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The flint mine site Wierzbica 'Zele' (Poland) and Bronze Age workshop materials after forty years of new research (1979-2018)

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Abstract

Between 1980-1988, the 'Zele' flint mine in Wierzbica, Radom district (Poland), was among the most extensively excavated prehistoric flint mine sites in Europe. 'Zele' is distinguished by the presence on the surface of small limestone slabs and rubble mixed with flints and ploughed soil. On the basis of research carried out so far, it is certain that the mine was operated for several hundred years in the Bronze Age. The purpose of the present article is to describe the excavations and the main research results. The paper presents new characteristics of the 'Zele' flint, a variety of 'chocolate' flint from Central Poland, and the morphological and weight structures of flint inventories from the mining site.

Keywords: Bronze Age, flint mine, chipped flints, 'paracore', 'chocolate' flint, Wierzbica 'Zele', archaeology of Poland.

Résumé

De 1980 et 1988, la minière à silex de « Zele » à Wierzbica dans le district de Radom (Pologne) fut l'une des mines de silex préhistoriques la mieux fouillée d'Europe. Le site de « Zele » se caractérise par la présence en surface des plaquettes et débris de calcaire mélangés à du silex et du sol cultivé. Sur base des recherches réalisées jusqu'à présent, il est certain que la minière fut en activité durant plusieurs siècles, au cours de l'Âge du Bronze. Cette contribution a pour objet de décrire les fouilles et les principaux résultats des recherches. L'article présente également les nouvelles caractérisations du silex de type « Zele », une variété de silex « chocolat » du centre de la Pologne ainsi que la structure morphologique et quantitative de l'assemblage lithique du site minier.

Mots-clés *: âge du Bronze, minière à silex, silex taillés, « paranucléus », silex « chocolat », Wierzbica « Zele », archéologie de Pologne.*

1. INTRODUCTION

Wierzbica is a large village with medieval roots, the seat of the municipality, twenty kilometres south of Radom, a medium sized city in Central Poland. The village and the Wierzbica 'Zele' flint mine site lie in the area of the Iłża Foreland, near the border with the Radom Plain (Fig. 1).

The site (51°14'47''N, 21°03'10''E) has been the subject of several articles and several unpublished conference papers (e.g. MŁYNARCZYK, 1983; LECH, 1984, 1995, 1997a, 1997b; LECH *et al*., 2011, LECH *et al*., 2015).

Fig. 1 – Wierzbica, Radom District (Poland). Autumn 1979. A general view on the area of the prehistoric flint mine site 'Zele' and its surroundings. Photo by J. Lech.

2. THE 'ZELE' FLINT

The site is situated in a belt of chocolate flint deposits which occur in the Upper Jurassic limestone and karstic clays. Under topsoil, in the natural stratification of the site, there is a layer of Pleistocene sands mixed with boulder clay. Underneath, there is a layer of clay containing flints of different shapes and sizes and, still deeper, a layer of weathered Upper Jurassic (Late Oxfordian) oolitic and clayey limestones, also with flints (LECH, 1984, p. 186, 1995, p. 467; PŘICHYSTAL, 2013, p. 108). In some places, small flattened flint nodules and tabular flint plates occur just below the surface, but the large nodules of flint are found at deeper and at the deepest exploitation levels.

The 'Zele' flint exploited only at Wierzbica is a variant of 'chocolate coloured flint' from Central Poland. It has been given the general name of 'Zele' type chocolate flint, whose weak gloss and the appearance, at times, of sharp borders between the black and brown colours in the silica distinguishes it from other types of chocolate flint (Fig. 2). The raw material appears in various forms from small, flat nodules to large plate shaped and bulbous nodules, very large bulbous nodules, reaching even 100 cm in diameter. The latter occurs in prehistoric features very rarely, because their deposits are situated deeper and usually were not exploited (SCHILD, 1971, p. 8-11, 34-35, 1976, p. 147-150, 1987, p. 137-139, 148; LECH *et al.*, 2011, p. 109-111).

Fig. 2 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'. Nodules of 'chocolate' flint of the 'Zele' type (medium size), originating from excavations in Cutting I/80. Photo by J. Lech.

The 'Zele' flint is characterised by low porosity (Fig. 3:1). The pores are usually small and are often formed by the dissolving of calcite crystals present in the nodule. Negatives of rhombohedral calcium carbonate crystals (Fig. 3:2) and traces of completely silicified microfossils have often been found. Their presence is usually visible at the edges of nodules that have undergone a patination process. Removal of even a small amount of silica reveals the primary sedimentation structures.

When analysing the 'Zele' flint, the cathodoluminescence of accessory minerals was observed, most often orange luminescence of calcite (Fig. 3:3). The character of the luminescence does not depend on the form in which the calcium carbonate occurs. Both the syngenesis calcite and small, relic extrusions of calcite luminesce in the same way. In one case calcite was observed to glow orange, forming irregular shaped aggregates occurring in 'chocolate' flint from the old quarry of the 'Przyjaźń' cement works in Wierzbica. A bright yellow luminescence in cathodoluminescence radiation is characteristic of small concentrations of baryte occurring in flint from the Wierzbica 'Zele' site and from the Wierzbica quarry (Fig. 3:4). This type of luminescence is connected with the presence of apatite. Apatite usually has a very weak grey-brown glow, a characteristic feature when it builds phosphate organic remains present in flint. The second type of luminescence of apatite is a blue colour, observed only in the case of small autogenous apatite hexagonal prisms. This type of apatite was found in flint from the Wierzbica quarry and from the Wierzbica 'Zele' site (see Fig. 3:5; WERRA & SIUDA, 2015a and b; the presented results were obtained during work on the project financed with funds provided by the National Science Centre – PRELUDIUM 2 DEC-2011/03/N/HS3/03973).

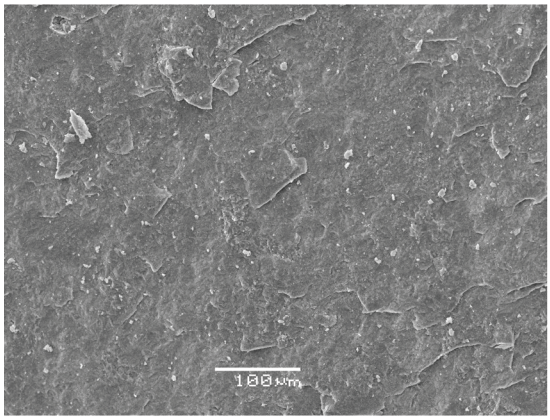
3. THE FIRST RESEARCH AND EXCAVATIONS OF THE WIERZBICA 'ZELE' FLINT MINE

The site was discovered before the Second World War by the well-known Polish prehistorian Stefan Krukowski (SCHILD, 1997-1998, p. 347-348). S. Krukowski (1890-1982), a

pre-eminent researcher of the Palaeolithic and chipped industries, was also a pioneer in studies of prehistoric flint mining in Poland (LECH & PIOTROWSKA, 2009).

In the beginning of 1972 the government of the Polish Peoples Republic began to build a new cement plant in Wierzbica. As part of the project, a concrete road adapted to the traffic of heavy vehicles was built across 'Zele', leading to a quarry of Jurassic limestone, being prepared for the new plant. The road on its south side, by about one metre cut into a slight elevation of the terrain. The rescue excavations were necessary.

In the summer of 1979 it was decided to divide the research project into two stages. Stage I – the reconnaissance, 1979-1980, was to decide about the scope of the work and the methods used in the next stage. Stage II was to begin with excavations in 1981. The aim was to reconnoitre the mine – to determine the type of



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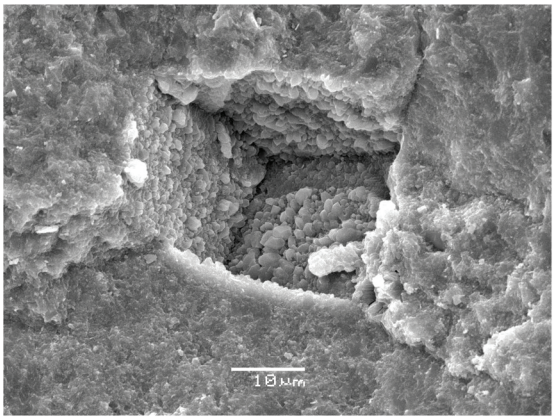

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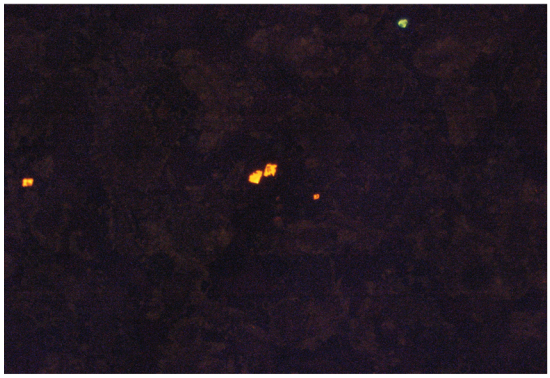

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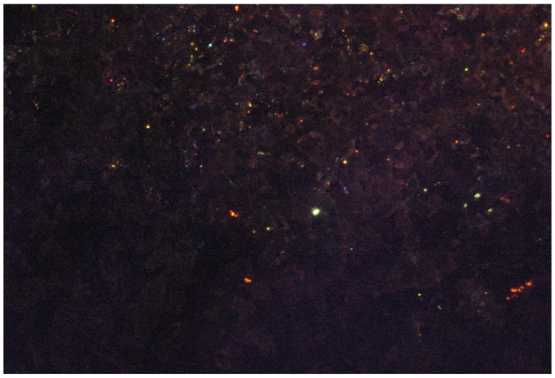

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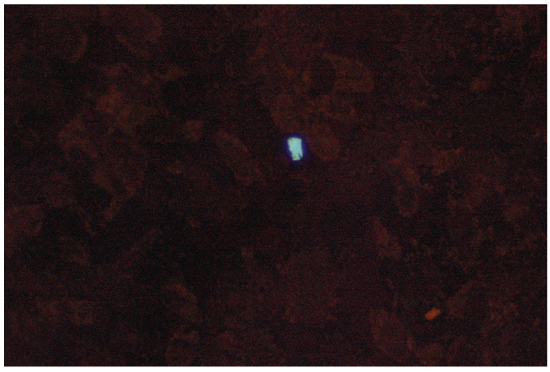

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Fig. 3 – Wierzbica 'Zele', Radom district (Poland). Scanning electron microscope photos: 1. Surface of 'Zele' type chocolate flint; 2. Negatives of rhombohedral calcium carbonate crystals. Luminescence in cathodoluminescence radiation; 3. Orange colour luminescence of calcite; 4. Yellow colour luminescence of small concentrations of baryte; 5. Blue colour luminescence of small autogenous apatite hexagonal prisms. Photos 1 and 2 by R. Siuda. Photos 3-5 by M. Sikorska-Jaworowska.

exploitation units, their extent, the boundaries of the mining field, the period when the deposit was exploited and directions of the flint work. These were rescue excavations as the area was still intended for industrial investment. The excavations were to make such use possible.

From October 10-17, 1979 a systematic survey of the 'Zele' surface was carried out by Hanna Młynarczyk with the participation of three other archaeologists (Jacek Lech, Piotr Miglus and Franciszek M. Stępniowski). In one week, the team drew a map showing the occurrence of basic categories of archaeological materials (flints and limestone pieces) on the surface of the site on a scale of 1:500. The area of distribution of the materials, resembling in shape a human kidney, was determined. In 1979 its longer axis stretched 400 m and shorter 300 m (MŁYNARCZYK, 1983, p. 88-91; LECH, 1983, p. 64-67; LECH, 1984, fig. 1, 2, p. 188-190). On the surface of the ploughed fields, there were numerous flint specimens – natural (mostly) and worked. No fragments of pottery, either from prehistoric or medieval times were found. It was believed that the Wierzbica 'Zele' flint mine was used intermittently from the Late Palaeolithic to the Early Bronze Age (LECH, 1983, p. 67; MŁYNARCZYK, 1983, p. 105).

In 1980 Tomasz Herbich, conducted the first electrical resistivity imaging on part of the site where the first cutting was being planned (HERBICH, 1993). The results were used to locate Cutting I/80 (Fig. 4). The first excavations in 1980 were aimed at determining the natural geological stratigraphy of the site, determining the type and size of features used to exploit the raw material and documenting the features that were impaired by the concrete road. They were carried out by H. Młynarczyk, with the participation of J. Lech, in the summer of 1980. The cutting, 10 x 5 m, included two zones of ground resistivity, distinguished as a result of the electrical resistivity survey. The archaeologists were looking for the key to applying this method in the course of further excavations of the site. At a depth of 30 cm, the area of further exploration was limited to 3 m x 10 m. The obtained profile was cut through the zones with the greatest diversity of substrate resistance. Cutting I/80 was dug near the slope of the road passing through the

Fig. 4 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'. View of Cutting I/1980. The excavations were supervised by Hanna Młynarczyk. Photo by J. Lech.

site, so as to be sure of coming across the shafts. Five open shafts of up to several metres width at the surface were found. Their depth ranged from 4.5 m to 5.5 m. Trench II/80, 240 m^2 in area, was located at the side of the road between the edge of the concrete road surface and the slope. The slope of the road and the roadside were cleared and recorded (Fig. 5).

In the years 1981-1988 stage II was completed. H. Młynarczyk (from 1982 H. Lech) led the excavations in 1982. In 1983 the 'Zele' excavations were conducted by J. Lech and, in the years 1985-1988 further excavations were conducted by H. Lech (LECH, 1984, 1995, 1997a, 1997b; see LECH & PERLIKOWSKA-PUSZKARSKA, 2009, p. 269-270).

During the first two excavation seasons (1980 and 1981), 23 shafts and 3 other features, probably also shafts, were located. Fifteen shafts were discovered in the archaeological cuttings. Fragmentary sections were determined for 12 of them in the profiles of the cuttings and in the balk. Full vertical cross-sections were obtained for shafts 1, 6 and 7 (Fig. 4 and Fig. 5). The results of the first three excavation seasons at the 'Zele' site were summed up in an article by H. Młynarczyk (1983). The purpose of further investigations of the

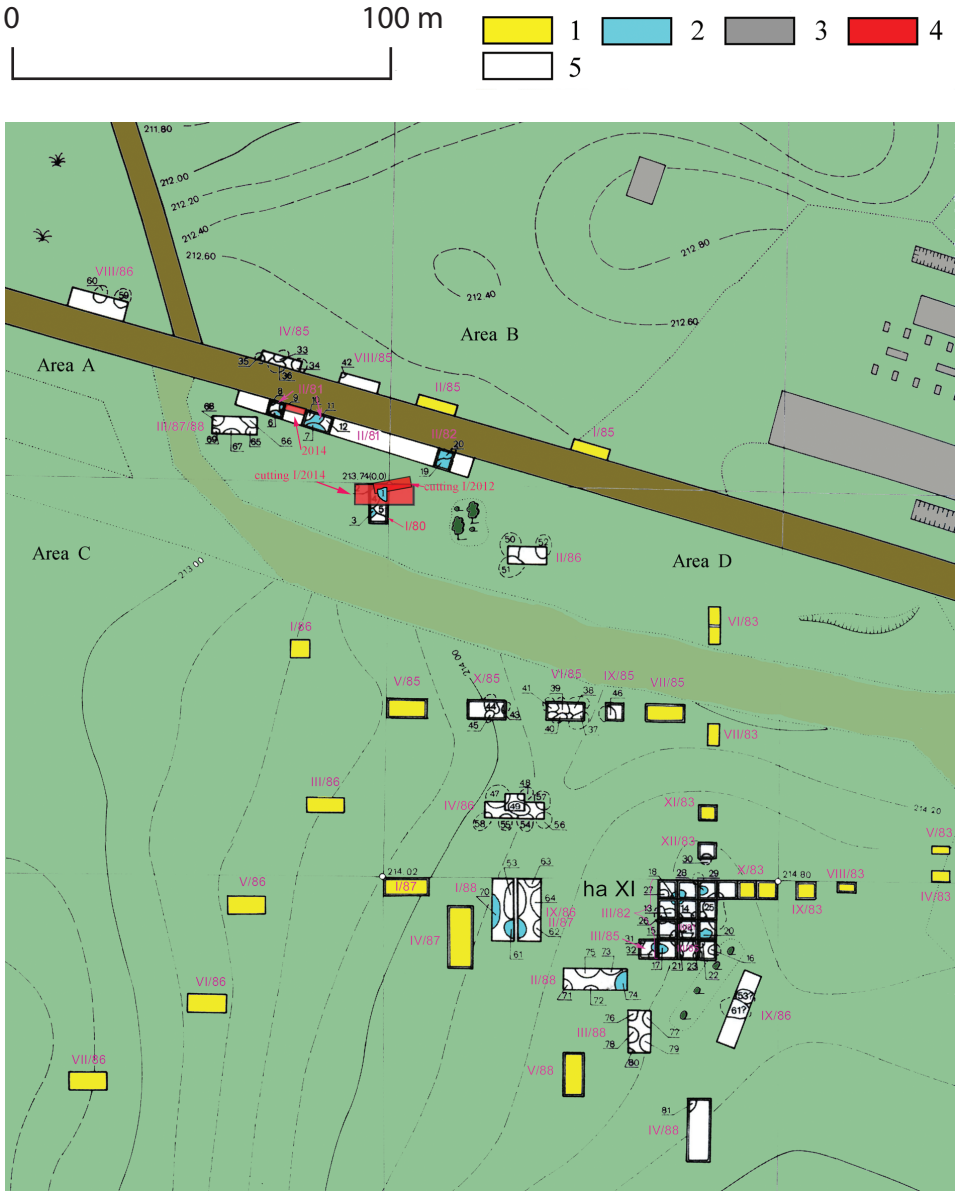


Fig. 5 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'.
Map of the distribution of cuttings and shafts 1980-2014:
1. Cuttings without shafts; 2. Shafts mentioned in the text;
3. Remains of unfinished buildings and structures of a new limestone quarry;
4. Cuttings from 2012 and 2014; 5. Cutting with shafts.
Measurement and drawing by J. Fellmann; completed by H. Lech and D.H. Werra.

'Zele' mining field was to define its boundaries, to distinguish between the different mining features and to determine their chronology (Fig. 6).

Today we know that siliceous rocks were exploited and used since the Early Bronze Age to the end of the Bronze Age and beginning of the Iron Age (LECH *et al.*, 2011; LECH & WERRA, 2018, p. 580-581; Fig. 6), but in 1983 it became of great importance to obtain further charcoal samples to verify the first results. Therefore, the purpose of the 1983 excavations carried out by J. Lech was to investigate Shaft 28.

The excavation of Shaft 28 covered an area of 16 m^2 (Fig. 5). The shaft went down for

No.	*Site*	*Laboratory number*	*Origin of the sample (feature)*	*b.c.*	*+/-*	*Literature*
1	Ożarów, site "Za Garncarzami", Poland	Gd-2114	Shaft I/3	1570	80	BUDZISZEWSKI, 1997, p. 51
2		Gd-2115	Shaft I/4	1480	80	
3		Gd-2108	Shaft I/3	1420	80	
4	Polany, site II, Poland	Bln-4175	Shaft 1/1988	1800	80	HERBICH & LECH, 1995, p. 504
5		Bln-4176	Shaft 1/1988	1740	80	
6		BM-1235	Shaft 1/1972	1541	81	LECH & LELIGDOWICZ 2003, p. 151
7		Bln-4174	Shaft 3/1988	1540	80	HERBICH & LECH, 1995, p. 502
8		Bln-4173	Shaft 3/1988	1450	70	
9	Wierzbica, site "Zele", Poland	MKL-1107	Shaft 70	1830	60	Unpublished
10		GrN-11852	Shaft 17	1730	70	LECH, 1984, p. 194
11		GrN-11854	Shaft 17	1720	60	
12		Poz-44122	Shaft 61	1680	35	Unpublished
13		GrN-11853	Shaft 17	1620	90	LECH, 1984, p. 194
14		MKL-1106	Shaft 74	1500	50	Unpublished
15		BM-2383	Shaft 20	1200	80	LECH, 1997a, p. 103
16		BM-2386	Shaft 28	940	110	
17		BM-2386A	Shaft 28	850	100	
18		BM-2385A	Shaft 28	830	80	
19		OxA-5101	Shaft 19	830	45	HEDGES, *et al.*, 1996, p. 408
20		BM-2385	Shaft 28	800	70	LECH, 1997a, p. 103
21		GrN-11856	Shaft 18	720	60	LECH, 1984, p. 194
22	Krumlovský les, Moravia, Czech Republic	GrA-23556	Pit; trench I-1-1	1680	50	OLIVA, 2010, p. 266; 2011, p.100
23		GrA-23559	Shaft; trench III-1-1	1540	50	
24		GrA-22835	Spoil heap; trench IV-2-1	1390	45	
25		GrA-29162	Shaft; trench V-5-1	1560	50	
26		GrA-30352	Shaft; trench VII-4-1	1360	40	
27		GrA-34262	Shaft; trench II-10-3	1540	35	
28		GrA-38107	Workshop; trench I-13-1	1690	30	
29		GrA-38112	Shaft; trench II-20-1	1415	30	
30		GrA-38113	Shaft; trench II-22-1	1305	30	
31		OxA-22463	Shaft; trench I-13-1	1682	30	
32		OxA-22464	Shaft; trench I-13-1	1627	28	
33		GrA-28034	Shaft; trench V-2-2	1220	35	
34		GrN-28875	Shaft; trench II-9-1	890	50	
35		GrA-38081	Shaft; trench I-11-2	805	25	
36		GrA-38108	Shaft; trench II-2-2	810	30	
37		GrN-28873	Shaft; trench II-11-1	515	55	
38	Krasnaselsky (former name: Krasnoye Selo), Belarus	LE-915	no data	1560	110	GURINA, 1976, p. 127
39		LE-680	Shaft 12	1420	50	DOLUKHANOV, *et al.*, 1970, p. 132
40		LE-636	Shaft 2, 3 i 12	1240	60	
41	Polany Kolonie, site II, Poland	Gd-133	Shaft 7	1550	90	SCHILD, 1995a, p. 484
42	Karpaucy (former name: Karpovcy), Belarus	LE-914	no data	1540	70	GURINA, 1976, p. 127
43		LE-913	no data	1400	80	
44	Bečov, Czech Republic	Bln-552	Shaft 5	1530	80	KOHL & QUITTA, 1970, p. 403
45		Bln-553	Shaft 1	1455	80	
46	Tomaszów, Poland	Gd-5196	Neighborhood of a shaft in the NE part of the mine	1280	40	SCHILD, 1995b, p. 462

4.5 m, with 2.5 m cutting through weathered limestone rock in which flint nodules occurred at various levels (Fig. 7). Shaft 28 provided a rich sampling of charcoal contemporaneous with the time when it was sunk and from the early stages of its backfilling (Fig. 6). These samples, like the first ones from the 'Zele' shafts, were sent to the Research Laboratory of the British Museum (LECH, 1995, p. 469-479; LECH & LELIGDOWICZ, 2003, p. 293, tab. 1; LECH *et al.*, 2011, p. 111-113, fig. 5). The results showed unequivocally that Shaft 28 was dug in the Late Bronze Age, around 1000 cal BC, at the time of the Lusatian culture from the Central European Urnfield complex (cf. HARDING, 2002, p. 273-274). The dates for the four charcoal samples sent to Groningen arrived in October 1983. Three of them dated with certainty Shaft 17 from Cutting III/82 to the Early Bronze Age – the time of the Mierzanowice culture. The fourth sample, from the same cutting, collected below the waste dump of Shaft 18, again indicated the Late Bronze Age (LECH, 1984, p. 194, table 1). In total, all 15 radiocarbon dates for charcoal samples from 8 shafts located in two distant regions of the mine are from the Bronze Age or Early Iron Age (see LECH & LELIGDOWICZ, 2003, p. 293, tab. 1).

In the years 1985-1988 the boundaries of the mining field were defined in a series of excavations. In total, between 1980 and 1988, 44 archaeological digs were carried out at the site and in its immediate vicinity, and 81 shafts and different exploitation units were located (Fig. 5). Some of the shafts were explored.

Fig. 7 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'. Cutting III/1983. Cross-section of shaft 28. Drawing by M. Ślązak.

4. NEW EXCAVATIONS

Changes in Poland's political system, which entailed privatisation and rationalisation of the industry, led to the closure and liquidation of the cement plant in Wierzbica in 2000. Since 2010 research of the 'Zele' mine has been carried out by the Autonomous Unit for Prehistoric Flint Mining at the Institute of Archaeology and Ethnology Polish Academy of Sciences (IAE PAN).

In 2014, after a hiatus of almost 30 years, the Autonomous Unit from IAE PAN, in cooperation with the Institute of Archaeology of the Cardinal Stefan Wyszyński University in Warsaw (UKSW), returned to the excavations of Shaft 1. The reasons for the resumption of excavation work was that during the studying of flint materials obtained from this feature in 1980, fine fragments of flakes and waste, normally produced during the processing of raw material, were found to be absent. The purpose of the new excavations was to obtain the entire flint material, including the fine and very fine fractions, to recreate the original structure of the inventory from the filling

Fig. 6 – (opposite page) 'Zele' mine in Wierzbica, Radom district, compared to other mines of siliceous rock from the Bronze Age in the east part of Central Europe, in the light of radiocarbon dates (conventional dates b.c.). Dates with standard error greater than ± 110 radiocarbon years have been omitted.

of Shaft 1. An additional reason for returning to the excavation of Shaft 1 was the intention of again uncovering the natural stratigraphic sequence found in 1980 between shafts 1 and 2, in connection with the research project, "Differentiation of Upper Jurassic 'chocolate flint' from Central Poland, from the point of view of identification in archaeological research" headed by Dagmara H. Werra (project financed from funds provided by the National Science Centre – PRELUDIUM 2 DEC-2011/03/N/HS3/03973). The intention was to take from the different levels with chocolate flint nodules samples for petrographic, geochemical and palynological analyses (WERRA & SIUDA, 2015a; WERRA *et al.*, 2015). It was also hoped that charcoal would be found for the radiocarbon dating of Shaft 1, since none was obtained in 1980.

In 2014 excavations of the 'Zele' site were conducted by Dr Dagmara H. Werra in cooperation with Jacek Lech. Cutting I/2014, measuring 7 x 13 m was opened at the site, as well as a small probe trench (S1/2014), 2.13 x 1.37 m intended to determine the border of Cutting II/81 next to the concrete road which ran across the north part of the site. The edges of this trench were to serve as additional points stabilising the measuring grid. Altogether, Cutting I/2014 covered an area of 78 m^2. The exploration was done manually, in layers of 10-20 cm, as it was necessary to remove the layer of material thrown out from the road ditches. A digger was employed only when removing material that had been used in 1980 to fill in Cutting I/80 (Fig. 8).

The excavations yielded large amounts of flint material, most of it natural. Cutting I/2014 can be divided into two zones – the eastern (E), where waste heaps from the shafts were registered and the western (W) part, where the filling of Cuttings I/80 and I/2012 was located. In zone W of Cutting I/2014, where the filling of Cutting I/80 was expected, excavators reached the level at which work had ended in 2012 (level with protective plastic foil). Excavation work then continued in order to determine the borders of Cutting I/80. At the first level in the NW corner, the outline of the shaft's waste heap was noted. A 20 cm layer was removed in order to clear the heap. As exploration proceeded, material was collected separately from each metre and all the material from the excavated sediments was sifted. In part E, under a layer of freshly deposited earth from the beginning of the 21st century and an old layer of ploughed soil, a concentration of limestone rubble was uncovered, together with a few pieces of flint. The arrangement of the excavated

Fig. 8 – Wierzbica, Radom district (Poland).
'Zele' mine. View from E onto cutting from 2014. in the advanced phase of the excavations. In the foreground Shaft 82 is being drawn, while a digger is uncovering old cutting I/1980, supervised by Dr Dagmara H. Werra. Photo by J. Lech.

material suggests that the remains of shaft heaps were uncovered. Excavation here was done by hand, clearing the gradually revealed structure of the heap as it was preserved. Altogether, the uncovered waste heaps were spread over an area of 48 m^2. All the excavated layers were sifted. Work then concentrated on further exploration of the filling of Shaft 1 by making an additional cut along an east-west axis running half way through the feature. As work on clearing the newly uncovered waste heaps and their detailed recording was a laborious task, excavations of Shaft 1 were fragmentary. Only two 10 cm levelling layers were removed in the east part of the Shaft 1 filling. Of the 16,971 flint pieces obtained from Cutting I, 3577 were artefacts and 13,394 were natural fragments without any traces of knapping. There was also one stone. The average weight of one specimen was 11.95 g.

5. Bronze Age workshop materials

From the flint material found during the excavations in 2014, a sample of 999 pieces was analysed. The morphological analysis was carried out in four morphological groups using the method presented in earlier articles (LECH & LONGWORTH, 2006, p. 415; LECH, 2012, p. 91-109). The results are given in Fig. 9:1. Four specimens, i.e. 0.4 % of the whole inventory, were attributed to the first group (Fig. 9:2). Their total weight was 755.9 g, which comes to 13.6 % of the weight of the whole inventory. The group of blades and blade fragments included 22 specimens (2.2 %) weighing together 59.5 g (1 %). Group III – Flakes and waste was the most numerous and comprised, 972 pieces (97.4 %) weighing together 3820.9 g (68.9 %). The fourth morphological group – tools was represented by just one artefact – a stone hammer (0.1 %) weighing 906.2 g (16.3 %).

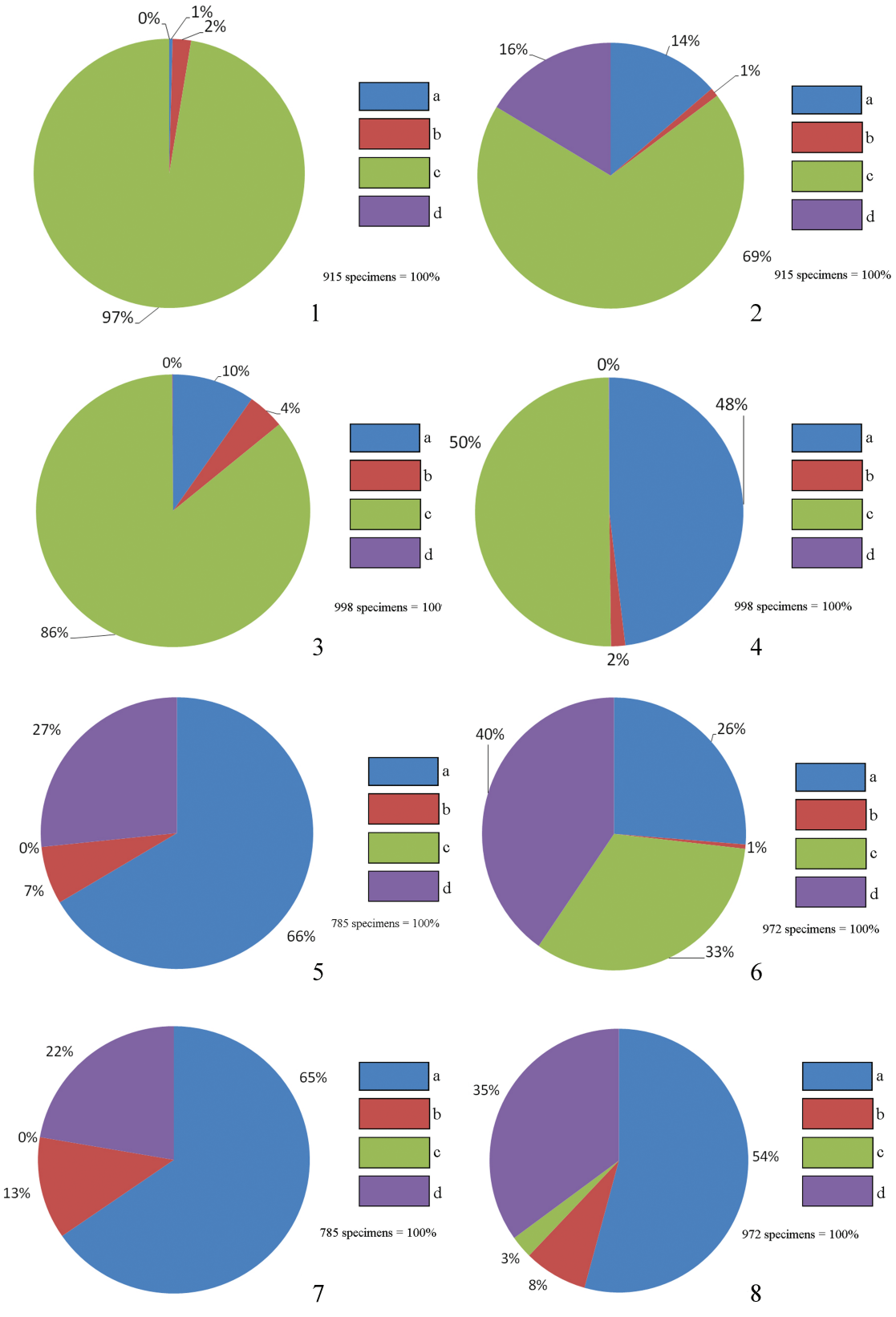
At the same time, at the Autonomous Unit for Prehistoric Flint Mining of IAE PAN material from the west part of Shaft 1, excavated in 1980, was also analysed. A sample of 915 flint specimens was also set apart and, after separating it into four morphological groups, was compared in terms of quantity and weight with the structure of the material from 2014 (Fig 9:3-4).

Owing to the small number of specimens in the morphological groups I, II and IV from the excavations in 2014, it was decided that for comparison with the 1980 research, the material from group III, flakes and waste, would be most suitable. In the material from Cutting I/1980, 3123 specimens from these groups were recorded, including 2338 natural fragments and flint nodules in group III. 576 pieces were counted as flakes and 209 as industrial waste (Fig. 9:5). While in Cutting I/2014 were found 3827 specimens and fragments. Among them 580 were flakes, microflakes and chips, and 392 were attributed to the group of industrial waste (Fig. 9:6).

The excavations of Cutting I/1980 yielded primarily complete flakes (522 specimens, weighing 30,625.7 g) and technical flakes. Microflakes and chips were not registered. The average weight of complete flakes was 58.72 g, and of technical flakes 107.31 g (54 specimens, weighing 5794.5 g). The combined average weight of specimens from Group III (without natural pieces) was 59.69 g (Fig. 9:7). Among the material from Cutting I/2014 microflakes and chips predominated – 320 specimens (weighing 107.3 g), followed by complete flakes (255 specimens weighing 2074.5 g) and with only – 5 technical flakes (weighing 302.7 g). The average weight of chips was 0.08 g, microflakes – 0.4 g, complete flakes – 4.24 g, technical flakes 60.54 g. The combined average weight of specimens from Group III (without natural pieces) was 3.93 g (Fig. 9:8).

The complete flakes were also compared in terms of size (Fig. 10:1-2) and weight (Fig. 10:3-4). In material from Cutting I/1980 average flakes predominated, from 50 to 80 mm in diameter (217 specimens), with an average weight of 32.72 g. Next came large flakes (above 80 mm in diameter), weighing on average 142.71 g. There were 149 small flakes, weighing on average 8.66 g. As previously mentioned, during these excavations no microflakes or chips were collected. The situation concerning the size and weight of flakes in the excavations of 2014 was reversed. There were most microflakes with a diameter of 10 to 20 mm – 258 specimens with an average weight

of 0.4 g. In second place were small flakes (20-50 mm) of which there were 225 specimens with an average weight of 4 g. 62 chips, weighing on average 0.08 g. were found, followed by 26 medium sized flakes (average weight 32.2 g), and only four large flakes weighing on average



82.75 g. This comparison illustrates the influence of research objectives and methods of collecting flint material on the flint inventories undergoing further investigations.

To sum up:

1. In both compared inventories, divided into four morphological groups, flakes and waste predominate;

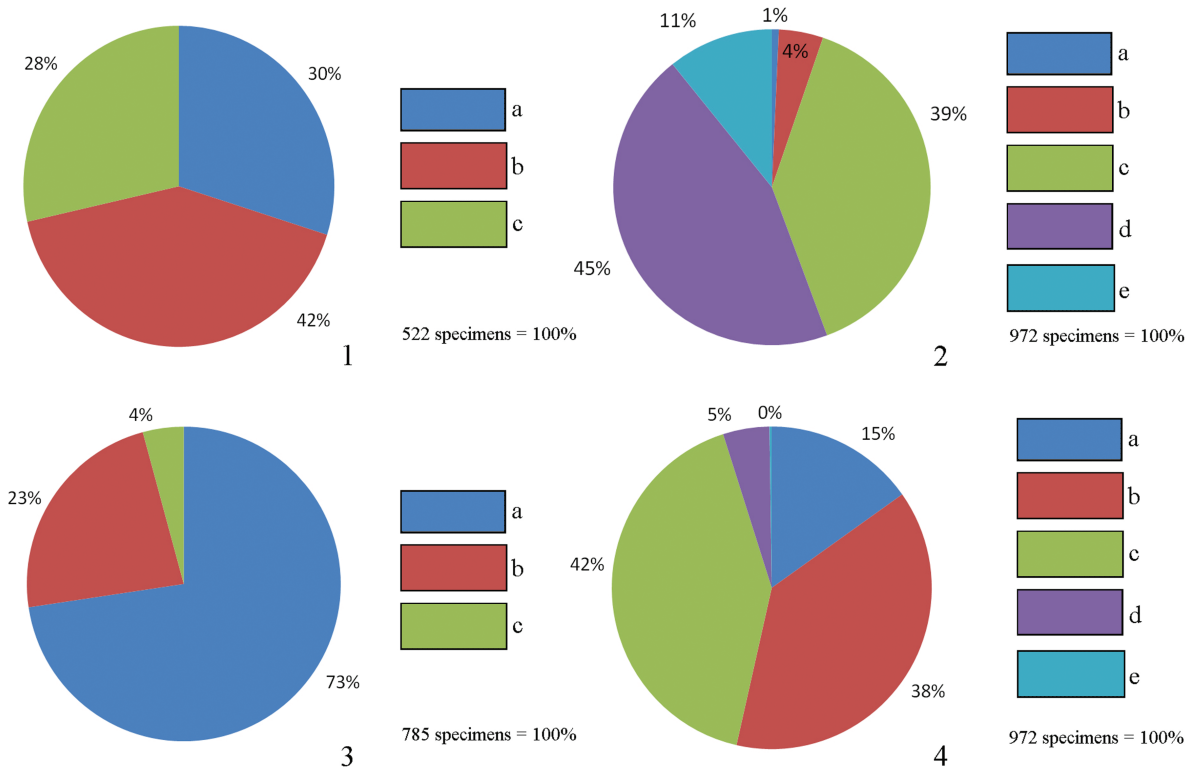


Fig. 10 – Wierzbica 'Zele', Radom district (Poland), structure of flint materials.
a. large flakes > 80 mm; b. medium flakes – 50 to < 80 mm;
c. small flakes 20 to < 50 mm; d. microflakes 10 to < 20 mm; e. chips ⩽ 10 mm;
1. Cutting I/2014. Structure of sample in the Third Morphological Group – flakes and waste (972 specimens); 2. Cutting I/1980. Structure of sample in the Third Morphological Group – flakes and waste, in terms of size (522 specimens); 3. Cutting I/2014. Structure of sample in the Third Morphological Group – flakes and waste, in terms of size (972 specimens); 4. Cutting I/1980. Weight structure of flint material from sample in the Third Morphological Group – flakes and waste, in terms of size (785 specimens). Prepared by D.H. Werra.

Fig. 9 – (opposite page) Wierzbica 'Zele', Radom district (Poland), structure of flint materials.
1-4: a. First Group: Natural nodules and their large fragments, roughouts, precores and cores; b. Second Group: Blades and their fragments; c. Third Group: Flakes and waste; d. Fourth Group: Implements;
1. Cutting I/2014. General structure of sample in the four morphological groups (915 specimens);
2. Cutting I/2014. Weight structure of flint material in the four morphological groups (915 specimens);
3. Cutting I/1980. General structure of flint material from sample in the four morphological groups (998 specimens); 4. Cutting I/1980. Structure in terms of weight of flint material from sample in the four morphological groups (998 specimens); 5-8: a. complete flakes; b. specific flake types; c. microflakes and chips; d. waste; 5. Cutting I/1980. Structure of flint material from sample in the Third Morphological Group – flakes and waste (785 specimens); 6. Cutting I/2014. Structure of flint material from sample in the Third Morphological Group – flakes and waste (972 specimens); 7. Cutting I/1980. Weight structure of flint material from sample in the Third Morphological Group – flakes and waste (785 specimens); 8. Cutting I/2014. Structure of flint material from sample in the Third Morphological Group – flakes and waste (972 specimens). Prepared by D.H. Werra.

2. Both inventories have fewest specimens from Group IV: Tools – below 1 %;
3. In the material from Cutting I/1980 there was a small number of blades and their fragments (group II) – 4.37 %, and in Cutting I/2014 the amounts were even smaller – 2.2%
4. In the material excavated in 1980 the First Morphological Group comprised 10 %, while in 2014 four items were found, including one tool, making up 0.4% of the whole inventory, which

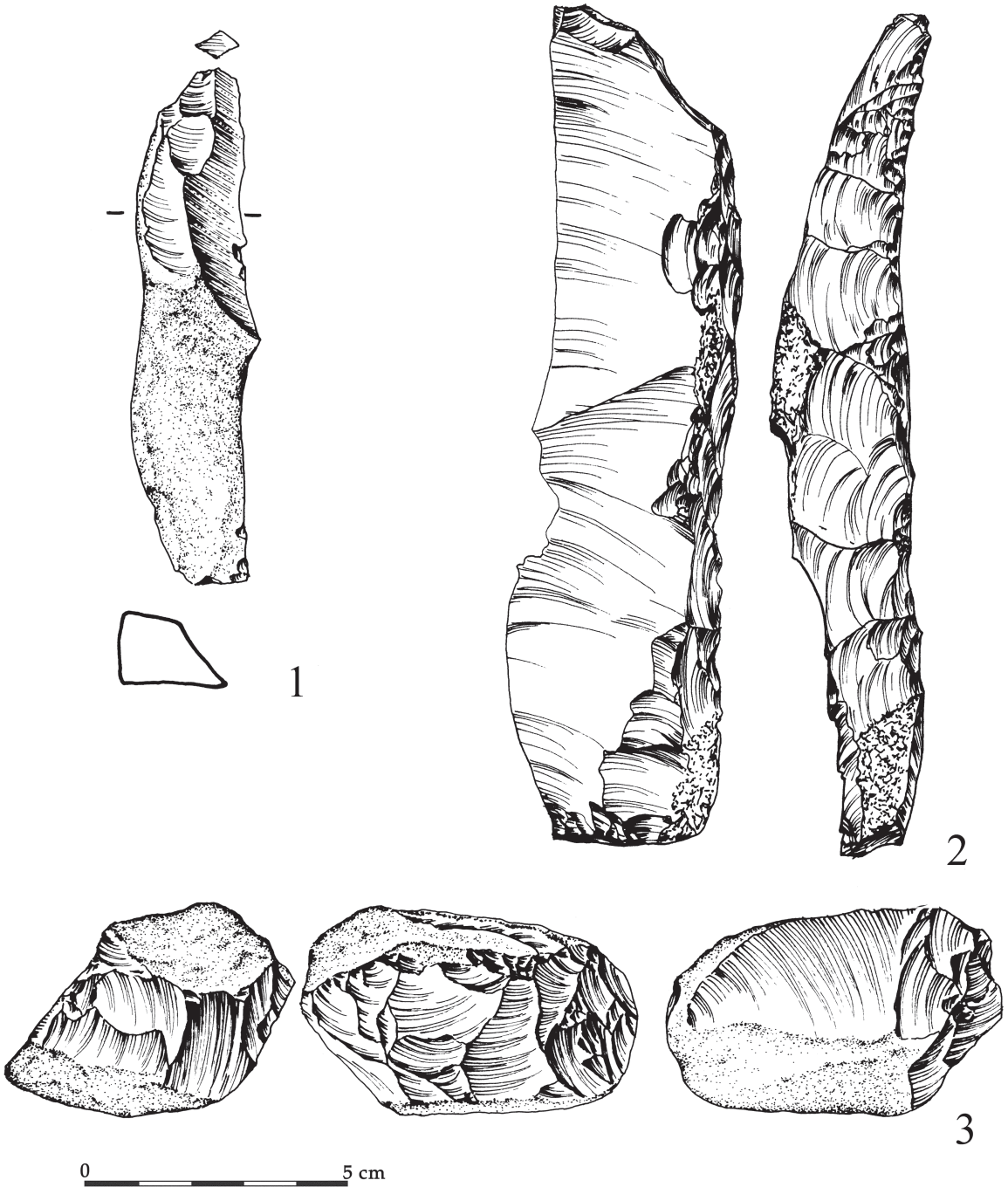


Fig. 11 – Wierzbica 'Zele', Radom district (Poland). Flint artefacts from the flint mine site. 1. Waste blade; 2. Backed blade of 'Zele' type; 3. Paracore. Drawing by E. Gumińska (1, 3) and I. Niewiadomska (2).

illustrates in this case the influence of small fractions of material on the image of its structure and, more widely, the necessity of comparing the inventories collected in the same way with the same or at least similar precision;

5. In terms of weight only group II was similar in both years: I/1980 – 1.7 % and I/2014 – 1.07 %
6. In material from Cuttings I/1980 and I/2014, group III has the largest percentage share in terms of weight. However, its internal structure is completely different. In Cutting I/1980, only large, medium and small flakes were registered. Microflakes and chips were not collected. Thus, the smallest specimens had a diameter of up to 20 mm. In Cutting I/2014, small flakes, microflakes and chips predominated, so the smallest collected specimens had a diameter of less than 10 mm.

7. In Cutting I/2014 medium flakes predominated in terms of weight (38 %), though being few in number, in second place were small flakes (42 %) and then large – 15 %. Microflakes, although numerous, by weight constituted only 5 % of the inventory.

6. On the morphology of artefacts

Among the artefacts associated with the 'Zele' mine are common flint flakes and waste, early bifacial axe roughouts and rare blades (Fig. 11:1). Very rare but important are backed knives of the 'Zele' type (Fig. 11:2) made from large blades or flakes (LECH, 1984, p. 195, 1997b, p. 96-97; LECH *et al.*, 2011, p. 114-115). Fresh analyses of flint materials from earlier excavations of the 'Zele' mine brought to our notice the presence of a group of artefacts which is difficult to interpret in the light of what we know so far about the use of flint by farming communities and in the light of our rationality. The group includes fragments of flint nodules worked by flint knappers seemingly without any useful purpose. Most of the specimens seem to qualify as cores but with closer analysis in most cases it is not possible to determine what might be the aim of exploiting such cores. Sometimes, one might conclude that the knapper's objective was to destroy the piece of flint he was working.

Professor Oliva had made similar observations with reference to late flint knapping when describing prehistoric mining in the 'Krumlovský les' in Moravia (OLIVA, 2010, p. 266 and others; OLIVA, 2011, p. 99-106). It would seem that what we have here is flint mining and knapping for partly ritualistic purposes, with limited practical use, maybe related to an ancestral cult (OLIVA, 2010, p. 294-302, 2011, p. 104-106; see LECH, 1997a, p. 110-112, 1997b, p. 96-97). In the light of studies of the material from the 'Zele' mine carried out in recent years, this explanation seems most convincing. The specimens treated in this way by knappers are not in fact cores but 'paracores' and such a category of artefacts can clearly be distinguished among the 'Zele' flints (Fig. 11:3). How these two completely different tendencies in flint working are related to each other, whether they are contemporaneous or from different periods, we cannot as yet explain.

7. Final remarks

Wierzbica 'Zele' was the first European flint mine dated exclusively to the entire Bronze Age, from its early to late period. What in the first half of the 1980s was a surprise and aroused doubts, was confirmed by excavations in the following years.

There are indications that towards the end of the Bronze Age flint mining served symbolic purposes and also for preparation of ordinary and sophisticated flint tools (LECH, 1984, p. 198-200; LECH *et al.*, 2011; OLIVA, 2011, p. 104-106; LECH *et al.*, 2015; LECH & WERRA 2018, p. 580-581). This is probably the meaning of the characteristic 'Zele' type knives, whose range of occurrence is much wider than initially thought. The presence of such backed knives is also associated with the ritual zones of southern Scandinavia (HÖGBERG, 2009, p. 263; MASOJĆ & BECH, 2011).

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