sites with chipped artefacts from Wetlina village, Lesko district, and its surroundings (labeled sites according to Fig. 2); 1 – Wetlina, site 6 (Połonina Wetlińska); 2 – Wetlina, site 23 (Orłowicz Pass); 3 – Wetlina, site 26 (Orłowicz Pass); 4 – Wetlina, site 12; 5 – Wetlina, site 22 (Orłowicz Pass); 6 – Wetlina, site 15 (Moczarne); 7 – Wetlina, site 25 (Czerteż Pass); 8 – Wetlina, site 17 (Moczarne).

the main Carpathian range (Fig. 2: g). Research conducted in 2015, on the Połonina Wetlińska and in Moczarne, revealed new evidence dated to the Late Neolithic and the Early Bronze Age. Of particular interest is a stone processing site focused on melinite hornstone discovered in Cisna, where a pre-form of a rectangular axe was found. An analogous site is known from Ropa (Valde-Nowak 1991, 1995b).

RAW MATERIAL

Raw material identification of all artifacts has not posed any problems (Fig. 4). However, distinguishing local rocks (i.e. originated from the Wetlina area) from those from other regions is problematic. In the first case we can say that the artifacts are most probably a local production in the second case – that they were fashioned somewhere else or brought as pre-forms or just as raw material for processing. In general, the presence of artifacts made from non-local raw materials in the area in question is interpreted

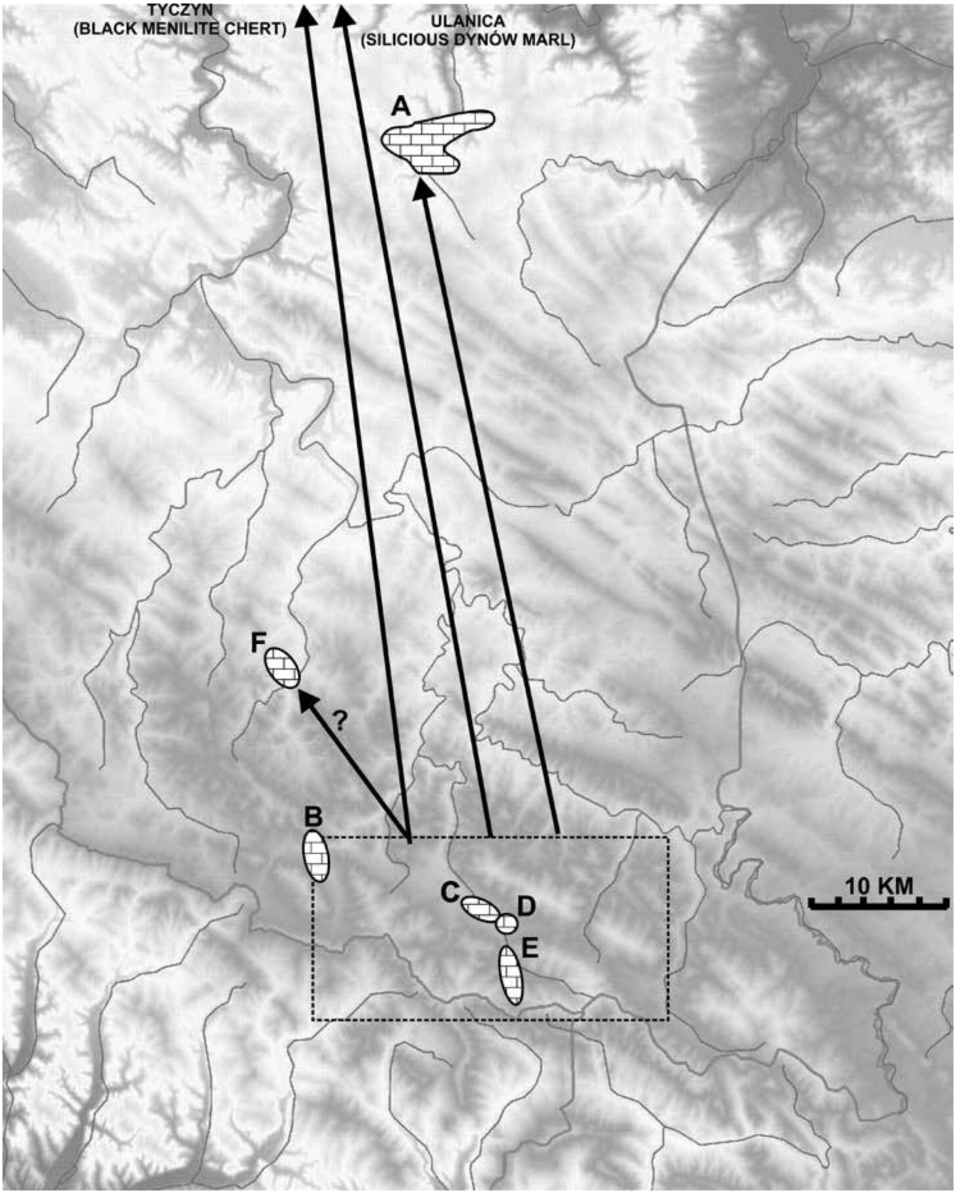

Fig. 4. Sources of raw material recognized in the Neolithic chipped artefacts found in the Wetlina, Lesko district, and its vicinity (study area). A – Bircza region, Przemyśl district (Bircza flint, menilite hornstones, brown-yellow tertiary cherts, tertiary siliceous marls), B – Cisna, Lesko district, and its vicinity (menilite hornstone), C – Wetlina, Lesko district (menilite hornstone, quartzite, mudstones), D – Wetlina, Lesko district (siliceous marls), E – Wetlina-Moczarne, Lesko district (siliceous sandstones), F – Bystre, Lesko district (Lower Cretaceous silicites).

as traces of transhumance (Pelisiak 2013a, 2013b, 2014a, 2014b; Pelisiak and Maj 2013). For that reason identification of the sources of raw materials is linked with a broader prehistoric issue – identification of territories of origin of Late Neolithic and Early Bronze Age pastoral people.

An example of an artifact of undoubted local provenience is the fragment of a blade of quartzite. Quartzites appear in high undercuts of the Wetlinka River valley, in dissected, steep river valley slopes usually in horizontal veins up to 20 cm thick, as well as in the immediate vicinity of the find. They are almost white and milky-grey in color, coarse-grained and opaque. It can be assumed that the artifact in question was most probably made at that place. The same can be said about cores of siliceous sandstone from Moczarne. Siliceous sandstone is fine-grained, and gray in color. Outcrops of that rock appear in beds of the Beskidnik Creek and the Solinka River (near the place of artifact discoveries) as almost vertical slabs up to 20 cm thick. Although difficult to flake when dry, wet blocks of siliceous sandstone extracted from the river-beds were easy for processing using chipping techniques. Cores from Moczarne should be dated to earlier periods of the Bronze Age. It is noteworthy that during the early Bronze Age sandstones rocks from Carpatian Flysch Belt formations were commonly used for producing tools (e.g. *Krummesser*; Valde-Nowak 2003: 49) so we cannot exclude the possibility that the artifacts from Moczarne, discovered within a belt about 300 m long, were produced for local *and* non-local use. This possibility is supported by a find of a Krummesser fragment of siliceous sandstone in the same region in 2015.

Artifacts of menilite hornstones have been recovered frequently in the Polish Outer Carpathians area (Olszewska 1985; Valde-Nowak 1991, 1995a, 1995b, 2003, 2013; Kuśmierek 2005; Haczewski *et al.*, 2007; Jankowski and Probulski 2011). Menilite is a rock of diverse characteristics, not always suitable for lithic artifact production. The materials from the High Bieszczady Mts. confirm this observation; only the arrowhead (Wetlina site 6) was made of high quality raw material, from a homogenous mass without inclusions or cracks. The other artifacts represent raw material of much inferior quality, supporting the supposition that rocks used for artifact production came from different sources. The closest outcrops of menilite hornstones are known from Wetlina and Cisna, where evidence for its processing also has been documented (Fig. 5: d–f). Exposures of menilite hornstones were discovered on steep slopes of the Solinka and Wetlinka rivers valley as well as on the dissections of adjacent hill. This material is black and dark-brawn in color, low transparent, and crumbling appearing in horizontal layers up to 15 cm thick interbedded in Carpatian Flysch Belt formations.

The so-called Bircza flint has been characterized from geological and archaeological points of view (Gucik 1961; Rajchel and Myszkowska 1998a, 1998b; Łoptaś *et al.*, 2002). As currently used, this term encompasses a group of flints of various physical characteristics and value for prehistoric tool manufacturing . This diversity is to a certain extent reflected in the outcrops identified so far (Łoptaś *et al.*, 2002: 324, 331), and those

Fig. 5. Samples of siliceous raw material from the eastern part of the Polish Carpathians. a-c – light-grey hornstone (a – Wetlina, Lesko district; b – Bircza, Przemyśl district; c – Leszczawa, near Bircza, Przemyśl district); d-f – menilite hornstone (d – Bircza-Krępak, Przemyśl district; e – Leszczawa, near Bircza, Przemyśl district; f – Cisna, Lesko district).

discovered during the recent research. Research is planned to better specify to physical and chemical characteristics of different variants of this raw material. In addition to Bircza flint, enilite hornstones and light-brown chert and siliceous marls exposures were recognized in the Bircza region (Fig. 5: a–c). The light-brown chert is matte and opaque with a cortex not delineate from the chert mass. This raw material is harder and compact, and better suited for artifact manufacturing than menilite hornstone. Menilite hornstones and chert appear in Leszczawa outcrop in form of layers up to 15 cm thick. Both black and dark-brown menilite hornstone as well as brown chert appear in horizontal layers interbedded in Carpatian Flysch Belt formations.

SUMMING-UP

The eastern part of the Polish Carpathians, including the Polish High Bieszczady Mountains, contains an abundance of siliceous raw materials. During the field research conducted during 2012–2015 in the Bircza region and in the High Bieszczady Mountains previously undocumented outcrops of melinite hornstones, brown cherts, siliceous sandstones, mudstones, and siliceous marls have been found. In addition, more than 30 archaeological sites, dated to the Late Neolithic and early periods the Bronze Age, have been recorded exclusively in the High Bieszczady Mountains. These new data significantly augment our knowledge of the prehistory of the region, in addition to documenting the presence of prehistorically important raw materials, such as the Bircza flint and the so-called Dynów marl. At the same time the research has revealed great gaps in knowledge of prehistoric raw materials of the region in question. These gaps will require more detailed studies in the near future.

Translated by Jerzy Kopacz

REFERENCES

Budziszewski, J. and Skowronek, M. 2001. Results of the preliminary archaeological research in the Mount Cergowa Massif, the Lower Beskid Mountains. In J. Machnik (ed.), *Archaeology and natural background of the Lower Beskid Mountains, Carpathians*. Prace Komisji Prehistorii Karpat 2: 144–164. Kraków.

Dagnan-Ginter, A. and Parczewski, M. 1976. Dwie kolekcje archeologiczne z Pogórza Dynowskiego. *Materiały Archeologiczne* 16: 5–28.

Foltyn, E.M., Foltyn, E. and Jochemczyk, L. 1998. Surowce kamienne w inwentarzach stanowisk epoki kamienia i brązu zachodniej części Karpat polskich. In J. Gancarski (ed.), *Dzieje podkarpacia* vol. 2: 165–175. Krosno.

Foltyn, E.M., Foltyn, E., Jochemczyk, L. and Waga, J.M. 2009. Radiolaryty gliwickie. Pochodzenie, występowanie, wykorzystanie, dystrybucja. In J. Garncarski (ed), *Surowce naturalne w Karpatach oraz ich wykorzystanie w pradziejach i wczesnym średniowieczu*, 141–165. Krosno.

Foltyn, E. and Jochemczyk, L. 2013. Mikuszowice chert. A local raw material in Western Polish Carpathians. Geology, Characteristics, usage. *Přehled výzkumů* 54: 9–25.

Gucik, S. 1961. Poziom wapieni detrytycznych z Birczy w Karpatach przemyskich i jego znaczenie dla stratygrafii górnej kredy i paleocenu w rejonie skibowym. *Geological Quarterly* 5: 669–685.

Haczewski, G., Kukulak, J. and Bąk, K. 2007. *Budowa geologiczna i rzeźba Bieszczadzkiego Parku Narodowego*. Kraków.

Jankowski, L. and Probulski, J. 2011. Rozwój tektoniczno-basenowy Karpat zewnętrznych na przykładzie budowy geologicznej złóż Grabownica, Strachocina i Łodyna oraz ich otoczenia. *Geologia* 37: 555–583.

Jarnot-Kozłowska, B. 1988. *Margiel krzemionkowy dynowski w kulturach neolitu i wczesnej epoki brązu obszaru Karpat polskich*. Unpublished MA thesis, Jagiellonian University. Kraków.

Kuśmierek, J. 2005. Morfotektonika przełomów Solinki i Wetlinki w świetle badań terenowych i interpretacji zdjęć lotniczych (Bieszczady Wysokie). *Geologia* 31: 225–244.

Łoptaś, A., Mitura, P., Muzyczuk, A., Olszewska, B., Paszkowski, M. and Valde-Nowak, P. 2002. Krzemień z Birczy. Geologia i wykorzystanie w pradziejach. In J. Gancarski (ed.), *Starsza i środkowa epoka kamienia w Karpatach polskich,* 315–337. Krosno.

Olszewska, B. 1985. Otwornice warstw menilitowych polskich Karpat zewnętrznych. *Annales Societatis Geologorum Poloniae* 55: 201–250.

Parczewski, M., Pelisiak, A. and Szczepanek, K. 2013. Bieszczady Zachodnie w pradziejach i średniowieczu w świetle danych archeologicznych oraz palinologicznych. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego* 33: 9–42.

Pawlikowski, M. 2009. Charakterystyka wybranych surowców krzemionkowych Karpat. In J. Gancarski (ed.), *Surowce naturalne w Karpatach oraz ich wykorzystanie w pradziejach i wczesnym średniowieczu*, 9–21. Krosno.

Pelisiak, A. 2013a. Pojedyncze przedmioty kamienne a strefy aktywności osadniczej i gospodarczej w neolicie we wschodniej części Karpat Polskich. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego* 34: 19–33.

Pelisiak, A. 2013b. Man and mountains. Settlement and economy of Neolithic communities in the Eastern part of the Polish Carpathians. In. S. Kadrow and P. Włodarczak (eds), *Environment and Subsistence –Forty Years After Janusz Kruk's 'Settlement Studies ...'*, 225–244. Rzeszów-Bonn.

Pelisiak, A. 2014a. Nowe znaleziska z neolitu i początków epoki brązu z polskich Bieszczadów Wysokich –rejon Wetlina-Moczarne. *Wiadomości Archeologiczne* 65: 212–217.

Pelisiak, A. 2014b. Settlement, Economy and Climate between 3200 and 2500 BC: Late Neolithic Transformations in South-Eastern Poland. In T.L. Kienlin, P. Valde-Nowak, M. Korczyńska, K. Cappenberg and J. Ociepka (eds), *Settlement, communication and exchange around the Western Carpathians*, 143–158. Oxford.

Pelisiak, A. and Maj, Z. 2013. New Neolithic and Early Bronze Age Finds from the Bieszczady Mountains (Wetlina River Valley and its surroundings). *Acta Archaeologica Carpathica* 49: 199–206.

Pelisiak, A., Maj, Z. and Bajda, Ł. 2015. Fist sites of Corded Ware culture from high part of the Bieszczady Mountains (south-east Poland). *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego* 36. *In print.*

Přichystal, A. 2009. *Kamenné suroviny v pravěku východni části Středni Evropy*. Brno.

Rajchel, J. and Myszkowska, J. 1998a. Litologia wapieni z warstwy wapienia litotaminowego z Birczy (wt) –jednostka skolska, zewnętrzne Karpaty fliszowe. *Przegląd Geograficzny* 46: 1247–1253.

Rajchel, J. and Myszkowska, J. 1998b. Exotic clasts of organodetritic algal limestones from lithosomes of the Bibica clay, Skole unit (outer Flysch Carpathians, Poland). *Annales Societatis Geologorum Poloniae* 68: 225–235.

Ralska-Jasiewiczowa, J. 1980. *Late-Glacial and Holocene vegetation of the Bieszczady Mts. (Polish Eastern Carpathians).* Warszawa.

Rydlewski, J. 1989a. Pienińskie złoża radiolarytu i ich eksploatacja w epoce kamienia i wczesnej epoce brązu na Podhalu. *Acta Archaeologica Carpathica* 28: 25–79.

Rydlewski, J. 1989b. Nowe surowce kamienne w paleolicie i neolicie Polski południowej. *Acta Archaeologica Carpathica* 28: 175–181.

Valde-Nowak, P. 1991. Menilite hornstone deposits and their prehistoric exploitation. *Acta Archaeologica Carpathica* 30: 55–85.

Valde-Nowak, P. 1995a. Stone sources from the North-Carpathian province in the Stone and Early Bronze Ages. *Archaeologia Polona* 33: 111–118.

Valde-Nowak, P. 1995b Early Bronze Age Hornstone mine at Ropa, site 2 (Polish Western Carpathians), *Archaeologia Polona* 33: 532–533.

Valde-Nowak, P. 2003. Wyroby kamienne z epoki brązu w Karpatach. In J. Gancarski (ed.), *Epoka brązu i wczesna epoka żelaza w Karpatach polskich,* 43–62. Krosno.

Valde-Nowak, P. 2009. Problem radiolarytu fliszowego w pradziejach. In J. Gancarski (ed.), *Surowce naturalne w Karpatach oraz ich wykorzystanie w pradziejach i wczesnym średniowieczu*, 121–127. Krosno.

Valde-Nowak, P. 2013. The north-Carpathians province of silica rocks during Stone Age In Zs. Mester (ed.), *The lithic raw materials sources and interregional human contacts in the Northern Carpathian regions*, 87–97. Kraków-Budapest.

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PL ISSN 0066-5924

Prehistoric exploitation of limnosilicites in Northern Hungary: Problems and perspectives

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Limnosilicites constitute a specific group of siliceous rocks originating in freshwater limnic (lake) environments. They are very common in the north Hungarian Range, due to the complicated plate tectonic movements building up the Carpathians and the related Tertiary volcanism. Because the local conditions were quite dynamic during their formations, limnosilicites show great petrographic variability. The archaeological record of northern Hungary idocuments that these siliceous rocks have been used by prehistoric human groups as raw materials for tool production. The identification of the provenience of raw materials is a very important but difficult task in most of the cases. More petroarchaeological investigations are needed to complement the good results obtained in the Tokaj Mountains, and even more work is required in the Cserhát, Mátra and Bükk mountains where systematic field surveys are lacking.

To better understand the procurement strategies and technical behaviour of prehistoric groups inhabiting the region, it is indispensable to have a comprehensive knowledge of potential raw materials and their sources. Geological maps and local geographical names could help to discover them during field surveys. Because intensive erosional processes have affected the foothill regions of the North Hungarian Range during the Pleistocene and the Early Holocene, geomorphologic studies are also crucial for estimating the accessibility of the limnosilicite sources.

KEY-WORDS: siliceous rocks, post-volcanic hydrothermal origin, lithic raw material sources, procurement strategy, Carpathian basin

INTRODUCTION

Twenty-one years ago, volume 33 of *Archaeologia Polona* published a series of papers as an appendix to the Bochum catalogue of prehistoric flint mines in Europe. Among them the Hungarian flint sources were summarized (Bácskay 1995a, 1995b, 1995c, 1995d, 1995e, 1995f, 1995g; Biró 1995; Simán 1995b). This publication represents the end of a period that began twenty years earlier (Bácskay 1981), during which intensive

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archaeological field work was carried out by Erzsébet Bácskay, Katalin T. Biró and Katalin Simán to study prehistoric flint mines and exploitation sites in Hungary. The signal event of this flourishing research period was the Budapest–Sümeg Conference in 1986 devoted to flint mining and lithic raw material identification (Biró 1986, 1987). The raw material samples collected from participants during the conference formed the base of the Lithotheca at the Hungarian National Museum (Biró and Dobosi 1991; Biró *et al.*, 2000). Unfortunately, field investigations centered on evidence for prehistoric raw material exploitations nearly ceased in late 1990s due to unfavourable research conditions and raw materials research shifted to analytical provenience studies and related archaeometry (Biró 2004).

As it is demonstrated by the site list in the abovementioned catalogue in *Archaeologia Polona*, field investigations were conducted mainly the western part of Hungary. Eight from the twelve sites are located in the Transdanubian Range, where the raw materials exploited were different radiolarites or radiolarian cherts of Mesozoic age. These kind of raw materials are almost exclusive in Transdanubia, while a wider range of siliceous rocks are known from the north Hungarian Range in the eastern part of the country (Biró 1985, 1988). This latter condition is the result of different volcanic activities occurring within the more complicated geological history of the inner part of the Carpathian arch, including territories in Slovakia, Transcarpathian Ukraine, and Romania (Harangi 2001; Harangi and Lenkey 2007). Different limnosilicites are of primary importance in these regions (Mišík 1969, 1975; Cheben and Illášová 2002; Kaminská 2013; Rácz 2013; Crandell 2014).

LIMNOSILICITES: A SPECIFIC GROUP OF SILICEOUS ROCKS

Antonín Přichystal (2010: 180) defined limnic silicites as a '*variety of silicite originating in freshwater limnic (lake) environment. The presence of plant relics is a typical sign for their determination.*' Přichystal proposed the term as a possible solution for a never-ending terminological debate (Přichystal 2013: 48–50), but the term of limnosilicite (or limnic silicite) is not yet common in Hungarian archaeological literature although Slovakian scholars have introduced it in theirs (e.g. Kaminská 2013 vs 2001).

Here we intend to bring this term into use in Hungarian prehistoric research. Until recently Hungarian scholars used the terms of hydroquartzite and limnoquartzite (or limnic quartzite) for identifying raw materials of post volcanic hydrothermal origins in the archaeological record (e.g. Dobosi 1978; Simán 1986; Biró 1998, 2010). In discussing the great variability of this group of raw materials, Biró (1998: 34) wrote that: '*its macroscopic features can be most varied even within a single source while different macroscopically similar types can be found at several localities within Hungary*". These raw materials dominate in the lithic materials of the majority of Palaeolithic and Neolithic

Table 1. Ratios of limnosilicites within the lithic assemblages of selected archaeological sites from the eastern part of Hungary. Age categories: MP – Middle Palaeolithic; UP – Upper Palaeolithic; MN – Middle Neolithic; LN – Late Neolithic.

site	age	number of lithics	ratio of limnosilicites	reference
Acsa, Pest dist.	UP	2630	97.60%	Dobosi 2008
Andornaktálya, Heves dist.	UP	1541	21.35%	Mester and Kozłowski 2014
Arka, Borsod-Abaúj-Zemplén dist.	UP	956	55.35%	Vértes 1964–1965
Aszód, Pest dist.	LN	3794	28.65%	Biró, 1998
Bodrogkeresztúr, Borsod-Abaúj-Zemplén dist.	UP	2976	30.70%	Lengyel 2015
Boldogkőváralja, Borsod-Abaúj-Zemplén dist.	MN	1083	96.93%	Mester and Tixier 2013
Eger-Kőporos, Heves dist.	MP, UP	422	42.90%	Dobosi 1995
Füzesabony, Heves dist.	MN	942	22.82%	Biró 2002
Hidasnémeti, Borsod-Abaúj-Zemplén dist.	UP	3993	92.51%	Simán 1989
Jászfelsőszentgyörgy, Jász-Nagykun-Szolnok dist.	UP	1303	60.97%	Dobosi 2001
Megyaszó, Borsod-Abaúj-Zemplén dist.	UP	8263	63.03%	Dobosi and Simán 1996
Mezőkövesd, Borsod-Abaúj-Zemplén dist.	MN	896	19.31%	Biró 2002
Nagyréde, Heves dist.	UP	191	77.35%	Lengyel *et al.*, 2006
Polgár-Csőszhalom, Hajdú-Bihar dist.	LN	12268	86.52%	N. Faragó, own study
Püspökhatvan, Pest dist.	UP	2966	98.55%	Csongrádi-Balogh and Dobosi 1995
Szécsény, Nógrád dist.	MN	438	24.43%	Biró 1998
Szeleta Cave, Borsod-Abaúj-Zemplén dist.	MP, UP	1364	40.62%	Ringer and Szolyák 2004
Vanyarc, Nógrád dist.	MP/UP	1949	62.03%	Markó 2009

sites locating to the east of the Danube River (Table 1; Fig. 1), but very little is known about their petrography and geology. At least, there are few publications on this topic (Biró *et al.*, 1984; Szekszárdi *et al.*, 2010).

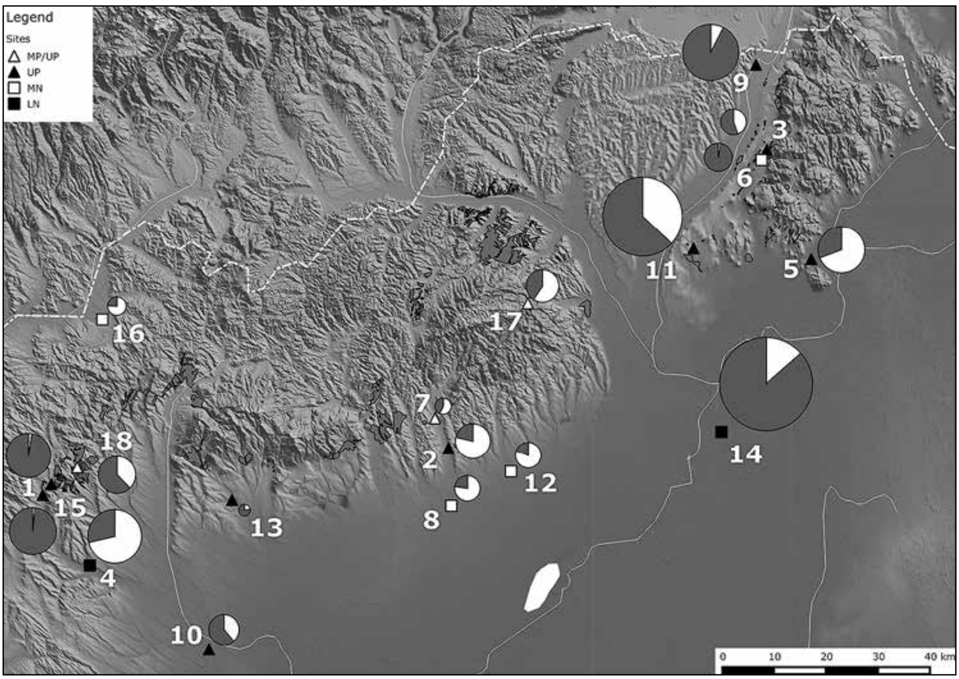

Fig. 1. Geological formations containing 'limnic quartzites' in the Northern Hungarian Range (Budai and Gyalog 2009), and selected Palaeolithic (MP/UP and UP) and Neolithic (MN and LN) sites with important ratios of limnosilicites in the lithic assemblages (see Table 1). The selected formations are marked with dark grey, as well as the ratio of the 'limnic quartzite' within each pie chart. The size of each chart indicates the extent of the given assemblage. 1 – Acsa, Pest dist.; 2 – Andornaktálya, Heves dist.; 3 – Arka, Borsod-Abaúj-Zemplén dist.; 4 – Aszód, Pest dist.; 5 – Bodrogkeresztúr, Borsod-Abaúj-Zemplén dist.; 6 – Boldogkőváralja, Borsod-Abaúj-Zemplén dist.; 7 – Eger-Kőporos, Heves dist.; 8 – Füzesabony, Heves dist.; 9 – Hidasnémeti, Borsod-Abaúj-Zemplén dist.; 10 – Jászfelsőszentgyörgy, Jász-Nagykun-Szolnok dist.; 11 – Megyaszó, Borsod-Abaúj-Zemplén dist.; 12 – Mezőkövesd, Borsod-Abaúj-Zemplén dist.; 13 – Nagyréde, Heves dist.; 14 – Polgár-Csőszhalom, Hajdú-Bihar dist.; 15 – Püspökhatvan, Pest dist.; 16 – Szécsény, Nógrád dist.; 17 – Szeleta Cave, Borsod-Abaúj-Zemplén dist.; 18 – Vanyarc, Nógrád dist. Graphics: N. Faragó.

PETROGRAPHY OF LIMNOSILICITES: DISTINGUISHING AND IDENTIFYING

Petrographic characterizations of rocks found at Palaeolithic cave sites first appeared around the beginning of the 20th century (Kadić 1916; Vendl 1933, 1940). The rock types which currently are attributed to the group of limnosilicites were then described as quartzites, chalcedonies, chalcedony-opals, etc., according to characteristics observed in thin sections. The original geological context of the given siliceous rock was rarely taken into account during these determinations. However, this context should be essential for applying Přichystal's definition because until now, only two examples of combined geological and petrographical investigations on limnosilicites have been undertaken in Hungary – one in the Avas Hill in Miskolc (Hartai and Szakáll 2005), the other in the Tokaj Mountains (Szekszárdi *et al.*, 2010).

Problem of the limnosilicites of the Avas Hill in Miskolc

The Avas Hill in the centre of Miskolc (Northeast-Hungary) was well-known for 'flints' since the Middle Ages – even a workshop for producing gunflints operated in the town (Simán 1995b: 382). Investigations related to limnosilicite outcrops have been made at two localities on the hill about 500 m distant from one another: at Pergola on the northern edge of the plateau (Simán 1995b) and at Tűzköves on the northeastern slope of the hill (Ringer 2003; Fig. 2).

According to Katalin Simán's observations (1995b: 375), the geological sequence at Pergola consists of three layers of andesite tuff separated by marl and sandy marl layers. Only the two lower layers evidence hydrothermal activities containing 'hydroquartzite'. Referring to Simán's publication, Přichystal (2013: 132–133) characterizes this raw material as a geyserite originating from thermal spring activity cropping out as lenses in the Tertiary rhyolite tuffs and marlstones. Using samples found at Karel Žebera's collection for analyses under stereomicroscope and in thin section, Přichystal describes this silicite as being smudged to banded rocks, of light brown to reddish colours, presenting small cavities (up to 1.5 cm) filled by chalcedony or fine crystallized quartz. No microfossils have been detected in the samples, which reinforces the determination as geyserite.

The geological situation at Tűzköves was studied by Éva Hartai and Sándor Szakáll (2005). The geological sequence seems to be more complicated than described at Pergola. The main mass of the hill is composed of andesitic and rhyolitic pyroclasts of Badenian-Sarmatian age (Middle and Late Miocene). In the deeper sections of the formation rhyolitic tuffs are characteristic, and above these tuffs andesitic pyroclasts and sedimentary layers form a sequence built up of highly variable layers. In its upper portion travertine layers and limnic silica beds and lenses occur. Due to volcanic activities there are silica-containing layers within the travertine where silica replaced calcite: the solution of vitric volcanic ash in the lacustrine environment acidified the water

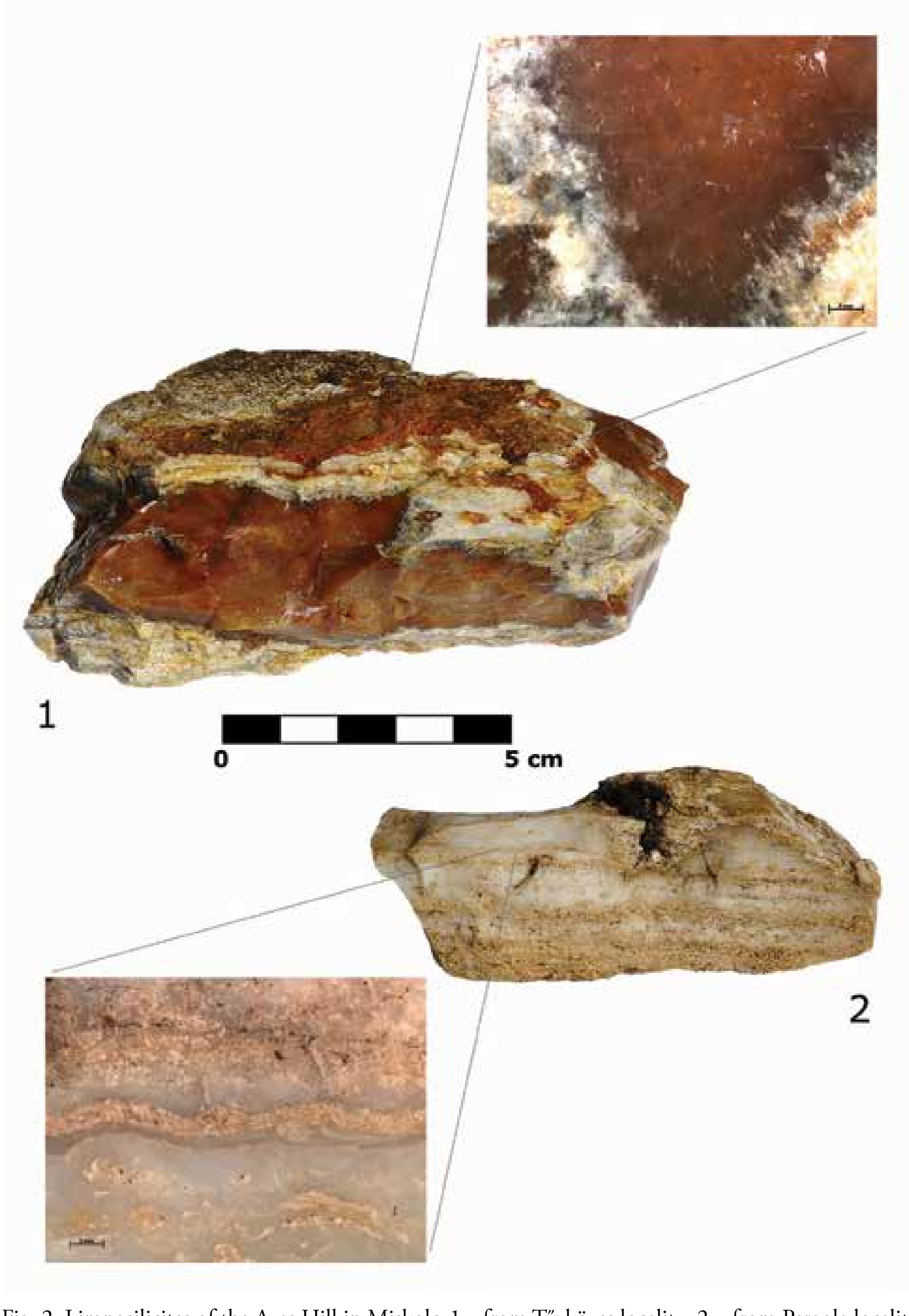

Fig. 2. Limnosilicites of the Avas Hill in Miskolc: 1 – from Tűzköves locality; 2 – from Pergola locality. Photos: N. Faragó, microphotos: Zs. Mester, magnification 10x and 12.5x respectively.

and promoted the precipitation of silica. Therefore, with further volcanic activity, pure silica layers could form. The characterization of this 'limnoquartzite' by microscopy is very similar to the abovementioned one published by Přichystal (colours, infillings by chalcedony, absence of microfossiles), the main difference being the presence of opal-CT among the microcrystalline silicate minerals.

We cannot resolve the question of whether these differences demonstrate the variability of this silicite or if they suggest the existence of different conditions of formation (springs and lake). On the one hand, further field investigations are needed to verify the geological situation at Pergola and to check the possibility of lacustrine environment. On the other hand, a thorough selection of more variants from both localities with detailed petrographic analyses should clarify the degree of the variability of this raw material. Regardless, this case study provides a good illustration of our problems from the petroarchaeological point of view. Even though both descriptions noted the absence of the microfossils which could lead us to the determination of geyserite for both localities, the lacustrine environment is strongly supported by geological survey at Tűzköves. Therefore, it seems reasonable for archaeological purposes to consider the group of limnosilicites more broadly than Přichystal's strict definition.

Problem of the limnosilicites of the Tokaj Mountains

The formation of the Tokaj Mountains was related to the history of the Pannon-Sea in the Neogene, featuring a series of volcanic activities from the Badenian to Pannonian periods. Due to tectonic ascension and sediment in-filling from neighboring Carpathian regions, lagoons and lakes developed at the northeastern part of the basin (Hámor 2001). Rocks building up the Tokaj Mountains originate from the Neogene volcanism between 15 and 9 million years ago (Gyarmati 1977). Related postvolcanic hydrothermal activities caused the formation of limnosilicites in the lacustrine environments in Late Badenian and Sarmatian periods (Szekszárdi 2005; Szekszárdi *et al.*, 2010). A comprehensive study of limnic siliceous rocks within five lacustrine basins from the Tokaj Mountains (Szekszárdi *et al.*, 2010: Fig. 1) has been performed by different analytical methods for petroarchaeological purposes (Szekszárdi 2007).

According to the published data (Szekszárdi *et al.*, 2010), the classification based on *macro*scopic differences was not always correlated with *micro*scopic characteristics. In the southern part of the mountains, at the Rátka–Mád area, limnosilicites occur in three levels which are macroscopically different. The uppermost level yielded grey-blue colored rocks rich in plant fossils, showing microcracks in thin section. Limnosilicites from the middle level are yellowish or light brown with dark brown or blackish bands, due to the presence of organic matters and limonite, without fossils and microcracks. A special variant from this level is the so-called stone-marrow which was formed probably in a transition zone by the silicification of a fine-grained clayey sediment. In thin section, it consists of isotropic opal. Fifteen km to the northeast, at the Erdőbénye area, siliceous rocks are quite uniform. Opals and limnoopals dominate, and fossils are extremely rarely. The uniformity is especially evident in thin sections. Twenty more km to the northwest, at the Arka–Korlát area, limnosilicites are brownish, sometimes translucent, in color with a white patina, and they contain a significant amount of fossils. In thin section, they are highly variabile due to differences in the degree of silicification of plant fossils, as well as to the presence of chalcedony filling cracks and places of fossils. Ten km to the east of this locality, at the Óhuta area, limnosilicites form two distinct groups according to the presence of fossils: one is rich, the other is poor. As might be expected, the groups have very different thin sections. At the northern part of the mountains, the Gönc–Telkibánya area shows the highest variability, both macroscopically and in thin section. No special features occur, but some variants are very similar to the limnoopals of the Erdőbénye area.

Our field survey observations (Mester and Faragó 2013) made it abundantly clear that one can observe variability in texture and color even within blocks. At the Korlát–Arka area, we collected samples showing a combination of three different characteristics (Fig. 3): translucent, silica gel-like appearance; light brown and opaque part; white opal or opalized component. Very often, there are intergradations from one to another, suggesting that, in the absence of this knowledge, the knapped items found in archaeological sites could misakenly be interpreted as coming from different varieties of limnosilicites.

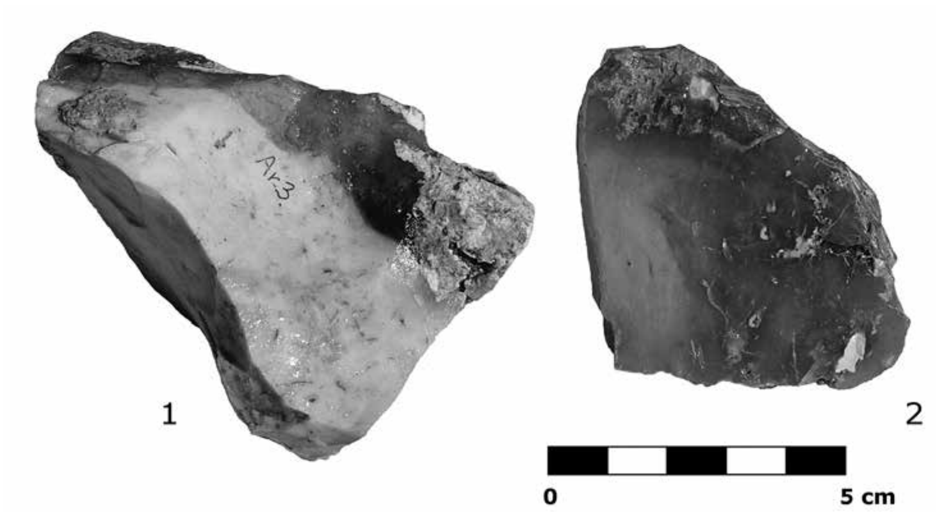

Fig. 3. 1 – Block of limnosilicite with different macroscopic appearance from Korlát–Arka area; 2 – Blade core made of similar raw material from the Boldogkőváralja site. Photo: N. Faragó.

GEOLOGY OF LIMNOSILICITES: DISCOVERING AND CHARACTERIZING THE SOURCES

Many of the known outcrops of the limnosilicites in northern Hungary have been discovered by chance during field work by geologists, palaeontologists, archaeologists, and other professionals (e.g. Csongrádi-Balogh and Dobosi 1995; Markó 2005), including information from private collectors. Systematic field prospection for raw material outcrops has been rare, one of the few examples being the abovementioned investigation in the Tokaj Mountains (Szekszárdi *et al.*, 2010).

The survey for sources of limnosilicites should be systematized using geological maps (Mester and Faragó 2013). Geological formations (e.g. Erdőbénye, Sajóvölgy and Szurdokpüspöki formations of the Miocene – Budai and Gyalog 2009) need to be field checked when limnic quartzite is mentioned by their descriptions (Fig. 1). The siliceous material in the embedding rock may sometimes appear to be very low quality for knapping, although macroscopically identical raw material is known in prehistoric toolkits. In addition as we have discovered, lack of obvious macroscopic similarity is not necessarily definitive, because better quality nodules from the same formation can sometimes be found in nearby eroded material, which is why surveying stream beds or river valley slopes can be fruitful (Mester and Faragó 2013). A recently developed method in sedimentary petrography, the fine-grained pebble examination (FPE), allows us to determine the geological background of a sedimentary sequence by examining the mineralogy and petrology of debris eroded from the source area (Bradák *et al.*, 2014: 123–124). The method consists of a thorough selection of all types of rock pebbles on the sampling place from a fluvial deposit, followed by microscopic analysis of a thin section made on the artificial conglomerate of the selected small pebbles (2–2.5 mm). In this way, it is possible to discover siliceous rocks, including limnosilicites, which do not have outcrops now in the study area.

Another possibility is to check localities having a local geographic name with the reference 'flint' or 'silex' (in Hungarian: 'tűzkő' and 'kova'). In northern Hungary, the referred materials are very often in fact limnosilicites or different silicified materials of metasomatic origin. On the Great Hungarian Plain (Alföld), these geographic names mainly refer to prehistoric (tell) settlements, but several times during our field surveys, such places actually proved to be Quaternary formations with redeposited sediments containing blocks of siliceous rocks.

From an archaeological point of view, it is also very important to characterize the sources. We use the classification published by Alain Turq (2000, 2005): 1 – primary autochthonous source: in the original context of the formation (embedded in the parent rock); 2 – secondary autochthonous source: extracted by erosion and accumulated in the vicinity of the original primary autochthonous source (in a slope deposit or in a stream bed); 3 – sub-allochthonous or residual source: in new geological context resulted of transformation and re-deposition by weathering (in a weathered and decayed rock or colluvium); 4 – allochthonous or exotic source: the eroded and/or accumulated raw material had been transported long distances by water courses and deposited with fluvial sediments. We find these categories very useful for archaeological purposes because they correlate with types of accessibility and possibilities for human exploitation.

ARCHAEOLOGY OF LIMNOSILICITES: ACCESSIBILITY AND EXPLOITATION

For a better understanding of the behavior of prehistoric human groups, it is important to approach their archaeological remains as being the imprints of their past activities. Among these activities, humans transform natural resources to create artifacts using objects and the human body (Lemonnier 1991). All the related elements – i.e. the material to transform, the used objects, the processes of the transformation, and the necessary knowledge and skills – are components. These components – together with the relations and interactions between them – constitute the technical system of a given human group or society (Lemonnier 1983, 1991, 2010). This theoretical framework allows us to study past human technical activities in their complexity.

Raw material procurement constitutes one of the subsystems of the technical system of each human group. By technological analysis of the lithic assemblage, we are able to recognize strategies applied for the acquisition, the treatment, and the economy of the raw materials (Binder and Perlès 1990; Perlès 1990; Montet-White and Holen 1991; Féblot-Augustins 1997). The procurement strategies are determined by the conditions of the natural and cultural environment, which influence the accessibility and the modes of exploitation of raw material sources.

The cultural environment of the group consists of its technical traditions and its relations to other groups. Its effects could be evaluated by analysing archaeological data on local, regional or extraregional level, and confronting them eventually with anthropological models (Andrefsky 1994; Lech 2003; Whallon 2006; Mester and Kozłowski 2014).

The effects of the natural environment are much more important for understanding the role limnosilicites have played in raw material procurement and economy of prehistoric human groups. A series of factors have to be taken into consideration in relation to human technical behaviour (Tixier 2012: 80–84). The size, form and quantity of the lithic resource must be estimated by observations made in the field at potential sources, while the suitability of the material for tool production has to be evaluated by experimentation (Lengyel 2013). For studying accessibility it is crucial to keep in mind that the landscape might have been changed since the period in question. Geomorphological processes could result in the complete covering of raw material sources which were on the surface several millennia ago. For example, during our field survey near Mád in the Tokaj Mountains, we found a layer of limnosilicite blocks, seemingly in eroded and redeposited position, at the bottom of a dirt road which cut between two wineyards (Fig. 4). Despite cultivation, the wineyard areas did not yield any limnosilicites but limnosilicates were encountered about 1 m below the actual surface. Because the foothills of the northern Hungarian Range were affected by intensive erosional processes during the Final Pleistocene and Early Holocene (Pinczés *et al.*, 1993; Karátson 2006), raw material sources might be covered or even uncovered in the region.

The exploitation of raw material sources can be executed in several ways – from simple collecting on the surface to complex mining (Fober and Weisgerber 1981). There is a close relation between the modes of exploitation and the previously mentioned categories or types of raw material source. Allochtonous and secondary autochtonous sources yield raw material blocks or pebbles directly on the surface or slightly embedded in loose sediments. Acquiring raw materials from these sources does not require significant energy investment for extracting but it could take time to find material of appropriate quality (Mester *et al.*, 2012). As a consequence, it is almost impossible to recognize and archaeologically document these forms of exploitation. In fortunate cases, traces of testing the collected material could support arguments for such an interpretation. Primary autochtonous and sub-allochtonous sources yield raw material blocks or nodules embedded in the body of the geological formation. Acquiring them necessitates extraction techniques or even mining, and these techniques have been applied from the Middle Palaeolithic onwards (Vermeersch 2005). For limnosilicites in northern Hungary, archaeological investigations document the existence of mines operating with extraction pits, thought to be in use from the Middle Paleolithic to the Neolithic or even the Bronze Age (Simán 1986, 1995a, 1995b, 1999). The main archaeological problem of these mines is the chronological and cultural attributions. Usually, extraction methods are not culturally specific and, if there are no mining tools made from organic materials, radiometric dating is almost impossible. Diagnostic tools are very rare in the lithic assemblages. The fact that the outcrops were exploited in different periods, even in modern times, causes further difficulties for archaeological interpretations. The same problems exist for extraction sites (Fig. 5).

CONCLUSIONS

Due to the complicated plate tectonic movements building up the Carpathians and related Tertiary volcanism, limnosilicites are very common siliceous rocks in the territory of northern Hungary. Geological formations containing 'limnic quartzites' were mapped in the north Hungarian Range, mainly in the foothill regions. Based on what we know from

Fig. 4. Limnosilicites blocks about 1 m under the actual surface, uncovered by a dirt road near Mád (Tokaj Mountains). Photo: N. Faragó.

the archaeological record, these siliceous rocks have been used extensively by prehistoric human groups as raw materials for tool production.

Because local geological conditions were varied and dynamic during their formations, limnosilicites show great petrographic variability, accounting for why the identification of the provenience of raw materials of artifacts in archaeological assemblages is a very difficult task in most of cases. Samples collected during field surveys demonstrate that macroscopically different parts could be present within one block. As a consequence, flakes or blades characterized as representing different variants of limnosilicites in an archaeological assemblage might actually have originated from the same block of raw material.

To achieve a better understanding the procurement strategies and technical behaviour of prehistoric groups inhabiting the region, it is indispensable to have a comprehensive knowledge about potential raw materials and their sources. Geological maps and local geographic names could help to discover them during field surveys. We believe that it is necessary to characterize the sources according to categories adopted from French prehistoric research (Turq 2000, 2005) because these types of sources

Fig. 5. Limnosilicite extraction site at Gyöngyöstarján-Köves-tető (Mátra Mountains). Photo: M. Gutay.

correspond to types of exploitation methods for prehistoric humans. Geomorphologic studies are also crucial for estimating onetime accessibility of the limnosilicite sources due to the intensive erosional processes which have affected the foothill regions of the north Hungarian Range during the Pleistocene and the Early Holocene. Finally, additional petroarchaeological investigations are needed to complement the good results obtained in the Tokaj Mountains (Szekszárdi *et al.*, 2010), and even more research is needed in the Cserhát, Mátra and Bükk mountains where systematic field surveys have not been completed.

There is much research yet to do on the archaeological, geological, and petrologic problems of limnosilicites but, in the end, we will be better able to understand and reconstruct past human behaviors related to raw material economy.

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REFERENCES

Andrefsky, W.Jr. 1994. Raw-material availability and the organization of technology. *American Antiquity* 59(1): 21–34.

Bácskay, E. 1981. Zum Stand der Erforschung prähistorischer Feuersteingruben in Ungarn. In G. Weigerber, R. Slotta and J. Weiner (eds), *5000 Jahre Feiersteinbergbau. Die Suche nach dem Stahl der Steinzeit*, 179–182. Bochum.

Bácskay, E. 1995a. H2. Sümeg-Mogyorósdomb, Veszprém country. *Archaeologia Polona* 33: 383–395.

Bácskay, E. 1995b. H5. Erdöbénye-Sás patak, Borsod country *Archaeologia Polona* 33: 395–400.

Bácskay, E. 1995c. H7. Bakonycsernye-Tűzkövesárok, Fejer country. *Archaeologia Polona* 33: 402–402.

Bácskay, E. 1995d. H9. Hárskút-Édesvízmajor, Veszprém country. *Archaeologia Polona* 33: 408–409.

Bácskay, E. 1995e. H10. Dunaszentmiklós-Hosszúvontató, Komárom country. *Archaeologia Polona* 33: 409–410.

Bácskay, E. 1995f. H11. Lábatlan-Margittető, Komárom country. *Archaeologia Polona* 33: 410–411.
Bácskay, E. 1995g. H12. Lábatlan-Pisznicetető, Komárom country. *Archaeologia Polona* 33: 411–411.
Binder, D. and Perlès, C. 1990. Stratégies de gestion des outillages lithiques au Néolithique. *Paléo* 2: 257–283.
Biró, K.T. 1985. Neogene rocks as raw materials of the Prehistoric stone artifacts in Hungary. In J. Hála (ed.), *Neogene mineral resources in the Carpathian Basin: historical studies on their utilization*, 383–396. Budapest: Hungarian Geological Survey.
Biró, K.T. (ed.) 1986. *Papers for the 1st International Conference on Prehistoric Flint Mining and Lithic Raw Material Identification in the Carpathian Basin, Budapest–Sümeg 1986, vol. 1*. Budapest.
Biró, K.T. (ed.) 1987. *Papers for the 1st International Conference on Prehistoric Flint Mining and Lithic Raw Material Identification in the Carpathian Basin, Budapest–Sümeg 1986, vol. 2*. Budapest.
Biró, K.T. 1995. H8. Szentgál-Tűzköveshegy, Veszprém country. *Archaeologia Polona* 33: 402–408.
Biró, K.T. 1988. Distribution of lithic raw materials on Prehistoric sites: an interim report. *Acta Archaeologica Academiae Scientiarum Hungaricae* 40: 251–274.
Biró, K.T. 1998. *Lithic implements and the circulation of raw materials in the Great Hungarian Plain during the Late Neolithic Period.* Budapest.
Biró, K.T. 2002. Advances in the study of Early Neolithic lithic materials in Hungary. *Antaeus* 25: 119–168.
Biró, K.T. 2004. Provenancing: methods, possibilities, problems. *Antaeus* 27: 95–110.
Biró, K.T. 2010. Terminological practice for siliceous rocks in Hungary from petroarchaeological point of view. *Archeometriai Műhely* 2010 (3): 195–201.
Biró, K. and Dobosi, V. 1991. *Lithotheca – comparative raw material collection of the Hungarian National Museum*. Budapest.
Biró, K., Dobosi, V. and Schléder, Zs. 2000. *Lithotheca II – the comparative raw material collection of the Hungarian National Museum, Vol. II*. Budapest.
Bíró, T.K., Simán, K. and Szakáll, S. 1984. A characteristic SiO_2 raw material type group used in Prehistoric in Hungary. In K.S. Kunchev, I. Nachev and N.T. Tcholakov (eds), *IIIrd Seminar on Petroarcheology , Plovdiv, 27–30 August, 1984, Bulgaria*, 103–127. Plovdiv.
Bradák, B., Kiss, K., Barta, G., Varga, Gy., Szeberényi, J., Józsa, S., Novothny, Á., Kovács, J., Markó, A., Mészáros, E. and Szalai, Z. 2014. Different paleoenvironments of Late Pleistocene age identified in Verőce outcrop, Hungary: Preliminary results. *Quaternary International* 319: 119–136.
Budai, T. and Gyalog, L. (eds), 2009. *Geological map of Hungary for tourists – 1:200 000*. Budapest.
Cheben, I. and Illášová, Ľ. 2002. Chipped industry made of limnoquarzite from Žiarska kotlina hollow. In I. Cheben and I. Kuzma (eds), *Otázky neolitu a eneolitu našich krajín – 2001*, 105–112. Nitra.
Crandell, O. 2014. Knappable lithic resources of North-Western Romania: A mineralogical study. *Journal of Lithic Studies* 1 (1): 73–84.
Csongrádi-Balogh, É. and Dobosi, V.T. 1995. Palaeolithic settlement traces near Püspökhatvan. *Folia Archaeologica* 44: 37–59.
Dobosi, V.T. 1978. A pattintott kőeszközök nyersanyagáról. (Über das Rohmaterial der retuschierten Steingeräte.) *Folia Archaeologica* 29: 7–19.
Dobosi, V.T. 1995. Eger–Kőporostető. Révision d'une industrie à outils foliacés. In *Les industries à pointes foliacées d'Europe centrale. Actes du Colloque de Miskolc, 10–15 septembre 1991*, 45–55. Les Eyzies. Paléo – Supplément N° 1.
Dobosi, V.T. 2001. Antecedents: Upper Palaeolithic in the Jászság region. In R. Kertész and J. Makkay (eds), *From the Mesolithic to the Neolithic. Proceedings of the International Archaeological Conference held in the Damjanich Museum of Szolnok, September 22–27, 1996*, 177–191. Budapest.
Dobosi, V.T. 2008. Acsa: new open-air Aurignacian site in Hungary. In Z. Sulgostowska and A.J. Tomaszewski (eds), *Man – Millennia – Environment. Studies in Honour of Romuald Schild*, 151–159. Warsaw.

Dobosi, V.T. and Simán, K. 1996. New Upper Palaeolithic site at Megyaszó-Szelestető. *Communicationes Archaeologicae Hungaricae* 1996: 5–22.

Féblot-Augustins, J. 1997. *La circulation des matières premières au Paléolithique*. Liège.

Fober, L. and Weisgerber, G. 1981. Feuersteinbergbau – Typen und Techniken. In G. Weigerber, R. Slotta and J. Weiner (eds.), *5000 Jahre Feiersteinbergbau. Die Suche nach dem Stahl der Steinzeit*, 32–47. Bochum: Deutschen Bergbau-Museum Bochum 22.

Gyarmati, P. 1977. A Tokaj-hegység intermedier vulkanizmusa. *Magyar Állami Földtani Intézet Évkönyve* 58: 1–195.

Hámor, G. 2001. *A Kárpát-medence miocén ősföldrajza: Magyarázó a Kárpát-medence miocén ősföldrajzi és fáciestérképéhez 1:3 000 000*. Budapest.

Harangi, Sz. 2001. Neogen to Quaternary Volcanism of the Carpathian-Pannonian Region-a review. *Acta Geologica Hungarica* 44: 233–258.

Harangi, S. and Lenkey, L. 2007. Genesis of the Neogene to Quaternary volcanism in the Carpathian-Pannonian region: Role of subduction, extension, and mantle plume. In L. Beccaluva, G. Bianchini and M. Wilson (eds), *Cenozoic Volcanism in the Mediterranean Area*, 67–92. Boulder. Geological Society of America Special Paper 418.

Hartai, É. and Szakáll, S. 2005. Geological and mineralogical background of the Palaeolithic chert mining on the Avas Hill, Miskolc, Hungary. *Praehistoria* 6: 15–21.

Kadić, O. 1916. Ergebnisse der Erforschung der Szeletahöhle. *Mitteilungen aus dem Jahrbuche der königlichen Ungarischen Geologischen Reichsanstalt* 23: 161–301.

Kaminská, Ľ. 2001. Die Nutzung von Steinrohmaterialien im Paläolithikum der Slowakei. *Quartär* 51/52: 81–106.

Kaminská, Ľ. 2013. Sources of raw materials and their use in the Palaeolithic of Slovakia. In Zs. Mester (ed.), *The lithic raw material sources and interregional human contacts in the northern Carpathian regions*, 99–109. Kraków–Budapest.

Karátson, G. 2006. Aspects of Quaternary relief evolution of Miocene volcanic areas in Hungary: A review. *Acta Geologica Hungarica* 49: 285–309.

Lech, J. 2003. Mining and siliceous rock supply to the Danubian early farming communities (LBK) in Eastern Central Europe: A second approach. In L. Burnez-Lanotte (ed.), *Production and Management of Lithic Materials in the European Linearbandkeramik*, 19–30. Oxford: Archaeopress. British Archaeological Reports International Series 1200.

Lemmonier, P. 1983. L'étude des systèmes techniques: une urgence en technologie culturelle. *Techniques et culture* 1: 11–26.

Lemonnier, P. 1991. De la culture matérielle à la culture ? Ethnologie des techniques et Préhistoire. In *25 ans d'études technologiques en Préhistoire. XI[e] Rencontres Internationales d'Archéologie et d'Histoire d'Antibes*. Éditions APDCA, Juan-les-Pins, 15–20.

Lemmonier, P. 2010. Retour sur 'L'étude des systèmes techniques'. *Techniques et culture* 54–55 (1): 46–67.

Lengyel, Gy. 2013. Knapping experiments on lithic raw materials of the Early Gravettian in Hungary. In Zs. Mester (ed.), *The lithic raw material sources and interregional human contacts in the northern Carpathian regions*, 39–51. Kraków–Budapest.

Lengyel, Gy. 2015. Lithic raw material procurement at Bodrogkeresztúre Henye Gravettian site, northeast Hungary. *Quaternary International* 359–360: 292–303.

Lengyel, Gy., Béres, S. and Fodor, L. 2006. New lithic evidence of the Aurignacian in Hungary. *Eurasian Prehistory* 4 (1–2): 79–85.

Markó, A. 2005. Limnokvarcit a Cserhát hegységben. *Archeometriai Műhely* 2005 (4): 52–55.

Markó, A. 2009. Raw material circulation during the Middle Palaeolithic period in northern Hungary. In J. Gancarski (ed), *Surowce naturalne w Karpatach oraz ich wykorzystanie w pradziejach i wczesnym średniowieczu*, 107–120. Krosno.

Mester, Zs. and Faragó, N. 2013. The lithic raw material sources and interregional human contacts in the northern Carpathian regions: Report and preliminary results of the field surveys. In Zs. Mester (ed.), *The lithic raw material sources and interregional human contacts in the northern Carpathian regions*, 23–37. Kraków–Budapest.

Mester, Zs. and Kozłowski, J.K. 2014. Modes de contacts des Aurignaciens du site d'Andornaktálya (Hongrie) à la lumière de leur économie particulière de matières premières. In M. Otte and F. Le Brun-Ricalens (eds), *Modes de contacts et de déplacements au Paléolithique eurasiatique. Modes of contact and mobility during the Eurasian Palaeolithic*, 349–367. Luxembourg. E.R.A.U.L. 140, ArchéoLogiques 5, Université de Liège–Centre National de Recherche Archéologique.

Mester, Zs. and Tixier, J. 2013. '*Pot à lames*': The Neolithic blade depot from Boldogkőváralja (Northeast Hungary). In A. Anders and G. Kulcsár (eds), *Moments in time. Papers presented to Pál Raczky on his 60th birthday*, 173–185. Budapest. Ősrégészeti Tanulmányok/Prehistoric Studies 1.

Mester, Zs., Faragó, N. and Lengyel, Gy. 2012. The lithic raw material sources and interregional human contacts in the northern Carpathian regions: A research program. *Anthropologie* 50 (3): 275–293.

Mišík, M. 1969. Petrografická príslušnosť silicitov z paleolitických a neolitických artefaktov Slovenska. *Acta geologica et geographica Universitatis Comenianae, Geologica* 18: 117–135.

Mišík, M. 1975. Petograficko-mikropaleontologické kritériá pre zisťovanie proveniencie silicitových nástrojov na Slovensku. *Folia Fac. Sci. Natur. Univ. Purkyn. Brunensis 16, Geologia* 27, 89–107.

Montet-White, A. and Holen, S. (eds), 1991. *Raw material economies among Prehistoric hunter-gatherers*. Lawrence: University of Kansas. Publications in Anthropology 19.

Perlès, C. 1990. L'outillage de pierre taillée néolithique en Grèce: approvisionnement et exploitation des matières premières. *Bulletin de correspondance héllénique* 114: 1–42.

Pinczés, Z., Martonné Erdős, K. and Dobos, A. 1993. Eltérések és hasonlóságok a hegylábfelszínek pleisztocén felszínfejlődésében. *Földrajzi Közlemények* 117: 149–162.

Přichystal, A. 2010. Classification of lithic raw materials used for prehistoric chipped artefacts in general and siliceous sediments (silicites) in particular: the Czech proposal. *Archeometriai Műhely* 2010 (3): 177–181.

Přichystal, A. 2013. *Lithic raw materials in Prehistoric times of Central Europe*. Brno.

Rácz, B. 2013. Main raw materials of the Palaeolithic in Transcarpathian Ukraine: geological and petographical overview. In Zs. Mester (ed.), *The lithic raw material sources and interregional human contacts in the northern Carpathian regions*, 131–146. Kraków–Budapest.

Ringer, Á. 2003. Őskőkori kovabányászat és kovakő-feldolgozás a miskolci Avason. (Des mines et des ateliers de silex préhistoriques sur le mont Avas à Miskolc.) *Herman Ottó Múzeum Évkönyve* 42: 5–15.

Ringer, Á. and Szolyák, P. 2004. A Szeleta-barlang tűzhelyeinek és paleolit leleteinek topográfiai és sztratigráfiai eloszlása. Adalékok a leletegyüttes újraértékeléséhez. (The topographic and stratigraphic distribution of the Palaeolithic hearths and finds in the Szeleta Cave. Contribution to re-interpretation of the assemblage). *Herman Ottó Múzeum Évkönyve* 43: 13–32.

Simán, K. 1986. Limnic quartzite mines in Northeast-Hungary. In K.T. Biró (ed.), *Papers for the 1st International Conference on Prehistoric Flint Mining and Lithic Raw Material Identification in the Carpathian Basin, Budapest–Sümeg 1986, vol. 1*, 95–99. Budapest.

Simán, K. 1989. Hidasnémeti – Upper Palaeolithic site in the Hernád valley (Northeast Hungary). *Acta Archaeologica Carpathica* 28: 5–24.

Simán, K. 1995a. H4. The Korlát-Ravaszlyuktető workshop site in North-Eastern Hungary. *Archaeologia Polona* 33: 41–58.

Simán, K. 1995b. H1. Prehistoric mine on the Avas Hill at Miskolc. *Archaeologia Polona* 33: 371–382.

Simán, K. 1999. Bifaciális eszközök Korlát-Ravaszlyuk-tető lelőhelyen. (Bifacial implements on Korlát-Ravaszlyuk-tető site.). *Herman Ottó Múzeum Évkönyve* 37: 29–44.

Szekszárdi, A. 2005. A vizsgálati lehetőségek áttekintése a Tokaji-hegységi limnokvarciton és limnoopaliton, a pattintott kőeszközök eredetének azonosítása céljából. *Archeometriai Műhely* 2005 (4): 56–61.

Szekszárdi, A. 2007. *Tokaji-hegységi limnokvarcit-limnoopalit nyersanyagok és pattintott kőeszközök archaeometriai vizsgálati eredményei*. Unpublished MSc Thesis, Eötvös Loránd University, Budapest.

Szekszárdi, A., Szakmány, Gy. and Biró, K.T. 2010. Tokaji-hegységi limnokvarcit-limnoopalit nyersanyagok és pattintott kőeszközök archeometriai vizsgálata. I.: Földtani viszonyok, petrográfia. (Archaeometric analysis on limnic-quartzite limnic opalite raw materials and chipped stone tools, Tokaj Mts. NE-Hungary. I.: geological settings, petrography). *Archeometriai Műhely* 2010 (1): 1–17.

Tixier, J. 2012. *A method for the study of stone tools / Méthodes pour l'étude des outillages lithiques*. Luxembourg.

Turq, A. 2000. *Le Paléolithique inférieur et moyen entre Dordogne et Lot*. Les Eyzies. Paléo Supplément 2.

Turq, A. 2005. Réflexions méthodologiques sur les études de matières premières lithiques. *Paléo* 17: 111–132.

Vendl, A. 1933. Adatok a bükkhegységi paleolitos szilánkok kőzettani ismeretéhez. *Matematikai és Természettudományi Értesítő* 50: 573–587.

Vendl, A. 1940. Das Gesteinsmaterial der Paläolithe. In L. Bartucz, J. Dancza, F. Hollendonner, O. Kadić, M. Mottl, V. Pataki, E. Pálosi, J. Szabó and A. Vendl (eds), *Die Mussolini-Höhle (Subalyuk) bei Cserépfalu*, 169–199. Budapest.

Vermeersch, P.M. 2005. Middle Palaeolithic chert extraction structures in Egypt. *Praehistoria* 6: 57–69.

Vértes, L. 1964–1965. Das Jungpaläolithikum von Arka in Nord-Ungarn. *Quartär* 15–16: 79–132.

Whallon, R. 2006. Social networks and information: non-'utilitarian' mobility among hunter-gatherers. *Journal of Anthropological Archaeology* 25: 259–270.

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A Newly Discovered Source of 'Banded Flint' in the Polish Lowlands

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Rescue excavations at an artefact manufacturing site at Pęgów, Poddębice district, dated to the modern period, have produced several dozens of lumps of flint. The flint exhibits greyish and brownish bands and is macroscopically similar to the well-known banded flint occurring in the area of Krzemionki Opatowskie, Ostrowiec Świętokrzyski district. Artefacts made from this tentatively named 'Pęgów flint' have been identified in archaeological assemblages of different chronological age in the Koło Basin. To verify whether macroscopically similar nodules and artefacts come from the same outcrop and if the artefacts made of banded flint are made of the Krzemionki Opatowskie flint, instrumental neutron activation analysis (INAA) was conducted on samples of Pęgów flint and banded raw material from Krzemionki Opatowskie. Although most of the obtained results fall below INAA detection limits the compostion of chromium content in each sample may reflect common origin of all the analysed pieces from Pęgów. INAA data suggest that the artifacts made of banded flint were mot made from Krzemionki Opatowskie material.

KEY-WORDS: 'Pęgów flint', Instrumental Neutron Activation Analysis (INAA), Koło Basin

Prior to the construction of the A2 motorway, the Institute of Archaeology and Ethnology of the Polish Academy of Sciences carried out rescue excavations at Pęgów, Poddębice district, where an artefact manufacturing site was discovered (marked as site 2 – AUT 461). Remains of multicultural settlements were found (Lusatian Culture, Przeworsk Culture, Medieval Period), of which those dated to 16–17th century AD were the most intensive, including 17 pits, an animal burial, 3 lime kilns, 17 limestone extraction pits and 1264 fragments of pottery (Seroczyński and Wysocka 2006: 43).

Present among the limestone residue in excavated lime kilns were several dozen lumps of flint raw material in various shades of grey, with characteristic bands, partially covered with cortex. Late Palaeolithic, Mesolithic and younger flint assemblages from other archaeological sites in the Koło Basin, within which the Pęgów site is located, have yielded artefacts of analogous material. Tentatively termed Pęgów flint, after the archaeological site where it was first recognized, this 'banded flint' is macroscopically similar to the famous banded flint from Krzemionki Opatowskie, Ostrowiec

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Świętokrzyski district. The aim of this paper is to discuss the geological and archaeological occurrence of Pęgów flint and present the results of INAA geochemical analysis.

GEOGRAPHICAL AND GEOLOGICAL CONTEXT

As it flows from the south, the Warta River turns west at one point; the Koło Basin is the resultant extension of the Warta River valley (Fig. 1). The second large watercourse flowing through the Basin, the Ner River joins the Warta south of Koło. Its sources are located within the Łódź Hills. The Kłodawa Plateau abuts the Koło Basin from the north, the Łask Plateau from the south and the Turek Plateau from the west (Kondracki 2009: 158).

The Koło Basin was largely formed in the period of recession of the Oder/Warta Glaciation, during which the Koło Basin was cut through the Warsaw-Berlin ice-

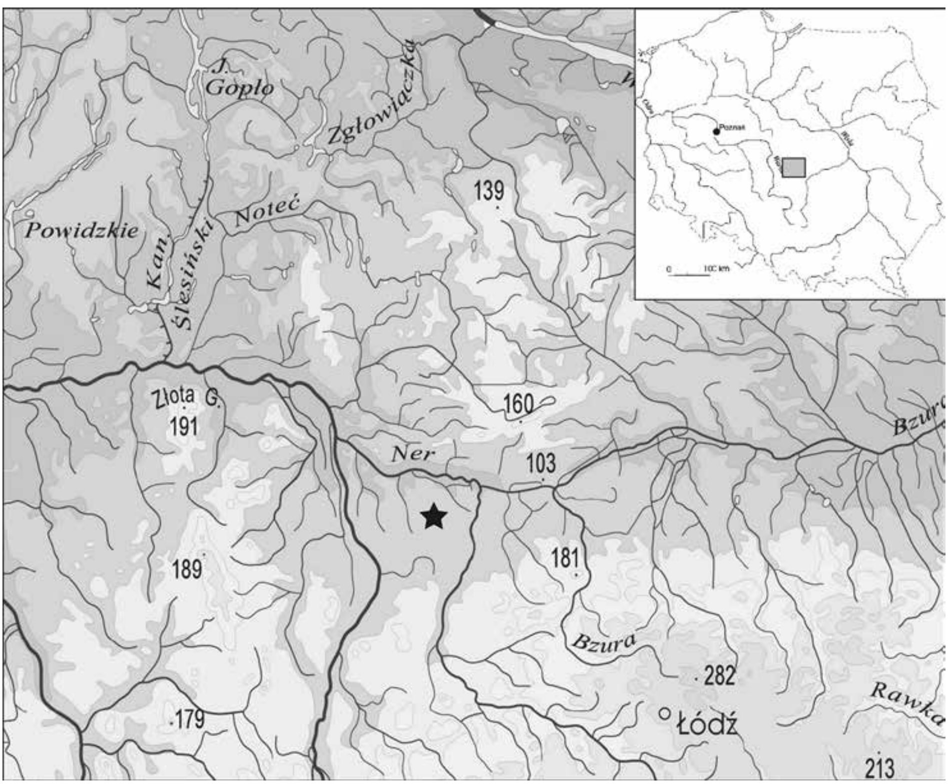


Fig. 1. Black star marks the location of the Pęgów site, Poddębice district.
Drawn by: P. Szejnoga, A. Tabaka.

marginal valley. This is one of the three great latitudinal valleys of the Polish Lowland, which discharged melt-water coming from the Scandinavian ice sheet in the Poznań phase of the North Polish glaciation (Stankowski 1995: 168).

A notable feature of the region is its considerable morphological diversity and the presence of extensive dune fields. The area of the Upper and central Bzura and Ner

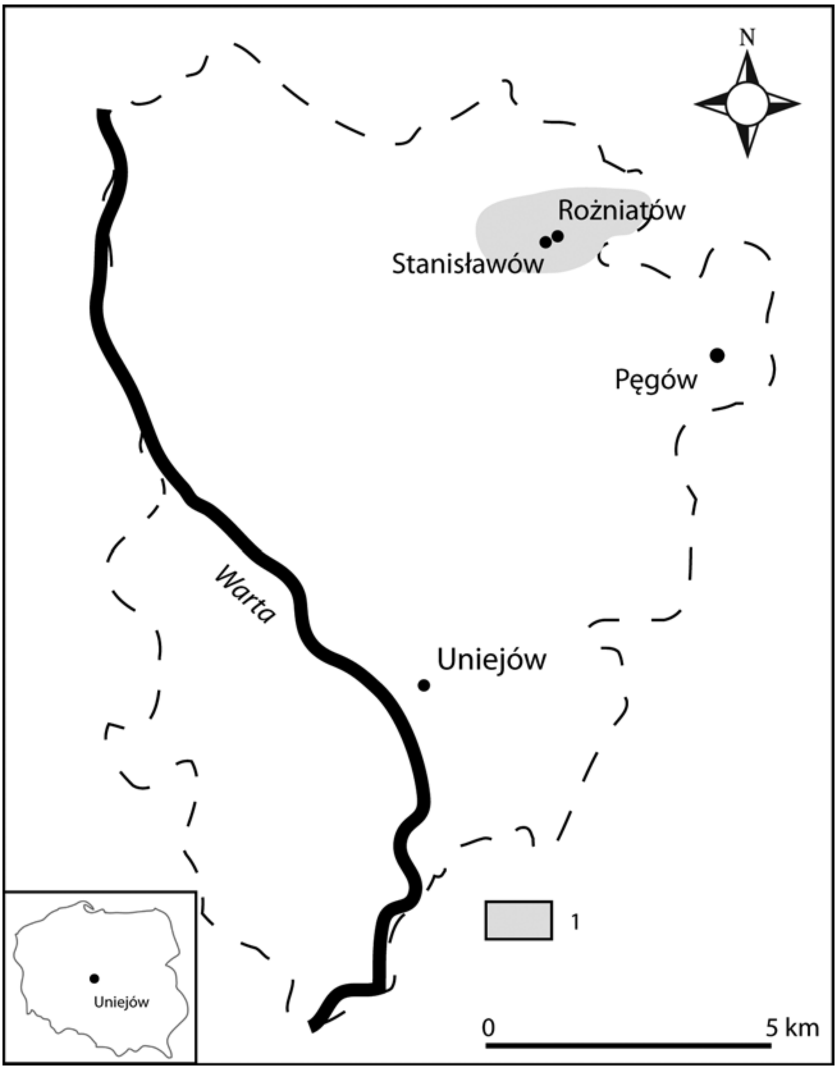


Fig. 2. Map showing the extent of Cretaceous limestone exploitation in the Uniejów district, along with the locations of archaeological sites mentioned in the text (acc. to Gorączko and Gorączko 2013). 1 – extent of modern day exploitation. Graphic design: J. Kabaciński.

▲ a▲ a

b ▼▼

Fig. 3. Structures built of calcareous marl. Sobótka, Poddębice district (a), Wilamów, Poddębice district (b). Photo: I. Sobkowiak-Tabaka.

rivers is marked by elevational differences and deep valley incisions (Chmielewska 1978: 90–94). These environmental conditions attracted several Late Palaeolithic communities and some Mesolithic groups. Particularly rich settlement remains were discovered near Cichmiana, Koło district (Kabaciński *et al.*, 2009: 111–378).

With respect to Polish Mesozoic geological units, the Koło Basin is located within the Szczecin-Łódź-Miechów Basin. Underlying Pleistocene and Holocene sediments are here Upper Cretaceous sediments, up to 3000 m thick, and partly Paleogene and Neogene sediments, mainly grey and green-grey marl, limestone and gaize, as well as carbonate/siliceous and sandy limestone (Mizerski 2009: 169–178). Occurring in the vicinity of Łódź and in the Miechów Basin, Upper Cretaceous beds, built up with carbonates and biogenic silica (Gorączko and Gorączko 2013: 54) are industrially exploited today by the local construction industry (Bolewski *et al.*, 1991: 234). Based on an analysis of microfauna, the sediments are dated to the Maastrichtian (Nowacki 1995: 11–12).

In Poddębice and the surrounding villages (Rożniatów, Dąbrowa, Zaborów, Kraski, Łęczyca district, and around the town of Uniejów), Cretaceous marls are overlaid by a thin layer of Pleistocene sediments (Fig. 2). The distinguishing traits of these sediments include their softness, porosity and low resistance to weathering. Easy to work, the rocks are a valuable construction material (Kozłowski 1986: 220–221). Houses and farm buildings constructed from the distinctive white raw material are still to be found near Pęgów, Rożniatów and Uniejów, Poddębice district. Owing to its thermal and mechanical properties, Cretaceous limestone exploited near Rożniatów is particularly suitable for building houses, making additional thermal insulation unnecessary (Fig. 3).

Nowadays the extraction activity at local limestone beds is largely limited to only one active quarry in Stanisławów, close to Rożniatów, where the limestone serves mostly as a decorative stone in gardens and buildings. However, according to the owner of the Stanisławów quarry, as late as the latter half of the 20th century local farmers continued to exploit limestone beds on a large scale for their own use or for sale. This activity ceased only after State regulations halted private exploitation of geological resources without a licence and today old extraction places are overgrown by vegetation and inaccessible for observation.

IDENTIFICATION OF THE PĘGÓW FLINT MATERIAL

The archaeological site yielding the analysed flint materials is located in the Pęgów hamlet, on the eastern slope of a valley of the Pisia River. This valley is densely cut by watercourses and ditches, and its bottom is filled with fluvioglacial sediments. Together with proglacial waters draining the front of the retreating glacier, the


0
1m

Fig. 4. Pęgów, site 2, Poddębice district, showing pits produced by the limestone extraction. General view. Photo: J. Pyzel.

sediments were deposited south of the zone of the terminal moraine of the Poznań phase (Górska 2004).

Based on construction details of lime kilns and the type of bricks manufactured at the site, the Pęgów production complex is dated to the seventeenth century (Chmielewski 2001: 27). Limestone was found to have been extracted next to the complex from deposits located just below the surface (cf. Fig. 4, 5). These open-pit mines (as Chmielewski called them) are up to several metres deep and the extracted material was heaped around the pits for transportation to nearby kilns.

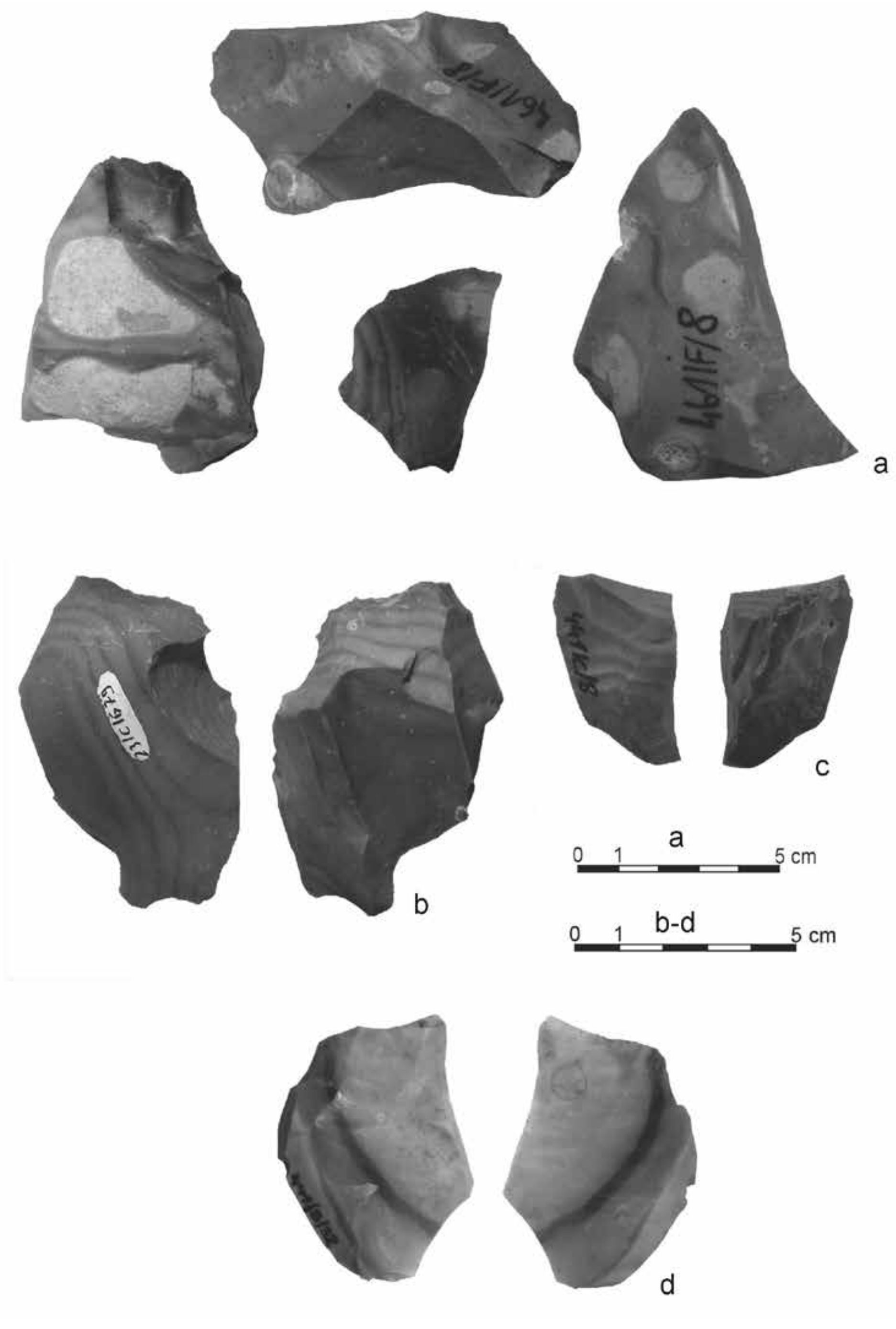
Archaeological works in the south-eastern part of the site (trench F90) recovered slightly more than ten-centimetre–large lumps of raw flint, deposited several dozen centimetres below the surface. Grey in colour and covered with cortex, they contain inclusions of limestone. Some nodules exhibit greyish or brownish bands (Fig. 6a).

The relation of flint nodules discovered during archaeological excavations to geological beds recognised in the area is not clear and two possibilities may be considered. The nodules may originate from Late Quaternary fluvioglacial deposits of the Vistulian. A thin layer of sand-gravel-clay sediments, usually less than 1 meter in thickness, overlay Cretaceous limestone beds throughout the area. However, it is also possible that banded flint occurs within Cretaceous limestone sediments. A number of arguments support the latter hypothesis. The flint nodules were found in the backfill of lime kilns made of limestone fragments so it very possible that they were originally emplaced within a limestone either from the limestone bedrock or from weathered subsurface Cretaceous layers. During our research to locate limestone quarries and related flint occurrences we have not located *in situ* flint nodules within Cretaceous beds. However our research has been limited and we have found only one active limestone quarry (Fig. 5) so such a possibility cannot be excluded. On the other hand, flint depositions within Upper Cretaceous sediments are known from relatively nearby deposits at Łódź (Ziomek 2002).

A small collection of artefacts made of grey flint with characteristic brownish or dark grey stripes exists in flint assemblages recovered from archaeological sites of various chronological periods (Fig. 6: b–d).

Four artefacts have been identified at site 2 (AUT 441) in Cichmiana and site 1 (AUT 23) in Powodów II, Poddębice district. One preparation flake was probably removed by a member of a Lusatian community that occupied site 1 (AUT 23) at Powodów II (Kabaciński and Sobkowiak-Tabaka 2006: 456). The specimen measures

Fig. 5. Stanisławów, Poddębice district. A limestone quarry – a section. Photo: J. Kabaciński.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68 x 54 x 28 mm (Fig. 6b). Other artefacts have been found in a Late Palaeolithic assemblage at site 2 in Cichmiana (Kabaciński *et al.*, 2009: 111–378). Out of more than 10,000 artefacts recovered from the latter site, only three were made from Pęgów flint. Other flint varieties used by Late Palaeolithic peoples inhabiting the site includ Baltic Cretaceous erratic flint, 'chocolate' flint, Jurassic flint and obsidian. The assemblage of artefacts made of Pęgów flint consists of an unspecified core, a chunk (Fig. 6c) and a fragment of retouched flake (Fig. 6d). Given the dimensions of its central part (60 x 39 x 5 mm; other parts are missing), at one time the flake was apparently of a considerable size. It was detached from a single-platform core. A fragment of the left edge of the flake shows retouch on the dorsal side; the broken edge was also retouched.

GEOCHEMICAL ANALYSIS[1]

We utilized geochemical analysis to determine whether samples from Pęgów, Cichmiana and Powodów, macroscopically very similar, came from the same outcrop and whether or not artefacts from Cichmiana and Powodów were made of a banded flint from Krzemionki Opatowskie. This latter possibility cannot be excluded, because Samsonowicz (1953: 107) has reported that loaf-shaped, epigenetically banded flints occur in a zone from the Holy Cross (Świętokrzyskie) Mountains to St. Margaret Mount (Góra Świętej Małgorzaty) near Łęczyca (that last mentioned locality is relatively close to our study area).

Despite nearly 100 years of research on raw flint, the origin of particular variations, the possibilities of its petrographic and mineralogical identification and exploitation in prehistory (Krukowski 1920: 185–206, 1922: 1–34; Michniak 1980: 83–106; Samsonowicz 1923: 17–24), only two varieties of raw flint have been documented in detail. These are 'chocolate' flint (Schild 1971: 1–60; Grafka *et al.*, 2014; Hughes *et al.*, this volume) and banded flint from Krzemionki Opatowskie (Budziszewski and Michniak 1984: 151–189; Pieńkowski and Gutowski 2004: 29–36; Migaszewski *et al.*, 2006, 11–28; Król and Migaszewski 2009: 12–45). Systematic investigations conducted since 2007 in the Kraków-Czestochowa Upland and Ryczów Upland have located a new region containing natural outcrops of banded flint (Krajcarz *et al.*, 2012; Krajcarz *et al.*, 2014).

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Fig. 6. (a) Pęgów, site 2, Poddębice district – flint lumps, (b) Powodów II, site 1, Poddębice district – preparation flake, (c) Cichmiana, site 2, Koło district – chunk, (d) Cichmiana, site 2, Koło district – fragment of retouched flake. Photo: A. Tabaka.

Table 1. Results of the INAA analysis (4A – basic set). Activation Laboratories Ltd. ACTLABS (Canada). Pracownia Analiz Geochemiczno–Mineralogicznych 'GeoAnaliza' [Laboratory of Geochemical–Mineralogical Analyses 'GeoAnaliza']

Analyte Symbol	Au	Ag	As	Ba	Ca	Co
Unit Symbol	ppb	ppm	ppm	ppm	%	ppm
Detection Limit	5	5	2	100	0,5	1
Analysis Method	INAA	INAA	INAA	INAA	INAA	INAA
Powodów II (flake)	< 5	< 5	< 2	< 100	< 0,5	< 1
Pęgów (nodule)	< 5	< 5	< 2	< 100	< 0,5	1
Krzemionki Opatowskie (nodule)	< 5	< 5	< 2	< 100	< 0,5	2
Cichmiana (core)	< 5	< 5	< 2	< 100	< 0,5	1
Cichmiana (chunk)	< 5	< 5	< 2	< 100	< 0,5	2

Analyte Symbol	Sc	Se	Sr	Ta	Th	U
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0,1	3	500	1	0,5	0,5
Analysis Method	INAA	INAA	INAA	INAA	INAA	INAA
Powodów II (flake)	0,2	< 3	< 500	< 1	< 0,5	< 0,5
Pęgów (nodule)	0,3	< 3	< 500	< 1	< 0,5	0,8
Krzemionki Opatowskie (nodule)	0,1	< 3	< 500	< 1	< 0,5	0,6
Cichmiana (core)	0,1	< 3	< 500	< 1	< 0,5	< 0,5
Cichmiana (chunk)	0,1	< 3	< 500	< 1	< 0,5	< 0,5

The chemical composition of flint is highly variable (Bolewski *et al.*, 1991: 128), so identifying a deposit of raw material from which a given artefact or a group of artefacts were made is challenging and usually requires geochemical composition analysis of a series of samples. In addition, micropaleontological identification is important to determine the age of the deposit. Only statistically significant repeatability of results guarantees their reliability.

INAA was employed in this study to determine the composition of major, minor, trace, and rare earth elements present in the 5 studied artefacts (Table 1). INAA has multi-elemental detection limits at the parts-per-million (ppm) level and an accuracy

Cr	Cs	Fe	Hf	Ir	Mo	Na	Ni	Rb	Sb
ppm	ppm	%	ppm	ppb	ppm	%	ppm	ppm	ppm
2	0,5	0,02	0,5	5	5	0,01	50	20	0,2
INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
36	< 0,5	0,56	< 0,5	< 5	< 5	0,03	< 50	< 20	< 0,2
23	< 0,5	0,73	< 0,5	< 5	< 5	0,03	< 50	< 20	< 0,2
202	< 0,5	0,91	< 0,5	< 5	< 5	0,03	< 50	< 20	< 0,2
20	< 0,5	0,61	< 0,5	< 5	< 5	0,03	< 50	< 20	< 0,2
18	< 0,5	1,82	< 0,5	< 5	< 5	0,05	< 50	< 20	< 0,2

W	Zn	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm
3	40	0,2	3	5	0,1	0,1	0,5	0,1	0,05
INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
< 3	40	< 0,2	< 3	< 5	< 0,1	< 0,1	< 0,5	< 0,1	< 0,05
< 3	< 40	1,9	< 3	< 5	0,3	< 0,1	< 0,5	0,2	< 0,05
< 3	< 40	< 0,2	< 3	< 5	< 0,1	< 0,1	< 0,5	< 0,1	< 0,05
< 3	< 40	0,3	< 3	< 5	< 0,1	< 0,1	< 0,5	< 0,1	< 0,05
5	< 40	0,4	< 3	< 5	< 0,1	< 0,1	< 0,5	< 0,1	< 0,05

range between 1 and 10% of the reported values for known standards (Glascock and Neff 2003). Although most of the results obtained here fall below detection limits the compositions of cobalt, chromium, iron, sodium and scandium (highlighted in Tab. 1) are noteworthy, with a particular variation in chromium content in each sample (Fig. 7) which reaches 202 ppm for banded flint from Krzemionki Opatowskie, and falls to 18–36 ppm for artefacts from the Pęgów area. Mindful of the limitations of small sample size, this result may reflect one source for all samples from Pęgów area and allow us to reject the possibility that artefacts from Cichmiana and Powodów were made from striped flint from Krzemionki Opatowskie.

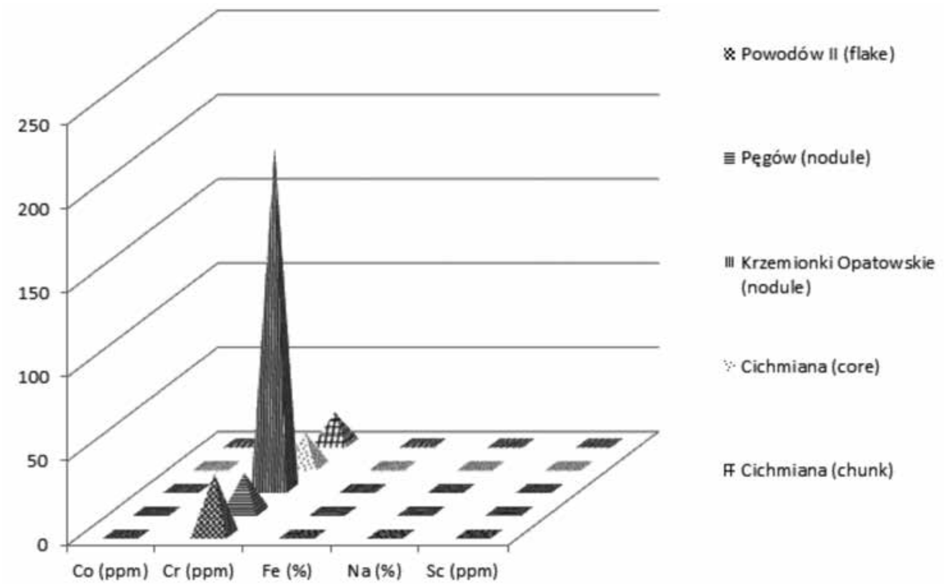

Fig. 7. Composition of selected elements determined by INAA analysis carried out at Activation Laboratories Ltd. ACTLABS (Canada). Pracownia Analiz Geochemiczno-Mineralogicznych 'GeoAnaliza'. Graphic design: J. Kabaciński.

THE USE OF THE PĘGÓW FLINT IN PREHISTORY

The small number of artefacts made from Pęgów flint suggests that it may not have been a significant resource for local prehistoric communities, although Marcin Wąs has raised the possibility that 'banded' flint, similar to Pęgów flint, may be identifiable in assemblages recovered from the village of Madeły, Wieluń district[2].

This also may be the result of lack of recognition of the raw material; characteristic bands are not distributed equally within the nodules (see Fig. 6a).

Sub-surface deposits of 'banded' flint, embedded in Upper Cretaceous limestone (Nowacki 1995: 11), were probably readily available and could be exploited by means of surface pits, as was Jurassic flint occurring in the upper part of flint-bearing limestones in the area of the upper Warta river (Ginter 1974: 12), or as were erratic materials at the settlement site in Goszczewo on Kujawy, inhabited by a community of the Globular Amphora Culture (Chachlikowski 1994: 110–112).

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2 Personal comment for which we are very grateful.

SUMMARY

The paper presents the early results of the study on the sources of 'banded flint' within the Polish Lowland. Because the investigations are still in the preliminary stages, we have focused on general findings about the location of the occurrences of Pęgów flint and have pointed to possible directions for further research.

Although the INAA method has been widely employed in archaeology (cf. Glascock and Neff 2003), in this study it was not particularly successful, so the issue of the origin of Pęgów flint and its possible geological connections remains unresolved pending further research. Geochemical analyses of many more artefacts and flint from outcrops will be required to develop a database that will allow comparisons between samples and support reliable correlations between artefacts and deposits of raw material. Recent isotopic analysis of beryllium (^{10}Be), produced inside rocks in response to exposure to cosmic radiation (Verii *et al.*, 2005: 213), seems worth pursuing as a possible 'sourcing' method but, unfortunately, at the moment further physico-chemical analyses have been prohibitive because of their high cost.

Due to different geological age there is no connection between Pęgów flint (possibly Upper Cretaceous) and banded Krzemionki Opatowskie flint (Upper Jurassic). Nevertheless, efforts oriented toward field identification of possible flint occurrences in Cretaceous limestones in the Rożniatów area should be continued to confirm (or exclude) that locality as a source of Pęgów banded flint.

REFERENCES

Bolewski, A., Budkiewicz, M. and Wyszomirski, P. 1991. *Surowce ceramiczne*. Warszawa.

Budziszewski, J. and Michniak, R. 1984. Z badań nad występowaniem, petrograficzną naturą oraz prehistoryczną eksploatacją krzemieni pasiastych w południowym skrzydle niecki Magoń-Folwarczyska. *Wiadomości Archeologiczne* 49: 151–189.

Chachlikowski, P. 1994. Późnoneolityczne wybierzysko surowców skał niekrzemiennych w miejscowości Goszczewo, gm. Aleksandrów Kujawski, pow. Włocławek, stanowisko 13. *Folia Praehistorica Posnaniensia* 6: 59–121.

Chmielewska, M. 1978. *Późny paleolit pradoliny warszawsko-berlińskiej*. Wrocław.

Chmielewski, D. 2001. *Zespół pieców wapienniczych w Pęgowie.* Unpublished manuscript, Institute of Archaeology and Ethnology, Polish Academy of Science.

Ginter, B. 1974. Wydobywanie, dystrybucja surowców i wyrobów krzemiennych w schyłkowym paleolicie północnej części Europy Środkowej. *Przegląd Archeologiczny* 22: 5–122.

Glascock, M.D. and Neff, H. 2003. Neutron activation analysis and provenance research in archaeology. *Measurement Science and Technology* 14: 1516–1526.

Gorączko, M. and Gorączko, A. 2013. Cechy regionalne w budownictwie na terenie gminy Uniejów. *Biuletyn Uniejowski* 2: 53–65.

Górska, M. 2004. Geomorfologia stanowisk archeologicznych badanych przez Instytut Archeologii i Etnologii PAN Zespół ds. Ratownictwa Archeologicznego na trasie autostrad A1, A2 i A4. Unpublished manuscript, Institute of Archaeology and Ethnology, Polish Academy of Science.

Grafka, O., Siuda, R. and Werra, D.H. 2014. First data on organic compounds of 'chocolate' flint from Holy Cross Mountains Mesozoic margin. *Mineralogia – Special Papers* 42: 53–54.

Kabaciński, J., Bobrowski, P. and Sobkowiak-Tabaka, I. 2009. *Cichmiana, stanowisko 2 (AUT 441)*. In J. Kabaciński and I. Sobkowiak-Tabaka (eds), *Późny paleolit i mezolit basenu środkowej Warty. Ratownicze Badania archeologiczne Instytutu Archeologii i Etnologii PAN, Oddział w Poznaniu* I, 111–378. Poznań.

Hughes, R.E., Werra, D.H. and Siuda, R. 2016. On the Chemical Composition of 'Chocolate' Flint from Central Poland. This volume.

Kabaciński, J. and Sobkowiak-Tabaka, I. 2006. Wytwórczość krzemieniarska społeczności kultury łużyckiej. In J. Kabaciński (ed.), *Osadnictwo pradziejowe i wczesnośredniowieczne i nowożytne na stanowisku nr 1 (AUT 23) w Powodowie II, gm. Wartkowice, pow. poddębicki, woj. łódzkie*, 454–484. Poznań. Institute of Archaeology and Ethnology, Polish Academy of Science.

Kondracki, J. 2009. *Geografia regionalna Polski*. Warszawa.

Kozłowski, S. 1986. *Surowce skalne Polski*. Warszawa.

Krajcarz, M.T., Krajcarz, M., Sudoł, M. and Cyrek, K. 2012. From far or from near? Sources of Kraków-Częstochowa banded and chocolate silicite raw material used during the stone age in Biśnik Cave (southern Poland). *Anthropologie* 50 (4): 411–425.

Krajcarz, M.T., Sudoł, M., Krajcarz, M. and Cyrek, K. 2014. Wychodnie krzemienia pasiastego na Wyżynie Ryczowskiej (Wyżyna Krakowsko-Częstochowska). In D. Piotrowska, W. Piotrowski, K. Kaptur and A. jedynak (eds), *Górnictwo z epoki kamienia:Krzemionki – Polska – Europa. W 90. Rocznicę odkrycia kopalni w Krzemionkach*, 225–244. Ostrowiec Świętokrzyski. Silex et ferrum I.

Król, P. and Migaszewski, Z.A. 2009. *Rodzaje, występowanie i geneza krzemieni. Zarys problematyki*. In J. Król (ed.), *Historia krzemienia*, 12–45. Kielce.

Krukowski, S. 1920. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski, cz. 1. *Wiadomości Archeologiczne* 5: 185–206.

Krukowski, S. 1922. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski, cz. 2. *Wiadomości Archeologiczne* 7: 1–34.

Michniak, R. 1980. Petrografia i geneza ciemnych krzemieni z dolnoturońskich osadów okolic Ożarowa nad środkową Wisłą. *Archiwum Mineralogiczne* 36: 83–106.

Migaszewski, Z.M., Gałuszka, A., Durakiewicz, T. and Starnawska, E. 2006. Middle Oxfordian – Lower Kimmeridgian chert nodules in the Holy Mountains, south-central Poland. *Sedimentary Geology* 187: 11–28.

Mizerski, W. 2009. *Geologia dynamiczna.* Warszawa.

Nowacki, K. 1995. *Objaśnienia do szczegółowej mapy geologicznej Polski 1:50 000. Arkusz Dąbie (551).* Warszawa.

Pieńkowski, G. and Gutowski, J. 2004. *Geneza krzemieni górnego Oksfordu w Krzemionkach Opatowskich. Tomy Jurajskie* II, 29–36. Warszawa.

Samsonowicz, J. 1923. O złożach krzemieni w utworach jurajskich północno-wschodniego zbocza Gór Świętokrzyskich. *Wiadomości Archeologiczne* 8: 17–24.

Samsonowicz, J. 1953. Era mezozoiczna w Polsce (z wyjątkiem Karpat). In M. Książkiewicz and J. Samsonowicz (eds), *Zarys geologii Polski*, 90–130. Warszawa.

Schild, R. 1971. Lokalizacja prahistorycznych punktów eksploatacji krzemienia czekoladowego na północno-wschodnim obniżeniu Gór Świętokrzyskich. *Folia Quaternaria* 39: 1–61.

Seroczyński, Z. and Wysocka, M. 2006. Osadnictwo z okresu nowożytnego In *Osadnictwo pradziejowe, średniowieczne i nowożytne na stanowisku nr 2 (AUT 461) w Pęgowie, gm. Uniejów, pow. Turek*. 43–56. Poznań. Unpublished manuscript, Institute of Archaeology and Ethnology, Polish Academy of Science.

Stankowski, W. 1995. *Wstęp do geologii kenozoiku.* Poznań.

Verri, G., Barkai, R., Gopher, A., Hass, M., Kubik, P.W., Paul M., Ronen, A., Weiner, S. and Boaretoo, E. 2005. Flint procurement strategies in the Late Lower Palaeolithic recoreded by in situ produced cosmogenic ^{10}Be in Tabun and Quesem Caves (Israel). *Journal of Archaeological Science* 32: 207–213.

Ziomek, J. 2002. Atlas miasta Łodzi, Plansza VII. Geologia i gleby, mapa 2. Geologia – utwory starsze od czwartorzędu, http://mapa.lodz.pl/index.php?strona=atlas.

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Erratic Flint from Poland: Preliminary results of petrographic and geochemical analyses

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The paper presents the preliminary results of petrographic and geochemical analyses of erratic flint found throughout present-day Poland. Three different methods have been applied: electron probe micro analysis (EPMA), scanning electron method (SEM) and energy-dispersive x-ray fluorescence (EDXRF) spectrometry. The results of the EPMA and SEM analyses of erratic flint have revealed a largely homogeneous mineral composition, which suggests that mineral composition will be of limited utility in in distinguishing erratic flint. However, EDXRF analysis of a small sample of erratic flint has identified differences in calcium (Ca) and iron (Fe) content between and among samples of erratic and 'chocolate' flint but a much larger sample of erratic flint specimens needs to be analysed to determine the range of chemical composition they contain.

KEY-WORDS: erratic flint, geochemical analysis, EDXRF, SEM, EPMA

INTRODUCTION

Archaeological sites in Poland, and elsewhere in western Europe, document that flint and chert have a long history of use. The most commonly knapped raw materials throughout the Stone Age and Early Bronze Age, flints from a number of different sources were used for making tools and weapons, fire-lighting tools, etc. Given their utilitarian properties, raw flint and chert continued to be exploited in the Modern Period, serving as gunflints for flintlock guns (de Latour 2009) and even today, flints

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are utilised in the production of pottery, glass, and in pharmaceutical and cosmetic industries (Muszyński 2008: 348).

But from an archaeological perspective, detailed knowledge of the outcrops of siliceous rocks and the identification of the mineral and the chemical composition of raw materials is prequisite to archaeological studies devoted to documenting long distance distribution, exchange networks, and mobility patterns in the Stone Age (Sulgostowska 2005: 8). Fast developing methods of instrumental analysis, e.g. Prompt Gamma Activation analysis (PGAA; Révay and Belgya 2004), Energy-Dispersive X-ray Fluorescence (EDXRF) analysis (Hughes *et al.*, 2012), and Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS; Pettit *et al.*, 2012) have all been employed to help determine the origin of raw materials used to produce a given artefact and to chemically distinguish between and among individual varieties of siliceous rocks. With respect to identification of Polish raw materials, until recently most has been limited to macroscopic determination. Since the late 1980s, however, the situation has been gradually changing in Poland (Schild 1976; Lech 1980; Kozłowski and Pawlikowski 1989; Pawlikowski 1994; Högberg *et al.*, 2014; Hughes and Werra 2014; Sobkowiak-Tabaka *et al.*, 2015) and in Lithuania and Belarus (Baltrūnas *et al.*, 2006; Hughes *et al.*, 2011).

This paper is an initial attempt to investigate the petrographic-geochemical characteristics of Erratic flint, based on Scanning Electron Method (SEM), Electron Probe Micro Analysis (EPMA) and Energy-Dispersive X-ray Fluorescence (EDXRF). The results provide a context for a wider discussion on the possibilities, usefulness, and restrictions of the applied methods for recognition of links between outcrops, raw material and flint artefacts.

ERRATIC FLINT – CHARACTERISATION AND OCCURRENCE

Flint is a siliceous sedimentary rock composed of opal, chalcedony, quartz with few accessory minerals; it may also contain sponge spicules (Muszyński 2008: 343). The colour and other properties of flint result from its mineral composition, e.g. red, brown or yellow colours manifest the presence of goethite, lepidocrocite or hematite; grey and bluish show the presence of iron sulphides (mostly pyrite and marcasite); dark grey to black colour attest to the presence of hydrocarbons. Several colouring minerals typically co-exist in the rock, occurring in the trace elements (Pawlikowski 1989: 8). Formation of flint is believed to occur as a result of the deposition of siliceous skeletons elements, the precipitation of the silica from aqueous solution, the concentration of silica minerals as a consequence of transformation of siliceous rocks or sedimentary rocks, and long-term weathering processes (Muszyński 2008: 330–336).

Cretaceous flint is the most widespread raw material in the area of present-day Poland, which has seen several glaciations throughout the Quaternary Period (Mojski 2005: 42).

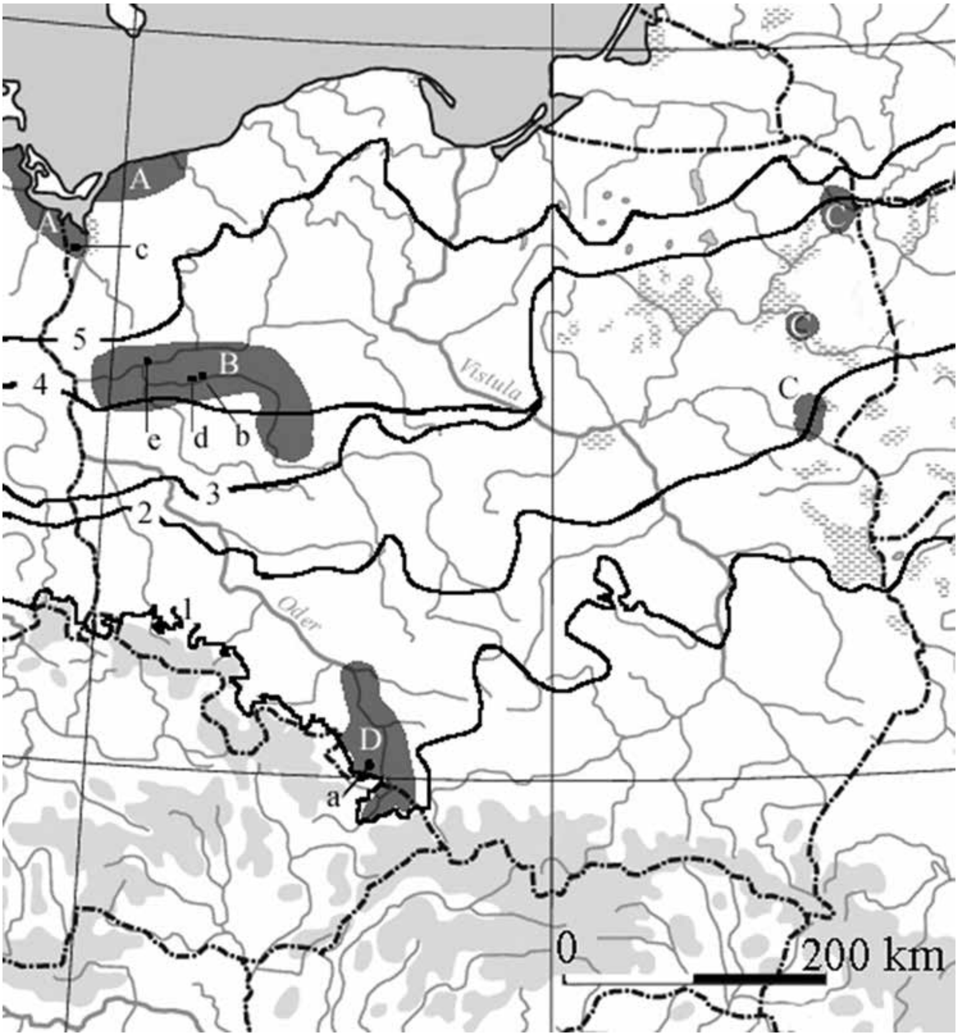

Fig. 1. Location of concentration of glacial rafts with Cretaceous flint (A, C) and concentration of glacial rafts with Cretaceous flint (B, D). 1 – Odra Glaciation (maximum of the Riss), 2 – Warta Glaciation, 3 – Leszno Stadial of the Vistulian, 4 – Poznaństadaial of the Vistulian, 5 – Pomeranian of the Vistulian; location of investigated flint samples: a – Racibórz, district of Racibórz, b – Radgoszcz, Międzychód district, c – Warnik, Police district, d – Łężce, Międzychód district, e – Gorzów Wielkopolski, Gorzów Wielkopolski district.

Owing to glacial movements, moraine deposits covering the bedrock contain rocks from different sources. Unlike comparatively well-defined sources of crystalline and sedimentary erratic from Scandinavia deposited by a glacier in the territory of present-day Poland

(Górska-Zabielska 2008), the detailed localisation of primary sources of Erratic flints in Poland is not yet clear.

Two kinds of sources of Cretaceous flint have been recognised on the Polish Lowland. The first has been found in glacial rafts (Wilczyński 1962: 9) and the second, owing to its rich occurrence in fluvioglacial and till deposits or just on the surface (Bobrowski and Sobkowiak-Tabaka 2012), is referred to as erratic flint (Krukowski 1920). As to the former, Cretaceous flint is known from a few sites in north-western Poland, e.g. from a quarry in Trzciągowo, Kamień Pomorski district, where grey or greyish nodules of flint with lenses or thin layers of chalcedony and opal containing sponge spicule, foraminifera and *Pithonela ovalis,* dated to the Upper Turonian (Alexandrowicz 1966: 30–31) occur. In Western Pomerania *in situ* deposits of Jurassic flint also have been identified. Fragments and nodules of black flints have been identified in limestone layers dated to Upper Jurassic times in quarries in Czarnogłowy, Świętoszewo, Goleniów district, Kłęby and Kamień Pomorski, Kamień Pomorski district (Czekalska and Krygowski 1957: 354; Wilczyński 1962: 30).

The dispersion of secondary sources of Cretaceous flints in Quaternary formations is closely related to Pleistocene glacial activity (Fig. 1). Rich occurrences of lithic raw materials are known from the Toruń-Eberswald marginal-ice valley, the central Warta Valley, and the region of the Silesian-Moravian border. Widely distributed, these raw flints vary in size, colour, and the presence of cortex, and, having been possibly transported by an ice sheet from several geographical locations, they come from various geological periods. This is particularly true for western Polish materials (Bobrowski 2009: 143–145; Högberg and Olausson 2007: 17).

GEOCHEMICAL ANALYSIS OF FLINT IN POLAND

The Vistula basin area is rich in siliceous rocks and it contains deposits of several varieties of flint. A 'chocolate', grey white-spotted, a striped (banded) variety, Volhynian flint on its eastern borders, and erratic flint, the latter occurring mostly in secondary deposits, were all widely used in prehistoric times.

Previous attempts at linking lithic artefacts recovered from archaeological sites to particular flint deposits have met with limited success. Thus far, the description of siliceous rocks occurring in Poland has been mostly confined to macroscopic observations (Krukowski 1920, 1922; Samsonowicz 1923; Schild 1971, 1976; Balcer 1976; Kaczanowska and Kozłowski 1976; Kaczanowska and Lech 1976; Kozłowski and Pawlikowski 1979; Lech 1980; Pelisiak 1987; Budziszewski and Michniak 1989; Michniak 1989; Schild and Sulgostowska 1997; Kamińska-Szymczak and Szymczak 2002; Pieńkowski and Gutkowski 2004; Krajcarz and Krajcarz 2009; Přichystal 2009, 2013; Krajcarz *et al.*, 2012) and classification was based typically on the colour of raw flint, the size of organic inclusions, transparency, the character of fracture, the shape of a nodule and the type of cortex (Schild 1971, 1976).

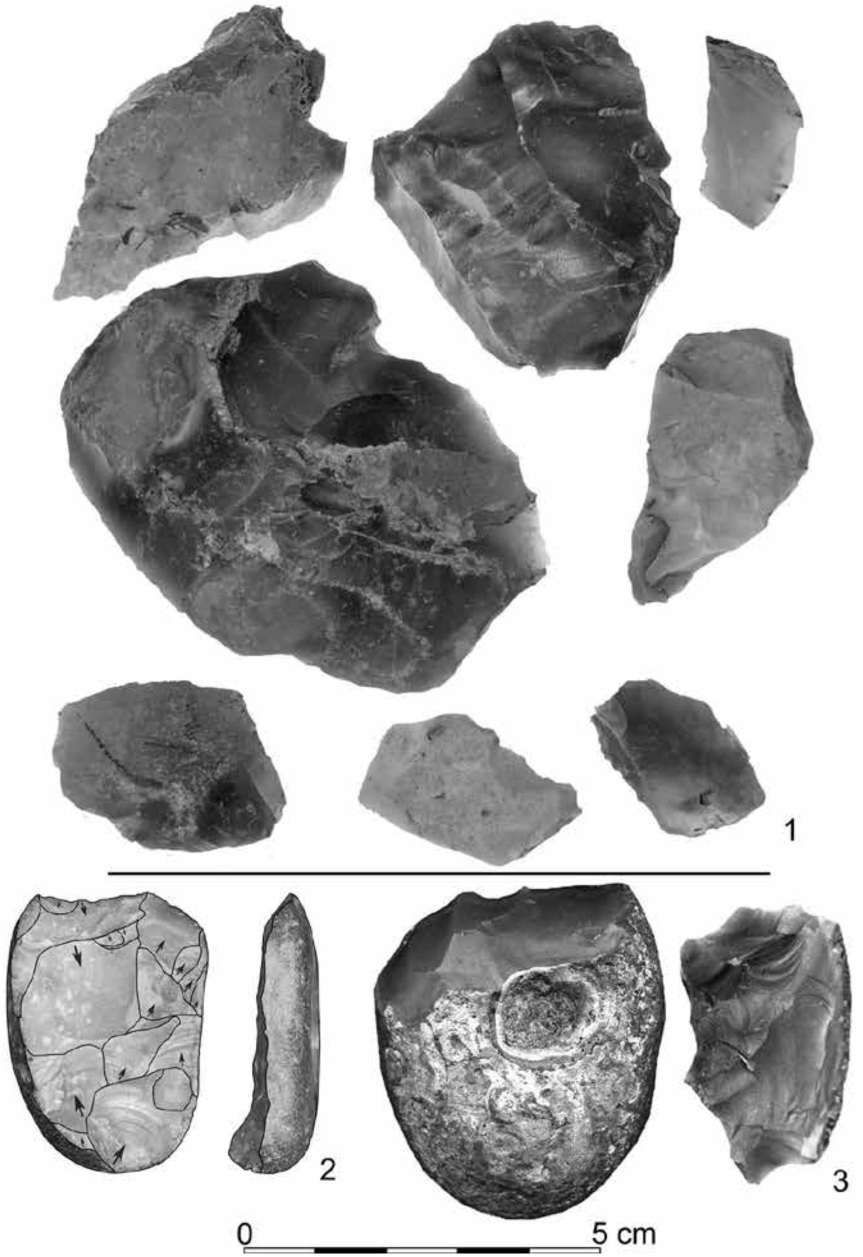

Fig. 2. Erratic flint samples: 1 – nodules of erratic flint from Chrzypsko Wielkie, Międzychód district (photo by P. Szejnoga); pebbles of Pomeranian flint (the so called *swallow eggs*); 2 – Kopydłowo, site 6, Konin district (photo by M. Gembicki); 3 – Dąbki, site 9, Sławno district. Photo: A. Tabaka.

In some cases, a general microscopic analysis of thin sections of flint samples by polarized light (Schild 1971; Přichystal 2009; 2013) and scanning electron microscopic studies (Kamińska-Szymczak and Szymczak 2002; Kamińska *et al.*, 1993) also were carried out.

To overcome some of the shortcomings of macroscopic approaches, a range of petrographic and geochemical methods were employed to define the diagnostic features of siliceous rocks (e.g. de Sieveking *et al.*, 1972; de Sieveking and Hart 1986; de Sieveking and Newcomer 1987). In recent years, a project has been developed using various instrumental methods to distinguish different varieties of siliceous rocks, with special attention devoted to a more precise description of diagnostic features of 'chocolate' flint. Supported by funds from the National Science Centre in Poland (PRELUDIUM 2; UMO-2011/03/N/HS3/03973), the project has employed several different methods, i.e., the Scanning Electron Microscope (SEM), analyses of molecular composition of organic compounds, Cathodoluminescence, energy dispersive X-ray fluorescence (EDXRF), Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), Electron Probe Micro Analysis (EPMA) and a micropaleontological analysis (Grafka *et al.*, 2014; Werra and Siuda 2015; Grafka *et al.*, 2015; Brandl *et al.*, in print).

Until the present pilot study, erratic flint has never been a specific subject of research, although some limited analyses have been published (Kozłowski and Pawlikowski 1989; Kamińska-Szymczak and Szymczak 2002: 302–303). Even in a recent publication, Antonín Přichystal presents only materials from Maków (Racibórz district; Přichystal 2013: 101). This perhaps stems from the fact that among several varieties of flint used by prehistoric people inhabiting the region of present-day Poland, erratic flint is the most challenging raw material because of its high variability in colour, the presence of fossil microorganisms and heterogeneous composition. Last but not least, its sources are unknown (see Instrumental Analysis section below).

Several visual classifications of Erratic flint have been presented so far, based mostly on size, colour, the presence or lack of microfossils (e.g. Bryzoe) and other properties (e.g. Balcer 1983: 49–50; Dmochowski 2006; Jurys 2006). In general, two main types of Cretaceous flint have been distinguished: the so-called variant A – bluish-grey nodules (Fig. 2.1), and variant B – Pomeranian flint in the form of pebbles (the so-called *swallow eggs*), yellowish-brown or pink in colour (Balcer 1983: 49–51; Fig. 2.2–3).

INSTRUMENTAL ANALYSIS[1]

Five erratic flint samples were selected for intrumental analysis based on the homogeneity or heterogeneity of the material, a uniform flat surface, and colour (Table 1, Fig. 1).

[1] The analysis were funded by the National Science Centre in Poland (PRELUDIUM 2; UMO-2011/03/N/HS3/03973).

The samples did not have inclusions or patina (see Hughes *et al.*, 2012: 781, 786). For the EPMA analysis, thin sections were prepared from flint from Radgoszcz, Międzychód district. To undertake the SEM analysis, small flakes of flint not larger than 20 mm in diameter were required. We used flint samples from Racibórz, Racibórz district, Radgoszcz, Międzychód district, and Łężce, Miedzychód district. Specially prepared samples from all five types of flint (Racibórz, Racibórz district, Radgoszcz, Międzychód district, and Łężce, Międzychód district, Warnik, Police district, and Gorzów Wielkopolski, Gorzów Wielkopolski district) were subject to EDXRF analysis. The samples analyzed by EDXRF were cut in cubes, 30 mm in diameter and at least 5 mm thick.

Table 1. List of Erratic flint geological samples from Poland presented in text.

Lab no.	Location	Origin of the sample
NB 1	Racibórz, Racibórz district, Silesia Province	Archaeological site no. 423
NB 2	Radgoszcz, Międzychód district, Wielkopolska Province	From the surface
NB 3	Warnik, Police district, West Pomerania Province	From the surface
NB 4	Łężce, Miedzychód district, Wielkopolska Province	Gravel-pit
NB 5	Gorzów Wielkopolski, Gorzów Wielkopolski district, Lubuskie Province	From the surface

Three methods were employed to examine the chemical distinctions between erratic flint samples from different parts of present-day Poland, deposited in secondary resources.

The Scanning Electron Method (SEM) is useful for the analysis of materials that are too small to be resolved by light microscopy. It provides spot microchemical data on uniform grains, heterogeneous rock fragments and soils, coatings and other pedofeatures (Goldberg and Macphail 2011: 362).

The Electron Probe Micro Analysis (EPMA) provides a high accuracy qualitative and quantitative chemical microanalysis and helps identify accessory elements. Polished blocks or thin sections are analysed in the electron microprobe (Goldberg and Macphail 2011: 363). The chemical composition in micro area in thin sections was analysed in the Laboratory of Electro Microprobe in the Institute on Mineralogy, Geochemistry and Petrology, Geology Department, Warsaw University, using EMPA – Elecron Probe Microanalyser produced by Cameca. All analyses were conducted by

Fig. 3. Core from Ośno Lubuskie, site 7, Słubice district, with visible inclusions. Photo: A. Tabaka.

Lidia Jeżak, and their results interpreted by Rafał Siuda from the Institute of Mineralogy, Geochemistry and Petrology (Faculty of Geology, University of Warsaw).

The Energy-Dispersive X-ray Fluorescence analysis (ED XRF) seeks to determine the quantitative composition of nine major, minor and some trace elements. This non-destructive method offers high precision for certain constituent elements, but care needs to be taken to avoid inclusions, e.g. fossils or calcium elements from sea creatures' shells (Fig. 3, 4). which might influence the measurements determined. It is noteworthy in this context that sedimentary rocks, such as flints, exhibit a fairly heterogeneous composition (Hughes *et al.*, 2010, 2012).

THE RESULTS OF INSTRUMENTAL ANALYSIS

SEM and EMPA

Results of the SEM and EMPA analysis are complementary and as such will be presented together.

Quartz

The main mineral component of Erratic flint is quartz (as a chalcedony), developed as cryptocrystalline clusters. Transmitted light sometimes shows parallel arrangements of its thin needle crystals. The presence of massive quartz aggregates (up to 100 μm in size)

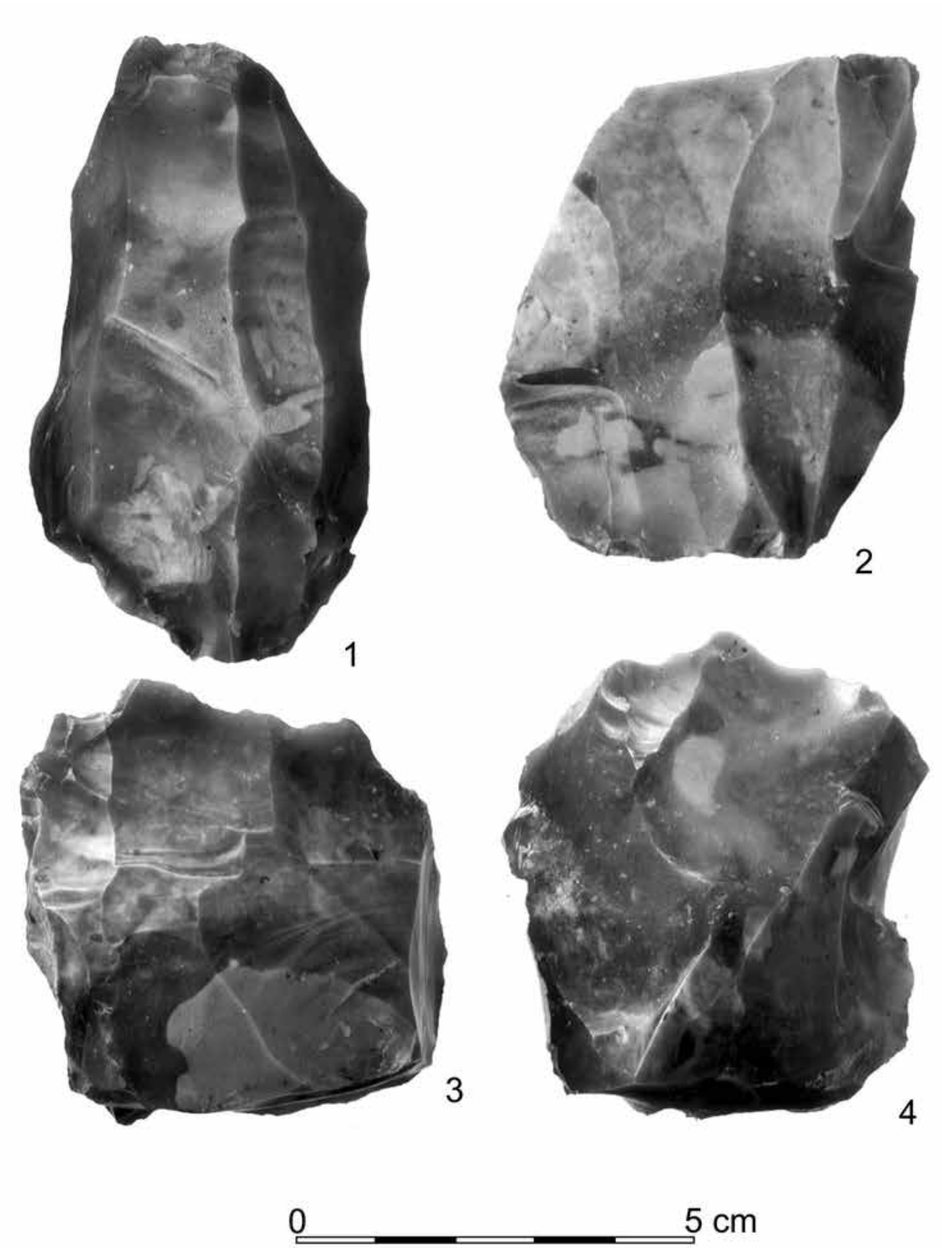

Fig. 4. Cores and perforator from Myszęcin, site 19, Świebodzin district, with visible variety of colour.
Photo: P. Szejnoga.

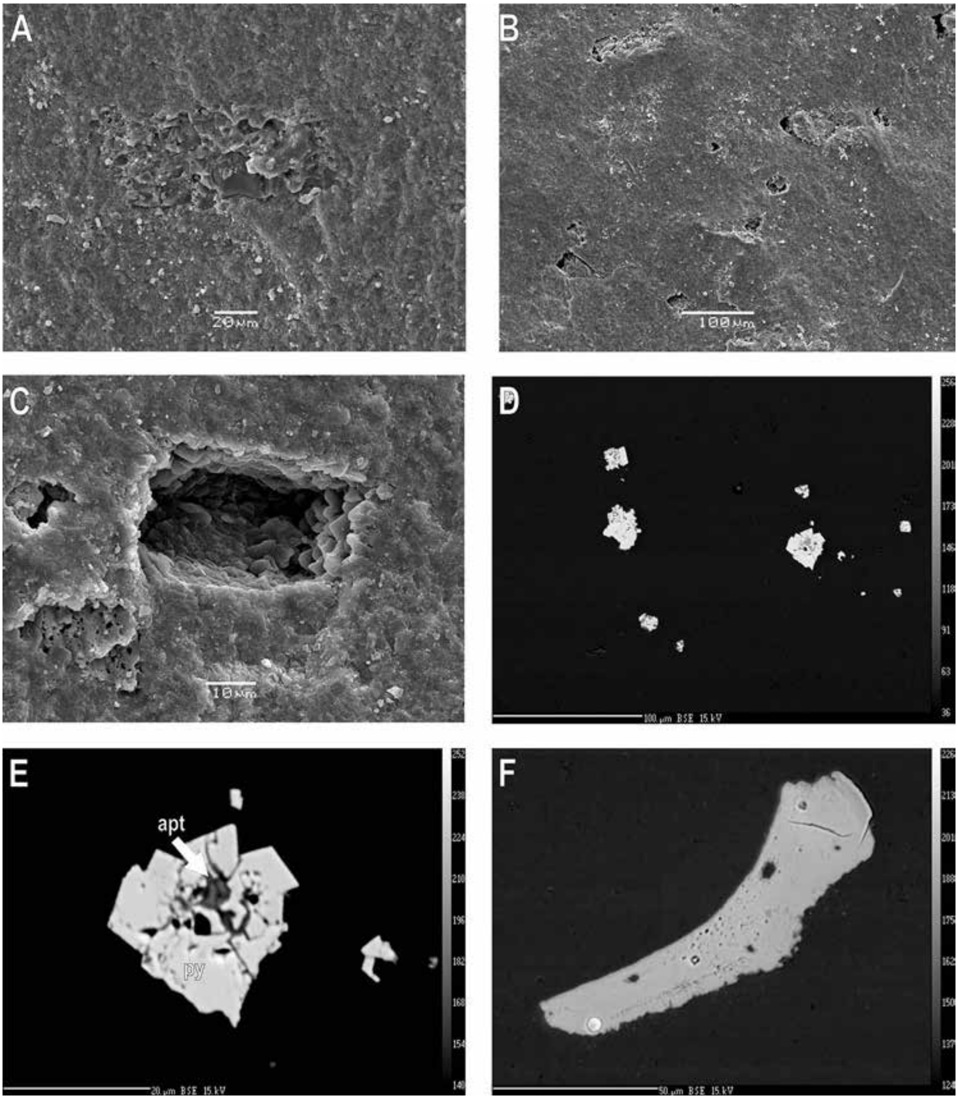

Fig. 5. SEM and BSE images of Erratic flint geological samples. A: SEM image of quartz aggregates; B: SEM image of small cavities in chalcedony matrix; C: SEM image of void with quartz automorphic crystals; D: BSE image of pyrite aggregates; E: BES image of pyrite aggregate with apatite (apt); F: BSE image of fragments of fish skeletal elements. Photo: R. Siuda.

has been observed in some cases. The formation of these aggregates is associated with recrystallization of chalcedony pseudomorphs after the organic remains (Fig. 5A). The last type of quartz contains small hipidiomorphic quartz crystals, reaching up to 5 μm, growing on the walls of small voids scattered in the chalcedony matrix (Fig. 5B, 5C).

Pyrite

The most common accessory mineral in flint, pyrite has been found in all analysed samples. The mineral forms fine automorphic crystals, up to 10 mm in size, such as cubes or octahedrons. Pyrite crystals form specific spherical aggregates, up to 20 mm in diameter (Fig. 5D). Residually preserved apatite aggregates are sometimes present in the central parts of pyrite aggregates (Fig. 5E).

Apatite

Apatite was identified only in one sample of Erratic flint. In flint from Radgoszcz (NB–2), this phase comes in two varieties. Apatite I builds fragments of fish skeletal elements (Fig. 5F), while Apatite II forms irregular aggregates up to 25 μm in size (Fig. 6A). Formation of this latter type of apatite is connected with dissolution of apatite I during the diagenetic processes and formation of flint nodules. In this case, apatite II co-occurs with small amounts of pyrite. Tiny apatite aggregates also are present in central parts of aggregates of pyrite (Fig. 5E). Due to the high porosity of the aggregates of apatite and the instability of the mineral under the electron beam it was not possible to perform micro probe analyses of this phase.

Calcite

Calcite is fairly frequent in Erratic flint. It forms very small aggregates, up 5 μm in diameter, irregularly dispersed in the chalcedony matrix of flint. Calcite identified in the analysed material represents the remains of calcium carbonate, which originally built a calcite sediment within which the flint concretions was formed.

Pseudomorphoses

Very common in the analysed samples are organic debris completely replaced by quartz. These usually include fragments of dinocysts (Fig. 6B), or silicified needles of sponges (Fig. 6C). Sometimes the sponge needles are perfectly preserved, with a visible ornamentation of the spicules. In many cases, the process of replacing microfossils by quartz is so extensive that it is not possible to accurately assign organic remains to a specific group of organisms. Perfectly preserved voids left after leached calcite crystals provide another type of pseudomorphoses (Fig. 6D). Up to 10 μm in size, they show a rhombohedral structure, typical for calcium carbonate. Their walls are overgrown by automorphic quartz crystals.

ENERGY-DISPERSIVE X-RAY FLUORESCENCE ANALYSIS (EDXRF)

As noted in previous studies using non-destructive EDXRF analysis (Hughes *et al.*, 2010, 2011, 2012), contrasts in calcium and iron composition help differentiate among and between different chemical varieties of flint. In this preliminary study, the CaO vs.

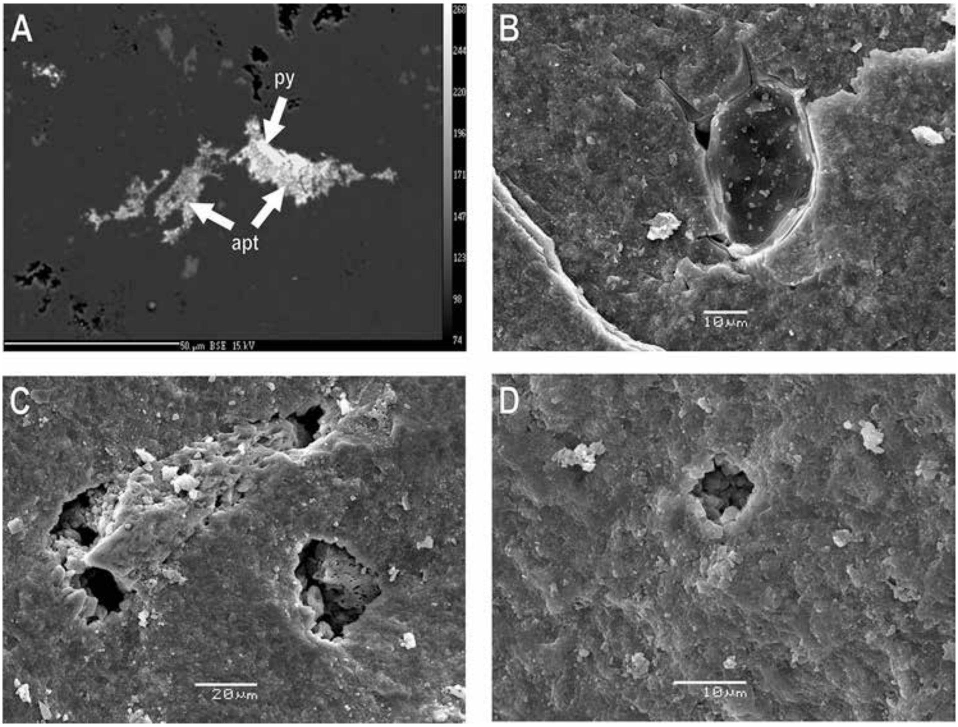

Fig. 6. SEM and BSE images of Erratic flint geological samples. A: BSE image of apatite II and pyrite intergrowths; B: quartz pseudomorph after dinocyste; C: quartz pseudomorph after urchin spike; D: void after calcite crystal dissolution. Photo: R. Siuda.

Fe composition determined for a small sample of erratic flint was compared with that of 'chocolate' flint from four different localities (Orońsko, Tomaszów, Szydłowiec distrit, Wierzbica and Prędocin, Radom district) in the Vistula River basin of south eastern Poland (Fig. 7). As this figure shows, the erratic flints analysed contain significantly lower iron composition than 'chocolate' flint, and the CaO composition for two of the four specimens analysed is greater than measured in 'chocolate' flint.

CONCLUSIONS

Because of its heterogeneous chemical composition, flint is notoriously difficult to source. This is particularly evident in the case of Erratic flint. The results of SEM and EMPA analyses have shown that the mineral composition of investigated samples is largely homogeneous and undiversified. Accessory minerals present in the composition (pyrite, apatite, calcite) are typical of other variants of flint used in the territory of

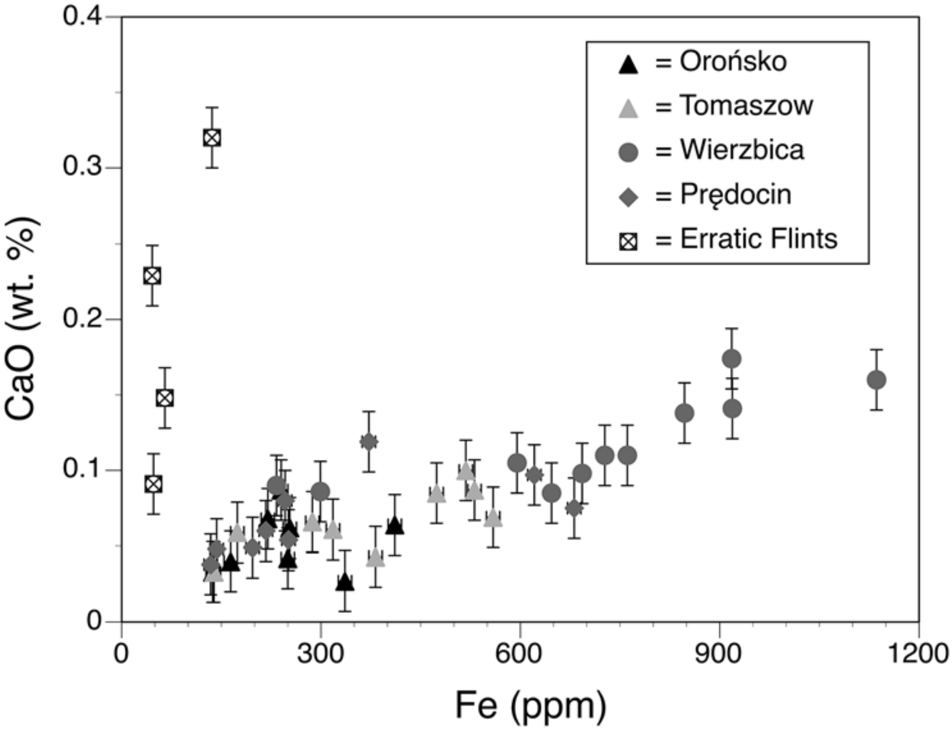

Fig. 7. The CaO versus Fe composition of 'chocolate' and Erratic flint geological samples from Poland.

present-day Poland. The differentiation between single variants of erratic flint by testing their mineral composition using the electron microscope and chemical composition of minerals in microprobe is therefore impossible. The similarity between single variants is caused by primary conditions of sedimentation and formation of flint nodules.

Of the laboratory-based instrumental analyses we have undertaken to date, only EDXRF analysis has offered some hope for differentiating between and among varieties of erratic flint. These pilot results are encouraging insofar as intersource discrimination is concerned, but additional erratic flint specimens need to be analysed before we can identify the range of chemical composition they contain.

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REFERENCES

Alexandrowicz, Z. 1966. Utwory kredowe w krach glacjalnych na Wyspie Wolin i w okolicy Kamienia Pomorskiego. *Prace Geologiczne* 35.

Balcer, B. 1976. Position and stratigraphy of flint deposits, development of exploitation and importance of the świeciechów flint in prehistory. *Acta Archaeologica Carpathica* 16: 179–199.

Balcer, B. 1983. *Wytwórczość narzędzi krzemiennych w neolicie ziem Polski.* Wrocław- Warszawa- Kraków-Gdańsk-Łódź.

Baltrūnas, V., Karamza, B., Kulbickas, D. and Ostrauskas, T. 2006. Siliceous rocks as a raw material of prehistoric artefacts in Lithuania. *Geologija* 56: 13–26.

Bobrowski, P. 2009. The exploitation of local sources of flint on the Polish Plain during the Final Palaeolithic. In M. Street, N. Barton and T. Terberger (eds), *Humans, environment and chronology of the Late Glacial on the North European Plain. Proceedings of Workshop 14 of the 15th. UISSPP Congress, Lisbon, September 2006,* 141–153. Mainz.

Bobrowski, P. and Sobkowiak-Tabaka, I. 2012. Eksploatacja surowców krzemiennych w rejonie Pojezierza Międzychodzkiego na przykładzie stanowiska 4 w Chrzypsku Wielkim, gm. loco. *Fontes Archaeologici Posnanienses* 48: 7–42.

Brandl, M., Hauzenberger, Ch., Martinez, M. M. Filzmoser, P. and Werra, D.H. in press. The Application of the Multi Layered Chert Sourcing Approach (MLA) for the Characterisation and Differentiation of 'Chocolate Silicites' from the Holy Cross Mountains, South-Central Poland.

Budziszewski, J. and Michniak, R. 1989. Z badań nad występowaniem, petrograficzną naturą oraz prahistoryczną eksploatacją krzemieni pasiastych w południowym skrzydle niecki Magoń-Folwarczyska. *Wiadomości Archeologiczne* 49: 151–190.

Czekalska, A. and Krygowski, B. 1957. Przewodnik do wycieczek XXVIII Zjazdu Polskiego Towarzystwa Geologicznego w r. 1955 w Szczecinie. *Rocznik Polskiego Towarzystwa Geologicznego* 25 (4).

Dmochowski, P. 2006. A new clasiffication of erratic flint from western Poland. In A. Wiśniewski, T. Płonka and J.M. Burdukiewicz (eds), *The stone technique and technology*, 217–226. Wrocław.

Goldberg, P. and Macphail, R.I. 2011. *Practical and Theoretical Geoarchaeology*. Oxford.

Górska-Zabielska, M. 2008. Obszary macierzyste skandynawskich eratyków przewodnich osadów ostatniego zlodowacenia północno-zachodniej Polski i północno-wschodnich Niemiec. *Geologos* 14 (2): 55–73.

Grafka, O., Siuda R. and Werra, D.H. 2014. First data of organic geochemistry of 'chocolate' flint from Holy Cross Mountains Mesozoic margin. *Mineralogia – Special Papers* 42: 53.

Grafka, O., Werra, D. H. and Siuda, R. 2015. Analysis of Organic Compounds: Applications in Archaeology and Earth Science, *Litikum* 3: 26–37.

Högberg, A., Hughes, R.E. and Olausson, D. 2014. Comparing Polish and Scandinavian flint using visual and chemical analysis: some preliminary results. *Fornvännen* 108: 256–252.

Högberg, A. and Olausson, D. 2007. *Scandinavian Flint – an Archaeological Perspective*. Aarhus.

Hughes, R.E., Baltrūnas, V. and Kulbickas, D. 2011. Comparison of two analytical methods for the chemical characterization of flint from Lithuania and Belarus. *Geologija* 53 (2): 69–74.

Hughes, R.E., Högberg, A. and Olausson, D. 2010. Sourcing flint from Sweden and Denmark. A pilot study employing non-destructive energy dispersive X-ray Fluorescence spectrometry, *Journal of Nordic Archaeological Science* 17: 15–25.

Hughes, R.E., Högberg, A. and Olausson, D. 2012. The chemical composition of some archaeologically significant flint from Denmark and Sweden. *Archaeometry* 54 (5): 779–795.

Hughes, R.E. and Werra, D.H. 2014. The source of Late Mesolithic obsidian recovered from Rydno XIII/1959, Central Poland. *Archeologia Polski* 59 (1–2): 31–46.

Jurys, L. 2006. Geologiczne możliwości pozyskiwania krzemieni na Pomorzu. *Paper presented at the 'XVI Sesji Pomorzoznawczej' the Archaeological Museum in Gdansk*.

Kaczanowska, M. and Kozłowski, J.K. 1976. Studia nad surowcami krzemiennymi południowej części Wyżyny Krakowsko-Częstochowskiej. *Acta Archaeologica Carpathica* 16: 201–216.

Kamińska-Szymczak, J. and Szymczak, K. 2002. Powierzchnie świeżych przełamów wybranych surowców krzemiennych z terenów Polski obserwowanych przy użyciu SEM. In B. Matraszek and S. Sałaciński (eds), *Krzemień świeciechowski w pradziejach. Materiały z konferencji w Ryni, 22–24.05.2000, Studia nad gospodarką surowcami krzemiennymi w Pradziejach* 4, 297–306. Warszawa.

Kamińska, J., Mycielska – Dowgiałło, E. and Szymczak, K. 1993. Postdepositional Changes on Surfaces of Flint Artifacts as Observed under a Scanning Electron Microscope. In P.C. Anderson, S. Beyries, M. Otte and H. Plisson (eds), *Traces et Fonction: les gestes retrouves, Actes du colloque international de Liege (8 –10 decembre 1990), vol. I and II*, Editions ERAUL, vol. 50, 467–476. Liege.

Kozłowski, J.K. and Pawlikowski, M. 1989. Investigation into the northern lithic raw materials in Upper Silesia (Poland) In J. K. Kozłowski (ed.), '*Northern' (Erratic and Jurassic) flint of southern Polish origin in the Upper Palaeolithic of Central Europe*, 17–46, Kraków.

Krajcarz, M.T. and Krajcarz, M. 2009. The outcrops of Jurassic flint raw materials from south-western margin of the Holy Cross Mountains. *Acta Archaeologica Carpathica* 44: 183–195.

Krajcarz, M.T., Krajcarz, M., Sudoł, M. and Cyrek, K. 2012. From far of from near? Sources of Kraków-Częstochowa banded and chocolate silicate raw material used during the stone age in Biśnik Cave (Southern Poland). *Anthropologie* 50 (4): 411–425.

Krukowski, S. 1920. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski. Wnioski z właściwości surowców i wyrobów. *Wiadomości Archeologiczne* 5 (3–4): 185–206.

Krukowski, S. 1922. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski. Wnioski z właściwości surowców i wyrobów. Część II. *Wiadomości Archeologiczne* 7: 34–57.

de Latour, R. 2009. O skałce krzemiennej słów kilka. In P. Król (ed.), *Historia krzemienia*, 75–87. Kielce.

Lech, J. 1980. Geologia krzemienia jurajskiego-podkrakowskiego na tle innych skał krzemionkowych. Wprowadzenie do badań z perspektywy archeologicznej. *Acta Archaeologica Carpathica* 20: 163–228.

Michniak, R. 1989. Nazewnictwo, geneza i występowanie krzemieni. *Przegląd Geologiczny* 37 (9): 452–458.

Mojski, E. 2005. *Ziemie polskie w czwartorzędzie. Zarys morfogenezy*. Warszawa.

Muszyński, M. 2008. Skały krzemionkowe. In. A. Manecki and M. Muszyński (eds.), *Przewodnik do petrografii*, 330–349. Kraków.

Pieńkowski, G. and Gutowski, J. 2004. Geneza krzemieni górnego oksfordu w Krzemionkach Opatowskich. *Tomy Jurajskie* 2: 29–36.

Pawlikowski, M. 1989. On the necessity of standarization of petrological investigations in archaeology. In J.K. Kozłowski (ed.), '*Northern' (Erratic and Jurassic) flint of southern Polish origin in the Upper Palaeolithic of Central Europe*, 7–15. Kraków.

Pawlikowski, M. 1994. Artefakt z obsydianu z osadów środkowoplejstoceńskich w Rusku, gm. Strzegom. *Śląskie Sprawozdania Archeologiczne* 35: 79–84.

Pelisiak, A. 1987. The flint raw material from the central part of the Polish Jura and its utilization in prehistory. In K.T. Biró (ed), *Proceeding of the Ith International Conference on Prehistoric Flint Mining and Lithic Raw Material Identification in the Carpathian Basin*, 123–127. Budapest.

Pettitt, P., Rockman, M, and Chenery S. 2012. The British Final Magdalenian: Society, settlement and raw material movements revealed through LA-ICP-MS trace element analysis of diagnostic artefacts. *Quaternary International* 272–273: 275–287.

Přichystal, A. 2009. *Kamenné suroviny v pravěku východní části střední Evropy*. Brno.

Přichystal, A. 2013. *Lithic Raw Materials in Prehistoric Times of Eastern Central Europe*. Brno.

Révay, Z. and Belgya, T. 2004. Principles of PGAA method. In G.L. Molnár (ed.), *Handbook of Prompt Gamma Activation Analysis with Neutron Beams*, 1–30. Dordrecht-Boston-New York.

Samsonowicz, J. 1923. O złożach krzemieni w utworach jurajskich północno-wschodniego zbocza Gór Świętokrzyskich. *Wiadomości Archeologiczne* 8 (1): 17–24.

Schild, R. 1971. Lokalizacja prahistorycznych punktów eksploatacji krzemienia czekoladowego na północno-wschodnim obrzeżeniu Gór Świętokrzyskich. *Folia Quaternaria* 39: 1–61.

Schild, R. 1976. Flint mining and trade in Polish prehistory as seen from the perspective of the chocolate flint of central Poland. A second approach. *Acta Archaeologica Carpathica* 16: 147–177.

Schild, R. and Sulgostowska, Z. (eds) 1997. *Man and flint. Proceedings of the VIIth International Flint Symposium*. Warszawa.

Sieveking, G. de G. and Hart, M.B. (eds) 1986. *The scientific study of flint and chert*. Cambridge.

Sieveking, G. de G. and Newcomer, M.H. (eds) 1987. *The human uses of flint and chert*. Cambridge.

Sieveking, G. de G., Bush, P., Ferguson, J., Craddock, P.T., Hughes, M.J. and Cowell M.R., 1972. Prehistoric flint mines and their identification as sources of raw material. *Archaeometry* 14: 151–76.

Sobkowiak-Tabaka, I., Kasztovszky, Zs., Kabaciński, J., Biró, K.T., Maróti, B. and Gméling, K. 2015. Transcarpathian contacts of the Late Glacial Societies of the Polish Lowlands. *Przegląd Archeologiczny* 63: 5–28.

Sulgostowska, Z. 2005. *Kontakty społeczności późnopaleolitycznych i mezolitycznych między Odrą, Dźwiną a Dnieprem. Studium dystrybucji wytworów ze skał krzemionkowych*. Warszawa.

Werra, D.H. and Siuda R. 2015. The mineral composition of 'chocolate' flint compared to other varieties of chert from Central and Southern Poland used by prehistoric communities. In. X. Mangado, O. Crandell, M. Sánchez and M. Cubero (eds), *International Symposium on Knappable Materials 'On the Rocks'. Barcelona 7-11 September 2015. Abstracts*, 128. Barcelona.

Wilczyński, A. 1962. Stratygrafia górnej jury w Czarnogłowach i Świętoszewie. *Acta Geologica Polonica* 17 (1): 3–112.

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Mineralogical and petrographic characteristic of basic types of Turonian flints from the north-eastern margin of the Holy Cross Mountains: a preliminary report

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This paper presents the preliminary results of mineralogical-petrographical investigations of several basic types of Turonian flints from the north-eastern margin of the Holy Cross (Świętokrzyskie) Mountains. To discriminate the character and degree of individual types of flints based on their mineralogic and petrographic features, microscopic analyses of series of representative samples of flint raw material from different parts of the Turonian outcrops and archaeological artefacts found at the early Neolithic site in Tominy (Opatów district) were performed. The microscopic investigations were conducted using a petrographic microscope and a scanning electron microscope (SEM–EDS). The results enable us to determine some characteristic properties of individual types of Turonian flints, and to identify the so-called Zawada flint in the Linear Pottery Culture inventory from Tominy.

KEY-WORDS: Turonian flints, Holy Cross (Świętokrzyskie) Mountains, Early Neolithic, Linear Pottery Culture, Microscopic analysis, SEM–EDS

The presence of flint-bearing cretaceous sediments within the north-eastern, Mesozoic margin of the Holy Cross (Świętokrzyskie) Mountains is limited, in greatest extent, to its eastern part, covering the fairly small area on both sides of the middle reaches of Vistula River (Fig. 1). These sediments are represented primarily by white and gray siliceous limestones and, to a lesser extent, by detrital bryozoan limestones, genetically linked with the sedimentation processes of the Lower Turonian transgression (Samsonowicz 1934a: 46–49, 1934b; Pożaryski 1948: 36–39; Złonkiewicz 1994: 22–23; 1998; Michniak and Budziszewski 1995a: 15–17). The coexisting flint outcrops occur as

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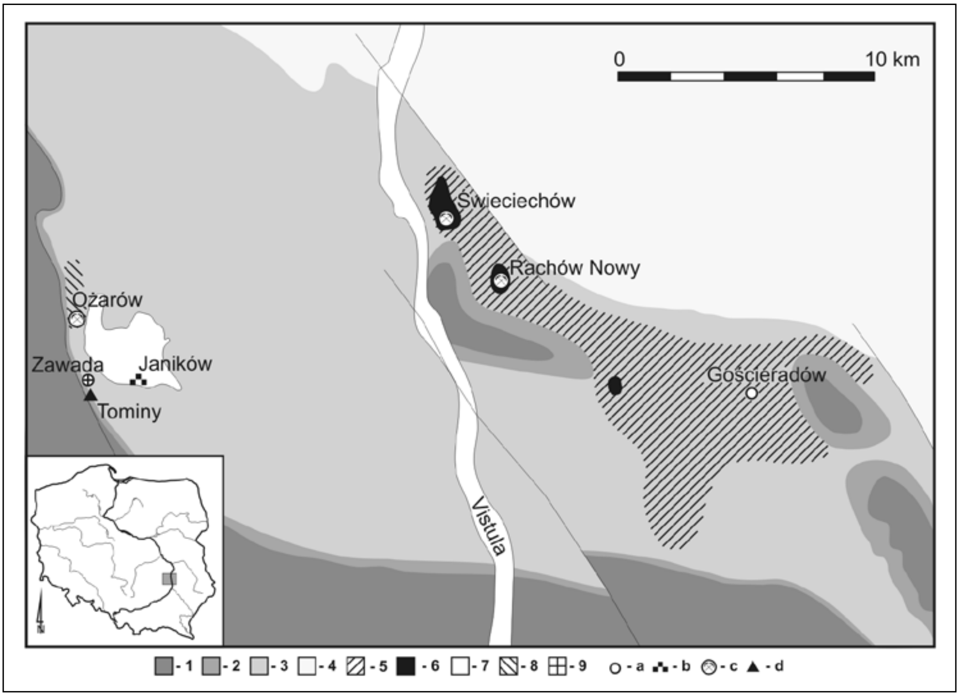


Fig. 1. Geological structure of the sub-Quaternary sediments of the north-eastern margin of the Holy Cross Mountains (1 – Jurassic; 2 – Lower Cretaceous and Cenomanian; 3 – Turonian; 4 – Coniacian-Upper Maastrichtian) with the range of occurrence of the basic types of Turonian flints with the location of analysed samples (5 – Gościeradów flint; 6 – Świeciechów flint; 7 – Janików flint; 8 – Ożarów flint; 9 – Zawada flint). Places of origin of analysed samples: a – surface concentraction of flint raw material; b – quarry; c – prehistorical flint mines; d – archaeological site 6 in Tominy (geological structure: after Pożaryski 1997, with Authors modifications; location of the outcrops of flints: after Samsonowicz 1934b; Michniak and Budziszewski 1995: Fig. 6; Libera and Zakościelna 2002: Ryc. 1).

primary deposits (within fairly numerous quarries) and as secondary surface deposits, defaulting in ceiling parts of Turonian rocks. These secondary deposits were a significant source of archaeological material during the Neolithic and Bronze Age (Balcer 1971: 118; 1976: 192–195; Budziszewski 1980: 604; 1986: 75–78; Fig. 1).

Despite the limited geographic range and lithological variety of Turonian sediments in the studied area, flints occurring therein show a significant degree of macroscopic diversity, particularly in color and transparency of primary mass and the nature and thickness of the cortex. These features were the primary criterion for almost all previous attempts of classification of this group of raw materials (Krukowski 1920: 195; Krzak 1965: 222, 1970: 292–295; Balcer 1975: 45–53; Libera and Zakościelna 2002: 96–100), leading to isolation of many local visual varieties (e.g. Gościeradów flint, Janików flint, Ożarów flint, Świeciechów flint or Zawada flint) with very diverse range of occurrence

Table 1. Basic data for analysed samples of Turonian flints of the north-eastern margin of the Holy Cross Mountains.

Number of sample	Type of sample	Place of origin of samples	Macroscopic classification of flint raw material
G 1–3	Fragments of natural flint concretions	Świeciechów, surface of a prehistoric flint mine	Gościeradów flint
G 4		Gościeradów, surface concentration of flint raw material	
J 1–5		Janików, a present quarry	Janików flint
O 1–4		Ożarów, 'Za Garncarzami' field, surface of a prehistoric flint mine	Ożarów flint
Ś 1–4		Świeciechów, surface of a prehistoric flint mine	Świeciechów flint
Z 1–11		Zawada, surface concentration of flint raw material	Zawada flint
T 1–11	Flint artefacts (flakes)	Tominy site 6, settlement objects from the early Neolithic (Linear Pottery Culture)	Zawada flint (?)

(Fig. 1). Unfortunately, only a few of them can generally be identified in archaeological contexts, regardless of state of preservation and size of the artifacts, because of unclear and ambiguous descriptions of their physical properties. The existing classifications only occasionally were confirmed by petrographic analyses and, however its range was limited, focusing only on selected varieties of flints from areas located on the left (Stawin 1970: tab. 7–8; Michniak 1980: 85–86) or right (Balcer 1975: 47–48) bank of Vistula did not lead to identification of diagnostic differences between particular varieties.

THE AIM OF THE STUDY

The main objective of the study presented here was to achieve a preliminary mineralogical and petrographic characterization of these varieties of Turonian flints, processing and use of which was confirmed in the Stone Age and Bronze Age[1]. The present study was based on the analysis of 28 geological samples (i.e. concretions fragments) representing the following varieties: Gościeradów flint (G), Janików flint (J) Ożarów

[1] The research was funded by National Science Centre in Poland (No DEC-2011/03/N/HS3/02016).

flint (O), Świeciechów flint (S) and Zawada flint (Z; Table 1). Particular emphasis was directed toward identification of all diagnostic properties of particular visual varieties from the standpoint of their suitability for the identification in archaeological materials. For this purpose, further analysis was conducted on an additional 11 artifacts ('T' samples) from the settlement of Linear Pottery culture (hereinafter LPC) site 6 in Tominy, Opatów district (Fig. 1) because the macroscopic properties of these artifacts suggested that they may have come from the outcrop in Zawada, about 100 m to the north (Fig. 2g–h). The objective of the study was to verify this convergence at the mineralogical and petrographic level in regard to Zawada flint samples.

MATERIALS AND METHODS

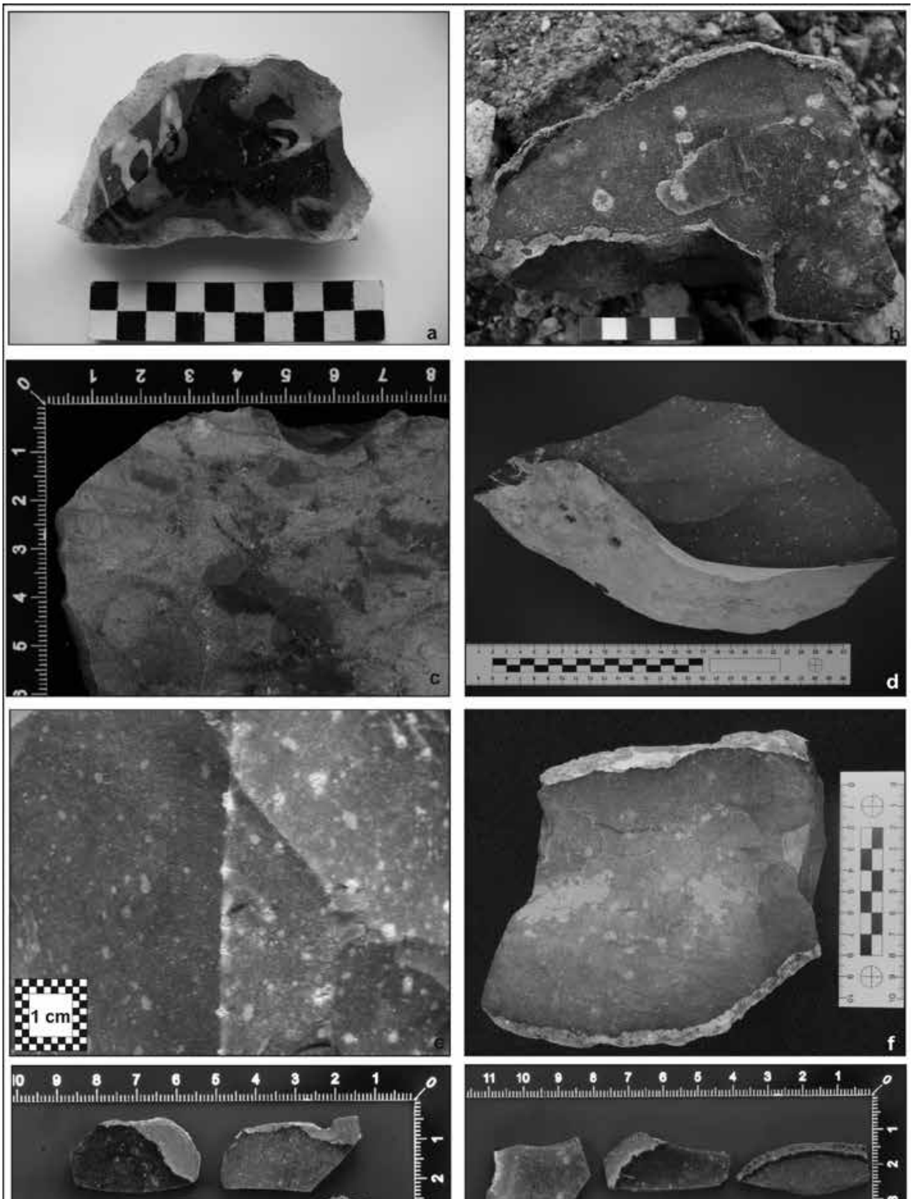
Thin sections and polished sections from 28 samples were analyzed. They were examined using a Leica DM 2500 P petrographic microscope in reflected and transmitted light, and also by use of a Hitachi SU6600 with EDS addition scanning electron microscope without spraying (SEM–EDS). The aim of the analyses was to determine the structure, texture and mineralogical composition of samples and to obtain information about the presence of mineral inclusions.

RESULTS OF THE STUDY

Gościeradów flint (G1–G4 samples)

This flint variety occurs on the right bank of the Vistula River, most commonly in the vicinity of Gościeradów, Kraśnik district (Fig. 1), in various physical sizes as surface concentrations of fragmented concretions eroded from primary deposits, often accompanied by rubble of weathered rocks (Balcer 1971: 75; Libera and Zakościelna 1987: 40). Concretions are large (up to 30–40 cm in diameter) ovoid in shape, and relatively thick with smooth cortex. The basic mass of silica is dark gray with the presence of very slight, bright spotting and – especially characteristic – whitish and ashy irregular spots with diameters of several tens of millimeters. The basic mass and cortex are separated by a light gray transition zone with a thickness of 0,5–1 cm.

Fig. 2. Macroscopic differentiation of basic types of Turonian flints of the north-eastern margin of the Holy Cross Mountains: A – Gościeradów flint; B – Janików flint; C – Ożarów flint; D–E – Świeciechów flint; F – Zawada flint; G – selected polished cross-sections obtained from concretions of the Zawada flint; H – selected polished cross-sections obtained from the flint artefacts (flakes) found on the archaeological site 6 in Tominy.
A–B, E – photo: M. Szeliga; C–D, F–H – photo: T. Wiśniewski.


a
b
c
d
1 cm
e
f
g
h

Previous archaeological studies indicated the use of this variety of flint from the late Paleolithic to Neolithic (Kadrow and Kłosińska 1989: tab. 2; Zakościelna 1996: tab. 43; Libera 2002: 31–44). The samples analyzed and reported here were obtained from the surface of prehistoric flint mine in Świeciechów, Kraśnik district (G1–3) and arable fields in the area of Gościeradów (G4; Fig. 1; Table 1).

Microscopic analysis revealed the presence of oxides and hydroxides of iron and manganese oxides, forming black 'dots' in tested samples (Fig. 3a). These are the two types of grains: small spherical aggregations and single, recrystallized grains, which are accompanied by pyrite. In the background also are crystals of chalcedony, calcite and microfossils (Fig. 3a). Chalcedonic aggregates form spherically-shaped concentrations possibly corresponding to discoloration visible in macroscopic images of tested samples. Foraminifera bioclasts also were found (Fig. 3a) and in the cortical area there also are a number of calcite grains. These data were confirmed by SEM–EDS research, which also identified the presence of aluminosilicates and undefined compounds of iron and manganese, infrequent (especially in non-cortical areas of samples) scattered grains of dolomite and calcite, as well as sulfate (gypsum).

Janików flint (J1–J5 samples)

The occurrence of this flint coincides with the range of detrital bryozoan limestones, defaulting on a small area of Turonian outcrops on the left bank of the Vistula (Fig. 1). The largest exposed deposits occur at a quarry in Janików, Opatów district, where concretions form a series of a dozen of regular layers, each separated by intervals of several tens of centimeters (e.g. Samsonowicz 1934a: 46–47; Pożaryski 1948: 37; Balcer 1975: 53; Michniak 1980: 83; Michniak and Budziszewski 1995b: 50, Fig. 25). Concretions are oval or strongly flattened, irregular and frequently occur in gnarled or jagged shapes. They are covered by quite thick, rough, light beige cortex, with the primary mass of silica a gray-brown or brown color containing numerous bright spots up to several millimeters in diameter (Fig. 2b). Previous studies suggested incidental and only local use of this variety of flint during the Late Neolithic and Early Bronze Age (Balcer 1975: 53; Michniak and Budziszewski 1995b: 52). All tested samples were obtained from quarry in Janików (Table 1).

Macroscopic analysis revealed opal-chalcedony background of these rocks containing fossils (foraminifera) that often were filled with iron oxides and hydroxides (Fig. 3b) or carbonates (especially closer to the cortex). SEM–EDS research indicates the presence of alkali feldspar (Fig. 4: a) and calcite, impurities of manganese and iron oxides and small undefined admixture of barite (Fig. 4d).

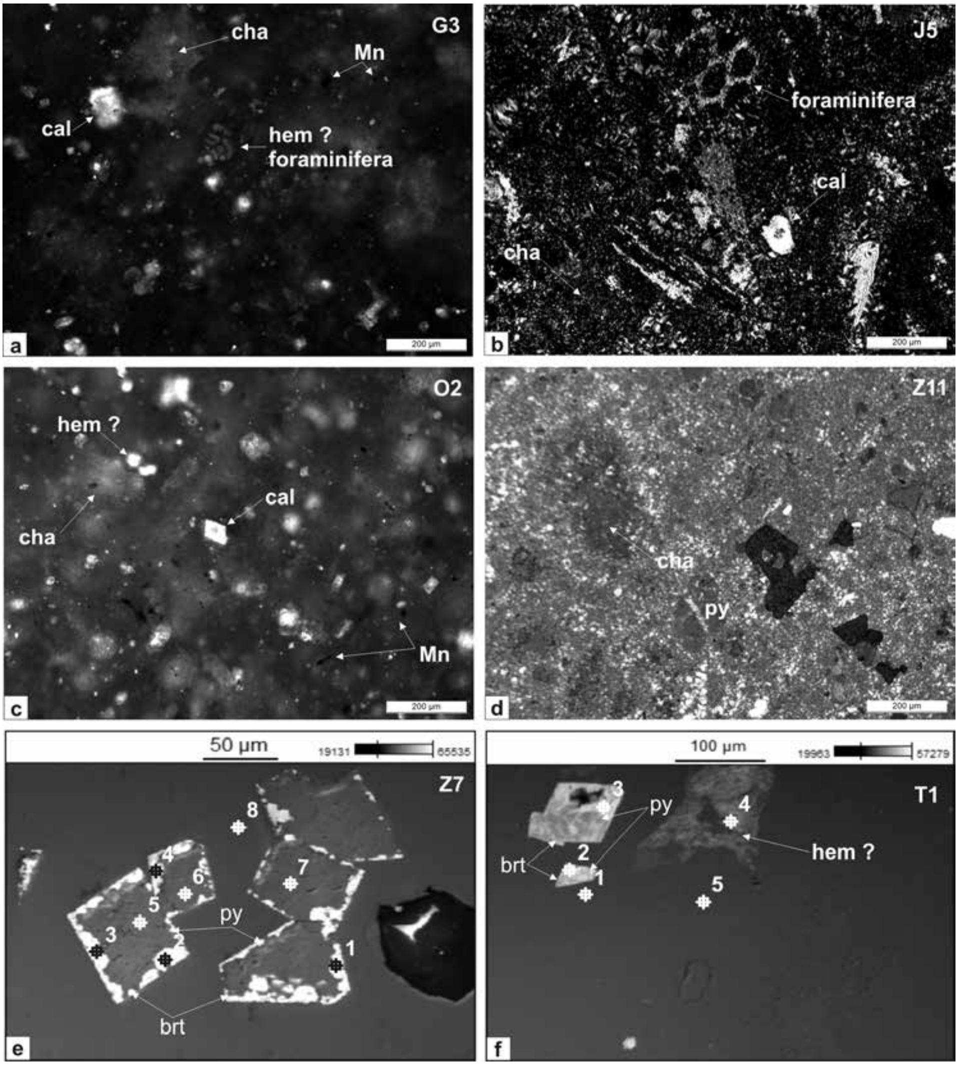


Fig. 3. Microphotographs of selected samples of Gościeradów flint (A), Janików flint (B), Ożarów flint (C), Zawada flint (D–E) and selected artefact from Tominy (F) made using a polarized microscope in transmitted (B) and reflected light (A, C–D; A–D – crossed Nicols), as well as using back-scattered electrons (BSE) technique by scanning electron microscope with location of places of punctual analyses (E–F). Symbols: brt – barite, cal – calcite, cha – chalcedony, hem ? – iron compounds, probably hematite, Mn – compounds of manganese, py – pyrite. Individual sample numbers appear in the top right corners of each microphotograph. Photo: M. Huber.

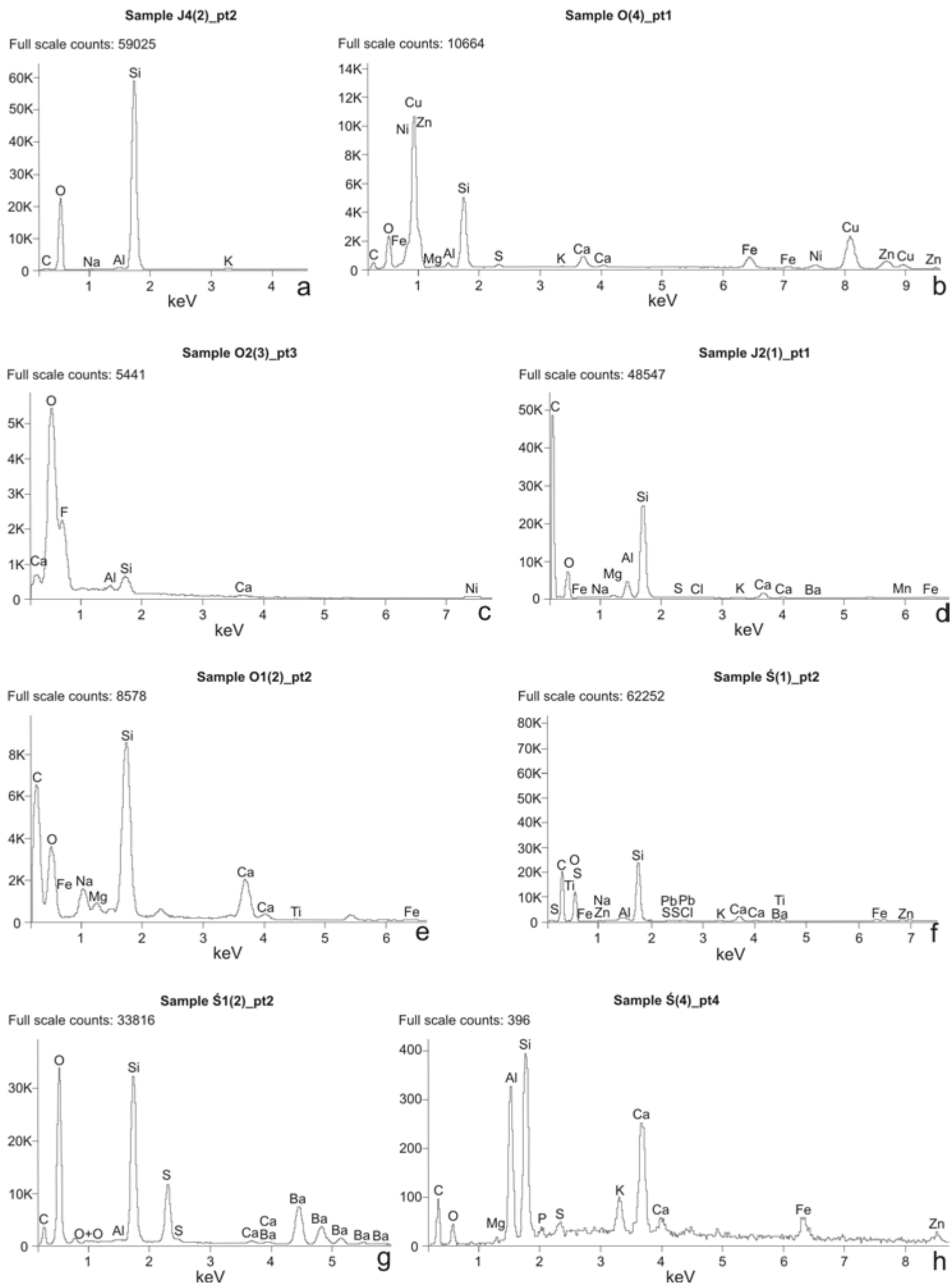


Fig. 4. EDS spectra of selected samples of Janików flint (a, d), Ożarów flint (b–c, e) and Świeciechów flint (f–h). Prepared by: M. Huber.

Ożarów flint (O1–O4 samples)

This flint occurs within a small area on left bank of Vistula River, in the immediate vicinity of Ożarów, Opatów district (Fig. 1), in large and very large[2] oval or flattened concretions with thick and rough white colored cortex (Krzak 1970: 292–295; Budziszewski 1995: 45, Fig. 23). It is has an uneven primary mass color, including different shades of gray which creates a distinctive mottled texture (Fig. 2c). Incidental and only local processing and use of this material has been suggested for early Neolithic with the greatest popularity attained during the early Bronze Age, during which relics of quarry and related workshops for the manufacture of sickles and axes were discovered at the site 'Za Garncarzami' in Ożarów, Opatów district (Budziszewski 1980: 604; 1986: 75–78). All samples analyzed for purposes of this article were obtained from fragments of natural concretions defaulting on the surface of this site (Table 1).

Analysis of samples in transmitted and reflected light revealed spherical and streak concentrations of chalcedony of varying degree of crystallinity and the presence of small inclusions of iron and manganese oxides, as well as bioclastic (crushed detritus of mollusk shells) constituents. In the background rhombic grains of calcite were identified, as well as single grains of iron and manganese oxides (Fig. 3c). SEM–EDS research confirmed the presence of K-feldspar-like phase, mica and apatite inclusions, and also iron compounds (oxides, hydroxides). In the case of sample O2 the analysis also revealed a high amount of fluorine, with a minimal calcium content (Fig. 4c). Determination of its nature and phase requires further research. Small amounts of titanium, nickel, zinc, and copper of indeterminate phase (Fig. 4b, e) also was identified in the samples tested. The titanium and nickel may derive from silicates or oxides, whose presence was recognized in a previous study of this kind of flint (Michniak 1980: Tab. 1).

Świeciechów flint (Ś1–Ś4 samples)

This variety of flint occurs on the right bank of Vistula River, where there are several known areas of secondary, surface concentrations of concretions[3]. The largest of them (about 180 ha) was recorded in Świeciechów, Kraśnik district, while

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[2] Concretions usually reach a diameter of up to several tens of centimeters. In the profile of one of the quarries in Karsy, north of Ożarów, flattened concretions at least 12 meters long and several tens of centimeters thick have been documented (Budziszewski 1980: Fig. 618).

[3] Primary deposits of this raw material were documented during geological surveys in 1st half of 20th century. In one of the Świeciechów quarries it occurred as large (diameter up to 50 cm), flattened concretions, occurring in the rock about 2 meters below the surface (Samsonowicz 1924: 100). The primary deposit also was observed in a road cut near the local cemetery (Pożaryski 1948: 47). Despite later attempts (Balcer 1971: 93, 1976: 184), we failed to re-locate the primary deposits of this variety of flint and verify previous observations.

the remaining, much smaller, is located near Rachów Nowy, Kraśnik district, and Wymysłów, Ostrowiec Świętokrzyski district (Fig. 1). Outcrops in Świeciechów and in Rachów Nowy were connected with relics of intensive mining and processing activity in the Neolithic, Bronze Age and early Iron Age (Balcer 1971: 118; 1976: 192–195; Bargieł and Libera 1996: 37–38).

The silica primary mass of this flint is characterized by gray and olive-gray colors (Fig. 2d) and various shades of gray often co-occur with each other (Fig. 2e). The primary mass contains white or yellowish calcite precipitates (Balcer 1975: 47–48) and slightly less frequently, small spots a few millimeters diameter. The contact juncture between the silica primary mass and the surrounding rock has a rough textured white or light beige surface of varying thickness (Fig. 2d). Fragments of concretions found on the surface may not preserve this contact juncture because of smoothing and polishing resulting from aeolian processes. The presence of aeolized natural faces is one of the diagnostic macroscopic properties of this variety (Samsonowicz 1924: 99–100; Krzak 1965: 220; Balcer 1971: 110–111, 1975: 50; Libera and Zakościelna 2002: 96). The use of Świeciechów flint has been suggested for the Paleolithic and Mesolithic (e.g. Cyrek 1981: Fig. 24–25; Libera, 2002: 31–34; Kaczanowska and Kozłowski 2005: Fig. 5–6), but the most intense processing and use took place in the Neolithic, during development of the Funnel Baker Culture (Balcer 1976: 192–195). All samples of this variety analyzed in the present study, represent fragments of natural concretions collected from the surface of a Neolithic quarry in Świeciechów (Table 1).

SEM analysis of the background of silica represented by concentrations of chalcedony (in varying degree of crystallinity) revealed visible fillings composed by chalcedony with admixture of opal. Calcite and clay minerals crystals occur in the background, forming irregular concentrations, along with a few ore minerals (pyrite and iron oxides), isolated parts of bioclastic content (e.g. foraminifera, needles of sponges) and single grains of feldspar. In some specimens micro-faults filled by recrystallized quartz and opaque minerals are visible. Therefore, characteristic discolorations occurring in these flints may be the result of concentration of clay minerals, carbonate crystals and secondary epigenetic quartz (with a much lower share of coloring iron compounds). SEM–EDS analyses also revealed the presence of apatite, aluminosilicates and manganese oxides. In some samples were found small admixture of barite and titanium (Fig. 4g), as well as lead and zinc - most likely as sulphides (Fig. 4f, h).

Zawada flint (Z1–Z11 samples)

So far, the existence of this variety of flint is confined to a small quarry in Zawada, Opatów district (Budziszewski and Michniak 1989: 151; Szeliga 2014: 90, Fig. 5: A–B), backfilled during 2006. At the present time only a concentration of eroded

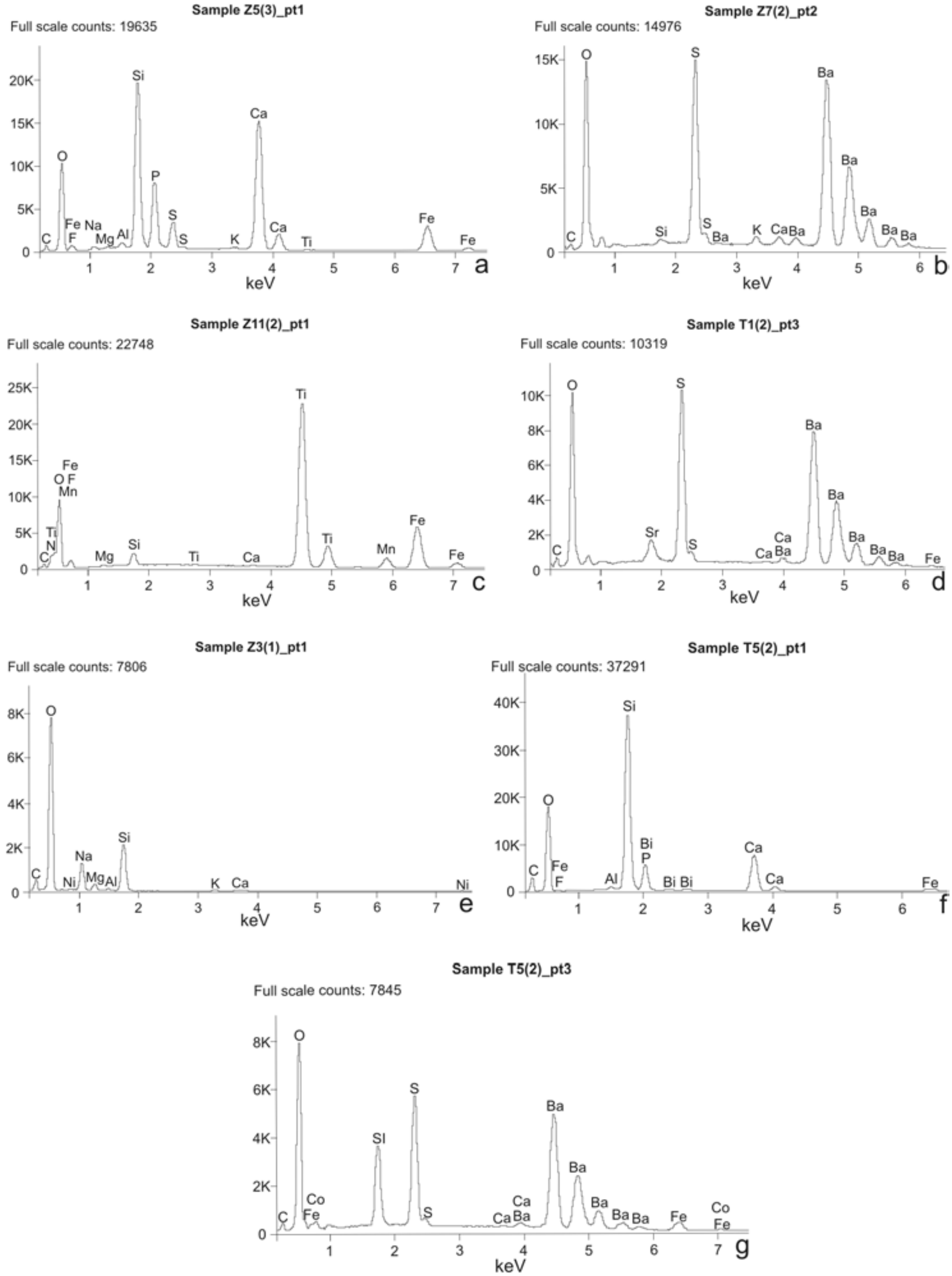

Fig. 5. EDS spectra of selected samples of Zawada flint (a–c, e) and artifacts ('T' samples) from site 6 in Tominy (d, f–g). Prepared by: M. Huber.

flint concretion fragments remain, on the surface in the immediate vicinity of the quarry (Fig. 1). These fragments represent quite regular, round and slightly flattened shape of concretions, often reaching considerable size and weight, covered with thick (although easy to rub away) white and yellowish cortex. The primary mass of silica is dark gray, occasionally brightened toward the centre of the concretion, where it is noticeably tarnished. Within it occur quite regular, bright spots, up to several millimeters in size, sometimes taking the form of intensive mottling. Its characteristic feature is the presence of a thin (2–4 mm), generally brown or dark purple (sometimes black) layer between the primary mass and cortex (Fig. 2f–g). The presence of this feature provided the basis for our idenfication of this material in LPC flint inventory from nearby site 6 in Tominy (Fig. 1; 2h). All analyzed geological samples of this variety come from the surface outcrop in Zawada (Table 1).

The analysis of microscopic images revealed the presence of sulphides (pyrite occurring as euhedral crystals accompanyied by oxides and hydroxides of iron) visible on the background of numerous concentrations of chalcedony, including siliphicated organic fossils (foraminifera). In the background are crystals of calcite, along with single grains of feldspar (plagioclase) and quartz. SEM–EDS analysis also revealed the presence of apatite, pyrite and barite (Fig. 3d–e; 5a–b), with barite between the grains of pyrite and iron compounds. In those rocks there are also carbonates of glauconite-like phase. Inclusions of fluorspar also were identified, and certain undefined admixture of titanium and nickel (Fig. 5c, e).

Archaeological samples from Tominy (T1–T11)

SEM analysis was conducted on 11 flakes from LPC context at site 6 in Tominy, located approx. 100 m south of the outcrop in Zawada (Fig. 1), verify to the distinct convergence of macroscopic features of artifacts with Zawada flint.

Microscopic analyses revealed a large amount of pyrite, visible on the background of studied samples (similar to samples of Ożarów flint), although in this case the sulphides have anhedral forms. Oxides and hydroxides of iron and numerous concentrations of chalcedony were observed, as well as calcite and quartz. SEM–EDS analysis also revealed the admixture of barite, which lie between the grains of pyrite and iron compounds (Fig. 3f; 5d). The presence of undefined admixture of cobalt, bismuth, titanium and strontium also was confirmed, as well as concentrations of barite, phosphates and aluminosilicates (Fig. 5d, f–g).

CONCLUSIONS

The results of microscopic research reported here, including SEM–EDS, are in accord with the results of previous mineralogical analyses (Stawin 1970: Table 7–8; Balcer

1975: 47–48; Michniak 1980: 85–86). Despite the increasing knowledge about the nature and mineralogical and petrographic diversity of basic varieties of Turonian flints in the north-eastern margin of the Holy Cross (Świętokrzyskie) Mountains, microscopic analyses failed to capture the significant differences in mineral composition of analyzed samples, each time revealing the dominant content of silica group minerals, and presence of different admixture, represented by oxides and hydroxides of iron and manganese, as well as aluminosilicates, apatite, pyrite, and also calcite (especially nearby the cortex). Current data do not reveal unequivocal diagnostic features to allow unambiguous correspondences between archaeological materials and flint raw materials originating in particular exposures of Turonian outcrops.

Despite the large mineralogical convergence of tested samples, this study captured some individual features, manifested by greater or lesser intensity within different varieties of Turonian flints. These data allow positive promise for the future, revealing at the same time the need to broaden the scope of research with more samples and additional chemical analyzes (e.g. ICP–MS), aimed at more precise specification and quantification of the admixture of various minerals (sulphide, sulphate, including barite) and metals (e.g. manganese, lead, zinc, copper and strontium; see Fig: 4b, d, f, h; 5) identified here. The need for more precise, quantified corroborative analyses also applies to the observed mineralogical convergence between the samples of Zawada flint (Z1–11) and a series of archaeological samples from site in Tominy (T1–11), manifested primarily in the coexistence of pyrite grains with characteristic skeleton-like shape filled with barite, the presence of undefined compounds of titanium and other metals (Fig. 5), and enhanced of transition zone between the cortex and primary mass of silica by oxides and hydroxides of iron. Regardless, we conclude that the convergence of these microscopically generated features are sufficient to identify the outcrop in Zawada as the place of origin of the raw materials used in production of artifacts analyzed from site 6 at Tominy, confirming the knowledge, processing and use of Zawada flint by local early agrarian communities at the turn of the 6th and 5th millennia BC. This findings from Tominy represents the only instrumentally-based confirmation of processing and use of Zawada flint in prehistory.

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REFERENCES

Balcer, B. 1971. Kopalnia krzemienia w Świeciechowie-Lasku, pow. Kraśnik w świetle badań 1967 r. *Wiadomości Archeologiczne* 36: 71–132.

Balcer, B. 1975. *Krzemień świeciechowski w kulturze pucharów lejkowatych. Eksploatacja, obróbka i rozprzestrzenienie*. Wrocław–Warszawa–Kraków–Gdańsk.

Balcer, B. 1976. Position and Stratigraphy of Flint Deposits, Development of Exploitation and Importance of the Świeciechów Flint in Prehistory. *Acta Archaeologica Carpathica* 16: 179–199.

Bargieł, B. and Libera, J. 1996.Wyniki badań pracowni nakopalnianej w Nowym Rachowie. *Archeologia Polski Środkowowschodniej* 1: 35–48.

Budziszewski, J. 1980. Ożarów, Gemeinde Lęce, 'Za garncarzami', Wojw. Tarnobrzeg. In G. Weisgerber, R. Slotta and J. Weiner (eds), *5000 Jahre Feuersteinbergbau. Die Suche nach dem Stahl der Steinzeit*, 603–605. Bochum.

Budziszewski, J. 1986. Exploration ofthemininfield 'Zagarncarzami' in Ożarów, Tarnobrzegvoivodship. Preliminary report. In K. T. Biró (ed.), *Papers for the I[st] International Conference on Prehistoric Flint Mining and Lithic Raw Material Identification in the Carpathian Basin, Budapest – Sümeg, 20–22 May, 1986, vol. 1*, 69–82. Budapest.

Budziszewski, J. 1995. Exposure with Lower Turonian flints in Karsy, Tarnobrzeg district. In J. Budziszewski and R. Michniak (eds), *Guide-Book of Excursion 2: Northern Footslopes of Holy Cross Mountains VIIth International Flint Symposium. Warszawa-Ostrowiec Świętokrzyski. 4–8 September 1995*, 45–47. Warszawa.

Budziszewski, J. and Michniak, R. 1989. Z badań nad występowaniem, petrograficzną naturą oraz prahistoryczną eksploatacją krzemieni pasiastych w południowym skrzydle niecki Magoń-Folwarczyska. *Wiadomości Archeologiczne* 49: 151–190.

Cyrek, K. 1981. Uzyskiwanie i użytkowanie surowców krzemiennych w mezolicie dorzeczy Wisły i górnej Warty. *Prace i Materiały Muzeum Archeologicznego i Etnograficznego w Łodzi* 28: 5–108.

Kaczanowska, M. and Kozłowski, J.K. 2005. L'importance de silex de Świeciechówdansl' Âge de la Pierre: indicateur de changements de relations culturellesautour des Carpates occidentals. *Praehistoria* 6: 71–83.

Kadrow, S. and Kłosińska, E. 1989. Obiekt kultury lubelsko-wołyńskiej na stanowisku 10 w Łańcucie. *Sprawozdania Archeologiczne* 40: 9–25.

Krukowski, S. 1920. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski. Wnioski z właściwości surowców i wyrobów. *Wiadomości Archeologiczne* 5: 185–206.

Krzak, Z. 1965. Tymczasowa charakterystyka kopalni krzemienia w Świeciechowie. *Archeologia Polski* 10: 217–233.

Krzak, Z. 1970. Wstępna charakterystyka kopalni krzemienia w Ożarowie Opatowskim. *Archeologia Polski* 15: 291–303.

Libera, J. 2002. Wykorzystanie krzemienia świeciechowskiego i gościeradowskiego w paleolicie schyłkowym i mezolicie w międzyrzeczu Wisły i Bugu oraz w dorzeczu Sanu (zarys problematyki). In B. Matraszek and S. Sałaciński (eds), *Krzemień świeciechowski w pradziejach*, 29–49. Warszawa.

Libera, J. and Zakościelna, A. 1987. Złoża krzemieni turońskich na prawobrzeżu środkowej Wisły w świetle badań AZP. In J. Gurba (ed.), *Sprawozdania z badań terenowych Katedry Archeologii UMCS w 1987 roku*, 39–47. Lublin.

Libera, J. and Zakościelna, A. 2002. Złoża krzemieni turońskich w przełomowym odcinku Wisły. In B. Matraszek and S. Sałaciński (eds), *Krzemień świeciechowski w pradziejach*, 93–109. Warszawa.

Michniak, R. 1980. Petrografia i geneza ciemnych krzemieni z dolnoturońskich osadów okolic Ożarowa nad środkową Wisłą. *Archiwum Mineralogiczne* 36: 83–106.

Michniak, R. and Budziszewski, J. 1995a. Siliceous rocks of the North-Eastern Mesozoic margin of the Holy Cross Mountains. In J. Budziszewski and R. Michniak (eds), *Guide-Book of Excursion 2: Northern Footslopes of Holy Cross Mountains VIIth International Flint Symposium. Warszawa-Ostrowiec Świętokrzyski. 4–8 September 1995*, 11–19. Warszawa.

Michniak, R. and Budziszewski, J. 1995b. Exposure with Lower Turonian flints in Janików, Tarnobrzeg district. In J. Budziszewski and R. Michniak (eds), *Guide-Book of Excursion 2: Northern Footslopes of Holy Cross Mountains VIIth International Flint Symposium. Warszawa-Ostrowiec Świętokrzyski. 4–8 September 1995*, 50–52. Warszawa.

Pożaryski, W. 1948. *Jura i kreda między Radomiem, Zawichostem i Kraśnikiem*. Warszawa.

Pożaryski, W. 1997. Tektonika powaryscyjska obszaru świętokrzysko-lubelskiego na tle struktury podłoża. *Przegląd Geologiczny* 45: 1265–1270.

Samsonowicz, J. 1924. Odkrycie pierwotnych złóż krzemienia „szarego biało nakrapianego". *Wiadomości Archeologiczne* 9: 99–101.

Samsonowicz, J. 1934a. *Objaśnienia arkusza Opatów ogólnej mapy geologicznej Polski w skali 1:100000*. Warszawa.

Samsonowicz, J. 1934b. *Ogólna mapa geologiczna Polski w skali 1:100 000 ark. Opatów*. Warszawa.

Stawin, J. 1970. Własności techniczne krajowych krzemieni. *Biuletyn Państwowego Instytutu Geologicznego* 244: 105–157.

Szeliga, M. 2014. The distribution and importance of Turonian flints from the north-eastern margin of the Holy Cross Mountains in the flint raw material economy of the earliest Danubian communities. *Acta Archaeologica Carpathica* 49: 77–112.

Zakościelna, A. 1996. *Krzemieniarstwo kultury wołyńsko-lubelskiej ceramiki malowanej*. Lublin.

Złonkiewicz, Z. 1994. *Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000. Arkusz Ożarów (819)*. Warszawa.

Złonkiewicz, Z. 1998. *Szczegółowa Mapa Geologiczna Polski w skali 1:50 000. Arkusz Ożarów (819)*. Warszawa.

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On The Chemical Composition of 'Chocolate' Flint from Central Poland

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The paper presents the initial results of energy-dispersive x-ray fluorescence (EDXRF) spectrometric analysis of 'chocolate' flint from outcrops located on the northeastern slopes of the Świętokrzyskie (Holy Cross) Mountains in central Poland. EDXRF analysis shows that the composition of certain major and minor elements allow us to distinguish between and among some varieties of 'chocolate' flint. EDXRF analysis also was undertaken on other flints know from Poland (Jurassic-Cracow; Gray-white spotted; Striped Flint), providing a geochemical baseline for instrumental identification of these flints in archaeological sites.

KEY-WORD: 'chocolate' flint, EDXRF, Central Poland, flint identification

INTRODUCTION

In the years following World War I, Stefan Krukowski (1920, 1922) published two important articles emphasizing the relevance of the study of flint raw materials to research on prehistoric 'mining, transport and trade'. In the first of these he wrote that it:

> '[…] jest cel … zwrócić … uwagę naszych prehistoryków, wspomaganych przez petrografów i geologów, na doniosłość tych zagadnień [górnictwo, transport i handel] nie tylko dla cywilizacji neolitycznych wogóle, lecz szczególniej dla morfologii wyrobów z krzemienia, jakoteż łączności między współistniejącemi i nastepującemi po sobie kulturami.'

> '[…] the goal is ... to call ... the attention of our prehistorians, assisted by petrolographists and geologists, on the importance of these issues [mining, transport and trade], not only for the Neolithic civilization in general, but especially for the morphology of the products of flint, and also to communication between the coexistence and succession of the cultures.' (Krukowski 1920: 185; additions and translation by DHW).

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'Chocolate' flint held an important place in Krukowski's research. As early as 1922 he and Jan Samsonowicz discovered the first 'chocolate flint' outcrops located on the northeastern slopes of the Świętokrzyskie (Holy Cross) Mountains in central Poland (Krukowski 1922, 1923; Samsonowicz 1923).

Since Krukowski's work, a considerable amount of research on 'chocolate' flint has been undertaken over the past several decades (e.g., Schild 1971, 1976, 1987, 1995a, 1995b, 1997; Kaczanowska and Lech 1977; Schild *et al.*, 1977; 1985; 1997; Chmielewska 1980, 1988; Lech 1984, 1995, 1997; Lech 1987, 1990; Herbich 1993; Herbich and Lech 1995; Cyrek 1995; Bednarz and Budziszewski 1997; Małecka-Kukawka 1997; Sulgostowska 1997; Bednarz 2001; Borkowski *et al.*, 2008; Budziszewski 2008; Přichystal 2009, 2013). This research was pivotal to demonstrating that 'chocolate' flint was the most important raw material used by prehistoric communities from Paleolithic through Late Bronze Age times (Lech 1984; Sulgostowska 2005) from the north-east margin of the Świętokrzyskie (Holy Cross) Mountains to as far away as the Carpathian Mountains. In fact, it is has recently been identified as being present in the flint assemblages at archaeological sites in Belarus, the Czech Republic, Hungary, Latvia, Lithuania, Slovakia, and the Ukraine (Schild 1976; Budziszewski 2008; Sulgostowska 2008; Kozłowski 2013; Bíro 2014: 61).

BACKGROUND

Following Krukowski's (1920) pioneering description of the macroscopic characteristics of 'chocolate' flint there have been several other attempts to characterize it (e.g. Budziszewski 2008: 33). In perhaps the best known of these, Romuald Schild (1971: 7–17, 1976: 149) used macroscopic and microscopic criteria to identify 11 groups of 'chocolate' flint using material collected from 16 geological extraction points on the north-east rim of the Świętokrzyskie (Holy Cross) Mountains. He took into account the macroscopic properties of color, luster, composition, texture, structure, shape and size of nodule, and type of cortex (Schild 1976: 149), as well as microscopic characteristics revealed by a petrographic analysis of thin sections using laser light (Schild 1971: 6).

On the basis of these examinations Schild (1976: 149) wrote that of the 11 groups he identified 'three groups are of importance being the most common and possibility also the most popular in prehistory'. The first group is dark brown (10 YR 2/2) in color, waxy, usually not banded or occasionally microbanded rarely with a black central part (10 YR 2/1). This group occurs in central and eastern portion of 'chocolate' flint strip (Group I; see Fig. 1 and Table 1). The second group is dark grayish brown (10 YR 2/1) and brown (10 YR 4/3) in color. The nodules are waxy and transparent, not usually banded, and rarely irregularly laminated. This group occurs in the western portion of the strip (Group VI and VII; see Fig. 1). The last (third) group is typically black in the central portion of the nodule (10 YR 2/1) and very dark gray to dark brown (10 YR 3/1 – 10 YR 3/3), rarely dark grayish brown (10 YR 4/2), in the remaining mass. This variety is not banded, but dull to dull waxy and weakly transparent. This group occurs in the central part of the strip (Group X; see Fig. 1; Schild 1971: 7–17, 1976: 149). Schild (1971) also identified a Group IX, which is similar to Group VI. Group IX raw materials are brown in color (10 YR 4/3), sometimes gray-brown (10 YR 4/2), sometimes with gray spots. This flint, which occurs at Orońsko (Szydłowiec district;

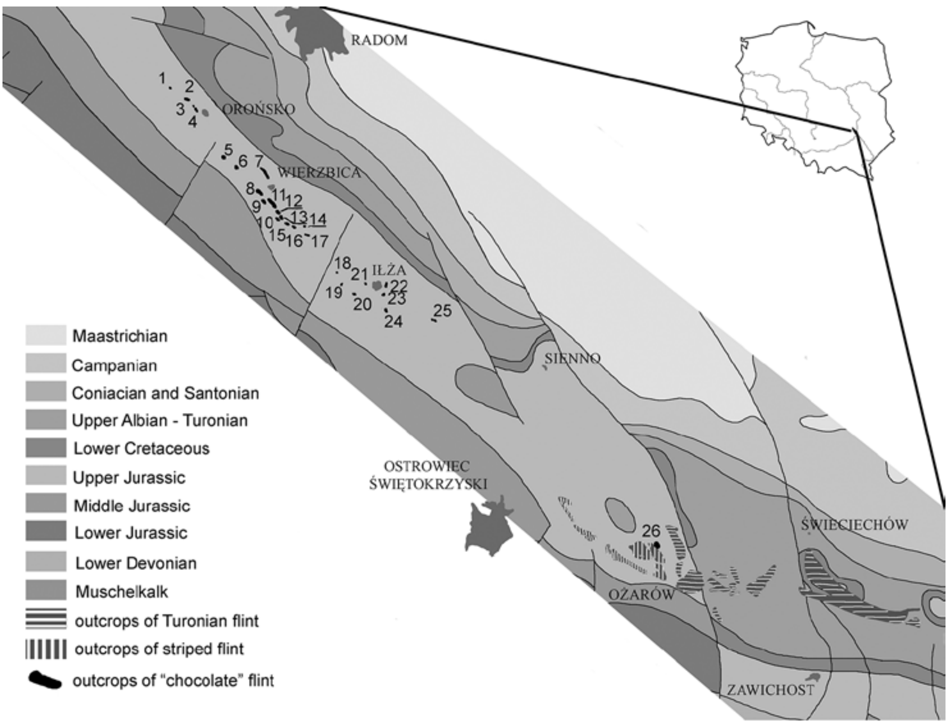

Fig. 1. 'Chocolate' flint locations in pre-Quaternary formations on the northeastern outskirts of the Holy Cross Mountains; 1 – Chronów-Kolonia, Szydłowiec dist.; 2 – Guzów Szydłowiec dist.; 3 – Orońsko 'Mały Orońsk' Szydłowiec dist.; **4 – Orońsko (Orońsk II) Szydłowiec dist.**; **5 – Tomaszów Szydłowiec dist.**; 6 – Rzeczków, Radom dist.; **7 – Wierzbica quarry, Radom dist.**; **8 – Wierzbica 'Zele', Radom dist.**; 9 – Wierzbica 'Krzemienica', Radom dist.; 10 – Polany kolonie IV, Radom dist.; 11 – Polany kolonie I, Radom dist.; 12 – Polany kolonie II, Radom dist.; 13 – Polany kolonie IIa, Radom dist.; 14 – Polany III, Radom dist.; 15 – Polany kolonie III, Radom dist.; 16 – Polany I, Radom dist.; 17 – Polany II, Radom dist.; 18 – Pakosław, Radom dist.; 19 – Seredzice, Radom dist.; 20 – Seredzice 'Kolonia', Radom dist.; 21 – Iłża 'Wąwóz Żuchowiec', Radom dist.; 22 – Iłża 'Krzemieniec' II, Radom dist.; 23 – Iłża 'Krzemieniec' I, Radom dist.; 24 – Błaziny Górne, Radom dist.; **25 – Prędocin, Radom dist.**; 26 – Gliniany 'Wzgórze Kruk', Opatów dist. (Schild 1971, 1976; Balcer 1976; Dadlez *et al.*, 2000; Budziszewski 2008; Budziszewski *et al.*, 2015; sites listed in boldface print are discussed in the text). Graphic design: D.H. Werra.

Table 1. Characteristics of the eleven groups of 'chocolate' flint distinguished by Schild (1971: 7–17)

Group	Colour	Trans-parency	Compo-sition	Luster	Shape and Size of Nodule	Type of Cortex	Occurrence
I	Dark brown (10 YR 2/2); black central part (10 YR 2/1)	good and medium	petite and medium	waxy	flat, diam-eter tens cm	Thin, up to 1 mm; rough or smooth	Chronów-Kolonia, Wierzbica 'Zele'; Polany I, Polany II, Polany kolonie II, Polany kolonie III, Iłża, Prędocin
II	Black (10 YR 2/1), thin rim dark brown (10 YR 2/2)	Medium and bad	Medium and thick	waxy	Round nod-ules, from few up to tens cm	Rough, some-times more than 5 mm	Iłża
III	Dark brown (10 YR 3/2)	good and medium	petite and medium	waxy	Flat and round	Thin and smooth	Wierzbica 'Zele', Polany I, Polany kolonie I and II, Prędocin
IV	Dark, red-brown (5 YR 3/2), with bald spots (%YR 2/1)	medium	thick	dull	Round, up to tens cm diameter	Up to 1mm very rough	Polany Kolonie II
V	Dark-gray-brown (10 YR 3/2) and dark-brown (10 YR 2/2), with gray spots	From good to bad	petite	Waxy, waxy-dull, dull	Big nod-ules maybe tablets	Thin, less than 1 mm	Chronów-Kolonia, Guzów, Wierzbica 'Zele', Polany Kolonia I, II and III
VI	Dark-gray-brown or brown (10 YR 4/2 – 10 YR 4/3)	good	petite	waxy	Big nodules and tablets	Thin, less than 1 mm	Orońsko, Tomaszów
VII	Dark-gray-brown (10 YR 4/2) and dark reddish-gray spots	Good and medium	Petite and medium	Dull-waxy and waxy	Big, irregular tablets	Thin	Guzów, Orońsko
VIII	Dark-gray-brown (10 YR 4/2) or dark-yellow-brown with gray, brown and black bands	Good and medium	petite	waxy	Tablets	Thin, less than 1 mm	Tomaszów

IX	Brown (10 YR 4/3) or dark-gray-brown (10 Yr 4/2)	Petite – with gray spots	good	waxy	Unknown	Rough 1–2 mm, under the cortex white rim	Orońsko
X	Black (10 YR 2/1), dark-gray (10 YR 3/1), dark-gray-brown (10 YR 3/2), dark-brown (10 YR 3/3) or dark-gray-brown (10 YR 4/2)	bad	thick	dull	Irregular nodules and tablets	Thin and thick	Guzów, Wierzbica 'Zele', Polany I, III, Polany kolonie I and III
XI	Dark-gray-brown (10 YR 4/2)	Medium and bad	Petite and medium	dull	Big, irregular tablets	Thin up to 1mm and smooth or thick 5 mm and rough	Tomaszów

Schild 1971: 14), can look very similar to Jurassic-Cracow flint.

However, attempts to distinguish these different flint varieties using macroscopic characteristics were not particularly successful. In fact Schild (1976: 150) concluded that 'the study of thin sections makes the recognition of the exact source almost impossible' although he held out hope that 'the use of other scientific techniques might help the identification of the exact source'.

THE PRESENT PROJECT

Almost forty years after those words were written a new project about 'chocolate' flint was undertaken by the Institute of Archeology and Ethnology Polish Academy of Science in cooperation with Geochemical Research Laboratory (USA)[1]. In recent studies (Hughes *et al.*, 2011, Hughes *et al.*, 2012, Högberg *et al.*, 2013) non-destructive energy-dispersive X-ray fluorescence (EDXRF) analysis was applied to the problem of drawing chemical distinctions between and among various types of Scandinavian flint and flints from Lithuania and Belarus. EDXRF results showed that using this method chemical differences between certain flints can be identified, so we applied this same method to a pilot study of 'chocolate' flint from Poland. The main goal was to see if it was possible to identify chemical differences among 'chocolate' flint from different outcrops, but we also investigated differences among other regional flint types in the Vistula River basin (*e.g.* Turonian flint; grey white-spotted – Świeciechów; striped, Jurassic-Cracow) and, on the eastern fringes of the region, Volhynian flint.

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From a geological standpoint, the siliceous rocks used by prehistoric communities occur in late Jurassic deposits – the highest Oxfordian limestone and Lower Kimmeridgian – but precise determination of the relative stratigraphic position of the 'chocolate' flint is difficult due to the lack of a clear chrono-stratigraphic division between of the rocks occurring in the area. The problem is exacerbated because of the lack of a clearly defined boundary between Oxford and Kimmeridgian in different parts of Europe. Samsonowicz (1934) wrote that 'chocolate' flint usually occurs in one thin level, in a stable stratigraphic position, but Pożaryski (1948) later argued that 'chocolate' flints are continuously distributed but can occur in thick deposits for several meters. Subsequent geological research appeared to support Pożaryski's view, but more recent studies (Dembowska 1953; Wyrwicki 1969) are more consonant with Samsonowicz's earlier findings. Although most geologists working in this area assign 'chocolate' flints to the upper part of Upper Oxford (Malinowska and Dembowska 1973; Dąbrowska 1983) others (e.g. Kutek 1983; Gutowski 2004) assigns 'chocolate' flint to the lower Kimmeridgian, and some other researchers believe that this flint occurs in both of these levels (Wyrwicka 1969; Migaszewski *et al.*, 2006). Archaeological research shows that prehistoric exploitations points for 'chocolate' flint are visible in one line and level around 6 m thick but it is still unclear whether 'chocolate' flints were created at one, discrete, level or whether they occur in several stratigraphic horizons (Budziszewski 2008: 45). To say the least, the dating issue is still far from settled and must await more detailed geological and archaeological study.

SAMPLE SELECTION

For the present study we selected 37 samples from four distinct archaeologically documented prehistoric 'chocolate' flint mines from Upper Oxfordian (ca. 157–164 Ma) and possibly Kimmeridgian (ca. 152–157 Ma) geological deposits in the Holy Cross Mountains. These include: Orońsko (n= 8; loc. 4 in Fig. 1), Tomaszów (Szydłowiec district; n= 9; loc. 5 in Fig. 1), Wierzbica (Radom district; n= 11; locs. 7–8 in Fig. 1), and Prędocin (Radom district; n= 9; loc. 25 in Fig. 1). From these sites we analyzed flint from the three main visual groups identified by Schild (1976). Prędocin represents Schild's (1976) group I, Orońsko and Tomaszów represent group II, and Wierzbica 'Zele' the last – III group (Table 1). Geographically they include the main locale in the north-west part of 'chocolate' flint belt (group II), the middle (group III) and the south-east part (Prędocin).

STUDY RESULTS AND DISCUSSION

Figure 1 shows the locations of the samples collected for this study, and Table 2 presents chemical data for the analyzed flint samples. All specimens were analyzed using non-destructive EDXRF using laboratory analysis conditions and instrumentation described in an earlier study (Hughes *et al.*, 2012). Samples chosen for analysis were cleaved from parent nodules collected during surface studies made during 2012–2014. Flints from Orońsko and Tomaszów were collected from the surface of the sites. In the case of Wierzbica, fresh raw material was collected directly from the flint layers exposed in the walls of the quarry and Wierzbica 'Zele' samples were selected from a deep shaft excavated in the 1980's. The specimens were cut into 30 cm squares using diamond saw blade (VC–50 2001 LECO Corp.) together with VC Cutting Oil and a 100 water cooled diamond saw blade manufactured by the Dedra company. The surface of flint samples so produced were not polished in any way. Prior to EDXRF analysis the sample surfaces were cleaned with distilled water to remove any noticeable surface contaminants. As discussed previously (Hughes *et al.*, 2012: 786), care was taken to avoid targeting the X-ray beam onto calcareous or fossil inclusions. Otherwise, the only other analysis requirement was that each sample be relatively flat, ≥ 15–20 mm in diameter, and have a minimum surface size of ≥ 2–3 mm.

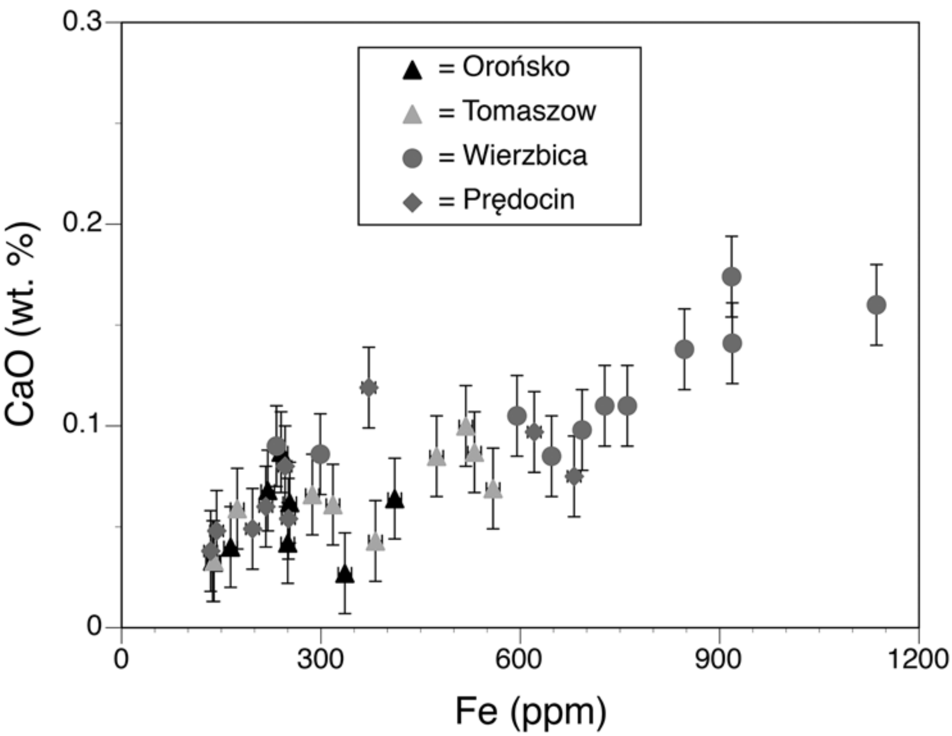

Fig. 2. The composition of Ca vs. Fe in geological specimens of 'chocolate' flint from the northeastern slopes of the Świętokrzyskie (Holy Cross) Mountains in central Poland. Error bars delimit 95% probability estimates for elemental composition. Graphic design: R.E. Hughes.

Table 2. The Chemical Composition of 'Chocolate' Flint from Poland

Locality	Lab I.D. #	Major and Minor Elements								
		Al_2O_3 (wt. %)	SiO_2 (wt. %)	SO_3 (wt. %)	Cl (ppm)	K_2O (wt. %)	CaO (wt. %)	Ti (ppm)	Mn (ppm)	Fe (ppm)
Orońsko psy się gryzły, Szydłowiec dist.	ORO-1	0	99,69	0,022	11	0,042	0,087	37	1	240
Orońsko 'Truskawki', Szydłowiec dist.	ORO-2	0,000	99,61	0,016	171	0,065	0,068	38	2	220
Orońsko 'Truskawki', Szydłowiec dist.	ORO-4	0,129	99,64	0,013	0	0,095	0,027	105	6	336
Orońsko 'Przy bramie', Szydłowiec dist.	ORO-5	0,000	99,67	0,023	17	0,036	0,033	26	1	137
Orońsko 'Przy bramie', Szydłowiec dist.	ORO-6	0,173	99,52	0	0	0,053	0,064	58	4	411
Orońsko 'Truskawki', Szydłowiec dist.	ORO-7	0	99,55	0,02	0	0,046	0,042	26	1	250
Orońsko 'Truskawki', Szydłowiec dist.	ORO-8	0	99,36	0,023	509	0,123	0,062	38	0	253
Orońsko szkółka, Szydłowiec dist.	ORO-10	0	99,66	0,017	0	0,031	0,04	64	3	164
Tomaszów, Szydłowiec dist.	TOM-1	0,000	99,53	0,009	226	0,091	0,087	46	0	531
Tomaszów, Szydłowiec dist.	TOM-2	0,000	99,56	0,002	0	0,06	0,069	66	3	559
Tomaszów, Szydłowiec dist.	TOM-3	0,000	99,49	0,029	400	0,101	0,085	62	3	474
Tomaszów, Szydłowiec dist.	TOM-4	0,000	99,37	0,013	247	0,075	0,059	57	3	174
Tomaszów, Szydłowiec dist.	TOM-5	0	99,49	0	0	0,037	0,066	51	2	287
Tomaszów, Szydłowiec dist.	TOM-6	0,000	99,37	0,031	187	0,1	0,1	183	5	518
Tomaszów, Szydłowiec dist.	TOM-7	0,124	99,50	0,022	104	0,083	0,043	66	4	382
Tomaszów, Szydłowiec dist.	TOM-8	0	99,43	0,021	0	0,052	0,061	57	1	318
Tomaszów, Szydłowiec dist.	TOM-9	0	99,50	0,021	0	0,04	0,03	36	1	115
Wierzbica Kamieniolom, tablica, Radom dist.	WiK-1 (run 2)	0,000	99,54	0,021	0	0,061	0,086	52	2	299
Wierzbica Kamieniolom, layer 1, Radom dist.	WiK-2 (run 2)	0,085	98,99	0,024	577	0,088	0,09	55	3	233
Wierzbica 'Zele' brown, Radom dist.	WZ1-B	0,067	99,15	0,028	737	0,083	0,141	105	3	919

Wierzbica 'Zele' brown, Radom dist.	WZ1-B1 (run 1)	0,000	99,32	0,02	308	0,074	0,138	93	2	847
Wierzbica 'Zele' black, Radom dist.	WZ2-C (run 2)	0,000	99,53	0,036	58	0,044	0,105	68	3	595
Wierzbica 'Zele' brown, Radom dist.	WZ3-B	0,000	99,49	0,027	58	0,031	0,11	66	1	727
Wierzbica 'Zele' brown, Radom dist.	WZ3-B1 (run 2)	0,000	99,43	0	0	0,051	0,085	95	0	647
Wierzbica 'Zele' black, Radom dist.	WZ3-C	0,000	99,50	0,021	0	0,045	0,101	104	5	573
Wierzbica 'Zele' black, Radom dist.	WZ3-C1 (run 2)	0,000	99,48	0,035	92	0,055	0,098	83	2	693
Wierzbica 'Zele', Radom dist.	WZp-1 (run 2)	0,039	99,18	0,028	566	0,077	0,174	114	5	918
Wierzbica 'Zele', Radom dist.	WZp-2	0,051	99,59	0,027	102	0,057	0,113	80	2	706
Prędocin, Radom dist.	PRE-1	1,260	98,35	0,025	194	0,128	0,097	130	117	621
Prędocin, Radom dist.	PRE-2	0,123	99,27	0,023	199	0,126	0,119	83	9	372
Prędocin, Radom dist.	PRE-3	0,000	99,77	0,012	0	0,043	0,06	48	1	217
Prędocin, Radom dist.	PRE-4	0,000	99,29	0,021	327	0,089	0,08	49	1	246
Prędocin, Radom dist.	PRE-6	0,000	99,54	0,015	0	0,03	0,038	23	2	134
Prędocin, Radom dist.	PRE-7	0,000	99,52	0,021	99	0,051	0,054	38	2	251
Prędocin, Radom dist.	PRE-8	0,000	99,50	0,021	0	0,058	0,048	37	3	143
Prędocin, Radom dist.	PRE-9	0,149	99,21	0	264	0,164	0,075	65	4	681
Prędocin, Radom dist.	PRE-10	0,000	99,38	0,018	0	0,03	0,049	31	1	197
JCh-1 measured (average of 9 analyses)		0,435	98,61	0,003	0	0,220	0,038	196	127	2754
S.D. (9 analyses)		0,139	0,27	0,001		0,006	0,004	10,52	5	36,6
CV% (9 analyses)		32,000	< 1	44,3		2,73	9,7	5,4	4	1,3
JCh-1 (recommended)		0,734	97,81	nr	14	0,221	0,045	189	134	2490

Recommended values for JCh-1 from Imai et al. (1996). nr = not reported. S.D. = standard deviation; CV% = coefficient of variation.
Detection limits for each element follow Hughes *et al.*, 2012: 781

Figure 2 plots the composition of Ca vs. Fe in the 'chocolate' flint geological specimens listed in Table 1. These aggregate data give a good overall picture of the Ca/Fe variability within the deposits, but there is a hint that finer scale discrimination might be possible. Note, in particular, the cluster of Fe values at around 300 ppm, separated by around 300 ppm from others of higher Fe composition (see Fig. 3 and 4). Significantly, the two samples with the lowest Fe composition from Wierzbica (labeled as tablica and Level 1 in Table 2) were freshly chipped from the modern quarry wall, while the others were undifferentiated by depth and selected from the Wierzbica 'Zele' archaeological mine. Taken together, these data suggest that we may be able to make finer chemical distinctions within some 'chocolate' flint deposits by separating the samples by geological strata (or at least on the basis of superposition in the deposits). This could be difficult to accomplish at some of the mines, but might be very possible at others (like Krzemionki Opatowskie flint mine, Ostrowiec Świętokrzyski district, see below).

Based on an admittedly small sample, we were not completely successful at discriminating between Jurassic-Cracow flint analyzed from Sąspów, Bębło (Kraków district), Jurassic

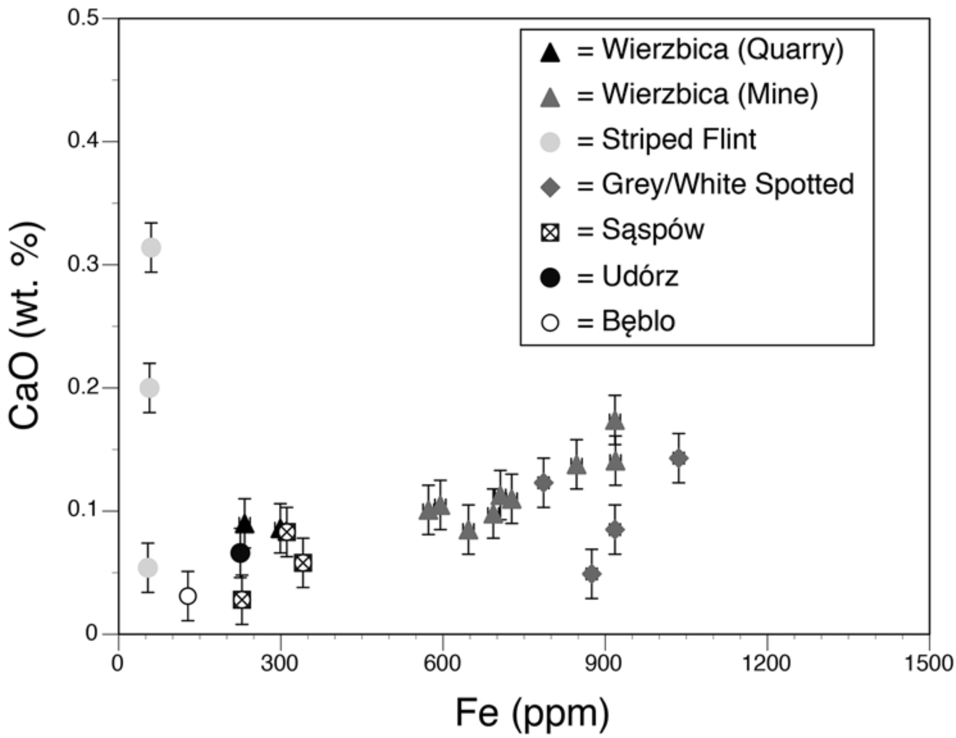

Fig. 3. The composition of Ca vs. Fe in geological samples of 'chocolate' flint compared with Gray-white spotted, Jurassic-Cracow and Striped Flint. Error bars delimit 95% probability estimates for elemental composition. Graphic design: R.E. Hughes.

flint from Udórz (Zawiercie district), and 'chocolate' flint, which several researchers (e.g., Krajcarz and Krajcarz 2009; Krajcarz *et al.*, 2012) have noted is very similar visually to 'chocolate' flint. With the exception of 'chocolate' flint from Tomaszów, Figure 3 does show, however, that overlap in Ca/Fe composition between Jurassic-Cracow and 'chocolate' flints occurs only in the lowest range of Fe compositions. Therefore, with a larger sample, we may be able to eliminate attributing visually similar brown flint artifacts to a Jurassic-Cracow flint 'source' if they contain Fe in concentration ≥ 600 ppm. This remains to be demonstrated, and will require additional analysis to confirm or refute.

Although it wasn't the specific focus of our project, we did collect and analyze flint from other localities for comparative purposes. One of the most dramatic chemical contrasts identified in these comparisons occurs with what has been referred to as Striped Flint, which is best known from occurrences at Krzemionki Opatowskie and Borownia (Ostrowiec Świętokrzyski district; see Fig. 1). This variety of flint is relatively depleted in iron compared with the other flints examined, and it contains no measurable amount of potassium (K). As Fig. 3 shows, Ca/Fe data were not adequate to distinguish between

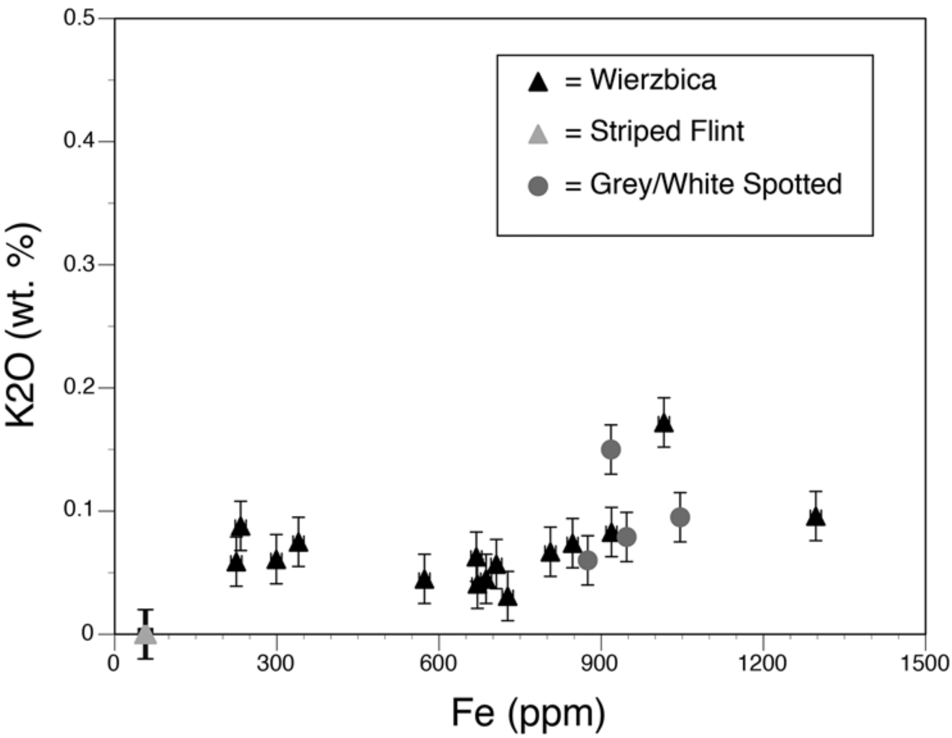

Fig. 4. The composition of K_2O vs. Fe in 'chocolate' flint from Wierzbica quarry and Wierzbica 'Zele' mine compared with geological samples of Gray-white spotted and Striped Flint. Error bars delimit 95% probability estimates for elemental composition. Graphic design: R.E. Hughes.

Gray-White spotted flint and 'chocolate' flint, but K vs. Fe data did effect a separation between them (see Fig. 4). We suspect that the reason for this is that the white spots in spotted flint contain large amounts of calcium, as do some varieties of Scandinavian flint. These spots (calcium-rich domains) are often so close together in gray-white spotted flint that it was rarely possible to direct the x-ray beam to a 'pure' surface, and the result was that these Ca-rich domains inflated the average concentration of Ca. This same inclusion problem exists, at more tractable scale, in flint from Krzemionki Opatowskie, but the Ca/Fe contrast with 'chocolate' flint makes it less of a problem.

More generally, as was the case in previous studies (Hughes *et al.*, 2011, 2012), the present work illustrates some of the advantages and disadvantages of non-destructive EDXRF for the characterization of flint. The advantages are that EDXRF is fast, relatively inexpensive, completely non-destructive, fully quantitative, and sensitive to a large number of elements that occur in flint and other rocks. The disadvantages are that it cannot measure minute concentrations of rare earth elements (like neutron activation [NAA] and inductively coupled plasma mass spectrometry [ICPMS] can) and it isn't as precise for certain elements as NAA and ICPMS. However, NAA and ICPMS are time-consuming, and they both require sacrificing some portion of the sample for analysis, which may not be problematic from a geological standpoint, but it certainly *is* a drawback when analyzing irreplaceable archaeological artifacts.

SUMMARY COMMENTS

As discussed above, one of the goals of the present project was to investigate the degree to which the visual and petrological classifications advanced by Schild (1976, 1987) corresponded with the geochemical data we generated here for a sample of 'chocolate' flint. Based on the major and minor elements we analyzed here, we were unable to distinguish between Schild's groups I and II flint. However, it may be possible to distinguish flints from Wierzbica 'Zele' mine. As discussed previously, we identified a distinction in Fe content between flint analyzed from the Wierzbica ('Zele') *mine* and the Wierzbica *quarry.* Microprobe and petrographic analysis (R. Siuda unpublished data) revealed a large number of small pyrite inclusions inside flint from the Wierzbica ('Zele') *mine*, while flint examined from the Wierzbica quarry contained very few pyrite inclusions. This fact helps explain the lower Fe content in the flint from the Wierzbica quarry and may assist in chemical and macroscopic identification. Based on these findings there may be a correspondence between Schild's (1976) group III flint and the Wierzbica ('Zele') *mine*.

In summary, the major and minor element data generate here were important in providing baseline information for the range of chemical composition within and among different 'chocolate' flint localities in the Świętokrzyskie (Holy Cross) Mountains of central Poland. In addition, based on the data presented here, Ca/Fe contrasts were identified between 'chocolate' flint and striped flint analyzed from Borownia and Wojciechówka (Opatów district; listed as Striped-Flint in Figs. 3 and 4), and K vs. Fe composition data documented a separation between Gray-White spotted flint (Świeciechów flint) and 'chocolate' flint (Fig. 4). Unfortunately based on a small sample of Jurassic-Cracow flint from Sąspów, Udórz, and Bębło we were not completely successful at discriminating between this flint and 'chocolate' flint. However a possible separation in Ca/Fe composition provides a starting point for future investigations (Fig. 3).

We are encouraged that *non-destructive* chemical signatures could be identified among different visual varieties of flint, and reckon that these contrasts should be of utility when applied to archaeological artifacts. Overall, the chemical profiles identified for 'chocolate' and some other flint in Poland flint provide a solid foundation for future research and for refinement of chemical signatures.

REFERENCES

Balcer, B. 1976. Position and stratigraphy of flint deposits, development of exploitation and importance of the świeciechów flint in prehistory. *Acta Archaeologica Carpathica* 16: 179–199.

Bednarz, M. 2001. Acheminementdu silex 'chocolat' pendant le Janisławicien et au Néolithique ancien dans le bassin de la Vistule. In R. Kertész and J. Makkay (eds), *From the Mesolithic to the Neolithic. Proceedings of the International Archaeological Conference held in the Damjanich Museum of Szolnok, September 22–27, 1996*, 23–54. Budapest. Archaeolinqua 11.

Bednarz, M. and Budziszewski, J. 1997. Potential of Detailed Archaeological Surveys of Flint Outcrop Areas. Case Study: Iłża Region (Central Poland). In R. Schild and Z. Sulgostowska (eds.), *Man and Flint. Proceedings of the VIIth International Flint Symposium, Warszawa-Ostrowiec Świętokrzyski, September 1995*, 23–28. Warszawa.

Borkowski, W., Libera, J., Sałacińska, B. and Sałaciński, S. (eds) 2008. *Krzemień czekoladowy w pradziejach. Materiały z konferencji w Orońsku 8–10 X 2003*. Warszawa-Lublin.

Budziszewski, J. 2008. Stan badań nad występowaniem i pradziejową eksploatacją krzemieni czekoladowych. In W. Borkowski, J. Libera, B. Sałacińska and S. Sałaciński (eds.), *Krzemień czekoladowy w pradziejach. Materiały z konferencji w Orońsku 8–10 X 2003*, 33–106. Warszawa-Lublin.

Budziszewski, J., Grużdź, W., Jakubczak, M. and Szubski, M. 2015. Chalcolithic raw material economy in light of new data from the 'Przyjaźń' mining field in Rzeczkowo (Central Poland). In: X. Mangado, O. Crandell, M. Sánchez, and M. Cubero (eds.), *International Symposium on Knappable Materials 'On the Rocks', 7–11 September 2015, Barcelona, Abstracts*, 56. Barcelona.

Chmielewska, M. 1980. PL 5 Polany, Fundstelle II, Wojw. Radom. In G. Weisgerber, R. Slotta and J. Weiner (eds.), *5000 Jahre Feuersteinbergbau. Die Suche nach dem Stahl der Steinzeit*, 583–586. Bochum.

Chmielewska, M. 1988 The Early Bronze Age Flint Mine at Site II, Polany, Radom District. *Przegląd Archeologiczny* 35: 139–181.

Cyrek, K. 1995. On the distribution of chocolate flint in the Late Mesolithic of the Vistula Basin. *Archaeologia Polona* 33: 99–109.

Dadlez, R., Marek, S. and Pokarski, J. (eds) 2000. Mapa geologiczna Polski bez utworów kenozoiku, skala 1: 1 000 000. Warszawa.

Dąbrowska, Z. 1983. Jura okolic Iłży. In *Paleontologia i stratygrafia jury i kredy okolic Iłży. Materiały VII Krajowej Konferencji Paleontologów. Iłża, 7–9 październik 1983*, 32–36. Iłża.

Dembowska, J. 1953. Górna jura między Radomiem i Jastrzębiem. *Biuletyn Instytut Geologicznego 218, Z badań geologicznych regionu świętokrzyskiego* 8: 31–46.

Gutowski, J. 2004. Oolitowy cykl sedymentacyjny wczesnego kimerydu w profilu Wierzbicy koło Radomia. *Volumina Jurassica* 2 (2): 37–48.

Herbich, T. 1993. The variations of shaft fills as the basis of the estimation of flint mine extent: a Wierzbica case study. *Archaeologia Polona* 31: 71–82.

Herbich, T. and Lech, J. 1995. PL 5 Polany II, Radom Province. *Archaeologia Polona* 31: 488–506.

Högberg, A., Hughes, R.E. and Olausson, D. 2013. Comparing Polish and Scandinavian flint using visual and chemical analysis: some preliminary results. *Fornvännen* 108: 257–262.

Hughes, R.E., Baltrūnas, V. and Kulbickas, D. 2011. Comparison of two analytical methods for the chemical characterization of flint from Lithuania and Belarus. *Geologija*, 53 (2): 69–74.

Hughes, R.E., Högberg, A. and Olausson, D. 2012. The chemical composition of some archaeologically significant flint from Denmark and Sweden. *Archaeometry* 54 (5): 779–795.

Imai, N., Terashima, S., Itoh, S. and Ando, A. 1996. 1996 compilation of analytical data on nine GSJ geochemical reference samples, 'sedimentary rock series'. *Geostandards Newsletter* 20: 165–216.

Kaczanowska, M. and Lech, J. 1977. The flint industry of danubian communities north of the Carpathians. *Acta Archaeologica Carpathica* 17: 5–28.

Kozłowski, J.K. 2013. Raw materials procurement in the Late Gravettian of the Carpatian Basin. In Z. Master (ed.), *The Lithic raw materials sources and interregional Human contacts in the Northern Carpathian Regions*, 63–85. Kraków-Budapest.

Krajcarz, M.T. and Krajcarz, M. 2009. The outcrops of Jurassic flint raw materials from south-western margin of the Holy Cross Mountains. *Acta Archaeologica Carpathica* 44: 183–195.

Krajcarz, M.T., Krajcarz, M., Sudoł, M. and Cyrek, K. 2012. From far or from near? Sources of Kraków-Częstochowa banded and chocolate silicate raw material used during the stone age in Biśnik Cave (Southern Poland). *Anthropologie* 50 (4): 411–425.

Krukowski, S. 1920. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski. Wnioski z właściwości surowców i wyrobów. *Wiadomości Archeologiczne* 5: 185–206.

Krukowski, S. 1922. Pierwociny krzemieniarskie górnictwa, transportu i handlu w holocenie Polski, cz. 2. *Wiadomości Archeologiczne* 7 (1): 34–57.

Krukowski, S. 1923. Sprawozdanie z działalności państwowego konserwatora zabytków prehistorycznych na okrąg kielecki w r. 1922. *Wiadomości Archeologiczne* 8: 64–84 .

Kutek, J. 1983. O stratygrafii górnej jury między Iłżą i Śniadkowem. In *Paleontologia i stratygrafia jury i kredy okolic Iłży. Materiały VII Krajowej Konferencji Paleontologów. Iłża, 7–9 październik 1983*, 32–36.

Lech, H. & J. 1984. The Prehistoric Flint Mine at Wierzbica 'Zele': a Case Study from Poland. *World Archaeology* 16 (2): 186–203.

Lech, H. & J. 1995. PL 3 Wierzbica 'Zele', Radom Province. *Archaeologia Polona* 33: 465–480.

Lech, H. & J. 1997. Flint Mining among Bronze Age Communities. A Case Study from Central Poland. In R. Schild and Z. Sulgostowska (eds), *Man and Flint. Proceedings of the VIIth International Flint Symposium, Warszawa – Ostrowiec Świętokrzyski, September 1995*, 91–98. Warszawa.

Lech, J. 1987. Danubian raw material distribution patterns in eastern central Europe. In G. de G. Sieveking and M.H. Newcomer (eds), *The human uses of flint and chert. Proceedings of the IVth International Flint Symposium held at Brighton Polytechnic 10–15 April 1983*, 241–248. Cambridge.

Lech, J. 1990. The organization of siliceous rocks supplies to the Danubian early farming communities (LBK): Central Europe an examples. In D. Cahen and M. Otte (eds), *Rubané et Cardial. Actes du Colloque de Liège, novem bre 1988, Etudes et Recherches Archéologiques de l'Université de Liège*, 51–59. Liège.

Malinowska, L. and Dembowska, J. 1973. Obrzeżenie Gór Świętokrzyskich w górnej jurze. In B. Słowańska and M. Bartyś-Pelc (eds), *Budowa geologiczna Polski t. 1: Stratygrafia, cz. 2 Mezozoik*, 381–389. Warszawa.

Małecka-Kukawka, J. 1997. Flint mining in south-eastern Poland and raw material 'economy' of early farming communities in the Chełmno land. A social exchange theory perspective. In R. Schild and Z. Sulgostowska (eds), *Man and Flint. Proceedings of the VIIth International Flint Symposium, Warszawa – Ostrowiec Świętokrzyski, September 1995*, 243–247. Warszawa.

Migaszewski, Z.M., Galuszka, A., Durakiewicz, T. and Starnawska, E. 2006. Middle Oxfordian –Lower Kimmeridgian chert nodules in the Holy Cross Mountains, south-central Poland. *Sedimentary Geology* 187: 11–28.

Pożaryski, W. 1948. Jura i kreda między Radomiem, Zawichostem i Kraśnikiem. *Biuletyn Państwowego Instytutu Geologicznego* 46: 1–141.

Přichystal, A. 2009. *Kamenné suroviny v pravěku východní části střední Evropy*. Brno.

Přichystal, A. 2013. *Lithic Raw Materials in Prehistoric Times of Eastern Central Europe*. Brno.

Samsonowicz, J. 1923. O złożach krzemieni w utworach jurajskich północno-wschodniego zbocza Gór Świętokrzyskich. *Wiadomości Archeologiczne* 8: 17–24.

Samsonowicz, J. 1934. *Ogólna mapa geologiczna Polski w skali 1:100 000 ark. Opatów*. Warszawa.

Schild, R. 1971. Lokalizacja prahistorycznych punktów eksploatacji krzemienia czekoladowego na północnowschodnim obrzeżeniu Gór Świętokrzyskich. *Folia Quaternaria* 39: 1–61.

Schild, R. 1976. Flint mining and trade in Polish prehistory as seen from the perspective of the chocolate flint of central Poland. A second approach. *Acta Archaeologica Carpathica* 16: 147–177.

Schild, R. 1987. The exploitation of chocolate flint in central Poland. In G. de G. Sieveking and M. H. Newcomer (eds), *The human uses of flint and chert. Proceedings of the IVth International Flint Symposium held at Brighton Polytechnic 10–15 April 1983*, 137–149. Cambridge.

Schild, R. 1995a. PL 2 Tomaszów I, Radom Province. *Archaeologia Polona* 33: 455–465.

Schild, R. 1995b. PL 4 Polany Kolonie II, Radom Province. *Archaeologia Polona* 33: 480–488.

Schild, R. 1997. Digging Open Flint Mines and Quarries. In A. Ramos-Millán and M. A. Bustillo (eds), *Siliceous Rocks and Culture, Monográfica Arte y Arqueologiá 42*, 119–136. Granada.

Schild, R., Królik H. and Marczak M. 1985. *Kopalnia krzemian czekoladowego w Tomaszowie*. Wrocław-Warszawa-Kraków.

Schild, R., Królik, H. and Mościbrodzka, J. 1977. *Kopalnia krzemian czekoladowego z przełomu neolitu i epoki brązu w Polanach Koloniach*. Wrocław-Warszawa-Kraków.

Schild, R., Królik, H. and Tomaszewski, J. 1997. A Raw Material Economy of the Palaeolithic and Mesolithic Occupants of the Rydno Complex. In R. Schild and Z. Sulgostowska (eds), *Man and Flint. Proceedings of the VIIth International Flint Symposium, Warszawa–Ostrowiec Świętokrzyski, September 1995*, 285–293. Warszawa.

Sulgostowska, Z. 1997. The phenomenon of chocolate flint distribution on the north European Plain during the Final Palaeolithic. In R. Schild and Z. Sulgostowska (eds), *Man and Flint. Proceedings of the VIIth International Flint Symposium, Warszawa – Ostrowiec Świętokrzyski, September 1995*, 313–318. Warszawa.

Sulgostowska, Z. 2005. *Kontakty społeczności późnopaleolitycznych i mezolitycznych między Odrą, Dźwiną i górnym Dniestrem. Studium dystrybucji wytworów ze skał krzemionkowych*. Warszawa.

Sulgostowska, Z. 2008. Szczególna pozycja krzemienia czekoladowego wśród społeczności między Odrą, Dźwiną i Dniestrem u schyłku paleolitu i w późnym mezolicie. In W. Borkowski, J. Libera, B. Sałacińska and S. Sałaciński (eds), *Krzemień czekoladowy w pradziejach. Materiały z konferencji w Orońsku 8–10 X 2003*, 151–170. Warszawa-Lublin.

Wyrwicka, K. 1969. Surowce węglanowe malmu Gór Świętokrzyskich – ich zastosowanie i perspektywy. *Kwartalnik Geologiczny* 13 (2): 357–369.

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Reflectance spectroscopy as a chert sourcing method

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The non-destructive application of reflectance spectroscopy within chert provenance studies is evaluated and the implications of archaeological source determination of chert artifacts are discussed. The combined use of Visible Near-infrared (VNIR) and Fourier Transform Infrared (FTIR) reflectance spectroscopy demonstrate the accurate, fast and relatively low cost for the characterization of geological deposits of chert and the potential identification of source for chert archaeological materials. Reflectance spectroscopy gathers data on the trace and minor mineral components within a sample as identified by subtle absorption peaks and slope changes. The variable range of spectral features per sample, per deposit, per geological formation is potentially diagnostic for a geographically isolated deposit of chert. A chert sample database consisting of 2430 samples from the Midwestern and Southeastern United States is utilized to illustrate the accuracy of reflectance spectroscopy at characterizing chert deposits for archaeological use.

KEY-WORDS: reflectance spectroscopy, chert, provenance research, Southeastern United States, Visible Near-infrared (VNIR), Fourier Transform Infrared (FTIR)

INTRODUCTION

Chert Sourcing

The objective of this study is to assess the application of reflectance spectroscopy as a chert provenance technique. The accurate determination of source for raw materials utilized by past peoples provides a proxy for modeling a wide range of human behaviors. The source or provenance of the raw material utilized in the manufacture of the particular artifact allows researchers to study human behavior relating to both group and environmental interactions.

Chert provenance research has produced varied results. However, the significant contribution chert provenance research has in archaeology cannot be overlooked and remains an important mechanism in studying past human behavior.

Current chert provenance research involves many methodologies and techniques (Church 1994). The multitude of chert sourcing techniques can be organized into three main groups, macroscopic attribute analysis, petrographic and geochemical.

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Geochemical techniques such as Neutron Activation Analysis (NAA), Inductively Coupled Plasma Mass Spectroscopy (ICPMS), X-ray Florescence (XRF) are used in recent chert provenance studies with varying degrees of success. In the study region, research conducted by Jack D. Nance (2000) successfully differentiated Lower St. Louis chert samples from Fort Payne (misidentified as Lower St. Louis in the study) using NAA. However, the majority of chert provenance studies in the Southeastern United States are conducted via qualitative visual identification.

Current chert provenance methods are limited by high cost, level of destructiveness, lengthy analysis, data management, reliability and precision (Frahm 2012; Crandell 2006). Arguably, the most critical issue limiting the use of chert provenance data is accuracy; the ability of the technique to identify the 'true' source of the material used to manufacture the artifact in question. Furthermore, a narrow geological and geographic perspective of tool stone availability limits our anthropological applications of chert provenance data.

A successful chert provenance study must characterize all possible sources at a geographic scale which matches the anthropological question and geological resource base. A chert provenance study must also be able to characterize a potential source through large geological sample sets and be able to differentiate the sampled source from other deposits. In addition, a provenance study must characterize the range of variation within an unknown artifact and match it to a particular range of variation at the source location (Harbottle 1982). Therefore, the 'fingerprint' analogy within provenance research is often a misnomer (Luedtke 1979). The current study examines the use of reflectance spectroscopy to gather spectral data within a chert samples database to specifically address the ability of the method in differentiating chert by parent formation, one deposit from another within the same formation, and to differentiate sub-sections within the same deposit.

Reflectance Spectroscopy

Spectroscopy is the study of the interaction of light (electromagnetic radiation) with matter. A spectrometer is an instrument that measures this interaction (Smith 2011). Reflectance spectroscopy encompasses a wide range of techniques that gather electromagnetic data which is reflected or emitted from matter. The reflected electromagnetic radiation contains information related to atomic and chemical functional groups within a compound. The incident radiation in the visible portion of the spectrum (350–750 nm) stimulates vibration of particular atoms whereas dipole bonded molecules are stimulated in the near and middle infrared (751–25,000 nm) regions. Absorption of the incident radiation is wavelength dependent meaning absorption occurs at the wavelength frequencies corresponding to particular vibration energy states of the atom or molecule present. Therefore, the absorption of the incident radiation at certain frequencies gives the researcher information regarding atomic and molecular structure and composition of the material. When graphically portrayed, the reflectance values per wave unit produce a line graph composed of Gaussian and Lorentzian curves (Fig. 1). Slight features and imperceptible slope changes in the chert's spectrum related to micro-mineral impurities are proving to be diagnostic for particular chert bearing formations and deposit locations (Table 1). Both qualitative and quantitative relationships can be studied using various mathematical functions, a subset of analytical chemistry termed chemometrics (Morin 2012).

The diagnostic micro-mineral groups causing particular spectral features may be directly related to the paleodepositional environment of the parent geological formation and the diagenetic processes influencing chert formation. Other researchers, using geochemical data, have speculated that chert diagnesis imparts a variable range of diagnostic characteristics (Foradas 2003; Malyk-Selivanova 1998) but the lengthy and costly analysis of large sample sizes have previously restricted efforts to tease out the geological and geographic relationships on a large scale. A variety of provenance studies are demonstrating the potential application of spectroscopy in archaeology (Beck *et al.*, 1965; Emerson *et al.*, 2013; Hubbard 2006; Morin 2012). The studies specifically related to the one presented here are chert provenance applications of both reflectance and transmission spectroscopy (Long *et al.*, 2001; Hubbard *et al.*, 2005; Hawkin *et al.*, 2008; Parish 2011; Hassler *et al.*, 2013; Parish *et al.*, 2013).

Reflectance spectroscopy as a chert source technique differs from current methodologies in four significant ways; 1) data acquired, 2) speed, 3) level of destruc-

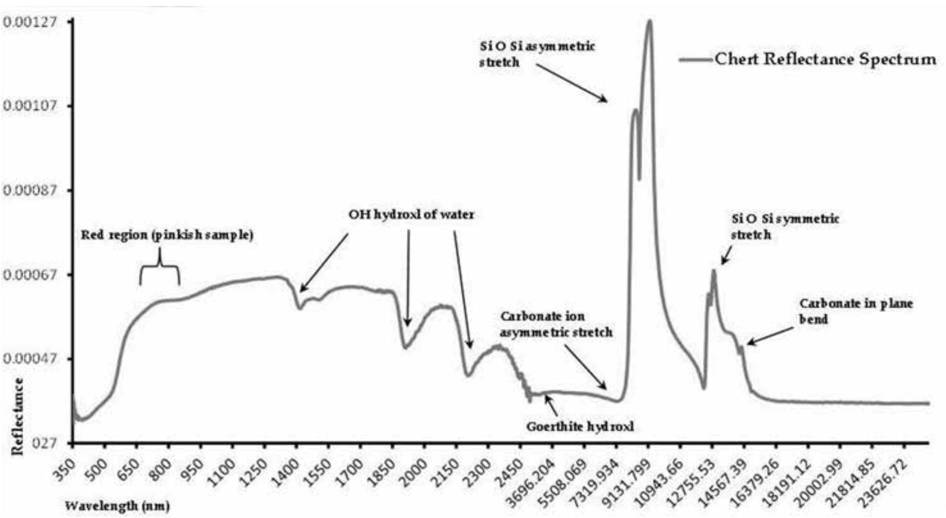

Fig. 1. A typical chert spectrum in the visible near-infrared and middle infrared with some spectral features labeled. The entire spectrum (350 – 15000 nm) is included in the analysis. Graphic design: R.M. Parish.

Table 1. Some diagnostic spectral features noted in both the current study and in preliminary studies (Hassler *et al.*, 2013; Hawkins *et al.*, 2008; Long *et al.*, 2001; Parish 2013).

Spectrometer	Spectral Feature	Reflectance Peak Locations (nm)	Diagnostic Attributes Detected
VNIR	Color regions	350 – 750	Unbound electrons, atomic structure, mineral impurities
	OH, H-O-H, SiOH bonds	1400, 1900, 2200	Silica phase, formation conditions (Rice *et al.* 2013)
	AL-OH, M-OH bonds	2200 – 2300	Kaolinite, Illite, Mont-morillonite, Limonite and other clay minerals
FTIR	AL-OH bonds	2700 – 2770	Kaolinite
	K-AL-SI-OH bonds	2800, 10100	Illite
	Na-Ca-Al-Si-O-OH bonds	2880 – 2980	Montmorillonite
	CH_3 bonds	3500 – 4080	Organic compounds
	Carbonate asymmetric stretch	6050 – 7200	Dolomite and Calcite
	Carbonate asymmetric stretch	5460 – 5500, 6570, 6860 – 6940, 13750	Dolomite
	Carbonate asymmetric stretch	6680, 11300 – 11340, 14070	Calcite
	Na-Ca-Al-Si-O-OH bonds	10730	Smectite
	TI-0 bonds	10030 – 10100, 14130 – 14190	Rutile
	Fe-O-OH bonds	11010 – 11080, 12600	Goethite
	Fe-O-OH . nH_2O bonds	11430	Limonite
	Fe-K hydroxide bonds	12320	Glauconite
	$Fe\text{-}S_2$ bonds	14370 – 14400	Pyrite
	Mn-O hydroxide bonds	14460	Manganite
	Mg oxide bonds	14500 –14550	Brucite
	Fe oxide bonds	14900 – 14940, 17540	Hematite
	Fe oxide bonds	18380–21650	Magnitite

tiveness, and 4) cost. Spectral data exists as arbitrary percent reflectance decimal numbers between 0 and 1 per wave frequency. Each reflectance value is a potentially 'diagnostic' variable relating to an atomic or molecular composition. Therefore, reflectance spectroscopy is not attribute information derived from empirical observations, nor is it purely geochemical data in the form of trace or rare earth element quantities.

METHODS

Experiment design

The application of reflectance spectroscopy to chert provenance research is assessed through three accuracy tests. The accuracy tests are designed to quantify the ability of reflectance spectroscopy in characterizing variation and differentiating ranges of variation both between and within chert bearing formations. The first test examines the accuracy of reflectance spectroscopy in distinguishing chert type, or chert found within different geological formations. The term formation is used in the study to describe geological material containing enough characteristics to distinguish it from adjacent rock. The second test refines the spatial scale of the provenance study through characterization and differentiation of multiple chert deposits within a single geological formation. The third and final test explores intra-deposit variability by differentiating sub-set samples of chert within a single deposit. By conducting internal tests within the chert database of known provenance, the accuracy of source assignment at different levels can be quantified.

Sampling

Arguably the first step in any provenance study is to identify potential sources and assemble a representative database of those sources. An ambitious sampling strategy is adopted for the current study in which 30 samples were selected across the lateral and vertical breadth of each spatially discrete chert deposit. Multiple deposits were sampled per chert bearing geological formation. In two instances 60 total samples were collected from a deposit in separate sub-sections to assess intra-deposit heterogeneity. All deposits sampled were marked using a handheld GPS unit. Additional, field notes and photographs were taken to document the chert deposits. In total 2430 samples from 81 deposits collectively representing seven chert types in the Midwestern and Southeastern United States were analyzed (Fig. 2; Table 2). All samples were derived from Ordovician and Mississippian epoch aged carbonate formations, with chert type sample names reflecting their parent geological formation. The seven chert types investigated were widely used intermittently by prehistoric peoples in the Southeastern United States.

Table 2. Chert deposits analyzed in the study and the results of the three accuracy assessment tests.

Inter-formation accuracy test				
Geologic Formation	*Deposits*	*# of samples*	Base Model misidentified	*10% test set misidentified*
Lower St. Louis (Dover)	6	180	8	2
Fort Payne	47	1410	3	4
Tuscaloosa	4	120	17	2
Upper St. Louis	11	330	2	2
Ste. Genevieve	11	330	4	5
Leipers and Catheys	1	30	1	0
Burlington	1	30	0	0
Total	81	2430	35	15
Intra-formation accuracy test				
Geologic Formation	*Deposit*	*# of samples*	Base Model misidentified	*10% test set misidentified*
Lower St. Louis (Dover)	control	120	0	0
Upper St. Louis	Adams, KY	30	0	0
	Cook 1, TN	30	0	0
	Dot, KY	30	0	0
	DVD, KY	30	0	0
	Port Royal, TN	30	0	0
	St. Louis 1, KY	30	0	0
	St. Louis 2, KY	30	0	0
	St. Louis 3, KY	30	0	0
	St. Louis 4, KY	30	0	0
	St. Louis 5, KY	30	0	0
	WFDC 1, KY	30	0	0
Total	11 deposits	330	0	0
Intra-deposit accuracy test				
Geologic Formation	*Deposit*	*# of samples*	Base Model misidentified	*10% test set misidentified*
Ste. Genevieve	40Pm103a	30	0	1
	40Pm103b	30	0	0
	40Wr48	30	0	0
Total	2 deposits	90	0	1

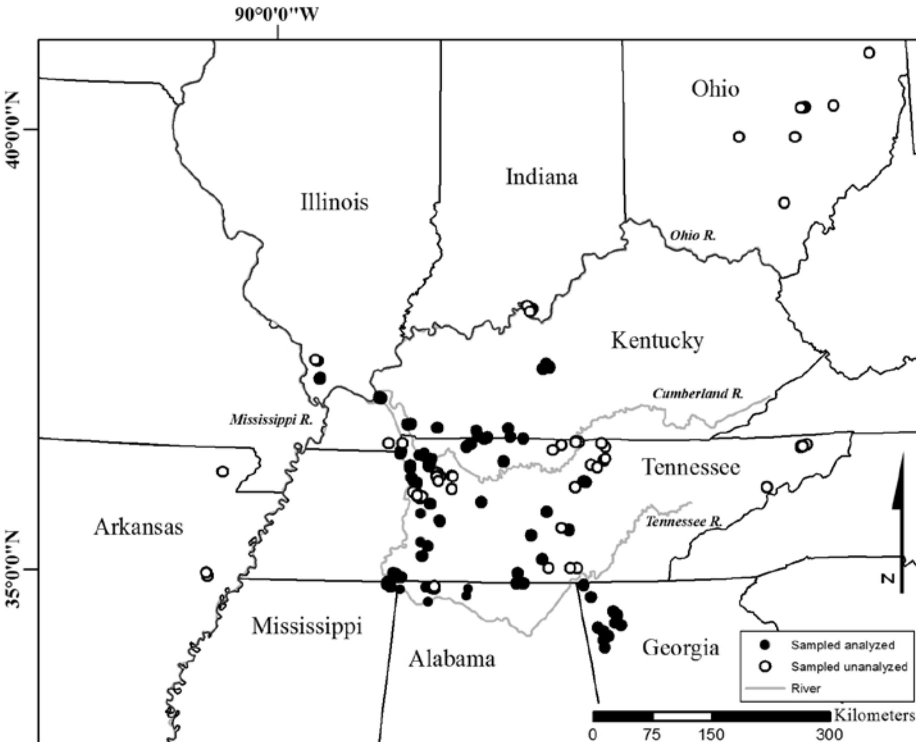

Fig. 2. All chert deposits sampled within the Midwestern and Southeastern United States. Deposits analyzed in the study are solid dots whereas sampled deposits needing analysis are circles. Graphic design: R.M. Parish.

All samples obtained were fractured conchoidally by direct hard hammer percussion using quartzite hammerstones. Six flakes were retained per sample so that the chert type collection can be duplicated six times. Thirty sample bags each containing six flakes collectively represent a single chert deposit. Just prior to analysis, lens tissue was used to lightly wipe the analyzed surface. No other treatments were used in preparing samples for spectral analysis.

Spectral Analysis

VNIR

Two reflectance spectrometers were used in the study. A FieldSpecPro® manufactured by ASD Inc. was used to collect 2150 reflectance values in the visible and near-infrared regions (350 – 2500 nm; Fig. 3). The probe-to-sample surface distance provided an approximate two centimeter diameter field of view upon the sample. The radiation (light) source, a quartz-halogen bulb, was mounted nearby, illuminating the sample tray below

Fig. 3. An ASD Inc. FieldSpec® spectrometer used to obtain spectra in the visible and near-infrared regions. Photo: R.M. Parish.

the detector. The sample was placed under the detector and a spectrum was recorded in less than one second producing a composite spectrum of the area of the specimen. A white reference reading was taken every ten samples to minimize instrument drift and atmospheric interference. All 2430 samples were analyzed in this manner with approximately 100 samples analyzed each hour.

FTIR

A Bio-Rad FTS 40 spectrometer collected spectra in the middle infrared region (2500 – 25,000 nm; Fig. 4). The device was given time to initialize and a background measurement was taken on a gold standard to calibrate and to minimize atmospheric interference. Spectral resolution of the device is 12 nm, and a total of 64 scans taking just over one minute per analysis provided good signal to noise ratio. Samples were placed under the spectrometer's optical scope and a spot 20 microns in diameter was drawn in to focus prior to rotating the IR detector into place.Three measurements in different locations were taken on each sample and later averaged to provide a more representative spectrum per sample. Ten samples were analyzed in just under an hour. A total of 1867 reflectance values collectively represent a single spectrum in the middle infrared region.

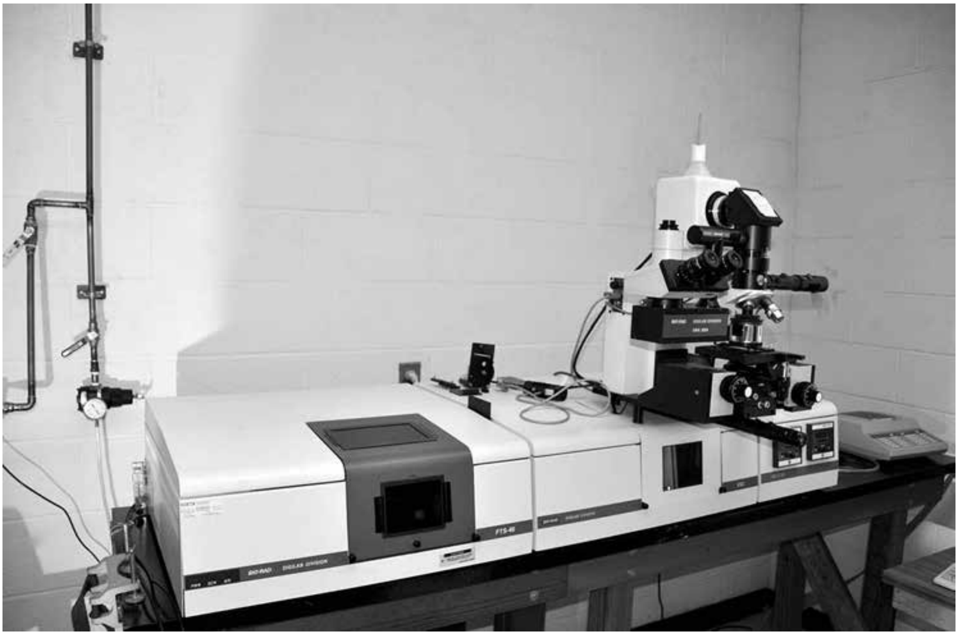

Fig. 4. A BioRad FTS-40 FTIR spectrometer used to obtain spectra in the middle infrared region. Photo: R.M. Parish.

SPECTRAL PROCESSING

All of the raw spectral data were processed using conventional techniques to eliminate or reduce atmospheric interference, instrument noise, sample surface roughness, probe angular effects, and to standardize measurements for comparison. In addition to spectral processing, the reflectance spectra were converted to absorbance and first derivative transformed. Both absorbance and first derivative transforms provide a more robust means for quantitative analysis as well as highlight subtle spectral slope changes. A more detailed discussion regarding spectral processing may be found in Parish (2013: 176–178). The final stage in spectral processing was the combining of the VNIR dataset to the FTIR dataset. Each chert sample's composite spectrum consists of 4017 reflectance values.

Statistical Analysis

A stepwise canonical discriminant function analysis was conducted on the VNIR and FTIR spectral datasets. The potentially diagnostic regions in the VNIR data include most of the visible and a portion of the near-infrared sections. Most of the middle-infrared diagnostic variables used in the study were selected from the 2600 to 7500 nm region; however, additional portions of the middle-infrared signal were also identified as diagnostic regions (Table 1). The discriminant function analysis evaluates each wavelength variable and enters or removes it from the model. Additionally, the groups were weighted to account for differences in group size. Visual identification of 'diagnostic' spectral features by stacking spectra proved an inadequate methodology as spectral variability prohibited direct presence vs. absence comparisons. Multivariate statistical analysis was necessary to characterize patterns and bracket variation.

RESULTS AND DISCUSSION

In the first experiment, all 2430 chert samples were grouped according to parent geological formation assessing inter-formation provenance. The second experiment focused on differentiating 11 chert deposits within the Upper St. Louis Formation sampled over a 400 km lateral extent. The third and final experiment examined the spectral differences within a single deposit of Ste. Genevieve chert as samples of prehistoric debitage were obtained in two sectors within a prehistoric procurement site. In each experiment a base discriminant function model was generated with all samples having known provenience followed by a second model where a random ten percent of the samples were treated as having unknown provenience by removal of their grouping variable.

Characterizing chert by formation (inter-formation)

The accuracy assessment by parent geological formation (type) returned 2395 correct source assignments out of 2430 (99% correct classification). A total of 35 samples were misclassified to other geological formations. Upon removal of a randomly selected ten percent sample (n = 243), the discriminant function model was run a second time with a reduced training set of samples. A total of 228 (94% correct classification) unknown samples were correctly assigned to their subsequent geological formations. Fifteen samples were misclassified to geological formations other than their correct provenience (Fig. 5a; Table 2).

Characterizing chert by deposit (intra-formation)

The accuracy of intra-formation chert provenance was assessed in the Upper St. Louis Formation among 330 Upper St. Louis chert samples from eleven individual deposits. Lower St. Louis 'Dover' chert samples (n=180 from 6 deposits) were included as a control. The base model successfully classified all 330 samples (100% correct classification) into their source deposits. A 10 percent (n = 33) random sample of specimens had their grouping variable removed, and the discriminant function model was rerun. All 33 unknown samples (100% correct classification) were correctly assigned to their spatially discrete source depositswithin the Upper St. Louis formation (Fig. 5b; Table 2).

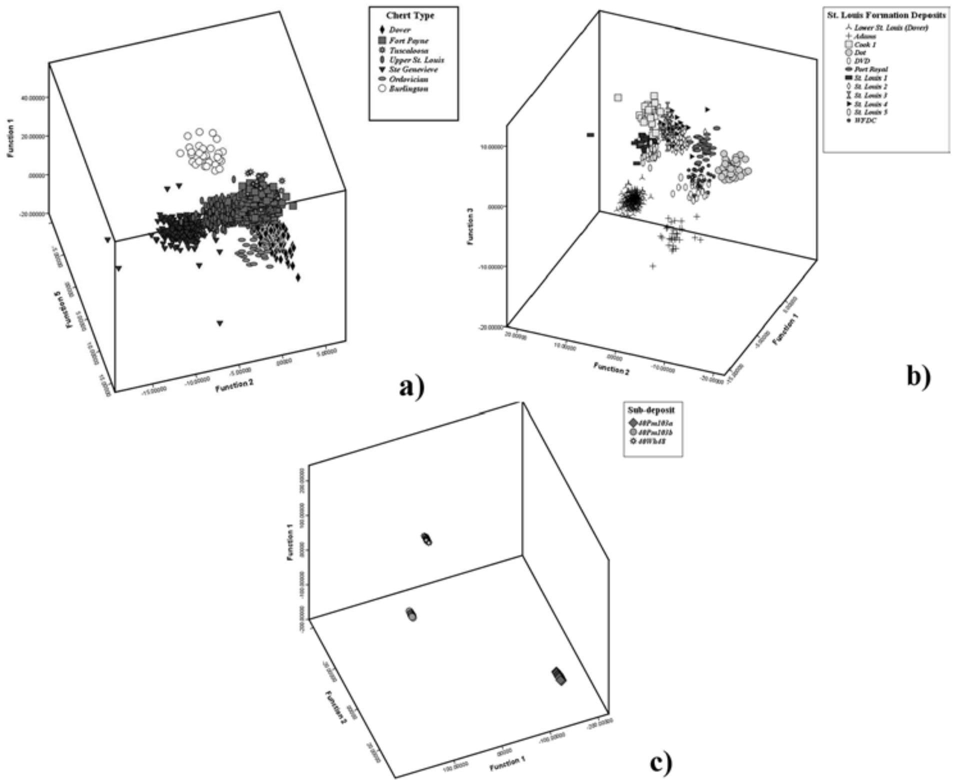

Fig. 5. Discriminant function analysis scatter plot showing;(a) delineation of chert by type/parent geological formation, (b) by deposit within the Upper St. Louis Formation, and (c) by sub-section within prehistoric procurement site 40Pm103. Graphic design: R.M. Parish.

Characterizing chert within a deposit (intra-deposit)

Prehistoric site 40Pm103 is a recorded quarry site of unknown cultural affiliation located in Putnam County, Tennessee[1]. Initially, 30 samples of primary chert debitage were collected from the northern section of the site followed by a collection of 30 samples of chert primary debitage from the southern section at a later date. The two groups of samples were treated as sub-samples within the single deposit of Ste. Genevieve chert and run in the discriminant function model. A third sample group of Ste. Genevieve chert from a prehistoric quarry further to the south (40Wr48) was included in the analysis as a control. The resulting intra-deposit assessment of the

[1] The Smithsonian Institution trinomial site system is used to here representing the one hundred and third (103) site recorded in Putnam County (Pm) in the state of Tennessee (40). The reporting protocol adopted by the Smithsonian lists the U.S. state first (in numerical alphabetical order), followed by county (usually a two or three letter abbreviation), followed by the sequential site number.

base discriminant function model correctly classified all 90 samples (100% correct classification). A randomly selected 10% sample (n = six) from the 60 obtained from the 40Pm103 deposit were treated as having unknown provenience. The discriminant function model correctly identified the sub-deposit source of five of the six samples (83% correct classification). The single misclassification identified the unknown sample as being from the control group location (Fig. 5c; Table 2).

CONCLUSIONS

Chert source is often assigned through the identification of macroscopic attributes often failing to quantify the range of variability between chert deposits with large associated error rates (Calogero 1991, 1992). The aid of type collections as a methodology is potentially limiting because the few samples representing a specific type of chert may constrain the analyst's ability to adequately characterize variation. Additionally, type collections typically limit identification of the chert artifact to relatively few locations on the landscape and it is quite probable that the inability of previous studies to distinguish among and between source relates to small unrepresentative sample sizes (Parish 2013: 214). A sampling strategy which assembles a large range of materials is necessary but unmanageable as a type collection.

The use of analytical techniques such as geochemical methods is restricted by the cost of analysis and the level of destructiveness. The results of the current study demonstrate that reflectance spectroscopy's application within chert provenance research is a viable methodology. The spectral variance within a deposit of chert due to the atomic structural arrangement and composition of molecular compounds is patterned. The results of the accuracy assessment tests demonstrate the ability of reflectance spectroscopy to correctly assign source greater than 90% of the time by formation and deposit and above 80% of the time by sub-deposit (Table 2).

The analysis of 2430 samples from seven geological formations and 81 deposits illustrates the reflectance spectroscopy's ability to identify a range of diagnostic spectral variables, speed of analysis, and low cost. Currently, another 2040 samples obtained from 68 deposits await analysis (Figure 2). The analysis of the entire chert database using conventional geochemical techniques (NAA, ICP-MS) would exceed most research budgets, take multiple years of analysis, and may still not adequately differentiate chert even by geological parent formation due to the heterogeneity of trace elements.

The positive attributes of reflectance spectroscopy promotes the construction of large representative databases of chert resources necessary to bracket variability at various scales of resolution. Additionally, the non-destructive application of reflectance spectroscopy is vital from a preservationist perspective. Future research will focus on controlled experiments of patinated archaeological materials and expand preliminary studies regarding heat treatment and outer surface weathering effects (Parish 2013). Much of the spectral variance due to surface roughness and outer surface weathering is alleviated through spectral processing which standardizes the spectra for comparison. Preliminary studies on heat treatment demonstrate the oxidization of iron minerals mainly occurs beyond the detectors limits (>15000 nm). However, more controlled experiments are designed to test outer surface weathering and heat treatment potential effects upon spectral source accuracy.

The prehistoric use of chert as tool-stone material across broad regional and temporal spans makes the application of chert source programs of paramount interest. The range of human behavioral questions addressed through chert source research illustrates the need for reliable methods. The capability of reflectance spectroscopy to accurately assign chert source is illustrated by the study and has the potential to track the movement and interaction of prehistoric people via their consumption of tool-stone resources.

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REFERENCES

Beck, C.W., Wilbur, E., Meret, S., Kossove, D. and Kermani, K. 1965. The Infrared Spectra of Amber and the Identification of Baltic Amber. *Archaeometry* 8: 96–109.

Calogero, B.L.A. 1991. Macroscopic and Petrographic Identification of the Rock Types Used for Stone Tools in Central Connecticut. Unpublished Ph.D. dissertation, Department of Anthropology, University of Connecticut.

Calogero, B.L.A. 1992. Lithic Misidentification. *Man in the Northeast* 43: 87–90.

Church, T. 1994. *Lithic Resources Studies: A Sourcebook for Archaeologists.* Tulsa. Special Publication No. 3. Lithic Technology. Department of Anthropology, University of Tulsa.

Crandell, O. 2006. Macroscopic and Microscopic Analysis of Chert. A Proposal for Standardization of Methodology and Terminology. *Buletinul Cercurilor Stiintifice Studentesti* 12: 7–30.

Emerson, T.E., Farnsworth, K.B., Wisseman, S.U. and Hughes, R.E. 2013. The Allure of the Exotic: Reexamining the Use of Local and Distant Pipestone Quarries in Ohio Hopewell Pipe Caches. *American Antiquity* 78: 48–67.

Foradas, J.G. 2003. Chemical Sourcing of Hopewell Bladelets: Implications for Building a Chert Database for Ohio. In P.N. Kardulias and R.W. Yerkes (eds), *Written in Stone: The Multiple Dimensions of Lithic Analysis*, 87–112. Lanham, Lexington Books.

Frahm, E. 2012. Evaluation of Archaeological Sourcing Techniques: Reconsidering and Re-deriving Hughes' Four-Fold Assessment Scheme. *Geoarchaeology: An International Journal* 27: 166–174.

Harbottle, G. 1982 Chemical Characterization in Archaeology. In J.E. Ericson and T.K. Earle (eds), *Contexts for Prehistoric Exchange*, 13–51. New York, Academic Press.

Hassler, E., Swihart, G.H., Dye, D.H. and Sing Li,Y. 2013. Non-Destructive Provenance Study of Chert Using Infrared Reflectance Microscpectroscopy. *Journal of Archaeological Science* 40: 2001–2006.

Hawkins, A.L., Tourigny, E., Long, D.G.F., Julig, P.J. and Bursey, J. 2008. Fourier Transform Infrared Spectroscopy of Geological and Archaeological Chert from Southern Ontario. *North American Archaeologist* 29: 203–224.

Hubbard, M.J. 2006. *Soapstone Vessels in the Ohio River Valley and Determining their Source of Origin Using Visible/Near-infrared Reflectance Spectrometry*. Unpublished Master's Thesis, Department of Anthropology, Kent State University, Kent.

Hubbard, M.J., Waugh, D.A. and Ortiz, J.D. 2005. Provenance Determination of Archaeological Cherts by VIS/NIR Diffuse Reflectance Spectrometry. *The Compass* 78: 119–129.

Long, D.F., Silveria, B. and Julig, P. 2001. *Chert Analysis by Infrared Spectroscopy. A collection of papers presented at the 33rd annual meeting of the Canadian Archaeological Association*. Ontario, Ontario Archaeological Society.

Luedtke, B.E. 1979. The Identification of Sources of Chert Artifacts. *American Antiquity* 44: 744–756.

Malyk-Selivanova, N. 1998. Geological-Geochemical Approach to 'Sourcing' of Prehistoric Chert Artifacts, Northwestern Alaska. *Geoarchaeology* 13: 673–708.

Morin, J. 2012. *The Political Economy of stone Celt Exchange in Pre-contact British Columbia: The Salish Nephrite/Jade Industry*. Unpublished Ph.D. dissertation, Department of Anthropology, The University of British Columbia, Vancouver.

Nance, J.D. 2000. Elemental Composition Studies of Lithic Materials from Western Kentucky. *Midcontinent Journal of Archaeology* 26: 83–100.

Parish, R.M. 2011. The Application of Visible/Near-Infrared Reflectance (VNIR) Spectroscopy to Chert: A Case Study from the Dover Quarry Sites, Tennessee. *Geoarchaeology: An International Journal* 26: 420–439.

Parish, R.M. 2013. *The Application of Reflectance Spectroscopy to Chert Provenance of Mississippian Symbolic Weaponry*.Unpublished Ph.D. dissertation, Department of Earth Sciences, University of Memphis, Memphis.

Parish, R.M., Swihart, G.H. and Sing Li,Y. 2013. Evaluating Fourier Transform Infrared Spectroscopy as a Non-destructive Chert Sourcing Technique. *Geoarchaeology: An International Journal* 28: 289–307.

Smith, B.C. 2011. *Fundamentals of Fourier Transform Infrared Spectroscopy*. New York, CRC Press.

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Palaeolithic heat treating in Northeastern Hungary?: An archaeometric examination of the possible use of fire-setting in Stone Age quarries in the Bükk area

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During the excavations conducted by Árpád Ringer in the Palaeolithic quarries of Avas-Tűzköves in Miskolc, located at the eastern foot of the Bükk Mountains, signs of thermal alteration were observed on many of the finds. Within the scope of my PhD thesis, laboratory testing was carried out on those artefacts, with the support of experts from the University of Miskolc Department of Mineralogy and Petrology, including samples procured from other significant Stone Age sites of the area and results from experimental archaeology. On the basis of results achieved so far, the Palaeolithic use of fire-setting to extract lithic raw material in our region cannot be excluded.

KEY-WORDS: Bükk region, Stone Age, fire-setting, archaeometrical analysis

During the excavations conducted by Árpád Ringer (2011) in the Palaeolithic quarries of Avas-Tűzköves in Miskolc, located at the eastern foot of the Bükk Mountains, signs of thermal alteration were observed on many of the finds. These apparent thermal alterations led Ringer to hypothesize that prehistoric miners quarried the benches of limnic origin (in fact, postvolcanic siliceous rock, i.e. – limnosilicite) not only by using large hammerstones, but employing another technique. After clearing the limnosilicite benches, the quarrymen applied a thin layer of sand, then set extensive fire on this surface fed with fresh bones. The heat exploded the thick upper cortex of the rock, breaking it up into small pieces, and, at the same time, heat-treating the good quality Avas limnosilicite (Ringer and Szakáll 2005: 28). This method is basically similar to the fire-setting flint extracting technique employed in many places in the world (e. g. Norway, Australia), in which pieces of sizes easy to handle were split from bigger blocks of raw material by using small, controlled fire (Akerman 2006: 326; Storemyr 2013). Árpád Ringer presented several Palaeolithic artefacts made of Avas limnosilicite that he believed probably had been quarried by using the fire-setting method. To sup-

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port his hypothesis, the results of the short experiment conducted under laboratory conditions was published (Ringer and Szakáll 2005: 27, 30) but the conclusions met with scepticism in Hungarian academic circles although – sadly – written responses to the brief and generalized descriptions of the results have not been published.

During the course of my PhD thesis research I examined the available finds from the excavations carried out on the Avas hill in 1928–1935, 1961, 2001 and 2002 (Ringer 2011: 7, 8, 9). The lithic assemblage from the last excavations conducted contains a relatively high proportion (4,5%) of pieces showing macroscopic signs of thermal alteration, and many of them were subjected to infrared (IR) spectroscopic analysis at the University of Miskolc, Department of Mineralogy and Petrology. We used the following reference samples:

- 3 samples of cortical Avas limnosilicite with probable traces of thermal alteration from the excavations of 2001;
- 2 samples of the same rock type from the Szeleta-cave with probable signs of thermal alteration;
- 1 piece of Avas-type rock from the archaeological site of Méhész-tető, in Sajóbábony with probable traces of heat alteration;
- 87 samples from the debitage excavated in 2002 on Avas-Tűzköves were heat-treated in the laboratory in 2014. The Avas-type limnic silicite, called Avas

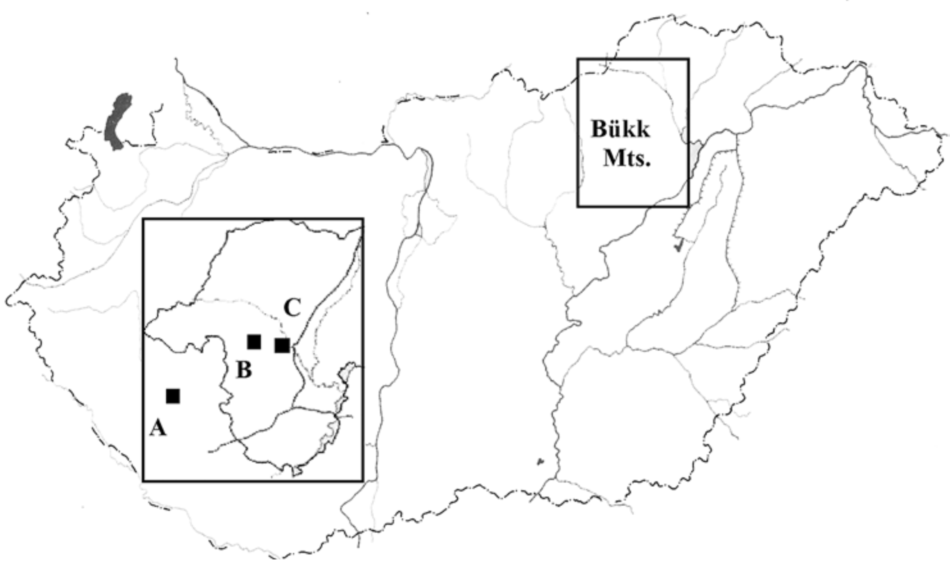

Fig. 1. Prehistoric stone quarries in the Bükk Mountains region. A. Egerbakta, Eger district (silicified tuffite); B. Bükkszentkereszt, Miskolc district (metarhyolite); C. Miskolc, Avas-Tűzköves, Miskolc district (Avas-type limnosilicite). Graphic design: Henrik Zoltán Tóth.

Flint – 'avasi kova' – in the Hungarian language, was divided into three groups by colour and exposed to heat (260°C and 360°C) in an annealing furnace.

– Geological samples collected on the Tűzköves site were also subjects of simulation experiments controlled by measuring instruments by different methods. Nine pieces from our experiments were also placed among the reference samples.

Effects of heat-treatment on the Avas rock were compared to other lithic types present in the same region. Principal among them is the silicified tuffite from Egerbakta, macroscopically very similar to certain variants of quartzite known from the Czech Republic and Germany. Though the number of artefacts made of this material is relatively low (Fig. 1), the beginning of its use is dated to the end of the Eemian interglacial (layers 1–3 of Subalyuk Cave), and the rock was still popular during the Middle Bronze Age (Mester 1989: 24; Fischl *et al.*, 2015: 360). Pieces discoloured possibly by elevated temperature are found in many places of the outcrop, where blocks with huge concave depressions (fracture negatives of pieces broken up by fire) also are observed (Fig. 2). Since this raw material was in use up to the end of the Prehistoric Age, the fire-setting extraction technique possibly employed here cannot be dated accurately. In our studies pieces from Egerbakta were heat treated both in simulation experiments and under laboratory conditions.

The other studied raw material is the glassy quartz-porphyry, felsitic porphyry, or, according to the modern terminology, metarhyolite. This rock was one of the most popular lithic raw materials in the Palaeolithic in Hungary (Szolyák 2011: 62–66), and so common on the archaeological sites of the Avas-hill that it was thought it might have been quarried on the spot. The best candidate for an exploitation site of metarhyolite was identified in 2012 (Tóth *et al.*, in press). In an area covering more than 40 acres large cores and pieces with reddened edges occured in great numbers, but only a dozen pieces

Fig. 2. Silicified tuffite block with huge concave depressions, Egerbakta, Eger district. Photo: Henrik Zoltán Tóth.

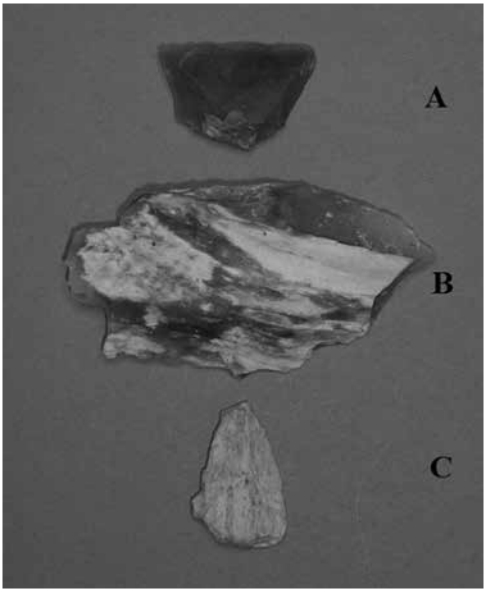

Fig. 3. Metarhyolite samlpes; A. Raw, grey flake; B. Raw, grey flake with partially patinated surface; C. Burned terminal end of a metarhyolite blade, Bükkszentkereszt, Miskolc district. Photo: Henrik Zoltán Tóth.

with dull, white colour have been found so far (Fig. 3). Macroscopically similar pieces also were reported from the Middle Palaeolithic site of Vanyarc, Pásztó district (Markó 2008–2009: 184–187). These artefacts are clearly not patinated but considered as traces of thermal impact. Importantly, metarhyolite, similarly to the tuffite of Egerbakta, reacts very slowly to elevated temperatures. During the simulation experiments using measuring instruments, only the samples that were heated over 600°C turned white (Tóth 2011: 12). Source collected samples heat-treated under laboratory conditions were also subjected to archaeometrical examination.

The heat release rate of bonfires fed with bone, wood or dried dung (Tóth *et al.*, in press) were compared to show the thermal effects on lithic samples placed next and underneath the fires.

CHARACTERISTICS OF THE AVAS LIMNOSILICITE

Due to its higher water content, the Avas rock made up of microcristalline quartz and moganite (Hartai and Szakáll 2005: 20) reacts more dramatically to heat than tuffite or metarhyolite. It is possible that Avas-type limnosilicite, heated over 360°C, explodes into pieces (Tóth and Kristály unp.ms.). That is the main reason, in my view, why the extensive fire setting method reconstucted by Rigner might not have been applied. Furthermore, there are a number of things that make it difficult to draw distinctions between heat-treated and untreated pieces:

- Unlike other rock types, it takes a long time for the Avas limnosilicite of brown colour variation to turn red (in mineralogical terms, for goethit to transform to hematite);
- the greasy luster of the layers underlying the cortex of the raw Avas rock is identical to that observed on the surface of the fractured stone altered by heat;
- microfractures typical of heat-treated pieces can also be found in the raw material without heating (perhaps the result of freezing);
- natural reddish discoloration occasionally occur under the cortex of the rock, as well as burgundy discoloration can be seen along the micro-fractures;
- it is virtually impossible to determine the origins of the signs of thermal alteration (e. g. pot lid fractures, micro-fractures – Schmidt *et al.*, 2012)

RESULTS OF ARCHAEOMETRIC ANALYSIS OF THE AVAS-TYPE RAW MATERIAL

Based on our earlier studies (Tóth and Kristály unp. ms.) scanning electron microscope (SEM), X-ray diffraction analyses and thermoanalytical techniques did not give satisfactory answers to the questions if the samples had ever been subjected to heat and how

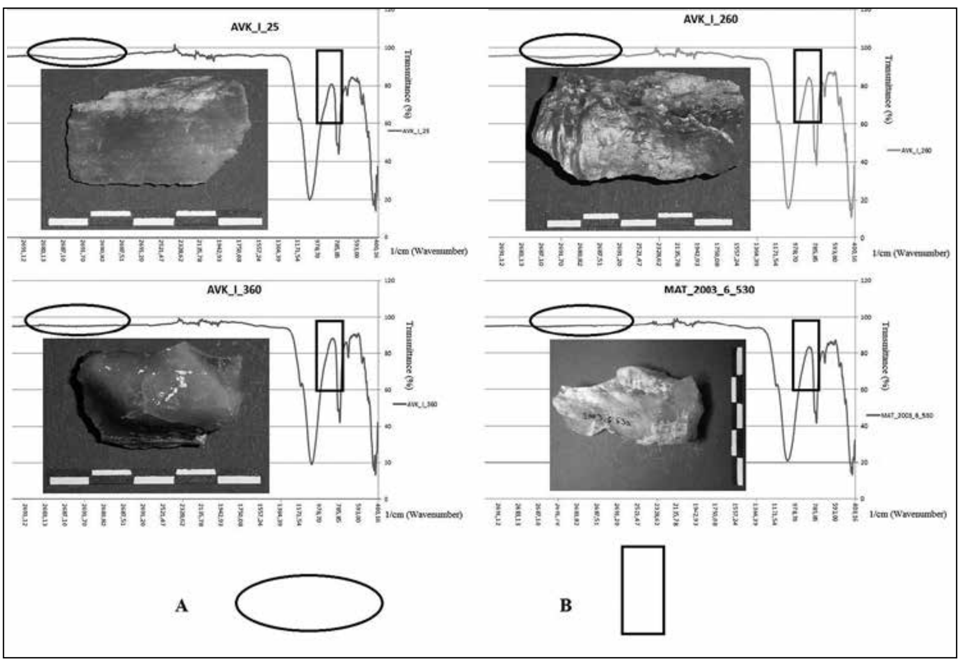

Fig. 4. IR spectroscopy diagrams: A. The decreasing of water content in the Avas-type limnosilicite (Typ 1.) samples; B. Recrystallization of the amorph SiO_2. Graphic design: Henrik Zoltán Tóth.

high had been the temperatures transmitted to them. Contrarily three discrete variants of Avas limnosilicite could have been distingushed by applying SEM and thermoanalytical methods (MOM Derivatograph). Sharing the view of colleagues studying the same area (Schmidt *et al.*, 2012), I am also of the opinion that those methods are unsuitable for analysing thermal effects on silicified rock. The application of infrared (IR) spectroscopic imaging, on the other hand, following the investigations of Schmidt *et al.*, (2011, 2012), yielded satisfactory results. Using this latter method, we could distinguish several pieces with greasy luster from the assemblage of the 2002 excavations at Avas-Tűzköves, which might have been made after being subjected to thermal alteration; for example, the broken blade of transparent material (Inventory number in the Herman Ottó Museum, Miskolc: 2003. 6. 530.) and three reference pieces – untreatened, heated 1 (260°C) and heated 2 (360°C), from the same type of Avas limnosilicite (Fig. 4; Tóth unp. ms.).

CONCLUSIONS: REASON FOR USING FIRE-SETTING

To support the hypothesis of heat treatment and to interpret the results of IR spectroscopy investigation it is important to ask: Why should Stone Age people have used fire-setting to extract stone in the Bükk region? The notion of producing more suitable raw material for toolmaking by using the method seems very unlikely, since hardly any palaeoliths have been found in the area made of heat-treated lithic raw material. It seems more reasonable to believe that, by creating high shear stress using small, controlled fires, the aim of prehistoric flint extractors was to crack bigger blocks of raw material and - in case of Avas-Tűzköves - limnosilicite benches, without using hammerstones that would have possibly pulverised the stone. This could have happened when they ran out of smaller pieces in the quarries, due to the increased need for raw material. On the basis of our results achieved so far, the palaeolithic use of fire-setting to extract lithic raw material in our region cannot be excluded.

REFERENCES

Akerman, K. 2006. High tech–low tech: lithic technology in the Kimberley Region of Western Australia. In J. Apel and K. Knuttson (eds), *Skilled production and social reproduction –aspects of traditional stone-tool technologies proceedings of a symposium in Uppsala, August 20–24, 2003 SAU Stone Studies 2,* 323–346. Uppsala

Fischl, P.K., Kienlin, T.L., Pusztai, T., Brückner, H., Klumpp, S., Tugya, B. and Lengyel, Gy. 2015. Tard-Tatárdomb: An Update on the Intensive Survey Work on the Multi-Layer Hatvan and Füzesabony Period Settlement. In: T.L. Kienlin, P. Valde-Nowak, M. Korcyńska, K. Cappenberg and J. Ociepka (eds), *Settlement, communication and exchange around the Western Carpathians*, 341–379. Cologne.

Hartai, É. and Szakáll, S. 2005. Geological and mineralogical background of the Palaeolithic Chert mining on the Avas Hill, Miskolc, Hungary. *Prehistoria* 6 : 15–21.

Markó, A. 2008–2009. Raw material use at the Middle Palaeolithic site of Vanyarc (northern Hungary). *Prehistoria* 9–10: 183–194.

Mester, Zs., 1989. The revision of the Middle-Palaeolithic industries of the Suba-lyuk Cave (A Subalyuk-barlang középső paleolitikus iparainak újraértékelése). *Folia Archaeologica* 40: 99–106.

Ringer, Á. and Szakáll, S. 2005. Palaeolithic stone raw material mining and processing on the Avas Hill of Miskolc. *Prehistoria* 6: 23–31.

Ringer, Á. 2011. Paleolithic chert mines on the Avas Hill in Bükk Mountains, North-East Hungary. *D'Université Valahia Targoviste* 13 (2): 7–11.

Schmidt, P., Badau, A. and Fröhlich, F. 2011. Detailed FT near-infrared study of the behaviour of water and hydroxyl in sedimentary length-fast chalcedony, SiO_2, upon heat treatmen. *Spectrochimica Acta Part A* (81): 552–559.

Schmidt, P., Masse, S., Laurent, G., Slodczyk, A., Le Bourhis, E., Perrenoud, C., Livage, J. and Frölich, F. 2012. Crystallographic and structural transformations of sedimentary chalcedony in flint upon heat treatment. *Journal of Archaeological Science* 39 (1): 135–144.

Szolyák, P. 2011. Primary processing of the raw material inthe site of the Szeletian Quartz-porphyry (Bükkszentlászló, Hungary). *A Herman Ottó Múzeum Évkönyve* 50: 47–66.

Storemyr, P. 2013. Burning rock: fire setting at the Stone Age Melsvik chert quarries. Electronic document, http://www.pasthorizonspr.com/index.php/archives/11/2013/burning-rock-fire-setting-stone-age-melsvik-chert-quarries

Tóth, Z.H. 2011. Heat-treatment experiment on the limnic-quartzite Raw Material of Rátka-Hercegköves. *Archeometriai Műhely* 8(3): 9–13.

Tóth, Z.H. 2015. Comparative heat-treating Experiments on Avas-Limnosilicite. Unpublished manuscript.

Tóth, Z.H., Németh, N. and Ringer, Á. 2015. Neuer Beitrag zum Vorkommen des Seletien Quartzporphyr in Bükkszentlászló und Bükkszentkereszt**.** Prehistoria. In press.

Tóth, Z.H. and Kristály, F. 2015. Laboratory comparative heat-treating experiments on Avas-type stone material. Unpublished manuscript.

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Archaeometric study of some functional tools from the Sąspów and Wierzbica 'Zele' flint mines sites

Jolanta Małecka-Kukawka[a], Grażyna Szczepańska[b], Marta Rauchfleisz[b] and Łukasz Kowalski[a]

In the present work, an archaeometric approach was used to investigate a sample of the functional tools collected from the Sąspów, Cracow district, and Wierzbica 'Zele', Radom district, flint mines sites. The investigated collection was completed on four non-use-worn specimens. The presence of areas enriched in iron (Fe) compounds has been noticed on the surfaces of all the specimens. They were analyzed by optical microscopy (OM) and scanning electron microscopy (SEM) coupled with an energy dispersive X-ray analysis system (EDS). Data sets were statistically evaluated using similarity analysis (DA, CA, MDS). The results indicated the variables that best discriminate the investigated flint artifacts collection in terms of either anthropoghenic or non-anthropoghenic nature of the residues preserved on their surfaces.

KEY-WORDS: use-wear analysis, residue analysis, SEM-EDS, archaeometry, flint mining

MATERIALS

The collection investigated here consist of two functional tools from the Sąspów, Cracow district (Dzieduszycka-Machnikowa and Lech 1976) and Wierzbica 'Zele', Radom district (Lech 1995: 465–480) flint mine sites and, for controlled comparison, four other non-use-worn specimens (Tab. 1 and Fig. 1). The presence of maroon-colored stains is clearly noticeable on the working edges and surfaces of all the specimens (Fig. 2). In our preliminary opinion, there is likely to be a correlation between the stains and the iron (Fe) enriched compounds. Since such areas are present on the working edges of functional tools (K_1 and K_2) only, it provides us a basis to consider them in terms of residues; defined here as non-parent materials adhered to or incorporated on the surface of a tool (Evans and Donahue 2005: 1734).

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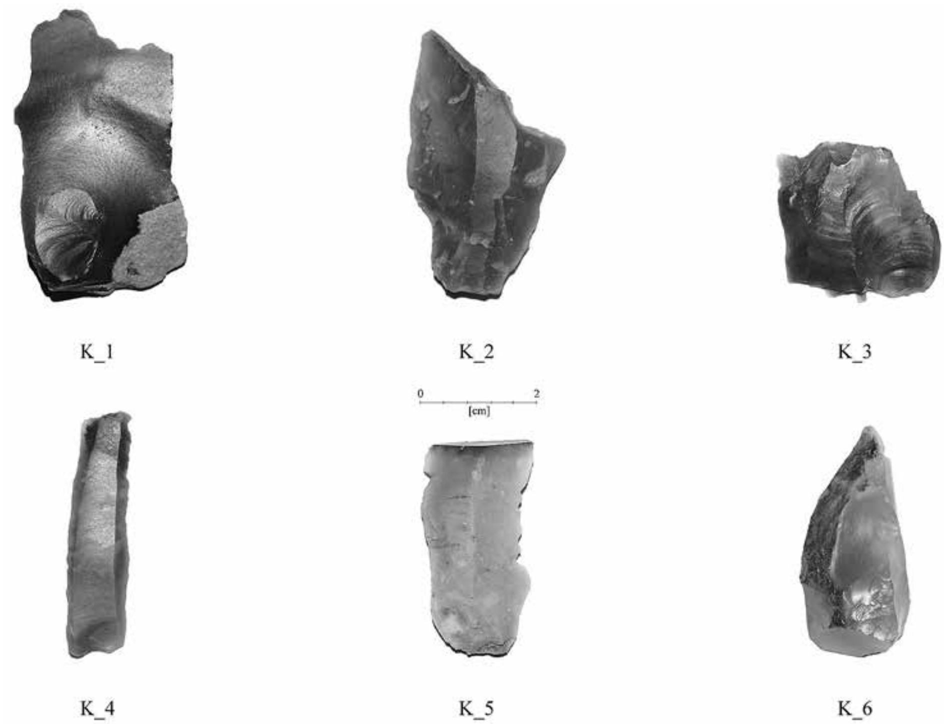


Fig. 1. The studied flint tools (K_3 and K_6 scaled as 3/2 with P_4 as 2/1). Photo: Ł. Kowalski.

Table 1. A comparision of the studied artifacts (N – Neolithic; EBA – Early Bronze Age; LBA – Late Bronze Age; EIA – Early Iron Age).

Artifact	Site	Province	Chronology	Raw material	Typology	Use-wear	Function
K_1	Wierzbica 'Zele'	Mazovia	LBA - EIA	'chocolate' flint	Flake	Yes	Scraper
K_2	Sąspów 1	Lesser Poland	N	Jurrasic-Cracow flint	Blade (bulb part)	Yes	Scraper
K_3	Toruń-Grębocin 243	Kuyavia-Pomerania	EBA	Baltic erractic flint	Flake	No	-
K_4	Skrzypkowo 13	Kuyavia-Pomerania	N - EBA	Baltic erractic flint	Blade	No	-
K_5	Skrzypkowo 13	Kuyavia-Pomerania	N - EBA	Baltic erractic flint	Blade	No	-
K_6	Toruń-Grębocin 243	Kuyavia-Pomerania	EBA	Baltic erractic flint	Flake	No	-

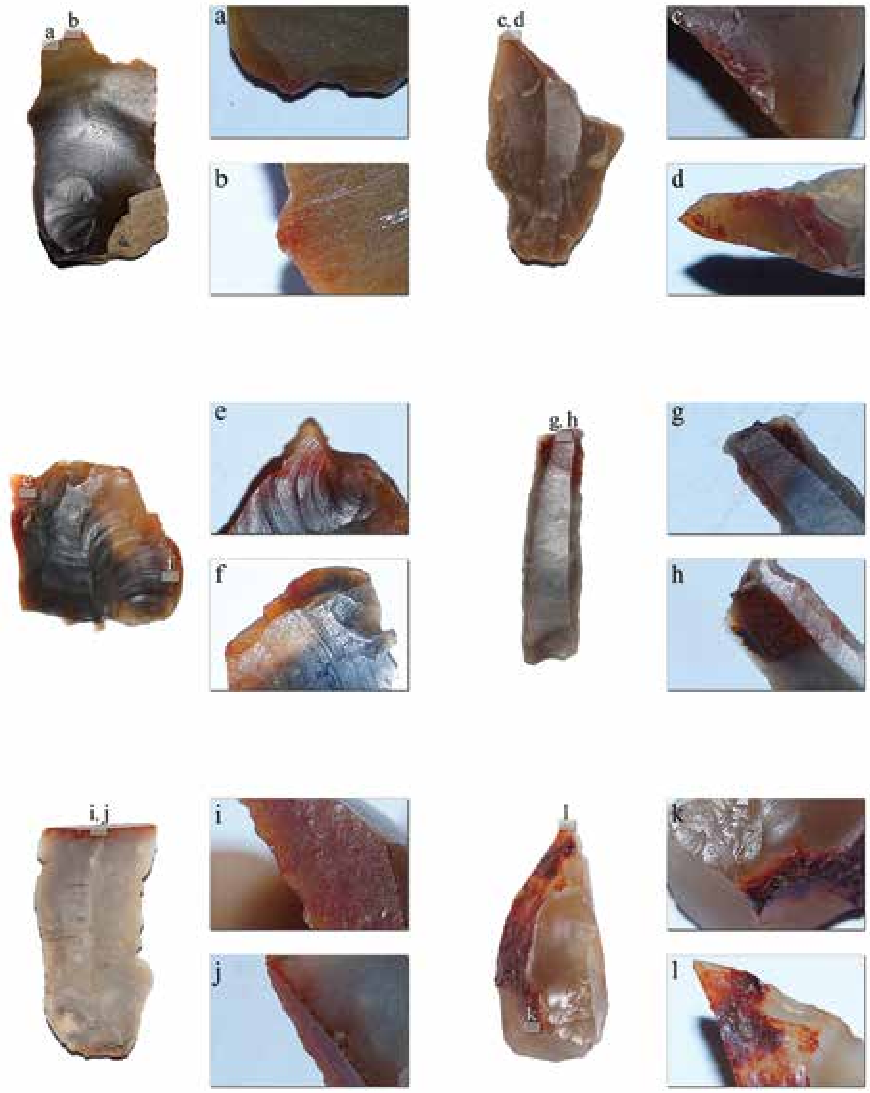


Fig. 2. The studied flint tools. Zoom in on the areas enriched in the iron (Fe) compounds. Photo: Ł. Kowalski.

METHODS

Use-wear analysis

Use-wear analysis (traceology) is an analytical method that allows the identification and interpretation of anthropogenic traces remaining on the surface of non-metallic tools (e.g., those made of silica, stone and organic raw materials). Use-wear analysis is also concerned with a wide range of deformations which might occur during the tools transport, deposition etc. (Małecka-Kukawka 2012: 464–471). Premilinary use-wear research was performed using a Nikon SMZ 2T stereomicroscope. Optical observations on the functional tools were carried out using a Zess Axiotech in reflection mode equipped with a AxioCam ICc 3 digital camera supported by an AxioVision 4.0 software. For identifying the use-wear profile of functional tools, the observations were directed on the working edges and areas just adjacent to the use-worn zone with optical imaging performed in the reflected light mode.

Laser ablation

Laser ablation technique was performed prior to the SEM-EDS investigations. As a result of impacting a high energy laser beam on a tool surface the removal (without a liquid state) of a secondary type residue (accumulated during pre- or postdepositional process) was completed.

Laser ablation was performed with a system for solid-state layers LSX-213 (CETAC Technologies, USA) equipped with Neodymium-pulsed Laser Nd:YAG. For ablating two scanning lines the laser was used at 755 V energy level and ablated at a speed of 100 μm/s, with a spot size set at 150 μm in diameter.

The ablation was carried out at two locations on each tool surface. The first was an area on the dorsal surface selected away from any locus exhibiting use-wear. The second

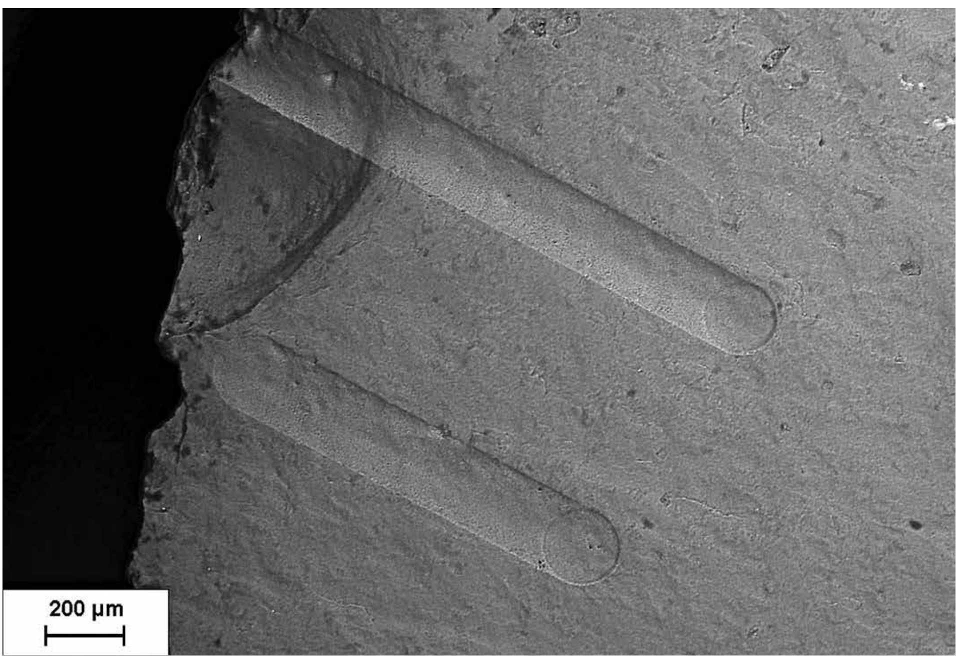


Fig. 3. The surface of sample K_1 with a visible ablated area. Photo: G. Szczepańska.

location was along an edge where use-wear analysis had confirmed surface polishing. The two areas were selected on the same tool since they are likely to have undergone the same post-depositional process (refer with Evans and Donahue 2005). For the non-archaeological specimens, the ablation was carried out on the surface selected away from any exibiting iron (Fe) enriched compounds. K_4 specimen was also ablated within the area enriched in Fe compounds. An exemplary ablated area is given in Fig. 3.

SEM-EDS

The SEM imaging was performed using a scaninnig electron microscope LEO 1430VP (Zeiss). Surface observations were carried out by means of a BSE detector with 28kV accelerating voltage and environmental vacuum mode (the chamber pressure of 50Pa). X-ray microanalyses were conducted using an EDS spectrometer Quantax 200 with XFlash 4010 detector (Bruker AXS) coupled with the scaninnig electron microscope LEO 1430VP (Zeiss). The EDS investigations were performed in semi-quantitative, surface and standardless mode completed by non-conducting material imaging using a BSE detector with pressure of 50Pa. The SEM-EDS was applied in order to achieve a chemical profile of the matrices and enriched areas (EA) including elemental mapping images.

RESULTS

The use-wear analysis results are in accordance with preliminary macroscopic observations indicating an absence of use-wear traces on the K_3-K_6 specimens. For the working edges of the functional tools (K_1 and K_2) the presence of a polish has been recognized. Due to a use-wear profile of the traces left on the functional tools, it is highly likely that both the K_1 and the K_2 were used to scrape an abrasive material (Małecka-Kukawka 2011: 139–147).

A polish present on the K_2 surface is indicative of a long-term use having been arranged along a working edge with smooth and greasy texture and with noticeable parallel strations (Fig. 4e–h). Unlike the well-formed K_2 polish, the one present on the working edges of K_1 exhibits a rough and greasy texture and no visible strations (Fig. 4a–d; see also van Gijn 1989) and therefore may reflect a short-term use of the tool.

Analytical areas for laser ablation and SEM-EDS investigations were selected based on the use-wear analysis results. Elemental mapping images for aluminum (Al), silicon (Si) and Fe distribution were obtained during the SEM research (Fig. 5).

The EDS investigations were performed in three analytical areas: (1) non-ablated silica matrix, (2) ablated silica matrix and (3) non-ablated enriched area and also for K_4 only in ablated enriched area. The resulting elemental weight fractions, excluding carbon (C), were converted to the corresponding oxide weight fractions and normalized to 100 (refer with Tab. 2).

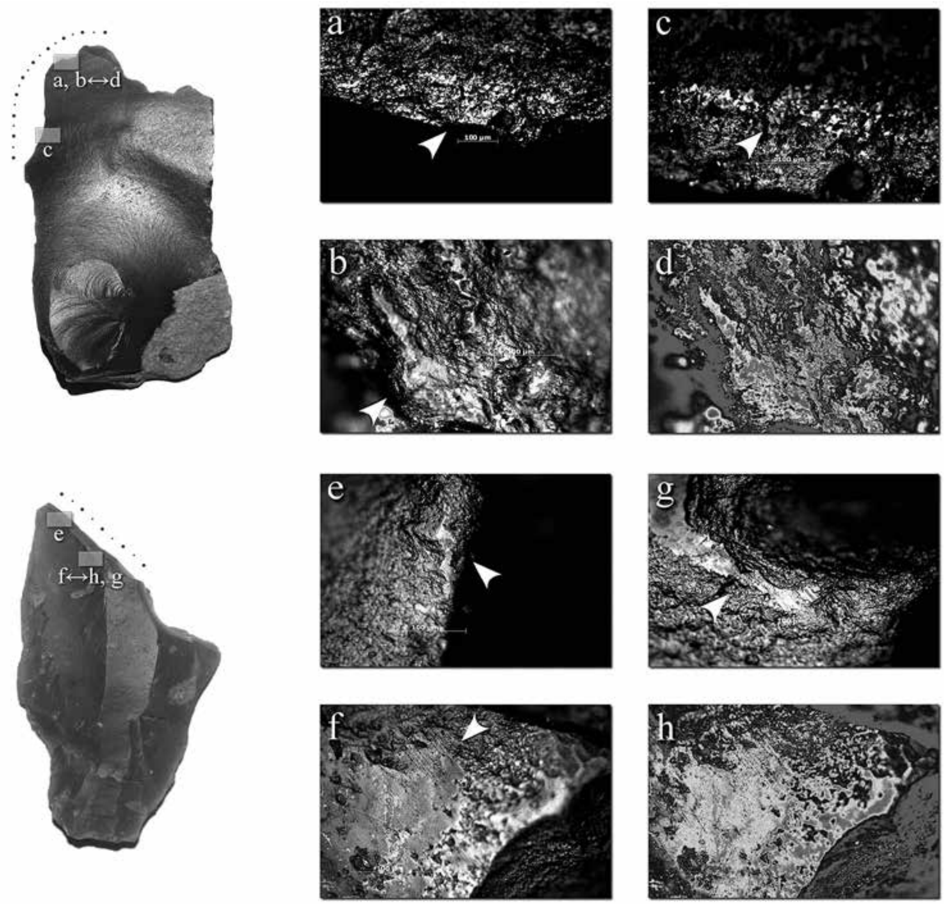
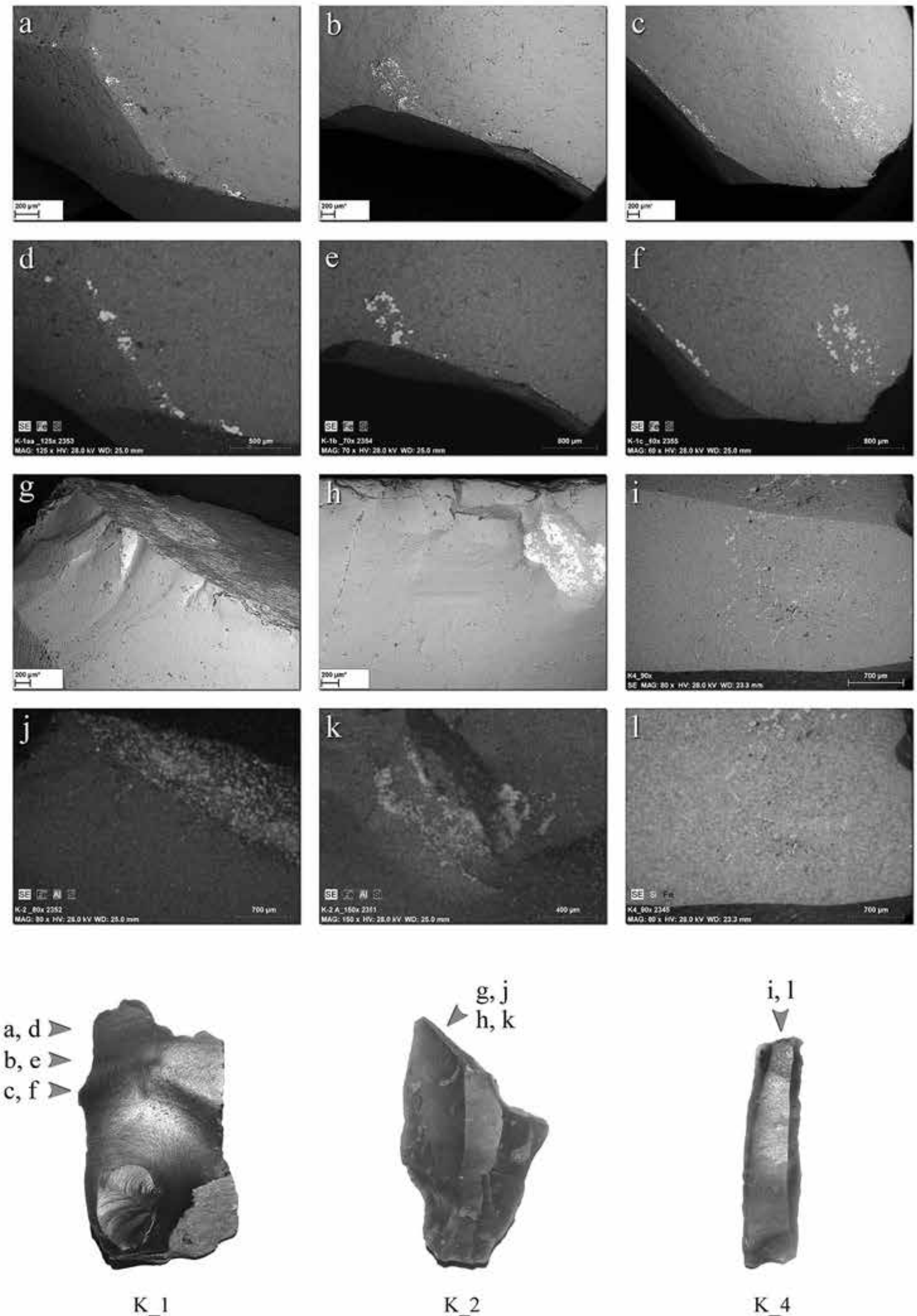


Fig. 4. The optical images of samples K_1 (a–d) and K_2 (e–h) working edges with a visible initial polish (a–d) and well-formed polish (e, g) with the noticeable parallel strations (f, h). Photo: J. Małecka-Kukawka and Ł. Kowalski.

Fig. 5. The SEM images of the EA for the selected tools with the corresponding elemental mapping images. Photo: G. Szczepańska and Ł. Kowalski.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K_1
K_2
K_4

Table 2. The oxide weight fractions (wt%) according to the EDS (M – silica matrix; EA – area enriched with a high Fe content; < DL – concentration below a detection limit; n-a – non-ablated area; a – ablated area).

Artifact	Area		C	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	MnO	Fe_2O_3
	Type	Preparation									
K_1	M	n-a	0,21	< DL	3,1	95	< DL	0,47	0,38	< DL	0,85
K_1	M	n-a	2,8	< DL	3,8	92	< DL	0,30	< DL	< DL	0,64
K_1	M	a	0,11	< DL	3,8	95	< DL	0,27	0,15	< DL	0,47
K_1	M	a	0,10	< DL	4,6	94	< DL	0,25	0,20	< DL	0,40
K_1	EA	n-a	3,3	0,74	5,0	48	< DL	0,22	0,36	0,59	42
K_1	EA	n-a	5,8	0,67	13	47	< DL	0,45	0,73	0,43	32
K_2	M	n-a	6,8	< DL	1,5	92	< DL	< DL	< DL	< DL	< DL
K_2	M	n-a	3,7	< DL	1,6	95	< DL	< DL	< DL	< DL	< DL
K_2	M	a	3,5	< DL	1,7	95	< DL	< DL	< DL	< DL	< DL
K_2	M	a	4,1	< DL	1,5	94	< DL	< DL	< DL	< DL	< DL
K_2	EA	n-a	7,3	< DL	1,3	74	< DL	0,19	0,35	< DL	17
K_2	EA	n-a	9,8	1,3	5,5	37	< DL	0,23	0,52	0,62	45
K_3	M	n-a	4,6	< DL	3,8	90	0,10	0,30	0,28	< DL	0,86
K_3	M	a	18	1,1	7,6	67	0,73	2,5	1,8	< DL	1,6
K_3	EA	n-a	6,4	1,5	9,2	64	0,78	0,52	0,33	< DL	17
K_4	M	n-a	5,3	< DL	1,4	93	< DL	< DL	< DL	< DL	0,45
K_4	M	a	13	< DL	2,1	81	< DL	0,48	0,41	< DL	2,6
K_4	M	a	11	< DL	2,2	85	< DL	0,44	0,48	< DL	1,5
K_4	EA	n-a	5,1	< DL	2,8	67	0,76	0,41	0,28	< DL	23
K_4	EA	a	3,4	< DL	3,8	68	0,99	0,47	0,28	< DL	23

K_5	M	n-a	5,2	< DL	1,8	92	< DL	< DL	< DL	< DL	0,72
K_5	M	a	4,2	< DL	1,3	94	< DL	< DL	< DL	< DL	0,70
K_5	M	a	3,7	< DL	1,4	94	< DL	< DL	< DL	< DL	0,61
K_6	M	n-a	2,9	0,79	11	84	< DL	0,36	< DL	< DL	1,5
K_6	M	a	2,1	0,20	8,6	87	< DL	0,34	< DL	< DL	2,0

Table 3. The factor structure matrix for the analytical areas ($Var._{cum.}$ – cumulative variance; n/a – not applicable due to a high value of partial correlation).

Area	Root	$Var._{cum}$	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	MnO	Fe_2O_3
Matrix	1	0,92	0,48	0,091	-0,064	0,22	0,18	0,056	n/a	0,013
	2	0,98	-0,67	-0,19	-0,0078	0,22	0,18	0,088	n/a	0,0042
	3	1,00	-0,10	-0,58	-0,019	0,49	0,13	0,11	n/a	-0,090
EA	1	0,99	-0,0026	n/a	n/a	-0,027	n/a	n/a	0,0053	0,0043
	2	0,99	-0,24	n/a	n/a	0,54	n/a	n/a	-0,076	-0,011
	3	1	-0,12	n/a	n/a	-0,84	n/a	n/a	-0,013	0,023
Matrix & EA	1	0,93	-0,021	-0,023	0,046	-0,037	-0,0010	-0,0036	-0,020	-0,069
	2	0,98	-0,018	-0,13	0,027	0,11	0,00066	0,0092	-0,069	-0,042
	3	0,99	-0,082	-0,23	-0,20	-0,24	-0,034	0,073	0,31	0,37
	8	1	0,60	-0,13	-0,57	0,36	0,29	0,19	0,68	0,72

To verify either an anthropogenic and non-anthropogenic origin for the enriched areas (EA), the data-set was standarized and statistically evaluated using discriminant analysis (DA). The data were categorized into three sets: (1) non-ablated silica matrix, (2) ablated silica matrix and (3) non-ablated enriched area (refer with Tab. 3). Since it is probable that contamination during curation was responsible for carbon (C) weight fractions presence (attaching the tools with a measuring table using a carbon tape or the presence of an egzogenic, organic surface impurities), they were not included in the DA model. The weights fractions below a detection limit (DL) were replaced by a value equal to its half (½ DL=0,05 wt%).

The results showed a very clear (Λ_W= 0,0000000) intergroup diversity within the silica matrices (Fig. 6a). With an exception of the K_3, K_4 and K_6, no significant differences were found between the non-ablated matrices and those ablated. A discrimination of the matrices of these three artifacts was made by the first and second canonical roots which are both correlated with MgO and P_2O_5 (refer with Tab. 3).

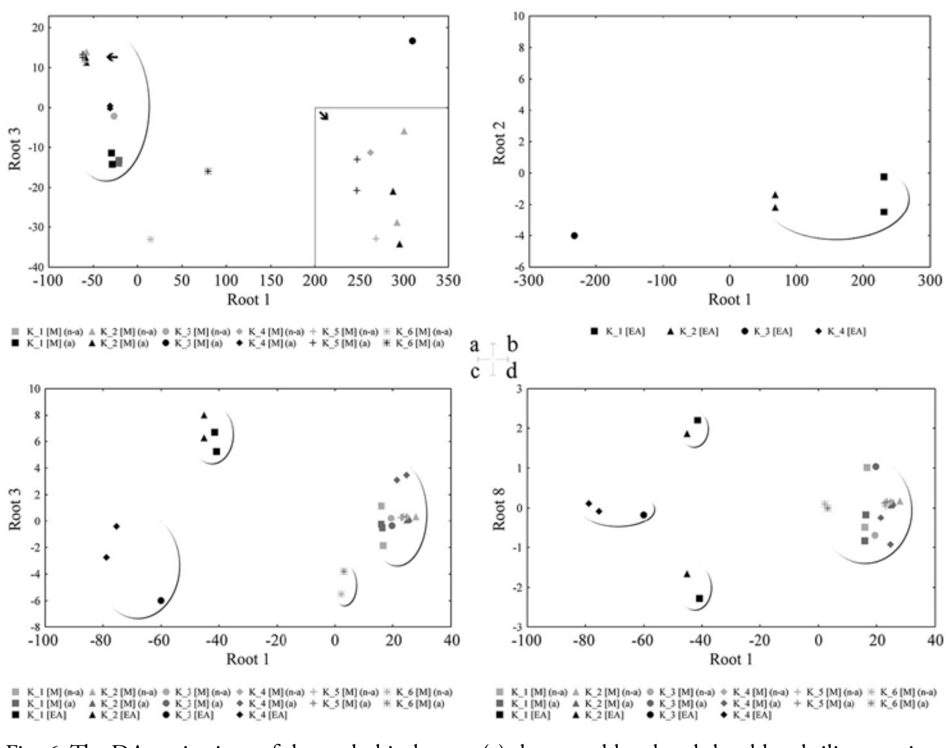

Fig. 6. The DA projections of the analythical areas: (a) the non-ablated and the ablated silica matrices on a root-plane 1–3; (b) the K_1–4 EA on a root-plane 1–2; (c) the silica matrices and the EA on a root-plane 1–3; (d) the silica matrices and the EA on a root-plane 1–8. Graphic design: Ł. Kowalski.

Given that the presence of the enriched areas (EA) on the K_5 and K_6 surfaces was not recognized by SEM-EDS (refer with Tab. 2) they were not included in the final DA model dedicated exclusively to EA. We found that the EA intergroup discrimination was of a high diversity (Λ_W= 0,0000001). K_1 and K_2 were agglomerating together and were separated from the K_3 and K_4 (Fig. 6b). Such a discrimination was made by positive (K_1 and K_2) and negative (K_3 and K_4) values of the first canonical root which is positively correlated with P_2O_5 and MnO (Tab. 3).

For all analytical areas, the DA results showed a very clear intergroup diversity (Λ_W=0,0000000). The K_1 and K_2 were agglomerating together nearby the K_3 and K_4. The enriched areas (EA) and the silica matrices areas (M) were separated from each other by negative (EA) and positive (M) values of the first canonical root (Fig. 6c). It is negatively correlated with Fe_2O_3 and positively with SiO_2 (refer with Tab. 3). The major contribution in the EA intergroup discrimination was made by the third canonacal root which is positively correlated with Fe_2O_3 and negatively with P_2O_5 and Al_2O_3 (refer with Tab. 3). Having been positively correlated with Fe_2O_3, MnO and MgO (refer with Tab. 3) the eighth canonical root generated an intragroup discriminant space for the K_1 and K_2 (Fig. 6d).

Normalized oxide weight fractions (=quantitative variables) were standarized and evaluated with a cluster analysis (CA) using Ward's linkage and Czebyshev's distance (Fig. 7a). The resulting distance matrix was used to perform multidimensional scaling (MDS). By means of the MDS a scatter plot bringing all the quantitative variables into relationship was generated (Fig. 7 b).

The results were used to plot the enriched areas (EA) on the ternary diagrams including the following scatter triads: CaO, P_2O_5, MnO and CaO, MgO, K_2O both with respect to Fe_2O_3 content. The oxide weight fractions were ranged in the range of <0, 1>. Due to P_2O_5 and MnO the first ternary scatter plot kept the K_1 and K_2 separate from the K_3 and K_4 (Fig. 7c). It was also found that contributions to the discrimination model was made by CaO and K_2O (Fig. 7d).

DISCUSSION

No significant qualitative differences were found between the chemical profiles of the non-ablated matrices and those ablated. Such an assumption however is not applicable to K_3 and K_4 since it was established that the differences recognized here are of a qualitative nature (presence of MgO and K_2O in the ablated matrices respectively). A tendency of decreasing carbon (C) amounts in the ablated matrices of the K_1, K_2, K_5 and K_6 and increasing in the K_3 and K_4 is quite noticeable. In K_3 and K_4, the increasing carbon could be due to its endogenic nature (=an accessory component) and it may be found in even-aged (syngenetic) growth of raw flint surrounded by organic silica (Bolewski and Parachoniak 1982: 322; Ryka and Maliszewska 1982: 171). The results are in accordance

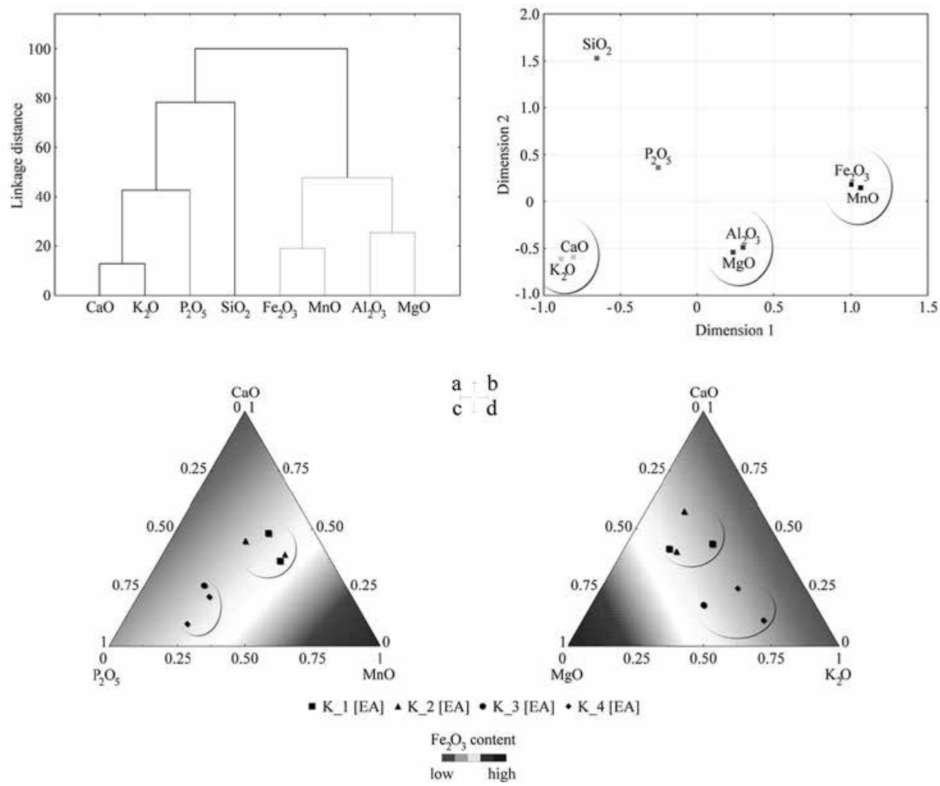

Fig. 7. (a) A dendrogram clustering the quantitative variables with Ward's linkage and Czebyshev's distance; (b) a scatter-plot for the quantitative variables on a 1–2 dimension-plane according to the MDS; (c) a ternary scatter plot for the EA on a CaO-P2O5-MnO plane and (d) CaO-MgO-K2O plane both with Fe2O3 content given as a linear function of corresponding oxides weight fractions. Graphic design: Ł. Kowalski.

with a tendency of K_2O and CaO to increase in these areas (= inclusions; Fig. 7a, b and d). For the rest of the samples, an increased carbon amount is probably of the egzogenic nature and thus may be seen as brought by anthropogenic (prehistoric or modern usage) or non-anthropogenic (epigenetic or post-depositional process) factors (refer with Anderson-Gerfaud 1984 and see also van Gijn 1989).

Presence of the enriched areas (EA) has not been recognized for the K_5 and K_6 samples during the SEM-EDS investigations. It is also not possible in the current study to indicate significant qualitative differences between the chemical profiles of the non-ablated matrices and those ablated. Nevertheless, the presence of such areas has been confirmed by the macroscopic observations (Fig. 5i–l). On the basis of the findings it is higly likely that these areas should be treated as natural inclusions in the silica matrices. The observation is analogous to the one from the K_3 and K_4. Since no significant differences were found between the chemical profiles of the K_4 non-ablated or the ablated EA, it is most probable that this area is not of a residual but inclusion nature. Having been not arranged linearly, neither increase on the edges nor in the microdepressions the distribution of Fe on the K_4 surface (Fig. 5i and l) supports such an assumption. By means of the similarity analysis it is likely to be a chemical profile matching between the K_3 and K_4 EA allowing us to treat them both as inclusions.

It is noticeable that Al_2O_3 decreases in the ablated matrices of the K_5 and K_6. For the rest samples, Al_2O_3 is tend to increase, both in ablated matrices and the enriched areas (EA). The presence of phosphorus (P) in the K_3 and K_4 enriched areas may therefore be a consequence of P-Fe-Al mineral inclusions, such as vivianite or glauconite (Ryka and Maliszewska 1982: 171–172; Brzeziński *et al.*, 1983: 278; Sapek 2014: 86; Stolarczyk and Drewnik 2014: 58).

With a major contribution made by MnO and P_2O_5 a significant discrimination of the K_1 and K_2 enriched areas (EA) has been established (Fig. 6b–d and Fig. 7c and d). Having increased Al_2O_3 together with a presence of MgO the K_1 and K_2 EA are even more likely to be of a none genetic connection with the silica matrices. Such a conclusion is also supported by the MDS results indicating a Fe_2O_3 and MnO co-variance (Fig. 7a and b). Given that iron (Fe) has a lower redox potential than manganese (Mn) and phosphorus (P), which means that P and Mn are more stable than Fe under the same physicochemical conditions (Sadowski 1997: 760; Evans and Donahue 2005: 1739) and also that phosphorus tends to accumulate in the high-Fe genetic levels (Sapek 2014: 87), it must be recognized that residues present on the K_1 and K_2 had already been phosphorus-free originally and should be therefore treated as anthropogenic in nature. The results generated by use-wear analysis are crucial indicating that the residues are present on areas just adjacent to the use-worn zone (smoothest) and tend to be located in microdepressions of the microstructures (Fig. 4 and Fig. 5). Such a localization indicates the residues are not epipgenic nor are a result of post-depositional soil deposits (refer with Anderson-Gerfaud 1984).

Due to the chemical profile of the residues preserved on the K_1 and K_2 it is highly likely that they represent an ochre-type material (=red ore, i.e. hematite and limonite gravel). As we know, ochre is a limonite rock containing some impurities including (1) clay minerals (SiO_2, Al_2O_3 and MgO presence in the EA), (2) fine-grained quartz (SiO_2 presence in the EA) and (3) organic remains (enhancement of C in the EA). Importantly, goethite is the main component of the limonite and theoretically contains about 63 wt% of Fe (more than 40 wt% amount of Fe_2O_3 in the EA) with up to 5 wt% of Mn (MnO presence in the EA) and mechanical SiO_2 (SiO_2 presence in the EA; Bolewski and Parachoniak 1982: 331–333; Bolewski and Manecki 1993: 180–183 and see also Hensel 2011). The strong probability that the material identified is ochre accords with the results of use-wear analysis indicating that the use-wear traces were left by the prehistoric people who worked the abrasive ochre-type material (Fig. 4).

FINAL REMARKS

An integrated, multidisciplinary approach used in this study allowed direct identification of the use-wear traces and residues accumulated on a sample of functional tools collected from the Sąspów and Wierzbica 'Zele' flint mines sites. Although the SEM-EDS is a semi-quantitative analytical method, by applicating both the use-wear analysis and similarity analysis we were able to fingerprint the anthropogenic nature of the residues preserved on two of the functional tools analyzed.

REFERENCES

Anderson-Gerfaud, P. 1984. A few comments concerning residue analysis of stone plant-processing tools. In L.R. Owen and G. Unrath (eds), *Technical aspects of microwear studies of stone tools, Part I*, 69–87. Early Man News 9/10/11. Tübingen.

Bolewski, A. and Manecki, A. 1993. *Mineralogia szczegółowa*. Warszawa.

Bolewski, A. and Parachoniak, W. 1982. *Petrografia*. Warszawa.

Brzeziński,W., Dulinicz, M. and Kobyliński, Z. 1983. Zawartość fosforu w glebie jako wskaźnik dawnej działalności ludzkiej. *Kwartalnik Historii Kultury Materialnej* 31(3): 277–297.

Dzieduszycka-Machnikowa, A. and Lech, J. 1976. *Neolityczne zespoły pracowniane z kopalni krzemienia w Sąspowie*. Wrocław. Polskie Badania Archeologiczne 19.

Evans, A.A. and Donahue, R.E. 2005. The elemental chemistry of lithic microwear: an experiment. *Journal of Archaeological Science* 32: 1733–1740.

van Gijn, A.L. 1989. The wear and tear of flint. Principles of functional analysis applied to Dutch Neolithic assemblages. *Analecta Praehistorica Leidensia* 22: 1–181.

Hensel, Z. 2011. Physical and chemical examination of hematite gravel from Rydno Quarry and the Final Paleolithic campsites of Całowanie. In R. Schild, H. Królik, A.J. Tomaszewski and E. Ciepielewska (eds), *Rydno. A Stone Age red ochre quarry and socioeconomic center. A century of research*, 405–407. Warszawa.

Lech, H. and J. 1995. PL 3 Wierzbica 'Zele', Radom Province. *Archaeologia Polona* 33: 463–480.

Małecka-Kukawka, J. 2011. Problem of the flint tools from the Sąspów mine site in the light of use-wear analysis. In M. Capote, S. Consuegra, P. Díaz-del-Río and X. Terradas (eds), *Proceedings of the 2nd International Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times (Madrid, 14-17 October 2009)*, 139–147. Oxford. British Archaeological Repots. International Series 2260.

Małecka-Kukawka, J. 2012. Traseologia – badanie mikrośladów. In S. Tabaczyński, A. Marciniak, D. Cyngot and A. Zalewska (eds), *Przeszłość społeczna. Próba konceptualizacji*, 464–471. Poznań.

Ryka, W. and Maliszewska, A. 1982. *Słownik petrograficzny*. Warszawa.

Sadowski, Z. 1997. Biogeochemistry of iron and manganese. *Wiadomości Chemiczne* 51 (11–12): 758–770.

Sapek, B. 2014. Soil phosphorus accumulation and release – sources, processes, causes. *Water-Environment-Rural Areas* 14 (1): 77–100.

Stolarczyk, M. and Drewnik, M. 2014. Diversity of different fractions of phosphorus in grassland soils of agricultural lands in the vicinity of a fertilizer stockpile in Tarnawa Wyżna (Western Bieszczady Mts). *Prace Geograficzne* 135: 57–71.

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The Lublin-Volhynian culture retouched blade daggers in light of usewear analysis of artefacts from burials at site 2 in Książnice, Poland

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The Lublin-Volhynian culture retouched blade daggers are unique forms of flint tools in the Eneolithic in Poland. They are most often found in male graves, around the chest or skull, as signs of prestige and high status of men possessing them. Anna Zakościelna also suggested that such kind of tools did not served utilitarian function. Contrary to prevailing opinion usewear analyses of retouched blade daggers from the Lublin-Volhynian culture burial ground site 2 in Książnice, Busko Zdrój district, showed that they bear intense and various traces of use.

KEY-WORDS: Lublin-Volhynian culture, Eneolithic, retouched blade daggers, usewear analyses, Książnice

INTRODUCTION

The Lublin-Volhynian culture retouched blade daggers are unique forms of flint tools in the Eneolithic in Poland. Their large size and the extreme precision evident in their manufacturing reflects on their function.

The majority of retouched blade daggers from well-defined archaeological context come from burial grounds. They typically occur as grave goods of adult men, very rarely of women (grave 1 from Gozdów, Hrubieszów district, Zakościelna and Prusicka-Kołcon 2006). Due to the fact that they occur most often around chest or skull, and less frequently near the waist, it has been assumed that they were worn around the neck in life and deposited in the same way with the dead in their graves. This supports the assumption of their symbolic meaning as a visible sign of prestige.

The subject of the retouched blade daggers in the Lublin-Volhynian culture was discussed in detail by Anna Zakościelna (2008). In her text, the author

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presented the technology and raw material characteristics of the type of artefacts in question along with their find context and advanced the hypothesis that retouched blade daggers were 'signs of high status of men possessing them' (Zakościelna 2008: 542). Searching for the origins of such treatment of macrolithic flint products, she presented numerous examples from the Balkan Peninsula and the Carpathian Basin, where within the Varna, the Tiszapolgar and the Bodrogkeresztur cultures, long blades were found in graves primarily of adult men (Zakościelna 2008: 542-543).

Theses presented in the aforementioned article were repeated in the monograph on the Lublin-Volhynian culture burial rites published two years later (Zakościelna 2010). Stressing that these blade daggers carried more than economic function, the author pointed out that, apart from retouched blades from grave VI on site 1C in Gródek nad Bugiem, Hrubieszów district, and from grave No. 1 on site 3 in Tyszowce, Tomaszów Lubelski district, the remaining 11 specimens did not bear any macroscopically perceptible traces of wear (Zakościelna 2010: 142).

An occasion to independently evaluate Zakościelna's thesis comes from use wear analysis research on flint artefacts from the Lublin-Volhynian culture burial ground site 2 in Książnice carried out by Bernadeta Kufel-Diakowska[1].

Site 2 in Książnice (Busko-Zdrój district, Świętokrzyskie Voivodeship) is located on top of a small hill (200.15 m above sea level) at the eastern end of Pińczów Hummock (AZP 95-67: 100). During systematic excavations carried out since 2001 a sepulchral-settlement complex dating from the Neolithic and the Early Bronze Age was discovered. One of its most important elements is the Lublin-Volhynian culture burial ground consisting of 17 graves which is, to date, the largest cemetery known for this culture (Wilk 2014).

The burial ground consists of two sepulchral fields located about a dozen metres apart. The 'eastern' field is divided into male and female parts, and it contains eight burials of the local elite members. The western field contains eight graves, which are poorer in grave goods, and mixed in terms of sex of the deceased. Among them is grave no. 17 discovered in 2014, perhaps playing the role of central burial within the entire cemetery. In addition, in the burial ground three completely destroyed graves were recorded, from which only individual vessels survived (Fig. 1).

[1] The usewear analysis was carried out in the Laboratory for Archaeological Conservation and Archaeometry in the Institute of Archaeology University of Wrocław, with the use of stereomicroscope Olympus SZX9 (up to 114×) and metallographic microscope Nikon ECLIPSE LV100 (50-500×).

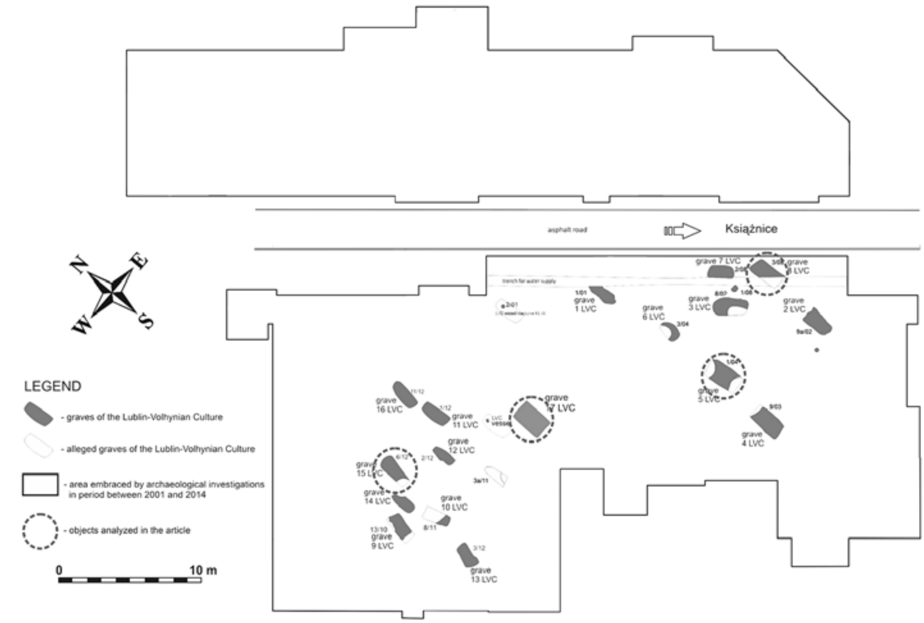

Fig. 1. Layout of graves at the Lublin-Volhynian Culture cemetery at site 2 in Książnice, Busko-Zdrój district. Drawing: S. Wilk.

GRAVES DESCRIPTION

Grave 5 (feature 1/04) discovered in August 2004, in plan view had a form similar to a rectangular pit measuring 240 x 120 cm, oriented along the NS line. The north part of the pit was damaged by feature 5/04. At a depth of 50 cm a completely preserved skeleton of a man (*senilis*) approximately 60 years old (Wilk 2006) was found, arranged in contracted position on the right side with the skull at the south end of the grave pit. The grave assemblage consisted of three pottery vessels located in front of the skull and behind it a copper axe, 16 flint products, of which 11 were deposited in two clusters near the left pelvic plate. The retouched blade (Ks/k/15/1/04) was located on ribs of the upper part of the chest, under the left arm (Wilk 2006; Fig. 2a).

Grave 8 (feature 3/08) discovered in August 2008, in plan view had the form of an elongated rectangle oriented along the NS line, measuring 177 x 105 cm. The south part of the pit was damaged by a water pipe trench. At the depth of 55-60 cm the nearly complete skeleton of a woman (*adultus*) was found, arranged in contracted position on the left side and on the back with the skull at the south end of the grave pit and lower limbs bent at an angle of approximately 90°. The grave assemblage

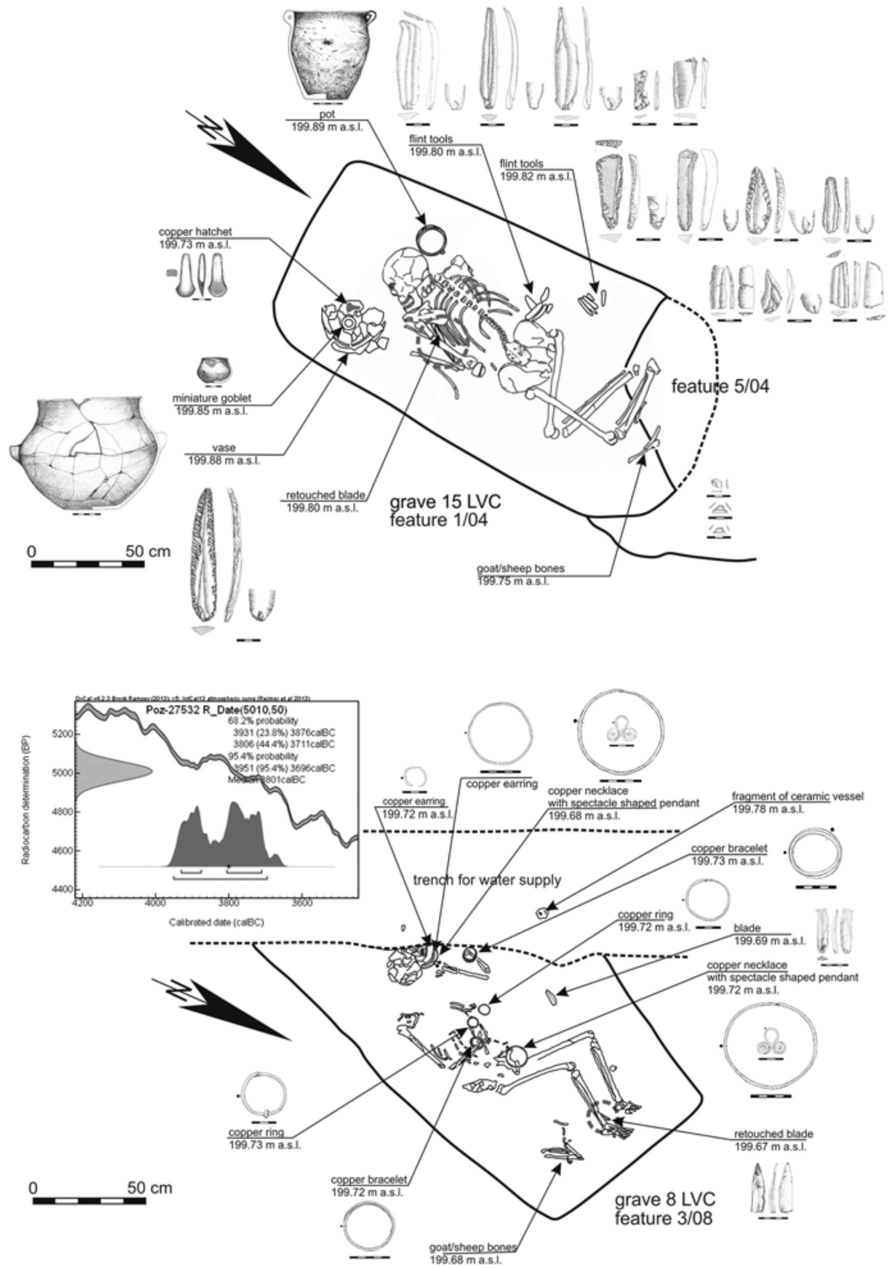

Fig. 2. Książnice, Busko-Zdrój district. A – Grave No. 5, plan with grave goods, B – Grave No. 8, plan with grave goods. Drawing: S. Wilk.

consisted of 10 copper wire ornaments deposited underneath the skull, on bones of both forearms, around the chest and on the pelvis; two pottery vessel fragments found within the water pipe trench, and two flint artefacts, one of which was found 30 cm to the east of the chest. The retouched blade (Ks/k/12/08) was found next to the individual's right foot in the north part of the pit (Wilk 2014; Fig. 2b).

Grave 15 (feature 6/12) discovered in August 2012, in plan view had the form of an elongated rectangle oriented along the NS line, measuring 164 x 133 cm. The south part of the pit was damaged by feature 5/12. At the depth of 40-50 cm the remains of a very poorly preserved skeleton lacking the skull were found, arranged in contracted position on the right side and with lower limbs to the north. The age and sex of this individual could not be determined. Within the grave pit four flint artefacts were found, including two retouched blades (Ks/k/30/12 and Ks/k/31/12) located next to each other, one around chest of the deceased, the other one around the pelvis (Fig. 3a).

Grave 17 (feature 1/14) discovered in August 2014, had the form of an elongated rectangle oriented along the NS line, measuring 234 x 152 cm. At the depth of 30-40 cm were found remains of an incomplete, poorly preserved skeleton, arranged in contracted position on the right side, with the skull at the south end of the grave pit and lower limbs to the north. As with Grave 15, the age and sex of this individual could not be determined. The grave assemblage consisted of three pottery vessels located in front of the face of the deceased, a copper earring discovered a few centimetres below the skeleton in chest area, and six flint artefacts, including one Las Stocki type truncated blade discovered around the pelvis, while the other artifacts were found in the southwestern part of the grave. The retouched blade (Ks/k/20/14) was deposited around the chest (Fig. 3b).

Among the six retouched blades recovered from these graves (nos. 5, 15, and 17), three can be initially classified as retouched blade daggers using Zakościelna's (2008) definition, i.e. in addition to large size and shaping by fluted retouch, they were found around chest or skull. Slight doubts arise over the original location of the larger retouched blade from grave 15. While it is true that this tool was found on the chest, its position at the moment of discovery could be a result of postdepositional processes, because it lay very close to the unpreserved pelvic plate (where it originally could have been stored in a bag, similar to the retouched blade Ks/k/31/12). The fifth retouched blade was found between the woman's feet (grave 8). However, rich grave goods accompanying women of high status prompted the authors to wonder whether the retouched blade found with the woman in grave 8 also was a sign of high prestige (as it was for men) or whether it may have been a utilitarian implement. The sixth artefact, which was not analysed, was found in grave 5. The dead was a man at age *senilis*. The retouched blade belonged to an assemblage of 10 flint artefacts, found around the right pelvic plate (Wilk 2006).

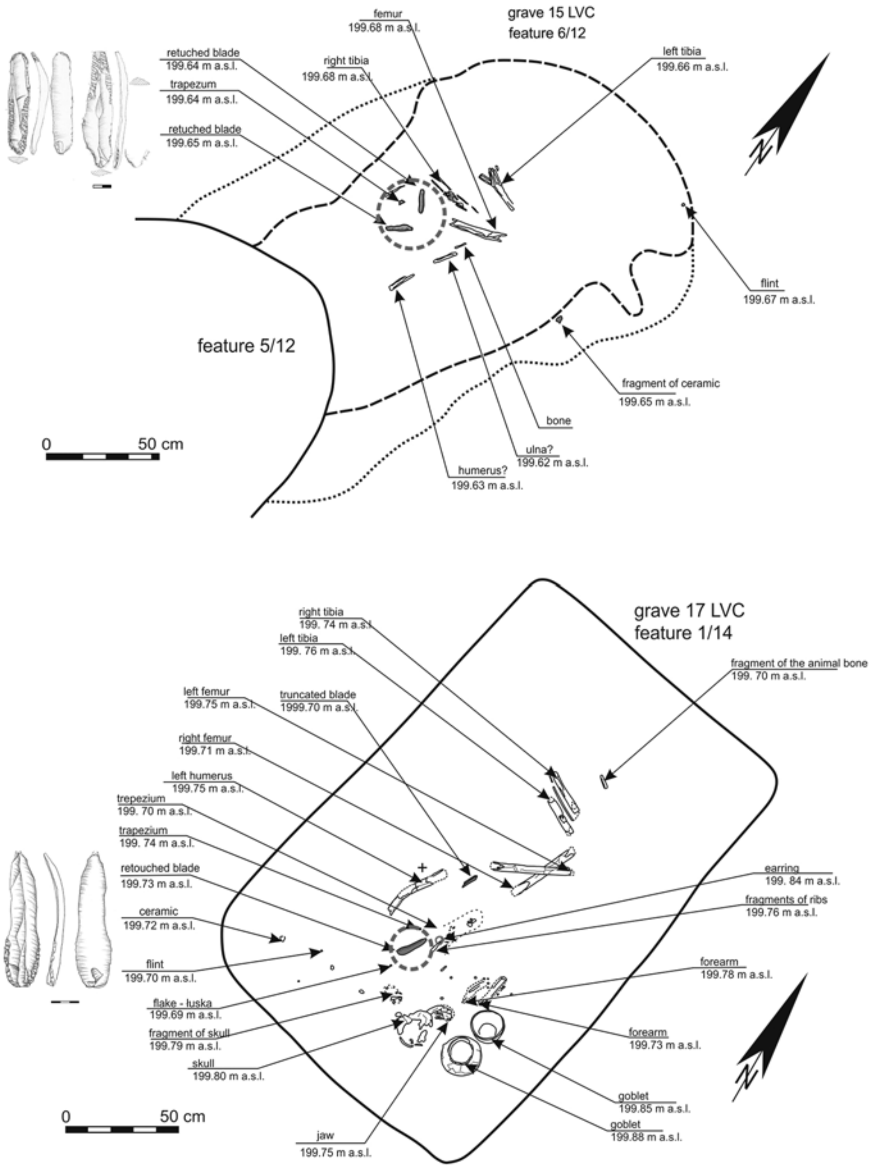

Fig. 3. Książnice, Busko-Zdrój district. A – Grave No. 15, plan with grave goods, B – Grave No.17, plan with grave goods. Drawing: S. Wilk.

ANALYSIS

Technological and raw material characteristic of artefacts

The description of the first artefact, the retouched blade from grave 5, was previously made by Zakościelna (Fig. 4). This is the bilateral convergent retouched blade (170 x 31 x 11 mm) with fluted retouch, from 2/3 of the length passing to irregular scalar retouch and partially fine edge retouch. The proximal part of the artifact was thinned by alternating retouch: fluted on the negative face and fine edge on the positive face. Ridges are gently smoothed and polished. The artefact, made of Volhynian flint (Zakościelna 2006), has a prepared flat butt, and 'spilled' bulb and chips are perceptible under the butt's edge. Both edges are gently bilaterally polished and the tip is slightly broken.

The artefact from grave 8 is a partial retouched blade made of chocolate flint with a perforator-shaped tip (85 x 22 x 9 mm), made from the distal part of a broken blade (Fig. 7.1). The right side is shaped to the half of its length by scalar retouch, the left side by semi-abrupt retouch, as is the tip of the artefact.

Two other artefacts come from grave 15; both of them are bilateral partial retouched blades but they differ in location of fluted retouch. The first one (128 x 32 x 8 mm), made of Volhynian flint, has the retouch on the distal part, and the butt portion was shaped as a blunt perforator by abrupt alternating retouch (Fig. 5). Its profile is slightly incurved and the tip is broken. The second specimen (113 x 23 x 9 mm), made of chocolate flint, shows fluted retouch along its proximal part and its tip is shaped as an end-scraper (Fig. 6). The artefact has prepared flat butt, clearly perceptible bulb and chips as well as a largely incurved profile.

The last of the artefacts was discovered in grave 17 (Fig. 7.2). This is the bilateral partial retouched blade (147 x 38 x 10 mm) was made of chocolate flint with semi-fluted retouch from 2/3 of the length of both edges. The artefact has prepared flat butt, 'spilled' bulb and chips as well as incurved profile. Its tip is slightly broken.

The results of the usewear analysis

Four of five analysed artefacts are very complex in terms of microwear traces preserved on their edges and surfaces. The retouched blade from grave 5 bears traces which can be associated with at least two stages of tool use. On the larger part of the left edge and on a fragment of the right edge of the retouched blade are perceptible traces of intensive use, most likely caused by scraping leather or plant (Fig. 4A-C); locally they resemble traces of wood scraping. The handle could have been mounted laterally (see Skakun 2008: Fig. 5), or located in the distal part - on the ridge traces transverse in relation to the axis of the blade are perceptible. Subsequently the location of hafting was changed, which partially removed the traces of use in the proximal part of the artifact, and the surface around the scar was dulled. The tip is heavily rounded, and

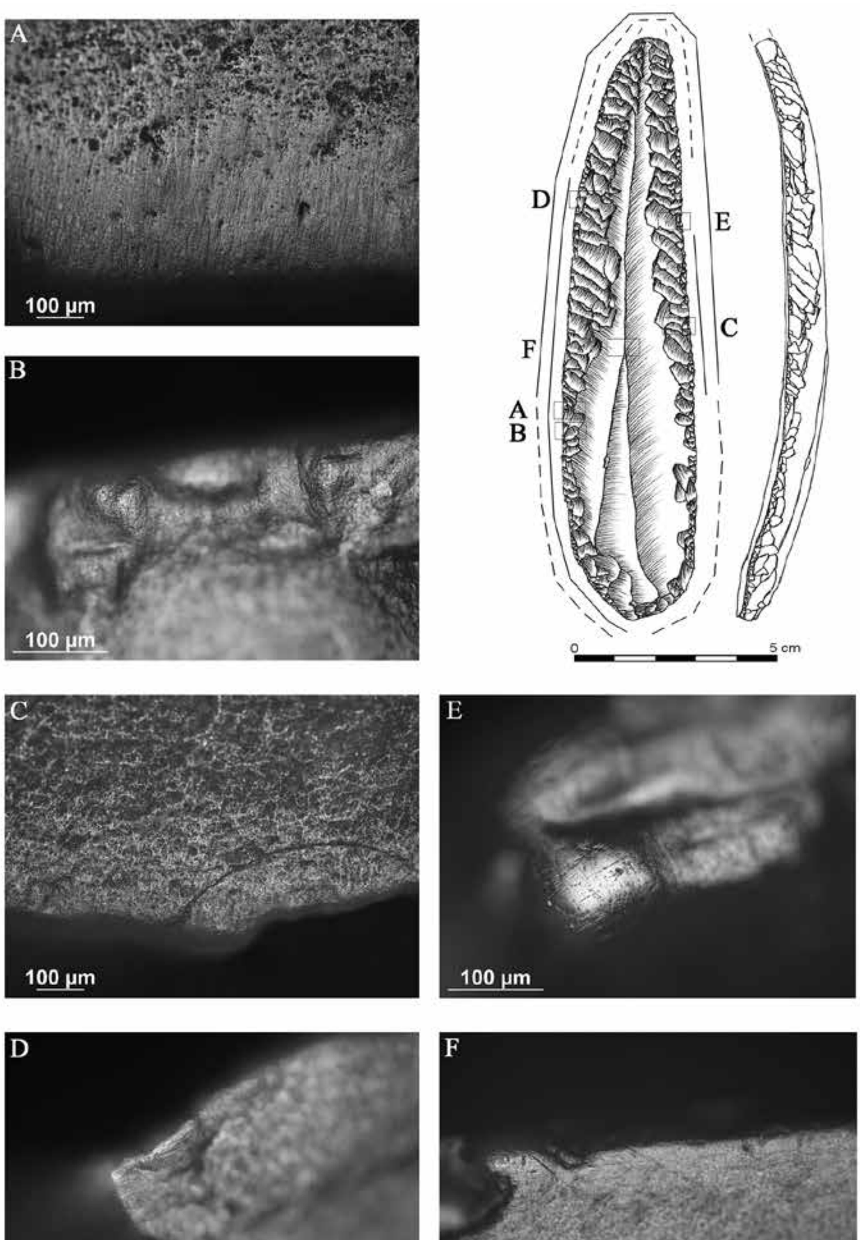

Fig. 4. Książnice, Busko-Zdrój district. Retouched blade from grave No. 5: A-C usewear traces; D-F traces probably from contact with a sheath. Drawing: M. Szeliga. Photo: B. Kufel-Diakowska.

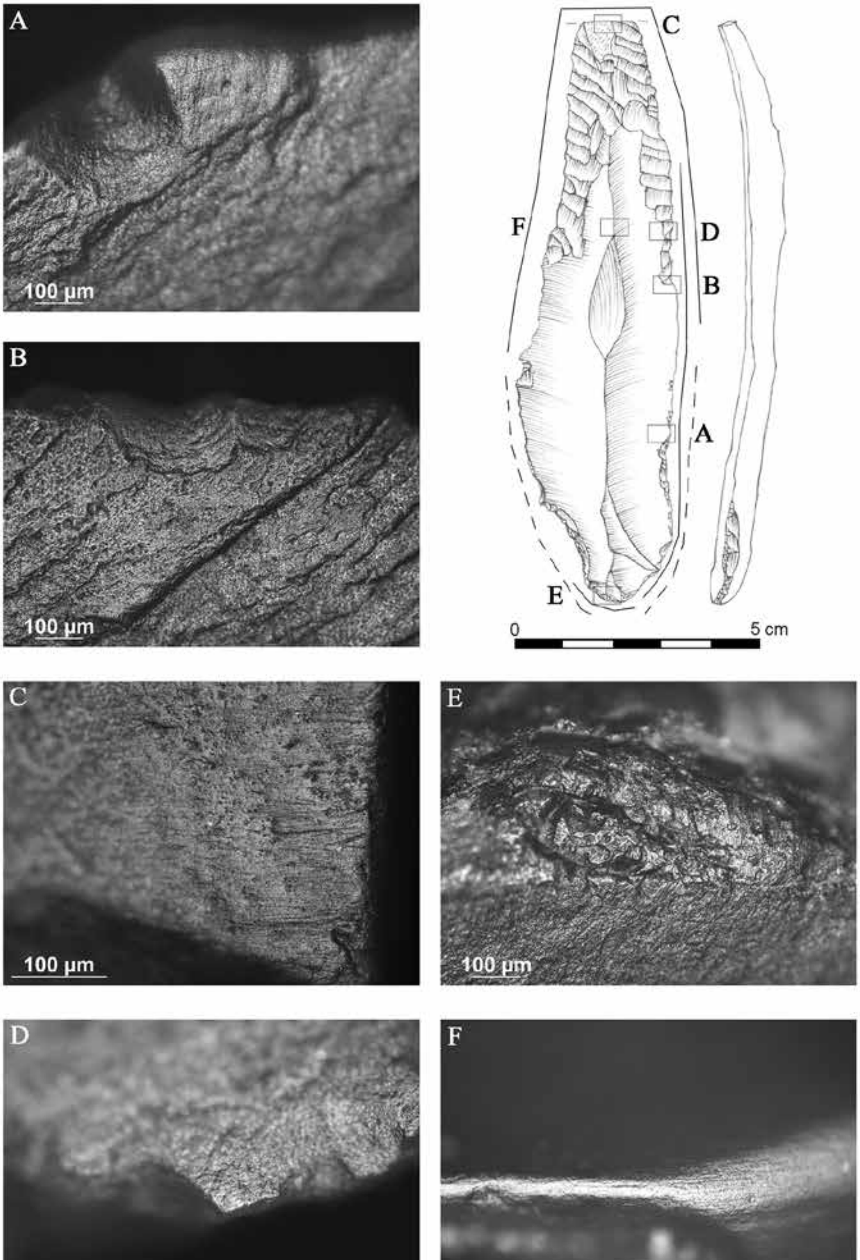

Fig. 5. Książnice, Busko-Zdrój district. Retouched blade from grave No. 15: A-B, E usewear traces; C-D, F traces probably from contact with a sheath. Drawing: J. Libera. Photo: B. Kufel-Diakowska.

on both edges of this part of the tool – but only on the very edges and retouch elevations – perceptible parallel, bright polish, intersected by dark scratches can be seen (Fig. 4.D-F) which could result from repeated pulling and putting the tool in and out of a leather sheath (see Beugnier and Plisson 2000: Fig. 12C-D).

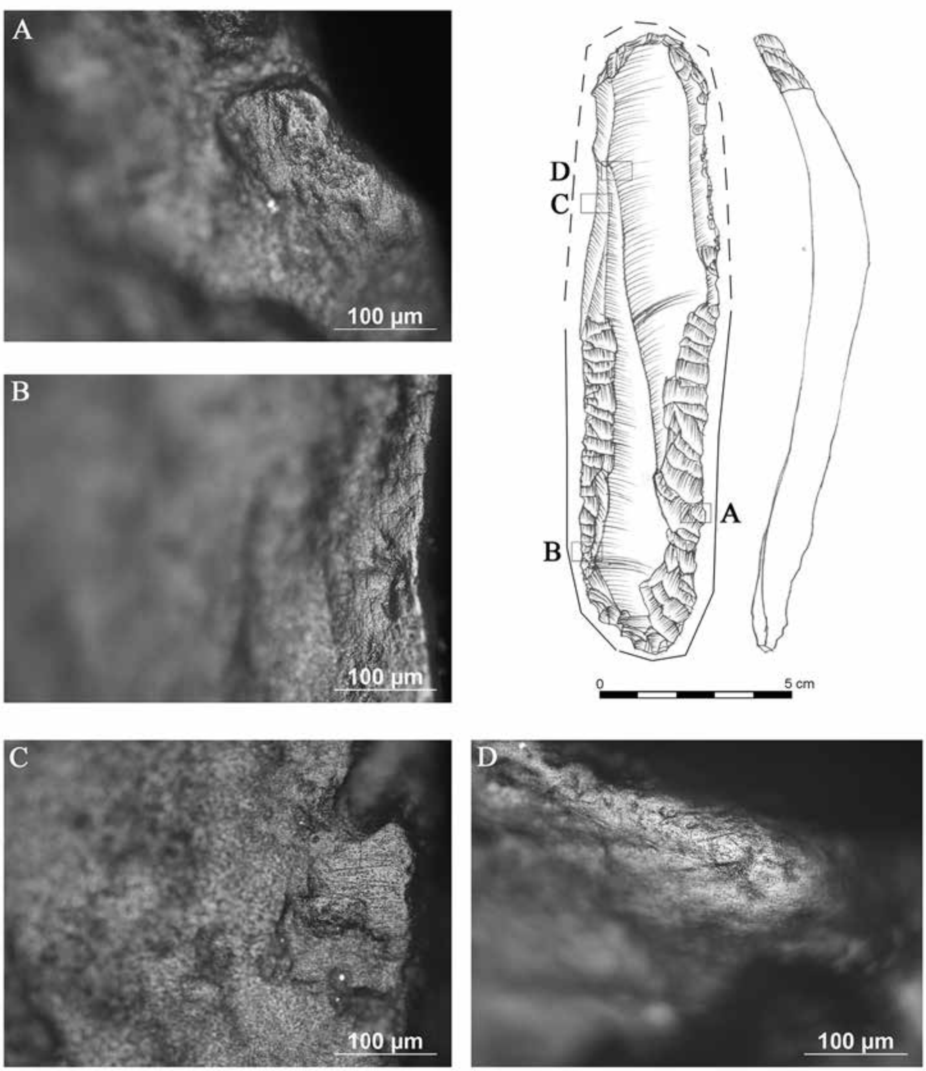

Fig. 6. Książnice, Busko-Zdrój district. Retouched blade from grave No. 15: A-B traces from contact with a sheath; C-D hafting traces? Drawing: J. Libera. Photo: B. Kufel-Diakowska.

Similarly worn was one of retouched blades from grave 15, also made of Volhynian flint. The right edge of the tool was intensively used. Traces of working leather and/or plant materials are perceptible on 2/3 of the edge's length (Fig. 5A-B). At that time in its use history the handle could have been placed at the distal part, where the edge

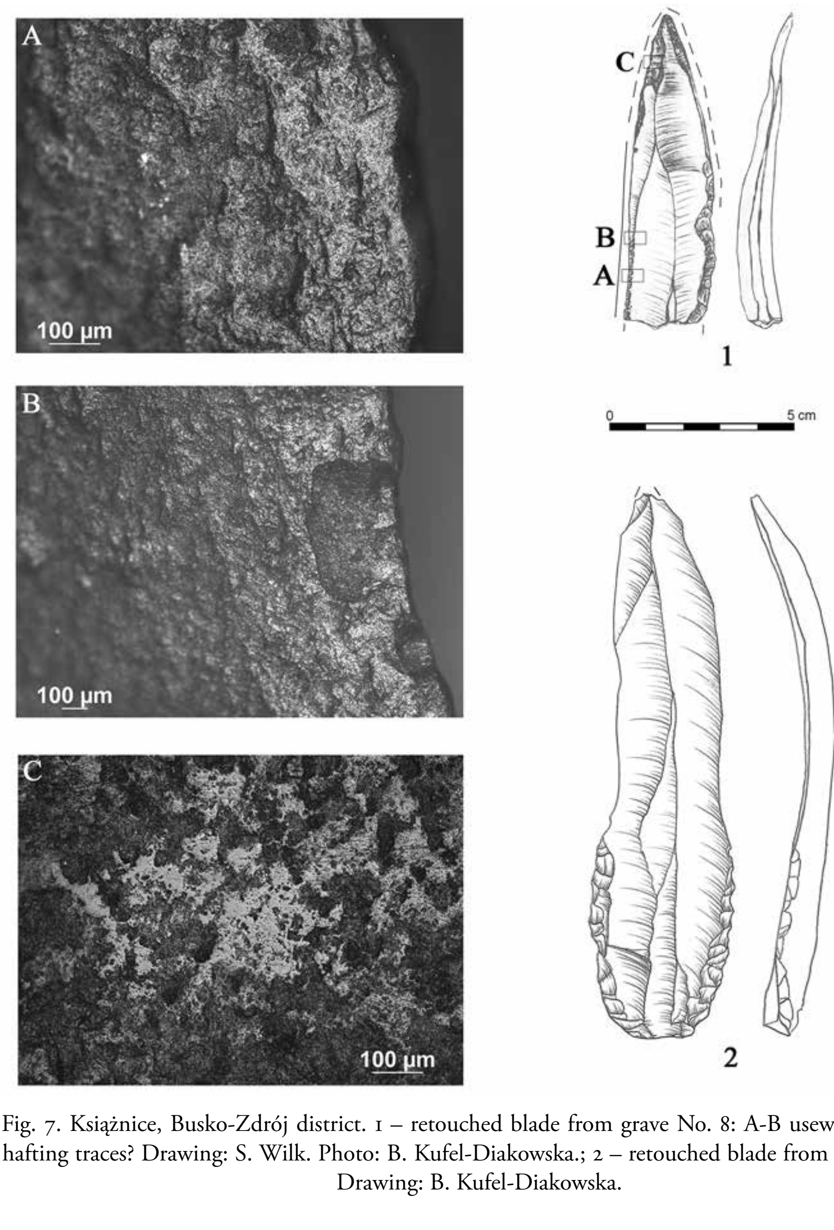

Fig. 7. Książnice, Busko-Zdrój district. 1 – retouched blade from grave No. 8: A-B usewear traces; C hafting traces? Drawing: S. Wilk. Photo: B. Kufel-Diakowska.; 2 – retouched blade from grave No. 17. Drawing: B. Kufel-Diakowska.

is chipped in many places, or at the left edge. The proximal part, shaped as a blunt perforator, bears traces of working hard mineral material (perhaps indicating fire production?; Fig. 5E; see Stapert and Johansen 1999: Figure 2). At some stage of the tool's use its proximal part was probably hafted, where the ridge is heavily rounded. In the distal part, on a fragment of the right edge and larger part of the left edge as well as on the ridge visible plant-like or leather-like polish was observed parallel to the tool axis (Fig. 5D, F), and the broken tip itself is heavily rounded (Fig. 5C). These traces could have been produced as a result of contact with organic sheath. It cannot be excluded that the left edge also had a utilitarian function because perpendicular and parallel traces indicative of working leather or plants were observed.

The second retouched blade from grave 15 is made on a largely incurved blade. Its tip, shaped as an end-scraper, bears no traces of use. On both edges parallel traces and polish indicate contact with leather or plant material (perhaps a sheath?; Fig. 6A-B). On the left edge both parallel and perpendicular striations occur, so it is difficult to identify which part could have been hafted (Fig. 6C). Most likely, the distal part was passive, because ridges in this area are heavily rounded and matte (Fig. 6D).

The microwear traces on the retouched blade discovered in grave 8 are not as distinct as observed on previously described three artefacts. The tip of this artifact, shaped as a perforator, bears no traces of use, and is only slightly rubbed. At this part of the tool there are bright spots of extensive distribution, although their origins are not clear (Fig. 7C). Traces of working soft materials were recorded on the left edge (Fig. 7A-B). A part of the right edge or the perforator-shaped distal part could have been hafted, because of the presence of the extensive bright spot. In addition, on small fragments of both edges, opposite each other, there are perceptible perpendicular traces and slight rounding.

The artefact from grave 17 is almost completely preserved, with secondary chippings evident on its unretouched part (Fig. 7: 2). The retouched blade bears no traces of use or other marks indicating that it was hafted or was kept in a sheath. Fragments of retouched edges are slightly rounded. Perhaps the proximal part of the tool was wrapped in a soft material, e.g. leather straps .

Despite the small number of analysed artefacts there are perceptible differences in state of their preservation, which is related to the length of use and the circulation of tools. Two of five specimens, both made of Volhynian flint analysed (graves 5 and 15) show very extreme microwear traces on their edges and surfaces, resulting from prolonged or intense use. These are both traces of use, in this case working leather and/or plants, probably fire production, as well as traces of contact with organic sheaths. The latter one is difficult to separate from traces of use, but limited distribution of polish on similar tools is emphasized (van Gijn 2010: 145-148; Grużdź *et al.*, 2015: 125-128).

The retouched blades made of chocolate flint are damaged in different ways. The microwear traces on the specimen with an end-scraper tip (grave 15) indicate contact with plant material or leather, possibly the result from use of the tool or from keeping it in a sheath. Another retouched blade discovered in man's grave 17 was probably made shortly before grave deposition, although we do not know with what intention. Regardless of whether it had a utilitarian or prestige role, it was very likely not made during the life of the man with whom the artefact was discovered, but after his death because it bears no traces of use, hafting or sheath. The artefact from woman's grave 8 differs from the others both in terms of form, as well as location in the grave. Differences are also perceptible in the manner of use of the tool and evidence for utilisation is not as obvious as in the case for other tools. This retouched blade could have served as the insert for a kind of general purpose tool.

Finally, it is worth noting that graves containing retouched blade daggers occurred in both in the eastern (the elite) part of sepulchral fields (grave 5), and in the central grave (17), between the eastern and the western (the poorer) part of sepulchral fields.

DISCUSSION

Of the five analysed flint artifacts, a techno-social definition of retouched blade daggers applies to only two: Ks/k/15/1/04 from grave 5 and Ks/k/20/14 from grave 17. The flint artifact from grave 12 (Ks/k/30/12), despite conforming to the technological definition of a retouched blade dagger, was not clearly associated enough with the burial to treat it in a similar way to artifacts from graves 5 and 17.

Results of the analysis of retouched blade daggers from Książnice provide an alternate perspective from which to approach the question of classification of wealth of graves containing these specimens. In the hierarchy of burial wealth in the Lublin-Volhynian culture retouched blade daggers appear both in rich and the richest graves, as well as in fairly rich and poor graves. Grave VI from site 1C in Gródek nad Bugiem scored 30 points (poor), grave 1 from site 3 in Tyszowce - 48 points (fairly rich), grave 4 from site Strzyżów - 26 - 75 points (rich), and grave 101 from site Grodzisko II in Złota as many as 336 points (the richest - off the scale; Zakościelna 2010: Table 47; therein also are the rules of evaluation and scoring). Grave 5 from Książnice was also included in the aforementioned hierarchy. It received 84 points and was listed as a class of very rich graves. Grave 17 would receive 39 points (poor).

If we accept that retouched blade daggers were symbols of a privileged social status of men who wore them, it is not necessarily the case that status was always expressed in a wealth of a grave. We can suppose that people who played important social roles in the Lublin-Volhynian culture may not have been assigned exclusively as either rich or poor representatives of the society.

CONCLUSIONS

Based on the usewear analysis we conclude that most of the retouched blades examined played utilitarian roles and were intensively used. The long-term use applies mainly the retouched blade-daggers, especially those made from Volhynian flint. It should be noted that these artefacts likely were multi-purpose, so a specific function cannot be attributed to them. Similar artifacts, discovered in regions distant from sources of raw materials, are also heavily worn in many different ways (Beugnier and Plisson 2000). The presence of traces of an intense use of the retouched blades from Książnice, as well as traces of other activities which might be of more than utilitarian nature, indicates that the long-term circulation carried both an economic and a symbolic significance. It is also worth noting the manner of the retouched blades' use – according to Beugnier and Plisson (2000) reflecting male activities. Microwear traces indicate contact with only certain raw materials, such as plant or leather, and mineral in one case. By contrast, the tool made of chocolate flint found in a woman's grave does not belong to this group. It bears traces of use as a knife's insert, laterally or apically hafted. Similarly worn flint artefacts were deposited in women's graves discovered in a burial ground in Domasław (Kufel-Diakowska *et al.*, 2016).

Finally, it is worth noting that graves containing retouched blade daggers occurred in both in the eastern (the elite) part of sepulchral fields (grave 5), and in the central grave (17), between the eastern and the western (the poorer) part of sepulchral fields.

Since only one of the graves (no. 8) has been radiocarbon dated at the present time we cannot address the chronological range and the duration of use of the sepulchral complex of the Lublin-Volhynian culture at Książnice. Whether these two grave containing the prestige flint artefacts are contemporary or whether they represent two different chronological phases of the burial ground remains an open question.

REFERENCES

Beugnier, V. and Plisson, H. 2000. Les poignards en silex: du Grand-Pressigny: fonction de signe et fonction d'usage. In. P. Bodu and C. Constantin (eds), *Approches fonctionelles en préhistoire. Actes du XXVe Congrès Préhistorique de France (24-26 novembre 2000, Nanterre)*, 139–154. Paris.

van Gijn, A.L., 2010. *Flint in focus. Lithic Biographies in the Neolithic and Bronze Age*. Leiden.

Gróżdź, W., Migal, W. and Pyżewicz, K. 2015. Bifacial flint daggers from the Early Bronze Age in Volhynia - Lesser Poland. In B.V. Eriksen and K. Frieman (eds), *Flint daggers in prehistoric Europe*, 116–132. Oxbow.

Kufel-Diakowska, B., Wiśniewski, A. and Chłoń, M. 2016. Wyroby ze skał krzemionkowych w pochówkach kultury jordanowskiej stanowiska Domasław, *Archeologiczne Zeszyty Autostradowe*, 18, *Badania na autostradzie A-4*, part XIV. Wrocław.

Skakun, N. 2008. Comprehensive analysis of prehistoric tools and its relevance for paleo-economic reconstructions. In L. Longo and N. Skakun (eds), Prehistoric Technology 40 years later: Functional Studies and the Russian Legacy, *Proceedings of the International Congress Verona (Italy), 20-23 April 2005*, 358–364. Oxford.

Stapert, D. and Johansen, L. 1999. Making fire in the Stone Age: Flint and pyrite, *Geologie en Mijnbouw* 78: 147–164.

Wilk, S. 2006. Graves of the Lublin-Volhynian culture at site 2 in Książnice, district of Busko Zdrój. 2004 exploration season. *Sprawozdania Archeologiczne* 58: 247–270.

Wilk, S. 2014. An elite burial from the Copper Age: Grave 8 at the cemetery of the Lublin-Volhynian culture at Site 2 in Książnice, the Świętokrzyskie province. *Analecta Archaeologica Ressoviensia* 9: 209–258.

Zakościelna, A. 2006. Flint inventory of grave 5 of the Lublin-Volhynia culture on site 2 in Książnice, Busko Zdrój district. *Sprawozdania Archeologiczne* 58: 271–291.

Zakościelna, A. 2008. Wiórowce-sztylety jako atrybuty pozycji społecznej mężczyzn kultury lubelsko--wołyńskiej. In J. Bednarczyk, J. Czebreszuk, P. Makarowicz and M. Szmyt (eds), *Na pograniczu światów. Studia z pradziejów międzymorza bałtycko- pontyjskiego ofiarowane Profesorowi Aleksandrowi Kośko w 60. rocznicę urodzin*, 577–591. Poznań.

Zakościelna, A. 2010. *Studium obrządku pogrzebowego kultury lubelsko-wołyńskiej*. Lublin.

Zakościelna, A. and Prusicka-Kołcon, E. 2006. Grób kultury lubelsko-wołyńskiej ze stanowiska 1 w Gozdowie, pow. hrubieszowski. *Archeologia Polski Środkowowschodniej* 8: 243–251.

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Early Neolithic flint mining at Södra Sallerup, Scania, Sweden

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The area around the villages of Kvarnby and Södra Sallerup in south-west Scania is the only known flint-mining site in Sweden. Radiocarbon dates show that the flint was mined mainly during the earliest phase of the Early Neolithic, between *c.* 4000 and 3600 BC, thus coinciding with the earliest evidence of the Funnel Beaker Culture in the region. The type of flint, the size of the flint nodules, production debris in the mining area and the concentration of point-butted axes to south-west Scania all suggest that the mining was related to the extraction of flint for the production of point-butted axes. However, considering the abundance of easily available flint elsewhere in the region, it seems clear that the mining was not motivated purely by economic reasons. We suggest that the very extraction of flint from pits and shafts in the chalk was socially and symbolically significant in itself.

KEY-WORDS: Early Neolithic, flint mining, southern Sweden, point-butted axes

INTRODUCTION AND HISTORY OF RESEARCH

The area around the villages of Kvarnby and Södra Sallerup, located two kilometres apart and about ten kilometres east of the city of Malmö in south-west Scania (Fig. 1a), is the only known location of prehistoric flint-mining in Sweden (Olausson *et al.*, 1980). It was in connection with chalk quarrying that the flint mines were first discovered in 1904 (Holst 1906). This led to a limited number of excavations during the first part of the 20th century (Schnittger 1910; Althin 1951). During the latter part of the 20th century the area experienced escalating rescue archaeological activity and systematic documentation and

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excavation of prehistoric mining areas was initiated in the late 1960s (Salomonsson 1971: 127–129). Archaeological excavations took place almost every year between 1977 and 1998 in the Södra Sallerup area (Fig. 1b), instigated by threats from chalk quarrying (Olausson *et al.*, 1980; Rudebeck 1986, 1987, 1994, 1998; Nielsen and Rudebeck 1991), excavations for gas pipelines, the building of local roads (Rosberg and Sarnäs 1996), and highway construction for the Öresund Fixed Link (*e.g.* Nilsson and Onsten-Molander 2004; Kishonti 2006). In addition to the flint mines, substantial settlement remains from all periods from the Early Neolithic to the Medieval Period have been documented, indicating continuous human settlement in the area. Chalk quarrying operations ceased in 1998 but the city of Malmö continues to grow and the most recent excavation was performed in 2014, due to a building project on the estate Pilbladet (marked with **P** in Fig. 1b; Berggren, in prep.).

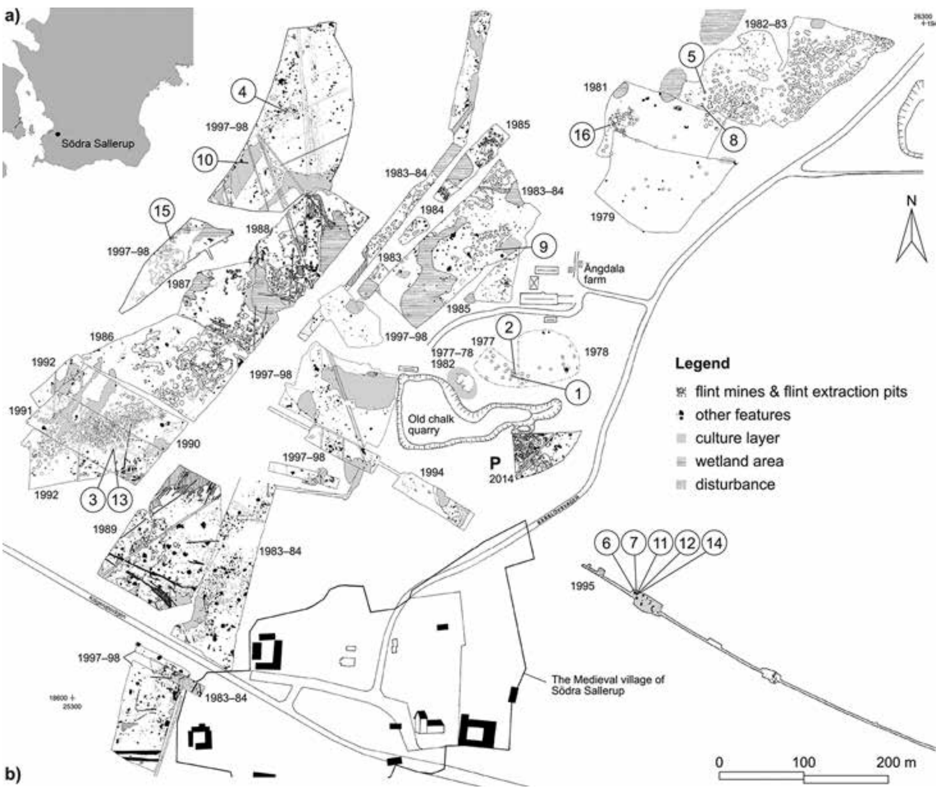


Fig. 1. (a) The location of the flint mine area of Södra Sallerup in Scania in Southern Sweden. (b) The archaeologically excavated areas are marked with the year of excavation. The most recent area excavated, Pilbladet, is marked with **P**. The numbers 1–16 indicate dated flint mines and other features from excavated areas around Pilbladet, corresponding to the dates with the same numbers in Fig. 6. Illustration: Map by Elisabeth Rudebeck, revised by Anders Gutehall and Joakim Frejd, Sydsvensk Arkeologi.

No synthesis on the Early Neolithic flint mining in the area is presently available. However Rudebeck will commence work with a comprehensive synthesis of evidence from all excavations in the Södra Sallerup area in 2016.

Rough estimates show that the flint mining areas documented since 1977 in the Södra Sallerup area covered *c.* 215,000 sq m (shown in Fig. 1b), with an additional *c.* 200,000 sq m removed by chalk quarrying in the whole Kvarnby – Södra Sallerup area prior to 1977 without previous archaeological investigation (Rudebeck 1994). This destruction was the reason for the Swedish National Heritage Board's decision in the early 1980s to protect an area with about 400 flint mines from future land development. As the area had been stripped of topsoil, it was possible to document the mines by aerial photography and mapping and to excavate a few mines and flint knapping floors (the north-eastern mining area in Fig. 1b; cf. Fig. 2a; Rudebeck 1987, 1994; Högberg *et al.*, 2001). The methods used for documentation of the flint mining areas have changed profoundly between the 1970s and the present; the most recent ones are illustrated in Fig. 2b.[1]

[1] In order to evaluate these methods, a research project will be conducted in 2015–2016 (by Åsa Berggren and Anders Gutehall, Sydsvensk Arkeologi).

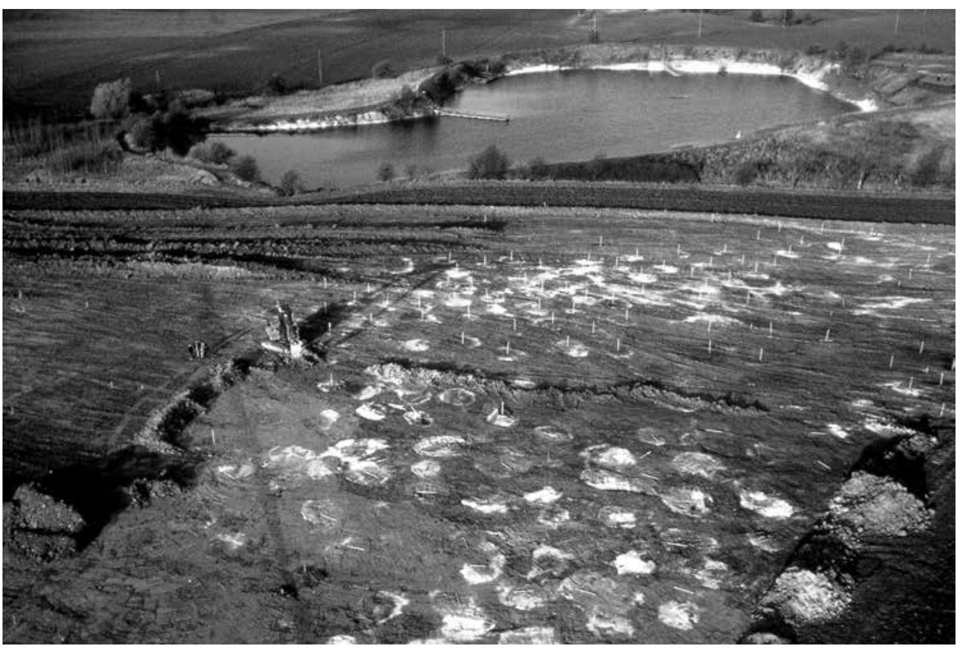


Fig. 2a. Aerial photo of uncovered flint mines in the north-eastern part of Södra Sallerup, 1982. These mines were documented, but not excavated and are now protected by the Swedish National Heritage Board. Photo: Lena Wilhelmsson, Malmö museer.

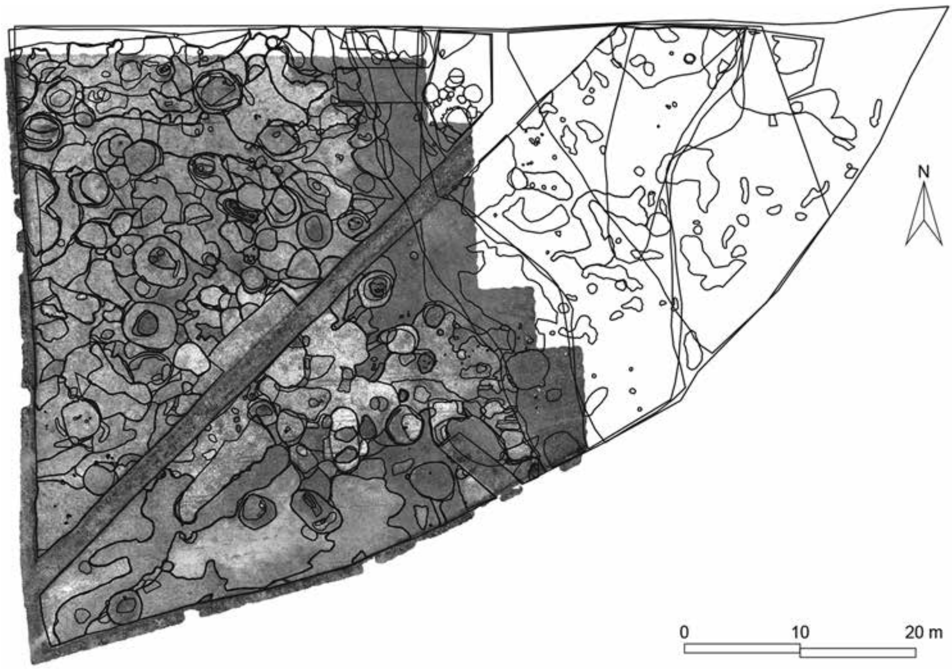


Fig. 2b. During the most recent excavation in 2014 at Pilbladet, a combination of methods was used to document the flint mines in plan, such as hand drawing, digital planning with GPS and orthophotography. The combined result of these documentation methods is shown here. The flint mines were confined to the western part of the excavated area, while the eastern part contained other types of features. Figure: Åsa Berggren and Anders Gutehall, Sydsvensk Arkeologi.

GEOLOGY AND ITS EFFECT ON MINING ACTIVITIES

Visual and geochemical provenience analyses show that flint from the chalk at Södra Sallerup is comparable to Senonian flint of Maastrichtian age from geological deposits in eastern Denmark and northern Jutland (Högberg and Olausson 2007; Hughes *et al.*, 2012). However, the geology of Södra Sallerup is different compared to other north European flint mining sites (e.g. Allard *et al.*, 2008). The chalk is not *in situ*; rather, the enormous chalk slabs were transported by glacial movement, deposited at the site as the ice melted, and subsequently covered by glacial till (Ringberg 1980). This affected prehistoric flint mining in three main ways: 1) the chalk is not solid and therefore it was not possible to dig horizontal galleries, but only minor extensions into the chalk (Fig. 3); 2) the flint nodules are unevenly distributed in the chalk, making it difficult to predict the yield; 3) the glacial till is rich in secondary flint (especially from Maastrichtian and Danian periods) which also was exploited by prehistoric people.

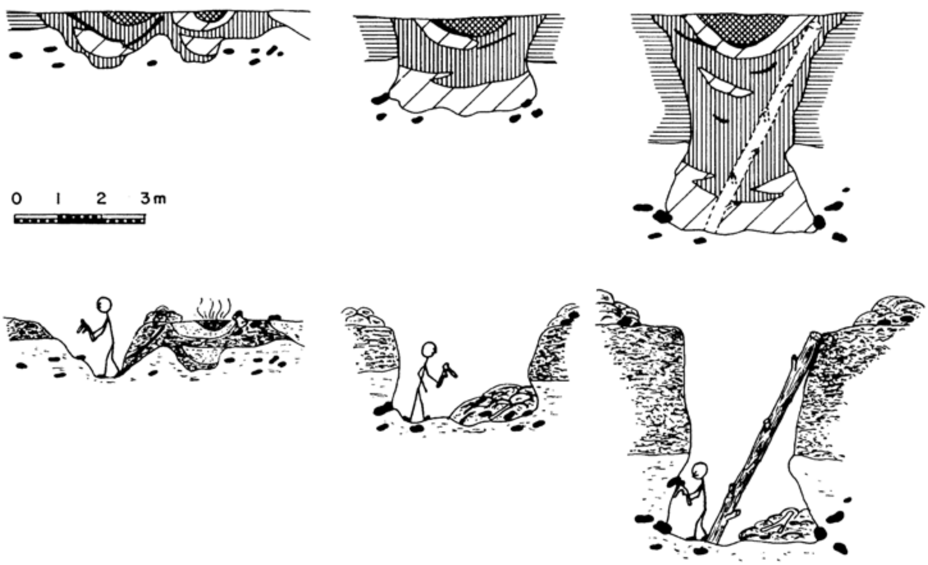


Fig. 3. A generalised sketch of the various types of flint mines at Södra Sallerup. The shallow open-cast pit type is shown to the left, the medium-sized type in the middle and the deeper mine shaft type to the right. Illustration: Elisabeth Rudebeck, Sydsvensk Arkeologi.

MINING METHODS AND TOOLS

The depth of flint extraction pits varies from one meter to about seven metres, depending on the thickness of the overlying clayey till and the occurrence of occasional intermixing layers of sand and gravel (Fig. 3 and 4). Pit diameter varies from one and a half to six metres. The shallow pits were often dug in direct proximity to each other, allowing deposition of the clay and chalk in the neighbouring exhausted pits. This open-cast mining created large areas, typically where the chalk was close to the surface, where the surface was entirely excavated. The deeper pits – often located at the periphery of open-cast areas where the chalk was more deeply buried – were probably also refilled soon after flint extraction was completed (Rudebeck 1987: 153). This is indicated by the fact that the fill in the lower parts of the deeper pits usually consists of almost pure chalk, indicating that each pit was refilled with the extracted material and not with material from adjacent pits. However, substantial volumes of clay and chalk must have been left on the surface because of the inevitable 'expansion' of the material removed. Therefore, the mines would have been surrounded by spoil heaps that subsequently became overgrown by vegetation and the landscape would have been characterised by a very uneven surface long after flint extraction had been discontinued.

Fig. 4. A flint mine during excavation in 2014. The large pit is half-sectioned using a mechanical excavator. Photo: Åsa Berggren, Sydsvensk Arkeologi.

The tools associated with the flint extraction are roughly-shaped flint picks, red deer antler picks (Fig. 5), wooden wedges and composite tools made from wooden handles, antler sockets, and pointed flint picks (Rudebeck 1986; Nielsen and Rudebeck 1991). Scapulae of red deer and cattle were used as shovels. Holes in the chalk walls of mines have been interpreted as the remains of structures of wood, such as ladders and platforms (Olausson *et al.*, 1980: 193; Rudebeck 1986: 8).

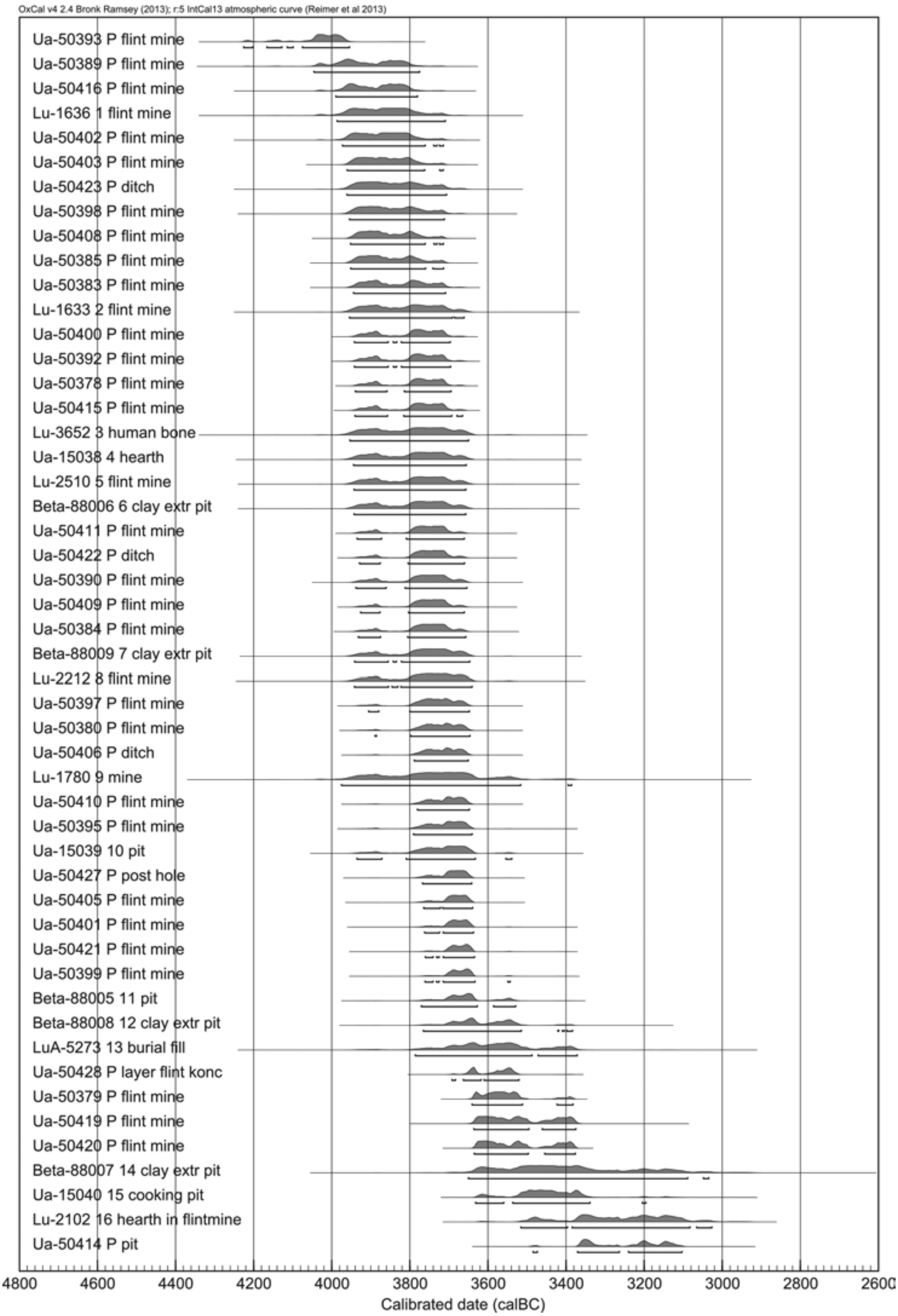
THE CHRONOLOGY AND STRUCTURE OF MINING ACTIVITIES

The dating of the flint mining activity was a matter of debate until the first radiocarbon dates of charcoal from pit contents excavated in the late 1960s and the 1970s showed mainly Early Neolithic dates, coinciding with the appearance of the Funnel Beaker Culture in the region (*c.* 4000–3600 BC), but also dates to the Middle Neolithic (Nielsen and Rudebeck 1991). In addition, a few tools and some flint knapping debris interpreted as dating to the Late Mesolithic indicate that flint extraction may have occurred prior to the Early Neolithic (Nilsson and Onsten-Molander 2004: 48f, 70ff). However, subsequent radiocarbon dating, in particular extensive sampling

Fig. 5. A red deer antler pick *in situ* in a flint mine excavated in 1978.
Photo: Ulf Säfvestad, Malmö museer.

from the recent excavation at Pilbladet (indicated by **P** in Fig. 1b and 6), confirmed that the main period of flint extraction occurred during the earliest Early Neolithic.

The samples dated to the Early Neolithic were taken both from the lower fill in flint mines, from open-cast pits and from other features such as hearths and pits, thus dating the flint extraction itself as well as other contemporary activities (Fig. 1b and 6). The dated material is mainly charcoal and hazelnuts, but also human bone from a burial in one mine (Lu-3652) and emmer wheat from a pit (Ua-50414). Equally early radiocarbon dates have been obtained from a flint mine in the Kvarnby area, one kilometre south-west of Södra Sallerup, indicating that flint extraction was taking place simultaneously over a larger area (Rudebeck 1994: 12).


OxCal v4 2.4 Bronk Ramsey (2013); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
Ua-50393 P flint mine
Ua-50389 P flint mine
Ua-50416 P flint mine
Lu-1636 1 flint mine
Ua-50402 P flint mine
Ua-50403 P flint mine
Ua-50423 P ditch
Ua-50398 P flint mine
Ua-50408 P flint mine
Ua-50385 P flint mine
Ua-50383 P flint mine
Lu-1633 2 flint mine
Ua-50400 P flint mine
Ua-50392 P flint mine
Ua-50378 P flint mine
Ua-50415 P flint mine
Lu-3652 3 human bone
Ua-15038 4 hearth
Lu-2510 5 flint mine
Beta-88006 6 clay extr pit
Ua-50411 P flint mine
Ua-50422 P ditch
Ua-50390 P flint mine
Ua-50409 P flint mine
Ua-50384 P flint mine
Beta-88009 7 clay extr pit
Lu-2212 8 flint mine
Ua-50397 P flint mine
Ua-50380 P flint mine
Ua-50406 P ditch
Lu-1780 9 mine
Ua-50410 P flint mine
Ua-50395 P flint mine
Ua-15039 10 pit
Ua-50427 P post hole
Ua-50405 P flint mine
Ua-50401 P flint mine
Ua-50421 P flint mine
Ua-50399 P flint mine
Beta-88005 11 pit
Beta-88008 12 clay extr pit
LuA-5273 13 burial fill
Ua-50428 P layer flint konc
Ua-50379 P flint mine
Ua-50419 P flint mine
Ua-50420 P flint mine
Beta-88007 14 clay extr pit
Ua-15040 15 cooking pit
Lu-2102 16 hearth in flintmine
Ua-50414 P pit
4800 4600 4400 4200 4000 3800 3600 3400 3200 3000 2800 2600
Calibrated date (calBC)

Based on calculations of the density of mines in the archaeologically documented areas and the extent of old chalk quarries, it has been estimated that there may originally have been thousands of mining pits in the Södra Sallerup area, probably 7000 or more (Nielsen and Rudebeck 1991: 67). Assuming that most mines were dug during the main phase of mining activity, a rough calculation is that 17–18 mines may have been dug every year (7000/400=17.5). However, it is likely that the intensity of mining varied within the time span of the 400 years of the Early Neolithic.

The interpretation of the spatio-temporal patterns in the mining area is inevitably biased by the fact that 68 % of the dates are from the most recent excavation at Pilbladet (Fig. 1b and 6), which constitutes a mere two percent of the documented area in Södra Sallerup. Taking this into account, the dates obtained from other mines in the area still indicate that the earliest extraction activities were simultaneously in progress at several places, or at close time intervals. Hence, it seems likely that flint mining activity was not initiated in just one place and fanned out from there over time, but rather that it was going on simultaneously over the entire area. The fact that the dates from adjacent pits may be separated by a couple of hundred years suggests that the flint miners probably returned to, or kept working in, certain areas. The dates also indicate that open-cast mining in shallow pits and mining in deep shafts occurred simultaneously from the very beginning. The patterning indicates that the mining operations were not subsumed under a central authority.

PRODUCTION

The flint in the chalk at Södra Sallerup was attractive for the knapper because it is glassy and easily worked (Högberg and Olausson 2007: 88–91). The majority of the flakes bear cortex, signalling that early manufacturing stages were carried out in the mining area (Fig. 7). However, as would be expected at a production site, few blanks or completed pieces are present (Rudebeck 1986: 29–35; Nielsen and Rudebeck 1991: 77). It is significant that the nodules available were not particularly large. Rudebeck (1998: 323–324) determined that only 10–15 % of the nodules from four test pits dug into the chalk were suitable in shape and size for the production of axe blades.

Per Jansson's analysis of debitage from two knapping floors in the preserved mining area revealed few flakes that were diagnostic of either of the two production schemes most common in the Neolithic: quadrifacial axehead production on the

Fig. 6. Radiocarbon dates showing the main period of flint mining in the Södra Sallerup area. The radiocarbon dates numbered 1–16 are from mines and other features in various excavated areas at Södra Sallerup, corresponding to the same numbers in Fig. 1b. The majority of radiocarbon dates, marked with **P**, are taken from mines and other features at Pilbladet, marked with **P** in figure 1b.

Fig. 7. A selection of flint debris from a mine at Södra Sallerup is being sorted.
Photo: Åsa Berggren, Sydsvensk Arkeologi.

one hand, and bifacial production leading to sickles or daggers on the other. Instead, he proposed that point-butted flint axes were the production target (Jansson 1999). This is supported by the concentration of point-butted axes, particularly the earliest type (type 1), in southwestern Scania (Sørensen 2014: 162–175). However, the mined flint was also used in the mining area for the production of tools such as flake axes, borers, scrapers and transverse arrowheads (Olausson *et al.*, 1980; Rudebeck 1986; Nielsen and Rudebeck 1991).

Högberg showed that flint in the area was also used in the Late Bronze Age for the production of large blade knives. However, it has not been proven that the flint used for these knives was actually mined during the Late Bronze Age, rather than the alternative possibility of being acquired from Neolithic waste dumps (Högberg 2009: 201–205).

MINERS' CAMPS AND SETTLEMENTS

Traces of Early Neolithic huts and tents as well as hearths, pits and cultural layers in and around the flint mining area have been interpreted as settlements connected to the mining operations. The find material is rich and, in addition to flint tools of various types, Funnel Beaker Culture pottery occurs, mainly of the Oxie-type (Rudebeck 1986). There is also a sizeable collection of animal bones, revealing the presence of cattle, domestic pig, sheep, goat, and dog, but also wild species, notably red deer, and fish, mainly cod (Nilsson 1991). It is not clear whether these settlements were short term and perhaps seasonal camps or whether they were more permanently inhabited.

However, there is one site in the vicinity from which there is substantial evidence to indicate a direct link to the flint mining area. This is the contemporary gathering site of Almhov, located *c.* 11 kms south-west of Södra Sallerup, which was excavated in 2001–2003. From this site we have some of the earliest dates of cereals in southern Scandinavia (Gidlöf *et al.*, 2006; Rudebeck 2010; Sørensen 2014: 74), and recent isotope analyses on cattle teeth from animals that have been indirectly dated to the same period indicate Early Neolithic dairying (Gron *et al.*, 2015).

Of the roughly 320 Early and Middle Neolithic features on the Almhov site, the majority were dated to the earliest phase of the Early Neolithic. Among these were long barrows and dolmens. The earliest features were *c.* 200 pits, many of which occurred in pairs, indicating specific norms for dwelling, pit use and waste deposition. Scattered cranial bones suggest that animal heads or crania were on display adjacent to the pits (Rudebeck and Macheridis 2015).

The Early Neolithic features at Almhov contained 700 kg of worked flint, mainly Scandinavian Senonian flint, including point-butted axes, drills, scrapers, flake axes, transverse arrowheads, blades and debitage from the manufacture of bifacial and quadrifacial objects. Forty point-butted axes, more or less fragmentary, were found, making this the largest known assemblage of this axe type at any one site in southern Scandinavia (Gidlöf *et al.*, 2006; Rudebeck 2010). Many axes retain small patches of cortex, which could have been a means of demonstrating that the flint originated from mines rather than from till or beach deposits (cf. Rudebeck 1998). In conclusion, the dates as well as the many similarities in the material suggests that the same people who extracted flint at Södra Sallerup also brought it to Almhov for the production of point-butted axes and other tools to be used and exchanged during seasonal gatherings (Rudebeck 2010).

THE SOCIAL AND CULTURAL CONTEXT OF THE EARLY NEOLITHIC FLINT MINING AT SÖDRA SALLERUP

Members of Early Neolithic society had access to a vast variety of high quality flint types in the glacial till, on beaches and at stream banks in southern Sweden and eastern Denmark (Högberg and Olausson 2007: 54–62). In fact, there is evidence for extensive flint extraction and axe preform production at beach-ridges along the south-western coast of Sweden, and one of these sites is within an hours' walk from Södra Sallerup (Högberg 2002). Hence, a shortage of high-quality flint was not the reason for digging through the till and chalk at Södra Sallerup (Högberg *et al.*, 2001). It is more likely that motivations for the mining of flint in the early Funnel Beaker Culture context were social and symbolic as well as practical and economic. This is indicated by the links between the flint mines and the gathering site of Almhov as well as by the fact that the deposition of point-butted Senonian flint axes in wetland areas appears to have been particularly concentrated in southwestern Scania (Karsten 1994: 54; Rudebeck 1998; Sørensen 2014: 162–175). Based on the overall similarities in the flint mining techniques within the Michelsberg Culture and the early Funnel Beaker Culture of southern Scandinavia, Lasse Sørensen has suggested that the practice of deep flint mining was introduced to Scandinavia in connection with the immigration of farmers from the Michelsberg Culture (Sørensen 2014: 174). Apart from flint mining techniques, further similarities between the earliest Funnel Beaker Culture (the Oxie-group) and the Michelsberg Culture include cereal types, domestic animal species, point-butted flint axes, pottery styles, the practice of displaying animal heads or crania on settlements and the building of long-barrows. However, there also are differences: e.g. bifacial arrowheads dominate in the Michelsberg Culture (although transverse arrowheads do occur), while transverse arrowheads (usually made from flakes) are characteristic of the Funnel Beaker Culture. This suggests that traditions from the Ertebølle Culture were an integral part of the early Funnel Beaker Culture in southern Scandinavia. Whether this was due to cultural choices among immigrants, a result of the mixing of populations, or a continued tradition among local populations that otherwise adopted new customs, is an issue that remains to be explored.

REFERENCES

Allard, P., Bostyn, F., Giligny, F. and Lech, J. (eds) 2008. *Flint Mining in Prehistoric Europe. Interpreting the archaeological records*. Oxford. British Archaeological Reports, International Series 1891.

Althin, C.-A. 1951. The Scanian Flint Mines. *Meddelanden från Lunds Universitets Historiska Museum* 1951:139–158.

Berggren, Å. In preparation. *Pilbladet. Södra Sallerup socken, Malmö kommun. Arkeologisk undersökning 2014*. Malmö.

Gidlöf, K., Hammarstrand Dehman, K. and Johansson, T. 2006. *City tunnel projektet Almhov – delområde I*. Malmö.

Gron, K., Montgomery, J. and Rowley-Conwy, P. 2015. Cattle Management for Dairying in Scandinavia's Earliest Neolithic. *PLoS ONE* 10(7): e0131267. doi:10.1371/journal.pone.0131267.

Högberg, A. 2002. Production sites on the beach ridge of Järavallen. Aspects on tool preforms, action, technology, ritual and the continuity of place. *Current Swedish Archaeology* 10: 137–162.

Högberg, A. 2009. *Lithics in the Scandinavian Late Bronze Age. Sociotechnical Change and Persistence*. Oxford. British Archaeological Reports, International Series 1932.

Högberg, A., Apel, J., Knutsson, K., Olausson, D. and Rudebeck, E. 2001. The spread of flint axes and daggers in Neolithic Scandinavia. *Památky Archeologické* 42 (2):193–221.

Högberg, A. and Olausson, D. 2007. *Scandinavian Flint. An Archaeological Perspective.* Aarhus.

Holst, N.O. 1906. Flintgrufvor och flintgräfvare i Tullstorpstrakten. *Ymer* 1906 (2):139–174.

Hughes, R.E., Högberg, A. and Olausson, D. 2012. The chemical composition of some archaeologically significant flint from Denmark and Sweden. *Archaeometry* 54 (5): 779–795.

Jansson, P. 1999. *Ängdalas gåta – Vad yxade man till vid flintgruvorna?* Unpublished BA thesis, Lund University.

Karsten, P. 1994. *Att kasta yxan i sjön. En studie över rituell tradition och förändring utifrån skånska neolitiska offerfynd*. Lund.

Kishonti, I. 2006. *Öresundsförbindelsen Södra Sallerup 15H*. Malmö.

Nielsen, B. and Rudebeck, E. 1991. Introduktion till arkeologi i Södra Sallerup. *Elbogen* 58: 64–97.

Nilsson, L.M.I. 1991. Analys av benmaterial från två tidigneolitiska gropar. *Elbogen* 58: 104–107.

Nilsson, A. and Onsten-Molander, A. 2004. *Öresundsförbindelsen Södra Sallerup 15F & I*. Malmö.

Olausson, D., Rudebeck, E. and Säfvestad, U. 1980. Die südschwedischen Feuersteingruben – Ergebnisse und Probleme. In G. Weisgerber, R. Slotta and J. Weiner (eds), *5000 Jahre Feuersteinbergbau*, 183–204. Bochum.

Ringberg, B. 1980. *Beskrivning till Jordartskartan Malmö SO*. Uppsala. Sveriges Geologiska Undersökning Serie Ae Nr 38.

Rosberg, A. and Sarnäs, P. 1996. En tidigneolitisk boplats i Södra Sallerup. *Elbogen* 1996: 7–21.

Rudebeck, E. 1986. *Ängdala. Flintgruvor från yngre stenåldern, S. Sallerup. Utgrävningar 1977–81. Rapport 1*. Malmö.

Rudebeck, E. 1987. Flintmining in Sweden during the Neolithic period: new evidence from the Kvarnby-S. Sallerup area. In G. de G. Sieveking and M. Newcomer (eds), *The Human Uses of Flint and Chert*, 151–157. Cambridge.

Rudebeck, E. 1994. Ängdala och meningen med arkeologin. *Arkeologi i Sverige* 3: 7–40.
Rudebeck, E. 1998. Flint extraction, axe offering, and the value of cortex. In M. Edmonds and C. Richards (eds), *Understanding the Neolithic of North-western Europe*, 312–327. Glasgow.
Rudebeck, E. 2010. I trästodernas skugga – monumentala möten i neolitiseringens tid. In B. Nilsson and E. Rudebeck (eds), *Arkeologiska och förhistoriska världar*, 83–262. Malmö.
Rudebeck, E. and Macheridis, S. 2015. The proper way of dwelling at the Early Neolithic gathering site of Almhov in Scania, Sweden. In K. Brink, S. Hydén, K. Jennbert, L. Larsson and D. Olausson (eds), *Neolithic Diversities. Perspectives from a conference in Lund, Sweden*, 173–187. Lund.
Salomonsson, B. 1971. Malmötraktens förhistoria, In O. Bjurling, B. Salomonsson, L. Tomner and E. Bager (eds), *Malmö Stads Historia. Första delen*, 13–170. Malmö.
Schnittger, B. 1910. Förhistoriska flintgrufvor och kulturlager vid Kvarnby och S. Sallerup i Skåne. *Antikvarisk Tidskrift för Sverige* 1910 (19):1–101.
Sørensen, L. 2014. *From Hunter to Farmer in Northern Europe*. Volume I. Oxford.

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The use of erratic stone by the communities of the Linear Pottery culture: a view from the excavations in Kostomłoty, site 27, province of Lower Silesia[1]

Mirosław Furmanek[a] and Mirosław Masojć[b]

The settlement of the Linear Pottery culture population documented in Kostomłoty, Środa Śląska district, consisted of characteristic longhouses accompanied by various pits forming isolated households. Seven such complexes were observed within the excavated area as well as a complex of spacious dug-out features differing from typical Linear Pottery culture pits. The analysis of the flintworking from this settlement provides new data on the function of this aspect of manufacturing and its context in the first farming communities in Silesia. The unusual character of flintworking in the settlement in Kostomłoty is attributed to being a probable result of the settlement's marginal location in relation to the centre of Linear Pottery culture settlement.

KEY-WORDS: erratic stone, Linear Pottery culture, Lower Silesia

The multicultural site of Kostomłoty (no. 27), Środa Śląska district, is located in south-western Poland at the fork of two small watercourses in a flat upland about 155-160 metres above sea level (see Figure 1). In the north and the west it borders on a denuded, undulating upland 160-170 metres above sea level, while in the east and the south it borders on a denuded, hilly upland about 170-185 metres in elevation. The region is a part of the Sudetic block, which subsided when it was formed by the tectonic processes in the Tertiary made of Old-Palaeozoic phyllite-schist and volcanic complex. During the Tertiary, sedimentation of predominantly argillaceous-sandy-dusty deposits occurred in the crevices, which appeared as a result of tectonic activity. The deposits include Miocene clays of the Poznan series as well as sands and gravel with kaolinite of the Gozdnica series. These are

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covered by Quaternary deposits, which in this case are made of glacial clays, whose thickness reaches 1 metre, accompanied by moraine pavements and fluvio-glacial sands and gravels. The top layer of the deposits is made up of rich dust formations with the admixture of dispersed humus (0.2 – 1.5 m thick), which are loess clays heavily transformed by soil processes, as well as by the humus level of contemporary soil (Szynkiewicz 2003).

The site was discovered during the excavations carried out as part of the Polish Archaeological Record (AZP) project in 1995. In 2002, during archaeological supervision of repairs of the southern road of the A4 motorway, several objects connected with the Linear Pottery culture (LPC) settlement were discovered and explored in the vicinity of the site (Wojciechowski 2003) and, three years later during the repairs of the northern road of the motorway, the team responsible for the archaeological supervision decided to conduct rescue excavations in an area larger than previously anticipated. Ultimately, excavations were completed over an area of 314.45 ares (ca. 7.8 acres; Fig. 1), which yielded 823 unmov-

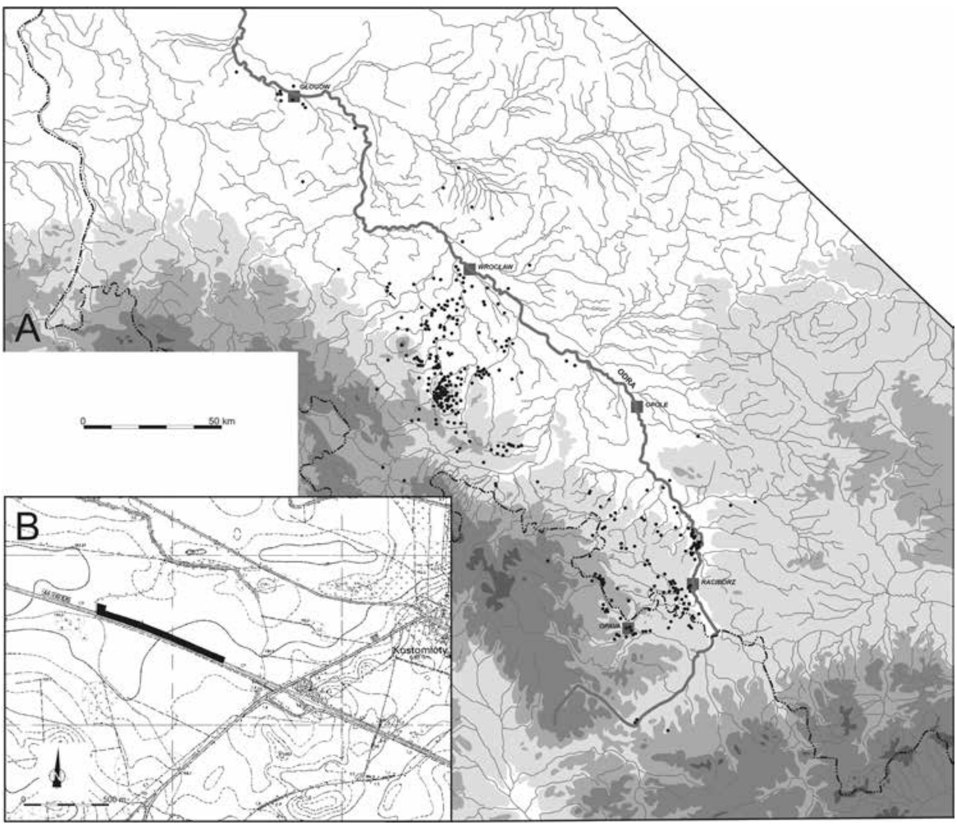

Figure 1. Map of location of LPC sites in south-western Poland (A) – the arrow marks site 27 in Kostomłoty, Środa Śląska district, and location of the trench from 2005 (B).

able objects diagnostic of six stages of the site's settlement – the settlements from Linear Pottery culture, Unětice culture, Lusatian culture, and early Middle Ages. Evidence for settlement from the late Middle ages and the modern period also was discovered (Furmanek and Masojć 2011; Furmanek *et al.*, 2014).

The settlement of the Linear Pottery culture is the oldest recorded during the excavations (Fig. 2). Its building development consisted of characteristic longhouses accompanied by various pits representing isolated households. Seven such complexes were recorded within the excavated area, including four which probably survived in a complete form (denoted with symbols KR1-7). No stratigraphic sequences were observed between them and their spatial arrangement has survived. It shows four rows of building developments located along the SW-NE axis, where the distances between individual households are very similar. The excavated portion of the settlement did not function in one period of time, and represents several consecutive construction phases. Individual households differ in many respects, which may prompt conclusions concerning the social organisation of the inhabitants. The houses have not survived in good condition; therefore it is not easy to determine their characteristic features, e.g. the length of some buildings.

Apart from the households a complex of spacious dug-out features differing from typical Linear Pottery culture pits was excavated in the area located between complexes KR1 and KR6. These features are typically irregular in projections and cross-sections, while their fills usually contain very few or are completely devoid of artefacts, although an impressive quantity of flint products was excavated from pit 265 in the southwestern part of the site. The complex's pits form a concentration approximating the shape of a quadrangle, whose orientation is the same as that of the Linear Pottery culture buildings. The concentration's southern boundary is distinctly marked, while the eastern and western are delimited by the farm objects of KR1 and KR6 households; the northern boundary is probably located outside the trench. The occurrence and arrangement of these objects most probably indicates an exploitation zone (denoted as KE), where local flint raw material was acquired and exploited (Fig. 2).

In terms of its technological and stylistic qualities, the pottery found among the Linear Pottery culture objects is considerably homogenous. Its characteristic features indicate that the settlement's chronology may be dated to the Šarka phase of Linear Pottery culture, primarily its younger period. Analogous finds were recorded in a few similar settlements in Lower Silesia, mainly in the late stages of their functioning, e.g. Strachów, site 2, Wrocław district (complexes SR VIII – SR – X; Kulczycka-Leciejewiczowa 1997), Skoroszowice, Strzelin district (Wojciechowski 1981), Strzelin, site 16, Strzelin district (Wojciechowski and Cholewa 1995).

Samples of charcoal and animal bones from 11 pits were subjected to radiocarbon analysis to determine absolute dating of the remains of the Linear Pottery culture settlement (Goslar 2006). Unfortunately, the dating attempted on animal bones was unsuccessful due to a small amount of collagen. As a consequence only the results of two

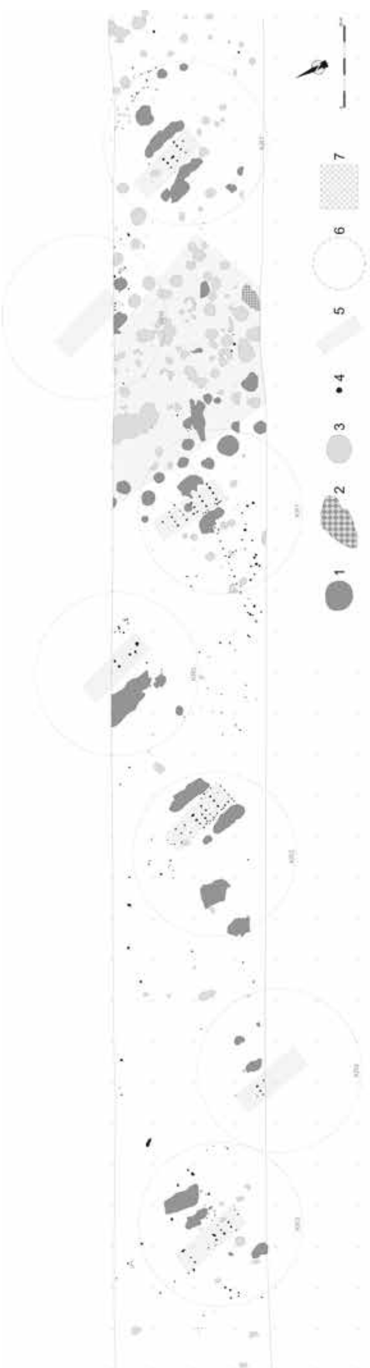

Figure 2. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Cross section of the trench with the preserved remains of the Linear Pottery culture settlement: 1 – Pits with the LPC material, 2 – pit 265, 3 – pits from other cultures or undetermined features, 4 – post holes, 5 – LPC houses, 6 – LPC building complexes (KR1-7; homesteads), 7 – exploitation zone (KE).

radiocarbon dates on charcoals from objects 161 and 315 were available, indicating that the settlement functioned in the two last centuries of the 6th millennium BC (Poz-16018: 6110±40 BP; 1σ: 5208-4942 BC; 2σ: 5201-4959 BC; Poz-16022: 6160±40 BP; 1σ: 5217-5000 BC; 2σ: 5207-5055 BC)[2].

Nearly 500 flint artifacts were excavated in 34 features of the Linear Pottery culture settlement (Table 1). Apart from them, outside the area occupied by the individual homesteads, a pit (no. 265) was excavated whose fill provided over 7000 artefacts.

The collections from individual housholds differ in the number of excavated flint products. The greatest number (n= 238) was excavated in the features of complex KR1 bordering on the exploitation zone in the west. Considerably fewer artifacts (n= 80 and n= 62 respectively) were recorded in complexes KR2 and KR3, and in the remaining households their number does not exceed 25 (Table 1).

Visual analysis suggests that erratic Baltic flint was mainly used in flintworking at Kostomłoty. In some assemblages it is the only type of raw material used by the inhabitants. Imported raw material was found in households KR1 and KR2, where its proportion does not exceed 3%, and in the objects from the exploitation

[2] The results of radiocarbon dating were calibrated with the use of the programme OxCal 4.2.4 based on the calibration curve IntCal13 (Bronk Ramsey 1994, 2009, 2013; Reimer *et al.*, 2013).

Table 1. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Quantity of flint products in LPC assemblages (NB – Baltic erratic flint, KJ – Jurassic flint from Cracow area).

Building complex	Total	NB	KJ	NB	KJ
KR1	238	232	6	97,48%	2,52%
KR2	80	79	1	98,75%	1,25%
KR3	62	62	0	100,00%	0,00%
KR4	17	17	0	100,00%	0,00%
KR5	25	25	0	100,00%	0,00%
KR6	2	2	0	100,00%	0,00%
KR7	15	12	3	80,00%	20,00%
KE	58	54	4	93,10%	6,90%
Total	497	483	14	97,18%	2,82%

zone, while its greatest proportion was recorded in a collection from complex KR7 (Table 1).

The composition of collections from individual assemblages differ (Table 2). The most distinct example comes from building complex KR7 with its substantial proportion of both blade and flake blanks (60%), tools – predominantly blades (13.3%) and a small proportion of chunks and undetermined forms. Houshold KR1, the collection of objects from the exploitation zone, and complex KR2 have different structures; the proportion of blanks is smaller (ca. 40%), among which the number of flakes is three times greater than that of blades, the number of tools and cores is small, while the number of chunks and undetermined forms is much greater, constituting half of the assemblage. In building complex KR3 blanks make up ca. 30% of the collection; they are mainly flakes but they do not substantially outnumber the blades. A significant difference also is reflected in the considerable number of tools made from blades and the greatest number of cores. The composition of the remaining assemblages vary, but because they were not subjected to intensive examination, they are not considered in detail here.

The most numerous among the 19 cores excavated in the homesteads (Table 3; Fig. 3: 1-4) are single-platform cores (8 specimens). In the remaining cases the striking platform changed when core reduction continued. No evidence of the use of the splinter technique was recorded, which is understandable considering the abundance of rock raw material available. Technical treatment of cores was limited to the preparation of the striking platform with single chippings. Only occasionally were the sides

Table 2. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Composition of LPC tool assemblages: I – quantity of blanks, II – quantity of blades, III – quantity of flakes, IV – quantity of tools from blades, V – quantity of tools from flakes, VI - quantity of burned pieces, VII – quantity of cores, VIII – quantity of chunks and other flakes, IX - quantity of chips, X - quantity of raw material blocks.

Building complex	Total	I	II	III	IV	V	VI	VII	VIII	IX	X
KR1	238	95	24	71	5	5	7	4	122	8	0
	100,0%	39,9%	10,1%	29,8%	2,1%	2,1%	2,9%	1,7%	51,3%	3,4%	0,0%
KR2	80	28	6	22	1	2	4	3	36	7	3
	100,0%	35,0%	7,5%	27,5%	1,3%	2,5%	5,0%	3,8%	45,0%	8,8%	3,8%
KR3	62	18	8	10	2	0	3	9	31	4	0
	100,0%	29,0%	12,9%	16,1%	3,2%	0,0%	4,8%	14,5%	50,0%	6,5%	0,0%
KR4	17	5	1	4	1	0	2	1	5	5	0
	100,0%	29,4%	5,9%	23,5%	5,9%	0,0%	11,8%	5,9%	29,4%	29,4%	0,0%
KR5	25	5	0	5	0	3	0	1	15	1	0
	100,0%	20,0%	0,0%	20,0%	0,0%	12,0%	0,0%	4,0%	60,0%	4,0%	0,0%
KR6	2	0	0	0	0	0	0	0	1	0	1
	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	50,0%	0,0%	50,0%
KR7	15	9	3	4	2	1	0	0	2	2	0
	100,0%	60,0%	20,0%	26,7%	13,3%	6,7%	0,0%	0,0%	13,3%	13,3%	0,0%
KE	58	24	7	21	2	0	0	1	27	2	0
	100,0%	41,4%	12,1%	36,2%	3,4%	0,0%	0,0%	1,7%	46,6%	3,4%	0,0%
Total	497	184	49	137	13	11	16	19	239	29	4
	100,0%	37,0%	9,9%	27,6%	2,6%	2,2%	3,2%	3,8%	48,1%	5,8%	0,8%

Table 3. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Characteristics of cores. Numbers are individual occurrences.

coring				blanks			shape of flaked surface			degree of exploitation		
single-platform	double-platform	multi-platform	technical treatment	blades	bladelets	flakes	circular	rounded	flat	initial	advanced	exhausted
8	0	11	5	4	1	15	1	5	13	3	2	14

or backs of cores modified with a few chippings – the forms resulting from forming crests are rare. No evidence of repair of cores was observed. The cores were used for the acquisition of flake blanks and only occasionally for blade blanks. One excep-

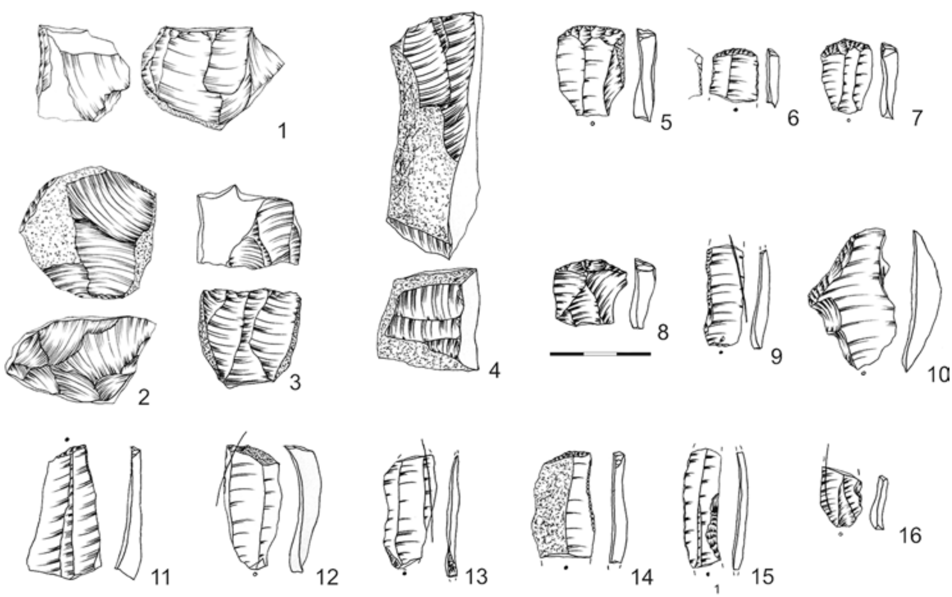

Figure 3. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Selection of flint artifacts: 1-3, 13-14 – building complex KR3; 4, 12 – KR4; 5-7, 9-10 – building complex KR 1; 8 – building complex KE; 11 – building complex KR2; 15-16 – building complex KR7. Drawing: M. Masojć.

Table 4. Kostomłoty, site 27, district of Środa Śląska, province of Lower Silesia. Characteristics of blade and flake blanks.

blanks	completeness				coring			presence of cortex			
	whole	proximal part	distal part	middle part	from single-platform core	from double-platform core	from core with changing orientation	non-cortical	cortex < 50%	cortex > 50%	cortex 100%
blades	15	19	7	4	41	1	3	33	10	2	-
flakes	98	29	8	2	59	1	77	62	52	20	3

tion was a specimen made from Jurassic flint from Cracow area displaying distinct evidence of blade – bladelet exploitation. However, most are exhausted forms, hardly ever exceeding of 3 x 3 cm in size.

Half of all 45 excavated blades are proximal forms resulting from intentional breaking. Most are non-cortical. The proportions of blanks correspond to those of cores – their average size never exceeds 3 cm in length and is less than 2 cm in width. However, there are occasional forms exceeding 7 cm in length. Flakes (n= 137) were more numerous and, contrary to blades, they have usually been preserved in a complete form. They display traces of reduction from single-platform cores and more advanced

Table 5. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Composition of tool types (quantity of products from Jurassic flint from Cracow area in brackets).

Type of tool	KR1	KR2	KR3	KR4	KR5	KR6	KR7	KE	Total	
									N	%
end-scrapers	3(1)	0	0	0	0	0	0	1(1)	4	16,7%
truncated pieces	0	1	1	1	0	0	0	0	3	12,5%
retouched flakes	4	1	0	0	0	0	1	0	6	25,0%
retouched blades	2(1)	0	1	0	0	0	2(2)	1(1)	6	25,0%
retouched chunks	1	1	0	0	3	0	0	0	5	20,8%
Total	12(2)	3	2	1	3	0	3(2)	2(2)	24	100,0%

flaking after the orientation was changed on the cores. Non-cortical cores of the average size of 3 x 3 cm predominate (Table 4).

Only 24 retouched forms were found within the homesteads, which makes up a mere 5% of the collection. Three groups of tools may be distinguished among the artefacts from Kostomłoty: end-scrapers, truncated pieces and retouched blades (Table 5; Fig. 3: 5-16). The remaining two groups – flakes and retouched chunks – are amorphic forms for very short-term use. The artifacts used as sickle inserts predominate in the assemblage. Truncated pieces and blades with retouched edges were used as harvesting tools, and they carry the traces of characteristic polishing. As many as

Table 6. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Pit 265, flint artefact totals.

Category of artefact	Number of artefacts (unburnt)	Number of artefacts (burnt)	Total of artefacts	
			%	Σ
tools	20	4	0,33	24
cores	66	6	0,99	72
other forms	16	2	0,24	18
flakes	2073	837	40,2	2910
blades	96	5	1,39	101
chips	1074	1208	31,52	2282
chunks + raw material	1098	735	25,33	1833
Total:	4443	2797	100	7240

Raw material	Quantity
sandstone	6
quartzite sandstone	15
vein quartz	17
petrified wood	2
granite pebble	2
quartz pebble	1
Total:	43

Table 7. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Pit 265, frequency of non-flint rocks.

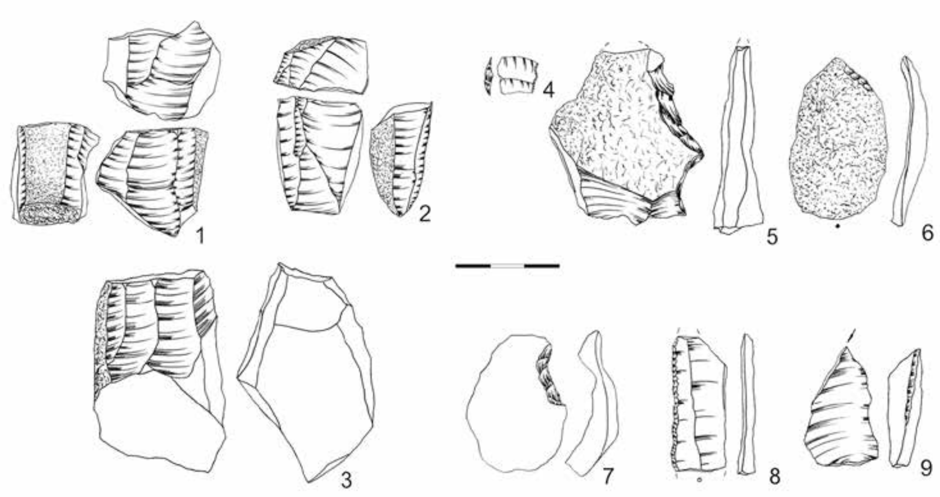

Figure 4. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Pit 265, selection of flint artifacts. Drawing: M. Masojć.

25% of the tools were made from imported raw material, which may testify to the special significance of Jurassic flint from Cracow area for the settlement's inhabitants.

As noted above, the most numerous assemblage of flint artifacts was excavated from pit 265, located at the southern edge of the KE exploitation zone. The artefacts come both from primary excavation of the feature and the flotation of its fill, which together yielded a collection of over 2000 flint chips between 0 and 1.5 cm. in size with the majority of chips recovered from flotation of the fill. The assemblage from feature 265 weighed over 46 kg, while the weight of the all the others did not exceed 4 kg.

The feature yielded 7240 flint artefacts (Table 6: Fig. 4-5) and more than 40 fragments of various rocks, mainly sandstone and quartzite, possibly intentionally broken into smaller fragments (Table 7). Some rock fragments can be refitted, indicating that they were broken into pieces within the feature (or in the near vicinity) as part of the activities carried out there.

The flake characteristics of nearly all the cores and a small group of blade blanks suggest that flintworking was devoted to the production of flake blanks. Reduction of cores, usually carried out without any preparation, was limited to knapping massive cortical flakes, or possibly a few other non-cortical forms. At this stage the cores were frequently abandoned. The cores presented in Figure 4 (nos. 1-3) are quite exceptional in the assemblage because they display preliminary preparation of the striking platform and regularly exploited flaked surfaces. Most of the remaining forms are amorphic nodules with occasional flake negatives.

Figure 5. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Pit 265, selection of flint products. Photo: M. Jórdeczka.

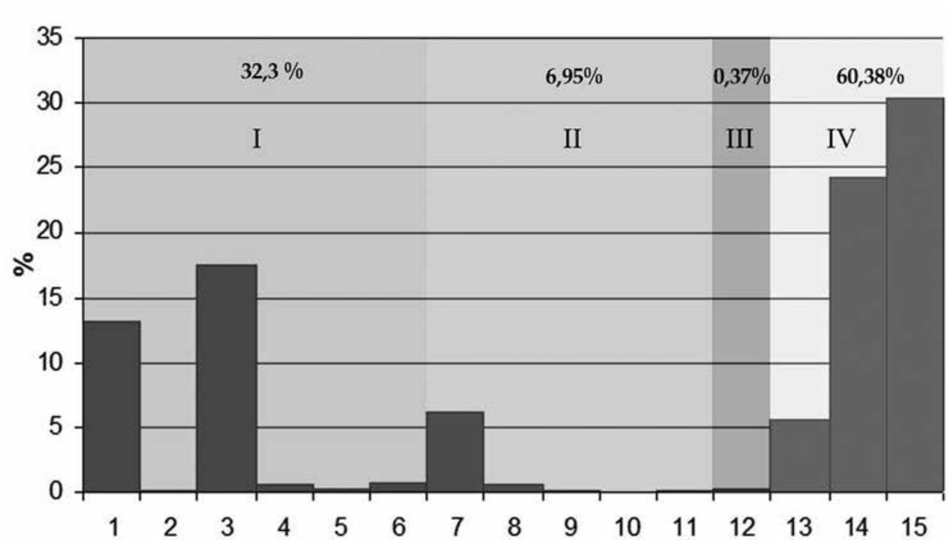

Fig. 6. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Pit 265, technological structure of the assemblage: I – group of preparation and early exploitation of cores (32,3%): 1 – cortical flakes (cortical surface up to 50%), 2 – cortical blades (cortical surface up to 50%), 3 – cortical flakes (cortical surface exceeding 50%), 4 – cortical blades (cortical surface exceeding 50%), 5 – blanks with traces of preparation, 6 – initial cores; II – group of core reduction (6,95%): 7 – non-cortical unidirectional flakes, 8 – non-cortical unidirectional blades, 9 – non-cortical multidirectional blades, 10 – blade cores, 11 – flake cores; III – group of tools (0,37%): 12 – flint tools and hammerstones (3?); IV – group of other flakes (60,38%): 13 – undetermined flakes and blades, 14 – chunks and nodules of the raw material, 15 – chips. The vertical axis represent percent of the whole assemblage. The horizontal axis represents number of categories within.

Category of tools	Quantity
trapeze	1
retouched blade	1
burin	3
retouched flake	10
flake with partial retouch	2
bladelet with partial retouch retouch	3
retouched chunks	4
Total:	24

Table 8. Kostomłoty, site 27, Środa Śląska district, Lower Silesia province. Pit 265, frequency of tools.

The artefacts (Fig. 6) are predominated by group (IV) of other flakes (including chips, chunks and nodules of raw material), followed by the group (I) of preparation and early exploitation materials. The products of the stage of advanced exploitation (II) and the tools (III) do not exceed 10% of the features assemblage. Such a technological composition is suggestive of shaping of the flint raw material within the feature. It is quite possible that the infrequently represented products from group II are rare because they were taken away from the settlement.

The group of tools consists of 24 artefacts (Table 8; Fig. 4: 4-9) which defy easy classification. The selection of blanks appears to have been random; they seem to have been made to perform short-lived, very ad hoc functions or they are forms of a functional character, like the microretouched blades. Lack of attention in selecting appropriate blanks is illustrated by the presence of four quite sizeable, amorphic or cortical retouched chunks. The retouched products made on flakes display similar features – they are cortical flakes, of random shape and size with irregular retouch most frequently on a short section of the artifact's edge. Three small bladelets display a functional retouch. Three burins were also carelessly made; one is probably a dihedral burin and the remaining ones were made on a cortical flake and a chunk. High quality of production is evident in a tall, alternately retouched trapeze (Fig. 4: 4) and a fragment of a narrow unifacial retouched blade (Fig. 4: 8). Both artefacts were made from regular blades resulting from advanced stages of a single-platform core reduction (non-cortical blades).

The good condition of the flint raw material, and the ubiquitous cortex with the remains of living organisms (sponges) preserved on external surfaces, suggest that the flint was not randomly collected but excavated from local fluvio-glacial deposits, where it occurred in better condition than the material eroded on the surface (Fig. 5; Szynkiewicz 2003). The feature also yielded occasional artefacts (chunks and blanks) displaying on their natural surfaces the traces of glacial transport (completely worn cortex and polished edges) typical of the erratic raw material.

Considering the number of cracked flint chunks, the majority resulting from breaking flint blocks (possibly to test their usefulness for flintworking), it may be safely assumed that in feature 265 flint was broken into pieces and the blocks unsuitable for further flaking were discarded, which may explain the presence of a very numerous category of flakes predominated by cortical forms. Most of the cores or negative forms discovered in the feature are very rudimentary specimens with just a few negatives; only a few display traces of flaking. The cores suitable for exploitation were quite possibly taken away from the feature or the settlement for further exploitation.

Despite a great amount of flint material, feature 265 did not yield artefacts which would enable unambiguous determination of cultural affiliation. The result of radiocarbon dating of the charcoal sample derived from this feature (Poz-16039: 5055±35 BP; 1σ: 3958-3773 BC; 2σ: 3942-3798 BC) indicates a time around the beginning of the 4th millennium BC, i.e. the period of functioning of Funnel Beaker culture or late groups of Danubian cultures. However, we can not rule out the possibility that the dated charcoal actually was connected with the subsequent in-filling of the feature and no artefacts were found in the excavated part of the site which could be attributed to Funnel Beaker or Danubian cultures. Contrary to the dating results two lines of evidence, based on spatial relations and the nature of the raw material utilized, suggest that pit 265 is a feature attributable to the Linear Pottery culture.

Feature 265 is situated between three Linear Pottery culture households at the edge of the quite uniform complex of features considered to mark the exploitation zone. Relatively regular and precisely determined boundaries within the zone seem to have prevented any stratigraphic mixing between and among features.

In addition, the presence of flint forms analogous to those recovered from pit 265 occur in practically all Linear Pottery culture households at the site. Apart from occasional low quality artefacts made from Jurassic flint, the most frequent forms are identical sharp-edged chunks with identical natural surface (thick 'pumice-like' cortex) and macroscopic properties (the same shades of grey, presence of numerous once-living organisms in the silica). Less numerous was debitage (made from the same raw material), occasionally used as *ad hoc* tools. We suggest that the flint raw material excavated in the features from the homesteads found its way there after preliminary flaking in feature 265 or in another analogous feature and assume that the source of the raw material, however difficult to determine, was the same as the chunks.

In view of the above, we take the view that the contents of pit 265 constitute evidence of the functioning of a flintworking workshop situated outside the existing Linear Pottery culture buildings, at the edge of several households of this culture, providing them with raw material and blanks. The raw material acquired from exposed fluvial-glacial deposits (deep objects) underwent preliminary flaking there and then it was transported to feature 265. The households received selected flakes, less frequently blades, as well as bigger and more massive broken flint nodules, frequently in the form of cortical chunks. They functioned there as mass material, used *ad hoc* next to good quality selected flint tools made from Jurassic flint from Cracow area.

The analysis of the flintworking from the Linear Pottery culture settlement in Kostomłoty provided important new data concerning the functioning of this area of manufacturing and its context in the first farming communities in Silesia. The composition of the raw material excavated here is distinct from the pattern characteristic of other sites from Lower Silesia. The contribution of the raw material imported from Polish Jura is very small, reaching barely 3% of the whole assemblage, not taking into consideration the material from feature 265 (in the latter case its contribution would decrease to less than 1%). It is thus of marginal significance compared with the universally used local erratic raw material.

However, the extent of use of erratic raw material in south-western Poland during the time of the Linear Pottery culture changed in time and through space (Table 9 and 10). Baltic erratic flint occurs almost exclusively in the oldest assemblages dated to the Gniechowice phase (e.g. Stary Zamek, Wrocław district, Gniechowice, Wrocław district, Strzelin, site 16; Lech 1985; Wojciechowski and Cholewa 1995). The significance of Jurassic flint from the Cracow area increases significantly at the beginning of the middle phase of Linear Pottery culture (in the assemblage from Strzelin, site 19, its contribution amounts to over 60%). On average, the proportion of this raw material is slightly greater than 60% and its contributions are different in different sites. The proportion of imported flint increases in the older period of Šarka phase and this tendency is also reflected in the consecutive construction phases observed within the sites. Spatial diversification of the collections is also clearly visible. The sites with the greatest contribution of Jurassic flint from the Cracow area are located in the Niemcza-Strzelin Hills: Niemcza, Dzierżoniów district, Skoroszowice, Strachów. The role of local erratic raw material increases with the increasing distance from the settlement complex mentioned above, reaching its extreme in the collections from Kostomłoty.

The structure of the Kostomłoty collections also differs from most LPC sites. For example, in Skoroszowice the proportion of retouched products is 32.5 %, in Strachów – 25.2 and in Strzelin 16 (Šarka phase) – 26,8 % (Wojciechowski 1981; Wojciechowski and Cholewa 1995; Lech 1997). Such a structure of the group of tools as distinct to the remaining morphological groups is hardly ever encountered in Lower Silesia. It is typical of the settlements processing siliceous rocks on a massive scale, such as Olszanica, Kraków district (Milisauskas 1976) or Vedrovice – Zábrdovice, Znojmo district (Mateiciucová 1997; Lech 1982). In Olszanica the contribution of tools in the collection is 4.63%, while in Vedrovice it is 8.6%. The composition of flint material within individual morphological groups from both sites mentioned above is very similar to that from the homesteads in Kostomłoty (Lech 2008: Fig. 26: B, H). In Olszanica flintworking took place on a massive scale, processing the locally occurring Jurassic flint from the Cracow area, while chert of the Krumlowský Les type was processed in Vedrovice. In one of the workshops from that site (object 098) a single trapeze occurred among the retouched products, similar to the artifact recovered from pit 265 in Kostomłoty (Lech 1982: 51-52).

The Verlaine site, Liège district, in Belgium provides an interesting analogy for pit 265 from Kostomłoty. In this site consisting of 6 – 10 houses a dozen concentrations of flint blanks (workshops) were excavated. In one, specialising in the production of blade blanks, ca. 30 thousand artefacts were recovered. The scale of flintworking in Verlaine clearly exceeded the needs of the settlement's inhabitants and the artifacts manufactured at the site – blanks – were distributed to other local settlements (Burnez-Lanotte and Allard 2003), similar to the case at Darion, Luik district, and Longchamps, Namur district (Keeley and Cahen 1989). The observations made in these sites suggest that the changes taking place in the late phase of the development

Table 9. Structure of raw material on the most important LPC assemblages in south-western Poland (NB – Baltic erratic flint, JP – Jurassic flint from Cracow area, CZ – chocolate flint, OB – obsi-dian, ? – undetermined), after Kulczycka-Leciejewiczowa and Romanow 1985; Lech 1981, 1985, 1997; Wojciechowski 1975, 1981, 1987; Wojciechowski and Cholewa 1995, 2000; Bednarek and Wojciechowski 2008.

Site	Building complex	Phase	NB	JP	CZ	OB	?	TOTAL
Gniechowice 8	GNI	IA	21	0	0	0	0	21
			100,00%	0,00%	0,00%	0,00%	0,00%	100,00%
Strzelin 16	ST16 I	IA	2	0	0	0	0	2
			100,00%	0,00%	0,00%	0,00%	0,00%	100,00%
Strzelin 16	ST16 II	IA	3	0	0	0	0	3
			100,00%	0,00%	0,00%	0,00%	0,00%	100,00%
Stary Zamek 5	SZI	IA	6	0	0	0	0	6
			100,00%	0,00%	0,00%	0,00%	0,00%	100,00%
Stary Zamek 5	SZII	IA	23	1	0	0	0	24
			95,83%	4,17%	0,00%	0,00%	0,00%	100,00%
Mochów A	MR	II	5	21	0	0	1	27
			18,52%	77,78%	0,00%	0,00%	3,70%	100,00%
Strzelin 19	ST19 I	IIA	6	14	1	1	0	22
			27,27%	63,64%	4,55%	4,55%	0,00%	100,00%
Muszkowice 9	MU	IIB	0	22	0	0	0	22
			0,00%	100,00%	0,00%	0,00%	0,00%	100,00%
Strzelin 16	ST16 III	IIB	1	0	0	0	0	1
			100,00%	0,00%	0,00%	0,00%	0,00%	100,00%

Strzelin 16	ST16 IV	IIB	17	12	0	0	0	29
			58,62%	41,38%	0,00%	0,00%	0,00%	100,00%
Strzelin 16	ST16 V	IIB	11	19	0	0	0	30
			36,67%	63,33%	0,00%	0,00%	0,00%	100,00%
Niemcza 4	NR I-IV	IIB-C	8	49	3	0	6	66
			12,12%	74,24%	4,55%	0,00%	9,09%	100,00%
Skoroszowice 1	SK I-VI	IIC-IIIB	77	242	0	1	37	357
			21,57%	67,79%	0,00%	0,28%	10,36%	100,00%
Strachów 2	SR I-II	IIIA	8	32	0	0	3	43
			18,60%	74,42%	0,00%	0,00%	6,98%	100,00%
Strachów 2	SR IV	IIIA	30	140	0	0	29	199
			15,08%	70,35%	0,00%	0,00%	14,57%	100,00%
Strachów 2	SR V-VI	IIIA	13	37	0	0	2	52
			25,00%	71,15%	0,00%	0,00%	3,85%	100,00%
Strzelin 16	ST16 VI	IIIA	22	29	0	0	5	56
			39,29%	51,79%	0,00%	0,00%	8,93%	100,00%
Smolec 14	SM	IIIA	19	17	0	0	0	36
			52,78%	47,22%	0,00%	0,00%	0,00%	100,00%
Strachów 2	SR VII-X	IIIB	17	56	0	0	14	87
			19,54%	64,37%	0,00%	0,00%	16,09%	100,00%
Strzelin 19	ST19 II	IIIB	8	5	1	0	0	14
			57,14%	35,71%	7,14%	0,00%	0,00%	100,00%

Table 10. Diversification of the raw material in consecutive phases of LPC in south-western Poland (NB – Baltic erratic flint, JP – Jurassic flint from Cracow area, CZ – chocolate flint, OB – obsidian, P – undetermined).

Phase	NB	JP	CZ	OB	P
LPC I	99,20%	0,80%	0%	0%	0%
LPC II	36,20%	60,10%	1,30%	0,60%	1,80%
LPC III	31,10%	60,40%	0,90%	0%	7,60%
LPC IIIA	30,10%	63%	0%	0%	6,90%
LPC IIIB	38,40%	50%	3,60%	0%	8%

of Linear Pottery culture resulted from social and economic transformation rather than from changes in the accessibility of the raw material. They may be attributed to the emerging specialisation in flintworking and appearance of production surplus, which was later distributed. In the case of Kostomłoty, the character of feature 265 is different, resulting from the need to satisfy local demand.

As Wojciechowski (2003) observed, the different character of flintworking in the settlement in Kostomłoty may have resulted from the settlement's marginal location in relation to the centre of Linear Pottery culture settlement. The conclusions concerning the changes in occurrence of imported raw material in Lower Silesian sites suggest the existence of a hierarchical system for the distribution of goods (raw material) between the local communities, which in the Šarka phase probably consisted in their redistribution, wherein the groups from the area of the Niemcza-Strzelin Hills (e.g. Skoroszowice, Strachów) played the leading role. However, the reasons for the specific character of the site in Kostomłoty are probably rooted in the wider context of the changes taking place at the end of the Linear Pottery culture. The extensive network of exchange and distribution of goods existing at that time included not only flint raw material but other commodities as well (e.g. products from metabasite of the Jizera Mountains type, Spondylus shells, etc.). Quite frequently, the tools used by these groups were made from imported raw material, despite the fact that local artifact-quality raw materials were easily accessible in the vicinity (cf. e.g. Ramminger 2009; Mateiciucová 2008). With time the system was reorganised, evident in the discontinuity in circulation of various categories of goods and the increased use of local raw material in flint and stoneworking. This may reflect the processes of 'atomisation' of local communities, isolation of settlement centres and disintegration of the long-lasting ties based on kinship, which intensified considerably at that time. The processes, observable in post-LPC groups (e.g. the older phase of Stroke Ornamented Pottery culture; cf. e.g. Wojciechowski 1988), actually began at the end of functioning of Linear Pottery culture. The settlement in Kostomłoty may mirror the effect of those changes and be a local reflection of that crisis. If so, the restrictions resulting from changes in the exchange system may have made it necessary to satisfy the demand for raw material at the local community level; hence the dramatic attempts at finding suitable raw material locally. That these attempts were not entirely successful is attested by overall poor character of flintworking in individual Kostomłoty households.

REFERENCES

Bednarek, M. and Wojciechowski, W. 2008. Osada ludności kultury ceramiki wstęgowej rytej na stan. 14 w Smolcu, pow. Wrocław. *Śląskie Sprawozdania Archeologiczne* 50: 75–90.

Bronk Ramsey, C. 1994. Analysis of Chronological Information and Radiocarbon Calibration: The Program OxCal. *Archaeological Computing Newsletter* 41: 11–16.

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1): 337–360.

Bronk Ramsey, C. 2013. Recent and Planned Developments of the Program OxCal. Radiocarbon 55 (2-3): 720–730.

Burnez-Lanotte, L. and Allard, P. 2003. Surplus production in the Belgian Linearbandkeramik: Blade debitage at Verlaine 'Pettit Paradis' (Hesbaye, Belgium). In L. Burnez-Lanotte (ed.), *Production and Management of Lithic Materials in the European Linearbandkeramik*, 59–64. Oxford. British Archaeological Reports, International Series 1200.

Furmanek, M. and Masojć, M. 2011. Wielokulturowe stanowisko w Kostomłotach, pow. średzki, In *Raport 2005-2006*. Warszawa.

Furmanek, M., Masojć, M. and Sady, A. 2014. Użytkowanie roślin przez społeczności wczesnoneolityczne na Śląsku. Wyniki badań archeobotanicznych z Kostomłotów, stan. 27, woj. dolnośląskie. In K. Czerniak, J. Kolenda and M. Markiewicz (eds), *Szkice neolityczne. Księga poświęcona pamięci Profesor Anny Kulczyckiej-Leciejewiczowej*, 161–186. Wrocław.

Goslar, T. 2006. *Raport nr 1529/06 z wykonania datowań C-14 w Poznańskim Laboratorium Radiowęglowym*. Poznań. Unpublished report, Archives Institute of Archaeology, Wroclaw University.

Keeley, L.H. and Cahen, D. 1989. Early Neolithic forts and villages in NE Belgium: a preliminary report. *Journal of Field Archaeology* 16: 157–176.

Kulczycka-Leciejewiczowa, A. 1997. *Strachów. Osiedla neolitycznych rolników na Śląsku*. Wrocław.

Kulczycka-Leciejewiczowa, A. and Romanow, J. 1985. Wczesnoneolityczne osiedla w Gniechowicach i Starym Zamku. *Silesia Antiqua* 27: 5–68.

Lech, J. 1981. Materiały krzemienne z osad społeczności wstęgowych w Niemczy, woj. Wałbrzych. Badania z lat 1971-1972. *Silesia Antiqua* 23: 39–45.

Lech, J. 1982. Flint Mining among the Early Farming Communities of Central Europe. Part II – The Basis of Research into Flint Workshops. *Przegląd Archeologiczny* 30: 47–80.

Lech, J. 1985. Najstarszy przemysł krzemienny wspólnot wczesnorolniczych w dorzeczu Odry. Materiały kultury ceramiki wstęgowej rytej z Gniechowic i Starego Zamku. *Silesia Antiqua* 28: 69–81.

Lech, J. 1997. Materiały krzemienne z osad społeczności wczesnorolniczych w Strachowie, woj. Wrocław, In A. Kulczycka-Leciejewiczowa, *Strachów. Osiedla neolitycznych rolników na Śląsku*, 229–265. Wrocław.

Lech, J. 2008. Materiały krzemienne społeczności kultury ceramiki wstęgowej rytej z Samborca, pow. Sandomierz, In A. Kulczycka-Leciejewiczowa, *Samborzec. Studium przemian kultury ceramiki wstęgowej rytej*, 151–204. Wrocław.

Mateiciucova, I. 1997. Local Hornstones among the First Farmers (LBK) of the Krumlovský Les Area. In R. Schild and Z. Sulgostowska, *Man and Flint. Proceedings of the VIIth International Flint Symposium, Warszawa-Ostrowiec Świętokrzyski, September 1995*, 249–253. Warszawa.

Mateiciucova, I. 2008. *Talking stones: the chipped stone industry in Lower Austria and Moravia and the beginnings of the Neolithic in Central Europe (LBK), 5700 - 4900 BC*. Brno.

Milisauskas, S. 1976. *Archeological investigations on the Linear Culture village of Olszanica*. Wrocław.

Ramminger, B. 2009. The exchange of LBK adze blades in central Europe: an example for economic investigations in archaeology. In D. Hofmann and P. Bickle (ed.), *Creating communities. New advances in Central European Neolithic research*, 80–94. Oxford.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatt, C., Heaton, T.J., Hoffmann, D. L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M., and van der Plicht, J. 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon* 55 (4): 1869–1887.

Szynkiewicz, A. 2003. *Sytuacja geomorfologiczna i geologiczna stanowisk archeologicznych Kostomłoty I i II (autostrada A4, 121 km)*. Wrocław. Unpublished report, Archives Institute of Archaeology, Wroclaw University.

Wojciechowski, W. 1975. Wyniki badań na neolitycznej osadzie w Muszkowicach, w powiecie ząbkowickim w roku 1974. *Śląskie Sprawozdania Archeologiczne* 17: 28–32.

Wojciechowski, W. 1981. Wczesnoneolityczna osada w Skoroszowicach. Wrocław. *Studia Archeologiczne* 12.

Wojciechowski, W. 1987. Periodyzacja młodszych kultur naddunajskich na Górnym Śląsku w świetle badań w Mochowie. Wrocław. *Studia Archeologiczne* 16.

Wojciechowski, W. 1988. Kontakty Dolnego Śląska z Małopolską Zachodnią w neolicie i wczesnej epoce brązu w świetle tzw. importów. *Silesia Antiqua* 30: 43–81.

Wojciechowski, W. 2003. Ślady osadnictwa kultury ceramiki wstęgowej w rejonie Kostomłotów. *Śląskie Sprawozdania Archeologiczne* 45: 125–150.

Wojciechowski, W. and Cholewa, P. 1995. Osady najwcześniejszych rolników i hodowców na stanowisku 16 w Strzelnie. Wrocław. *Studia Archeologiczne* 27.

Wojciechowski, W. and Cholewa, P. 2000. Osady neolityczne na stanowisku 19 w Strzelinie. Wrocław. *Studia Archeologiczne* 32.