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The Beginning of the Early Upper Paleolithic in Poland

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Abstract

Research on the timing of *Homo sapiens* dispersals in Central Europe is pivotal for understanding the behavioral trajectories of human adaptation to low biomass environments and cold climates. Previous studies on the Early Upper Paleolithic of Poland described a different scenario from the European panorama characterized by the local development of a laminar/lamellar technology from the foregoing Middle Paleolithic and the coexistence of different Aurignacian variants after 35 ka BP. In this paper, we examine this technical diversity by reassessing and revising the chronological and technological information of the key Aurignacian sites in Poland. Our study reveals that the distinctive techno-typological features of the different Aurignacian types are most likely the result of the mixing of artifacts from different chronologies. In our view, Poland was visited intermittently by *Homo sapiens* since the Early Aurignacian. The deterioration of the climatic conditions during the second half of MIS 3 converted the Polish territories into a satellite area of the Aurignacian settlement system.

Keywords *Homo sapiens* · Early Upper Paleolithic · Aurignacian · Lithic technology · Central Europe

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Introduction

A debated topic in human evolutionary studies is the nature and the timing of the dispersal of *Homo sapiens* from Africa to Eurasia and the subsequent interaction and substitution of the indigenous local populations (Bae et al., 2017; Benazzi et al., 2015; Dennell & Petraglia, 2012; Hublin, 2015; Hublin et al., 2020; Picin et al., 2021, 2022; Wedage et al., 2019). In Europe, the earliest migration of *Homo sapiens* that marks the beginning of the Initial Upper Paleolithic (IUP) is associated with a new lithic industry that appeared at ~ 50 ka in the Levant (Boaretto et al., 2021; Goring-Morris & Belfer-Cohen, 2020) and then spread at ~ 48/46 ka into Bulgaria (Fewlass et al., 2020; Talamo et al., 2023; Tsanova, 2008) and Czech Republic (Prüfer et al., 2021; Škrdla, 2013). In concomitance with this first dispersal, new technical behaviors (e.g., Szeletian, Châtelperronian, Lincombian-Ranisian-Jerzmanowician (LRJ)) emerged in the Neanderthal territories after more than 300 ka of technological stability (Carrión & Walker, 2019; Kuhn, 2013; Picin, 2018; Picin et al., 2013; Torre et al., 2013; Tuffreau, 1976; White & Ashton, 2003). Whether these improvements were the result of a process of acculturation of Neanderthals by the new groups of *Homo sapiens* or were developed independently by Neanderthals is still a matter of debate (Bar-Yosef & Bordes, 2010; d'Errico et al., 1998; Flas, 2011; Gravina et al., 2018; Hublin et al., 2012; Mester, 2014; Škrdla, 2017; Welker et al., 2016; Zilhão, 2012). The main issue in this discussion is the absence of human fossils in clear association with the transitional industries which makes it difficult to unequivocally decide whether the producer of these new stone tools were Neanderthals or *Homo sapiens* (Bailey et al., 2009).

Because of its restricted geographical extension, the European IUP is interpreted as a failed migration, and only after ~ 42 ka, *Homo sapiens* expand rapidly from the Balkans to Central-Western Europe, Italy, and the Iberian Peninsula (Hublin, 2015; Mellars, 2005). This second dispersal is named Aurignacian and comprises a succession of two culturally distinct variants: the Proto-Aurignacian (or Aurignacian 0), found mostly in the regions facing the Mediterranean Sea, and the Early Aurignacian (or Aurignacian 1), scattered along the upper Danube River and western France (Mellars, 2005). The Proto-Aurignacian always underlies the Early Aurignacian suggesting that it is the older technological background from which the successive laminar technical behaviors arose (Zilhão, 2007). However, recent chronological reassessments of some key sites in Central Europe (Higham et al., 2012; Nigst et al., 2014) and south-eastern France (Barshay-Szmidt et al., 2018) point out a rough contemporaneity between the two facies fostering intense discussions (Banks et al., 2013a, b; Higham et al., 2013; Teyssandier & Zilhão, 2018). In this perspective, some authors propose a short chronology for this cultural succession placing the Proto-Aurignacian between 41.5 and 39.9 ka cal BP and the Early Aurignacian between 39.8 and 37.9 ka cal BP (Banks et al., 2013a, b). Conversely, others place the beginning of the Early Aurignacian before the Heinrich 4 event (H4) at 43.5 ka cal BP at Willendorf II AH 3 (Nigst et al., 2014) or at 42.5 ka cal BP at Geißenklösterle AH III (Higham et al., 2012, 2013).

This issue of a chronological overlap or succession of the Proto-Aurignacian and Early Aurignacian has also major implications on the behavioral adaptability of *Homo sapiens* newcomers to the European ecological conditions. While the expansion of *Homo sapiens* from the Levant and the spread of the Proto-Aurignacian across the western Mediterranean are generally associated with phases of relative climatic ameliorations (Müller et al., 2011), some authors suggest that the H4 (40.2–38.3 ka) was the climatic driver that stimulated the technological change from the Proto-Aurignacian to the Early Aurignacian (Banks et al., 2013a) and the development of the split-based points (Tejero, 2014). Conversely, others postulate that these early groups, arriving with an Early Aurignacian toolkit before the H4, were fully capable of exploiting cooler steppe landscape (Higham et al., 2012; Nigst et al., 2014).

The discovery of fossils of *Homo sapiens* at Bacho Kiro (Hajdinjak et al., 2021; Hublin et al., 2020) and Peştera cu Oase (Trinkaus et al., 2003), as well as early forms of lamellar production in Bulgaria (Tsanova, 2008) and then in northern Italy, Austria, and southern Germany (Higham et al., 2009, 2012; Nigst et al., 2014; Uthmeier, 1996), support the hypothesis that the Danube River acted as the main corridor of dispersal facilitating the expansion into the western regions (Conard & Bolus, 2003). In the current scenario, *Homo sapiens* is thought to have spread rapidly westwards from the upper Danube to the Po Plain and Swabian Jura reaching successively western France and the Iberian Peninsula (Benazzi et al., 2015; Higham et al., 2011; Talamo et al., 2012, 2020; Wood et al., 2014). Conversely, the incursions into the east were limited to the Carpathian basin (Chu, 2018; Davies & Hedges, 2008; Demidenko et al., 2017, 2020; Nejman et al., 2017; Wright et al., 2014) and Crimea (Demidenko, 2014). The expansion in other regions above 49° latitude north seems to be uneven as dispersals in Belgium and England took place at 37 ka BP (Dinnis, 2012; Dinnis & Flas, 2016) whereas in other areas of Central Europe occurred only well after 35 ka BP suggesting that these territories were an ecological barrier or occupied by other groups (e.g., LRJ) (Flas, 2015; Kozłowski, 2002; Terberger et al., 2003). However, lamellar technology and bone tools are documented between 45 and 41 ka BP at 51° latitude north, at Kostenki 14 layer IVb and Kostenki 17 layer II (Anikovich et al., 2007; Dinnis et al., 2019b) whereas, at ~ 38–40 ka BP, the assemblages of Kostenki 14 (Markina Gora) and Kostenki 1 level III show many affinities with the Early Aurignacian of Central Europe (Hoffecker et al., 2016). This latter evidence reveals the broad behavioral adaptability of *Homo sapiens* to low biomass environments implying that the archaeological record of early settlements in the Central-Western European Plains could have been hampered by the lack of extensive investigations, or by the low resolution of the old excavation methods.

In this context, Poland is a crucial area for investigating this issue because after long-term settlements by Neanderthals (Cyrek et al., 2014; Valde-Nowak & Cieśla, 2020; Valde-Nowak & Nadachowski, 2014; Valde-Nowak et al., 2016; Wiśniewski et al., 2013), the appearance of Szeletian (Bobak et al., 2013; Połtowicz-Bobak et al., 2013), Jerzmanowician (Chmielewski, 1961; Flas, 2011; Krajcarz et al., 2018), and Zwierzyniecian (Stefański, 2018) it is thought that *Homo sapiens* crossed the Moravian Gate only during the late phase of the Aurignacian (Kozłowski, 2002; Sachse-Kozłowska, 1978) leaving the territory deserted for several millennia. In Poland, 16 Early Upper Paleolithic (EUP) sites scattered between the neighborhoods of the city of Kraków, the Kraków-Częstochowa Upland, the Western Carpathian Mountains, Lublin, and Upper Silesia are documented (Kozłowski & Kozłowski, 1996; Masojć & Bronowicki, 2003; Sachse-Kozłowska, 1978). Previous recapitulatory works highlighted the presence of four main Aurignacian variants in Poland: (1) the Zwierzyniec type — characterized by higher percentages of burins over endscrapers and retouched tools; (2) the Piekary type — characterized by higher percentages of end-scrapers over burins; (3) the Góra Puławska type — typified by the higher amount of end-scrapers, *Dufour* bladelets and few burins; (4) the Olševa Type — characterized by few artifacts and massive bone and mammoth tusk points with an unsplit base of Mladeč type (e.g., Mamutowa Cave) (Chmielewski, 1975a; Kozłowski, 1966, 1983; Kozłowski & Kozłowski, 1975; Sachse-Kozłowska, 1978). Following this subdivision, Góra Puławska was associated to the Proto-Aurignacian (Krems-*Dufour* facies), the Zwierzyniec and Piekary variants were related to the Typical Aurignacian (nowadays known as Late or Recent Aurignacian) whereas the Olševa variety was intended to represent low density lithic assemblages with bone/ivory points from caves sites (Kozłowski, 1983; Kozłowski & Kozłowski, 1975, 1977; Sachse-Kozłowska, 1978). Unfortunately, the assemblage of Góra Puławska I was lost during World War II, and it is known only from the drawings made by Krukowski (1939). Recently, the assemblage of Góra Puławska II has been ascribed to a new variant of the Evolved Aurignacian named Góra Puławska-type (Demidenko et al., 2017) whereas the industry of Piekary IIa level 6 and Kraków-Księcia Józefa Street layer II have been attributed to a non-Aurignacian UP rooted in the prior Middle Paleolithic (Sitlivy, 2016). In this panorama, the emergence of the Aurignacian in these territories appears to be heterogeneous in comparison with the other European areas and characterized by diversified toolkits and technologies. In this paper, we aim to disentangle the beginning of the EUP in Poland reviewing the techno-typological features of the main Aurignacian sites located at the Kraków Gate, the Kraków-Częstochowa Upland, and the Western Carpathian Mountains (Fig. 1). We provide an updated analysis of the lithic assemblages of Kraków-Zwierzyniec 1 trench III, Kraków-Księcia Józefa Street layer II, Piekary IIa level 6, Stajnia Cave, and Obłazowa layer VIII. Moreover, we revise the data published for other sites (Kraków-Spadzista Street, Piekary IIE, Mamutowa Cave, and Deszczowa Cave). We aim to compare the Polish data with the chrono-cultural models that are currently used for distinguishing the Aurignacian phases in Central-Western Europe (Bon, 2002; Conard & Bolus, 2006b; Dinnis et al., 2019a; Teyssandier, 2007; Zilhão, 2011). In this way, we intend to outline the patterns of dispersals of *Homo sapiens* in a region that, in the last decades, has been overlooked from broad-scale scenarios.

The Techno-typological Development of the Aurignacian

A wide consensus supports a diachronic development of bladelet and microblade technologies and stone tools in the Aurignacian, and interprets these techno-typological innovations as strict successions of chrono-cultural markers (Chiotti, 2005; Hahn, 1977; Le Brun-Ricalens & Bordes, 2005; Le Brun-Ricalens et al., 2006;

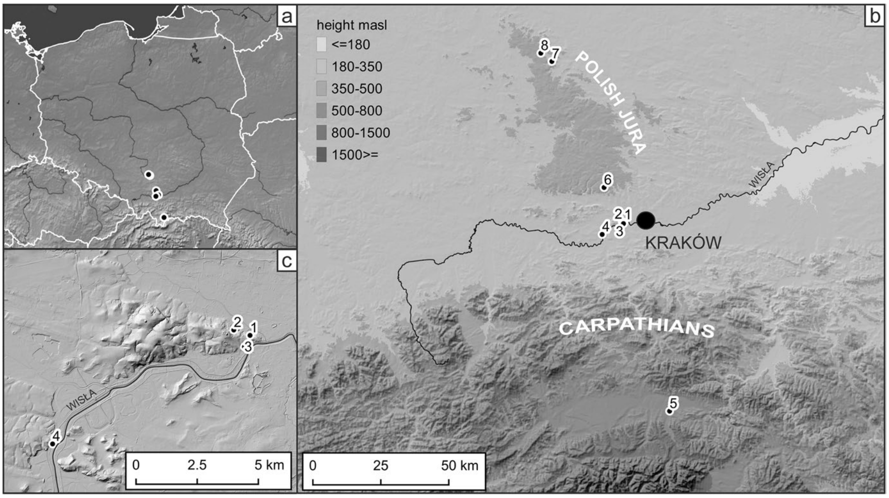

Fig. 1 Map of Poland (**a**) and geographical location of the sites mentioned in the text (**b–c**): 1 Kraków-Zwierzyniec 1; 2 Kraków-Spadzista Street; 3 Kraków-Księcia Józefa Street; 4 Piekary II; 5 Obłazowa Cave; 6 Mamutowa Cave; 7 Deszczowa Cave; 8 Stajnia Cave

Mellars, 2006; Michel, 2010; Teyssandier, 2008; Zilhão, 2011). However, over the years, some variability emerged at a regional level, as a reflection of the socio-cultural diversity of the EUP groups (Conard & Bolus, 2006b; Demidenko et al., 2012; Vanhaeren & d'Errico, 2006), raising the issue of the consistency of this approach, and if the absence or presence of a diagnostic artifact is necessarily ruling out a lithic assemblage from "its" chrono-cultural position (Conard & Bolus, 2006b; Flas et al., 2012; Lucas, 2006). To outline the development of the Aurignacian in Poland, an updated synthesis of these chrono-cultural trajectories and their inner variability is presented.

Hitherto the Proto-Aurignacian is characterized by a continuous blade to bladelet production (Bon, 2002; Teyssandier, 2008). These large bladelets (*c*. 30–45 mm), produced by sub-prismatic and sub-pyramidal cores, have generally a straight/slightly curved profile and often are modified with an inverse/alternate (subtype *Dufour*) or a direct bilateral retouch (Font-Yves and Krems point) (Teyssandier, 2008). The Early Aurignacian is instead divided into two independent knapping strategies (Bon, 2002; Teyssandier, 2008). Unidirectional cores produce large and robust blades, at times, modified by a steep/scaled Aurignacian retouch and strangled at the mid-section. On the other hand, carinated cores producing small bladelets (*c*. 30–10 mm) with curved/twisted profiles, sometimes retouched into *Dufour* bladelet subtype *Roc du Combe*, characterize the second reduction sequence (Teyssandier, 2008). Other typical features of the Early Aurignacian are also considered the presence of split-based bone points and a higher amount of endscrapers over burins (Hahn, 1977). However, this subdivision had been recently questioned (Bataille & Conard, 2018; Conard & Bolus, 2006a; Falcucci et al., 2017, 2020) because it is mostly based on evidence from Aquitaine (Bon, 2002), and the long sequence of Abri Pataud (Chiotti, 2005) is generally used as the main term of reference for western and eastern Europe. Lithic knapping is a dynamic process, and, within the same technological background, some variability in the toolkit composition should be expected especially in relation to the productivity of different environments, foraging strategies, and types of settlement (e.g. long- vs. short-term occupations, cave vs. open-air site) (Picin & Cascalheira, 2020). In this perspective, some authors raise the issue that the differences between the Proto-Aurignacian and the Early Aurignacian are more typological than technological, and regional variants could reflect different behaviors and foraging needs of the hunter-gatherers' groups (Bataille et al., 2018; Conard & Bolus, 2006a; Falcucci et al., 2017; Sitlivy et al., 2014b; Tafelmaier, 2017). Some examples are the presence of carinated cores in Proto-Aurignacian assemblages in Catalonia (Ortega Cobos et al., 2005), northern Pyrenees (Barshay-Szmidt et al., 2012; Normand et al., 2009), Cantabrian region (Maillo-Fernandez, 2005; Santamaría, 2012), and Eastern Europe (Bataille, 2017; Sitlivy et al., 2014a). Furthermore, curved and small bladelets are found together with straight blanks at Fumane (Falcucci et al., 2017), Mandrin (Slimak et al., 2002), Istuitz (Normand et al., 2009), and Labeko Koba (Tafelmaier, 2017). Independent blade and bladelet production are documented in the Proto-Aurignacian at Fumane (Broglio et al., 2005), Mandrin (Slimak et al., 2006), Les Cottés (Roussel & Soressi, 2013), Grotte du Renne/Arcy-sur-Cure (Bon & Bodu, 2002), and Isturitz (Normand, 2005). Another issue is split-based points as a marker of the Early Aurignacian when direct radiocarbon dating on osseous and ivory bone tools shows a chronological overlapping with other point forms (e.g., Mladeč points) (Davies et al., 2015).

The end of the Early Aurignacian and the transition to other stages is concomitant with the development of new knapping strategies and retouched tools (Hahn, 1977). However, these changes in the toolkit compositions are not homogenous and some variability is recorded. In some sites of western France and Belgium, the presence of asymmetrical nosed endscrapers has been classified as Middle Aurignacian (*c.* 37–35 ka BP) (Anderson et al., 2018; Chiotti, 2005; Flas, 2015; Michel, 2010) whereas in other regions, the transition from the Early Aurignacian to the Late (or Recent) Aurignacian is set at 37/35(?) to ~ 31 ka BP (Higham et al., 2011). In this phase, the lithic toolkit is characterized by a decrease in the frequency of carinated scrapers and a rise of microblade cores, such as nosed endscrapers and carinated burins (*busqué* and Vachons), for the production of short (*c.* 10–20 mm) twisted microblades often modified with an inverse/alternate retouch ('*Dufour* bladelets' *Roc-de-Combe* subtype) (Chiotti, 2005). Carinated scrapers have narrower scraper fronts than Early Aurignacian examples (Dinnis et al., 2019a) whereas, at some sites, large end-scrapers with a retouched truncation ("Caminade scrapers") are used for the production of small flakes (Anderson et al., 2016; Caux, 2017). The shape of organic points increases in variability with types characterized by massive bases or lozengic morphology (e.g., Mladeč or Lautsch points) made of ivory, bone, or deer antler (Liolios, 2006; Tejero, 2014).

The Final Aurignacian (31 to ~ 29 ka BP) is a phase still poorly documented due to scarce evidence and sedimentological hiatuses between the last Aurignacian and the beginning of the Gravettian (Higham et al., 2011; Jacobi et al., 2010;

Moreau, 2010). Generally, there are no foremost techno-typological breaks, and bladelet and microblade production continue in similar ways as during the Late Aurignacian, although a tendency towards longer and more rectilinear blanks has also been recorded (Chiotti, 2005; Pesesse, 2008). Microblades cores still include *busqué* and Vachons burins and nosed scrapers while Aurignacian retouch is used less frequently.

The transition from the Early to the Late Aurignacian is mostly based on the appearance of carinated burins and, in particular, the *busqué* burin that is interpreted as *fossile directeur* of the novel chronological phase. However, over the years, different types of carinated blanks were documented in the archaeological record yielding the classification of some tools/cores at times problematic due to the overlapping of some features (Almeida, 2001; Hahn, 1977; Kolobova et al., 2014; Movius & Brooks, 1971; Sachse-Kozłowska, 1978; Sonneville-Bordes & Perrot, 1954). In this perspective, carinated cores, burin-like cores, and carinated burins are all artifacts that often are interpreted differently. While a carinated endscraper is characterized by a front-edge bigger than the length of the bladelets scars (Movius & Brooks, 1971), a carinated core should display a volumetric organization and a curved flaking surface aimed to the production of bladelets (> 12 mm wide) (Kolobova et al., 2014). Demidenko (2012 p. 97) specifies further the features of a carinated core stating that "the flaking surface is convex or twisted with a sub-cylindrical or sub-pyramidal morphology, and the length of the flaking surface should be bigger than the width of the striking platform". Moreover, a carinated burin should display more than three burin spall removals on one burin edge; otherwise, it would reenter the definition of a dihedral burin (Demidenko et al., 2017).

Within this category, some cores in the archaeological record could resemble the morphology of burins raising the issue what features separate a carinated core, a burin-like core, and a carinated burin. Thus far, there is no clear definition for burin-like core, and often this term is used for implying a burin function on small narrow-sided or *tranche d'un éclat épais* cores although use-wear analyses were not performed (Bataille et al., 2018; Moreau, 2012; Sitlivy et al., 2012). Conversely, Demars and Laurent (1989 p. 52) define a carinated burin as a "tool generally on a flake, more rarely on a blade, having a first relatively flat striking platform formed by one or more burin spalls, opposite to a flaking surface more or less cylindrical, obtained by a series of bladelet removals, and creating a biseau with a rather curved delineation". However, this definition could embrace blanks of several sizes and morphologies, and the additional use of a threshold of ≤ 10 mm for the width of the flaking surface is useful for separating carinated burins sensu stricto from other types of carinated "burin-like" cores (Bergman, 1987). *Busqués* burins differ from carinated ones for a stop-notch (single or retouched) at the termination of the débitage surface that predetermines the length of the bladelets/microblades (Demars & Laurent, 1989). Lucas (2006) supports a correlation between the carinated and *busqués* burins proposing that the stop-notch is a technical element for recreating the longitudinal convexity in a reshaping and reduction continuum.

The other stone tools typical of the late phase of the Aurignacian are the Vachons burin (Le Brun-Ricalens & Bordes, 2005). This category of burin could be made on different types of blanks (e.g., flakes, laminar byproducts, blades), and it is characterized by a flat striking platform, created by a natural back or by abrupt direct retouch, opposed to a flaking surface used for the production of microblades creating a generally acute, or even pointed, plane *biseau* (Pesesse & Michel, 2006).

Methods

We analyze the lithic material following the *chaîne opératoire* concept, a methodological framework that defines the reconstruction of the various processes of flake production from the procurement of raw materials through the phases of manufacture and utilization until final discard (Inizian et al., 1992; Pelegrin et al., 1988). The categories analyzed include cores, flakes, blades/bladelets, fragments, and chips (fragments < 10 mm). The cores are analyzed according to their technological characteristics such as the number of striking platforms, the orientation of the flaking surfaces, and the direction of the blank removals (Pelegrin, 1995; Pigeot, 1987). Laminar and lamellar items are considered blanks in which the length is double the width and categorized, according to Tixier, 1963, in blades (width ≥ 12 mm), bladelets (width 7–11.99 mm), and microblades (width < 7 mm). The assemblages of retouched tools are analyzed following Demars and Laurent (1989). Taphonomic analysis of the lithic artifacts was not performed and will be carried out in the next studies of the assemblages.

The Polish Aurignacian Sites

Kraków Gate

Since the beginning of the twenty-first century, several archaeological sites were discovered in the southwestern area of Krakow, on the northern slope of the Vistula River Valley (Fig. 1). The Aurignacian evidence is scattered in different locations within a radius of about 10 km. In the district Zwierzyniec, on the northern slope of the Saint Bronisława Hill, at the interfluve between the Vistula River and its left-bank tributary, the Rudawa River, the sites Kraków-Zwierzyniec (Chmielewski et al., 1977; Sawicki, 1957) and Kraków-Spadzista Street (Kozłowski & Sobczyk, 1987; Sobczyk, 1996) are found. At ~ 4 km upstream along the Vistula River is located the site of Kraków-Księcia Józefa Street (Sitlivy et al., 2009) whereas at ~ 10 km on the same riverbank, at the Tyniec Gate, is situated the complex of Piekary (Morawski, 1975; Sawicki, 1957; Sitlivy et al., 2008).

Kraków-Zwierzyniec 1

Kraków-Zwierzyniec 1 is a multi-cultural stratified open-air site located on the eastern slope of the Bronisława Hill, at the corner of the intersection between the Rudawa River and the Vistula River (Fig. 1). Since the postwar years, the site was intensively exploited for brickworks and, in 1930, A. Jura investigated the area in different sectors (at the Gate, Point P, Jasiek's site, and Trench J) (Chmielewski, 1975b; Jura, 1951a, b). After World War II, Sawicki (1952) started a systematic exploration of the site, and in 1948, he opened Trench 1 running parallel to the vertical loess exposure left behind by brickworks. Then, between 1949 and 1957, Sawicki expanded the excavation on the western side opening trenches 2, 3, 4a, and 4b (Sawicki, 1952, 1957). Successively, between 1972 and 1974, Chmielewski et al. (1977) carried out other fieldwork at the site to clarify the stratigraphy. A first trench was opened from the west wall of the Sawicki's Trench 4a and 4b and another one between the Sawicki's Trench 1 and the Jura's Trench J.

The stratigraphy of the site is composed of a 15-m sedimentary sequence lying on an Upper Jurassic massive limestone (Łanczont et al., 2015a; Madeyska, 2006). Starting from the bottom, the limestone and the silty sediments remnant of the ice-dammed lake deposit of the Elsterian Glaciation are overlaid by 2–3 m of coarse–medium sands (layer 1) and by a 2-m well-developed argic illuvial horizon (layer 2). The sequence continues with a discontinuous whitish silty sand horizon (layer 3) of up 20 cm thick, superimposed by a level of silty sands with a net of veinlets (layer 4), that decreases in thickness as it goes uphill. Layer 5 is composed of silty sand overlaid by a more clayed horizon (layer 6) and covered by light brown sandy loess (layer 7) of a thickness of ~ 40 cm. Layer 8 is a 15–20 cm gleyic level covered by a series of layered loess with some lenses of sand (layer 9) and another gleyic horizon (layer 10). The succession of layers 2 and 3 is attributed to the Eemian whereas the series layer 4–10 is associated with the cycle of MIS 5a–d. The sequence continues with layer 11, laminated loess sediment dated to the MIS 4, overlapped by a reddish-yellow layer 12 of 20–30 cm thickness, and a greyish-brown loess layer 13 of variable thickness. The stratigraphic section ends with a gleyied loess (layer 14), affected by solifluction processes, superimposed by a 3–5 m thick loess (layer 15) (Łanczont et al., 2015a; Madeyska, 2006).

Middle Paleolithic lithic assemblages were discovered on top of layer 2 and in the upper part of layer 3 whereas Szeletian, Zwierzyniecian, and Aurignacian were found in the interpleniglacial soils embedded between thick loess levels. According to Sawicki (1957) and Chmielewski et al. (1977), the succession of the archaeological finds spans between layer 12, the original horizon of the artifacts and associated with the Komorniki soil, layer 13 (soil level) and layer 14 (solifluction layer). Recently, Łanczont et al. (2015a) revised the stratigraphic section of the site and dated the sequence by a thermoluminescent method. The series of interstadial soils are dated between 55.6 ± 5.2 ka and 40 ± 5.2 ka whereas a radiocarbon date on a *Picea*/*Larix* charcoal yielded a range between 42.750 and 41.824 years cal BP (68.3%) (Table 1). A thermoluminescent date at the beginning of the overlain loess layer yields an age of 36 ± 4.7 ka, whereas a sample, located more than 3 m above, is dated 29.3 ± 3.8 ka. In these relatively thin interpleniglacial soils, the archaeological excavations unearthed large collections of Szeletian stone tools, an arch-backed point industry, similar to the Uluzzian and named Zwierzyniecian, and hundreds of Aurignacian artefacts (Chmielewski et al., 1977; Kozłowski, 2006; Sachse-Kozłowska, 1978; Sawicki, 1957; Stefański, 2018). However, due to the slope gradient towards the Rudawa River and the solifluction processes several artifacts were displaced from their original positions and mixed. Although some authors analyzed

Table 1 Available thermoluminescence and radiocarbon dates of the Aurignacian occupation in Poland. The radiocarbon ages were calibrated using the IntCal20 data set (Reimer et al., 2020) and OxCal v4.4 (Ramsey, 2009)

Site	Layer	Code	Method	Sample	Date	error	68.3%		95.4%		References
Kraków-Zwierzyniec 1	Upper l1-s/l2-3 (loess)		TL	sediment	36,000	4700					Łanczont et al., 2015a
	Middle l1-s/l2-3 (soil zw5)		TL	sediment	40,000	5200					
	Middle l1-s/l2-3	Poz-94376	14C	Picea/Larix charcoal	38,000	900	42,750	41,824	43,785	41,136	Stefański, 2018
	Bottom l1-s/i2-3 (soil zw6)		TL	sediment	55,600	5200					Łanczont et al., 2015a
Kraków-Spadzista A	Level 7		14C	Charcoal	31,000	2000	38,652	33,661	41,334	31,717	Kozłowski & Kozłowski, 1996
Kraków-Spadzista C2	Upper l1-s/l2-3		TL	sediment	30,300	2300					Łanczont et al., 2015a
Kraków-Spadzista C2	Bottom l1-s/l2-3		TL	sediment	38,400	3400					
Kraków-Spadzista E	Upper l1-s/l2-3		TL	sediment	31,000	2500					
Kraków-Spadzista E	Middle l1-s/l2-3		TL	sediment	32,400	3200					
Kraków-Spadzista E	Bottom l1-s/l2-3		TL	sediment	32,500	2800					
Księcia Józefa	II	GifA-100387	14C	Charcoal	40,380	940	44,243	42,924	45,027	42,488	Sitlivy et al., 2009
Piekary IIE	6	OxA-7247	14C	Charcoal	31,100	1000	36,551	34,480	38,717	33,803	Sitlivy et al., 2008
Piekary II	6	GifA 32,692	14C	Charcoal	26,100	2000	33,082	28,376	37,246	26,920	
Mamutowa Cave	Unknown	OxA-14436	14C	Mladec point—ivory	33,640	250	39,177	38,178	39,299	37,623	Davies et al., 2015
	Unknown	OxA-14434	14C	Mladec point—ivory	32,280	220	36,836	36,347	37,078	36,174	

Table 1 (continued)

Site	Layer	Code	Method	Sample	Date	error	68.3%		95.4%		References
Stajnia Cave	D1	MAMS-35153	14C	Pendant—ivory	36,563	229	41,730	41,340	41,900	41,210	Talamo et al., 2021a
		ETH-99043.1.1	14C		37,360	330					
	D1	MAMS-35152 1	14C	Awl	37,360	330	42,270	42,070	42,360	41,960	
		ETH-99042.1	14C		37,903	267					
Deszczowa Cave	Layer VIII	Poz-3752	14C	Bird bone	30,100	400	35,054	34,225	35,382	33,871	Cyrek et al., 2000
Obłazowa Cave	Layer VIII sector C1	OxA-4584	14C	Red deer antler wedge	32,400	650	37,744	36,034	39,041	35,577	Housley, 2003
	Layer VIII sector C1	OxA-4585	14C	Bone perforator	30,600	550	35,488	34,479	36,170	34,180	
	Layer VIII	OxA-4586	14C	human finger	31,000	400	35,812	34,889	36,174	34,610	

the lithic assemblages maintaining the original stratigraphic attributions (Jarosińska, 2006a; Kozłowski, 2002, 2006; Sachse-Kozłowska, 1978, 1982a), the combination of artifacts originating from palimpsests of different ages resulted in collections with peculiar features (e.g., Aurignacian Zwierzyniec).

Here, we focus on the Aurignacian industry of Sawicki's Trench 3, the sector that following the previous taphonomic studies was affected to lesser extent by solifluction. In this study, 683 lithic items, related to the laminar and lamellar reduction, were selected, not including flake and flake fragments that will be looked at in a forthcoming analysis. The assortment includes blade and bladelet cores, associated byproducts, and retouched tools (Tables 2, 3, and 4). The raw material used at the site is Upper Oxfordian chert, abundant in the area. In the core assemblage, the discovery of some tested pebbles documents the technical strategies used during the early stages of the knapping reduction (Table 2). In the beginning, the striking platforms are created by removing one lateral portion of the nodule or by detaching a few thick cortical flakes. The striking platforms are crude and flat without any rounding or preparation of the *charnières* with the *débitage* surfaces. Then, the

Table 2 Total number and percentage of the cores at Kraków-Zwierzyniec 1 trench 3

		N	%
Preforms	Pre-core	12	*8.5*
	Pre-core fragment	2	*1.4*
Blade core	Unidirectional	12	*8.5*
	Unidirectional fragment	2	*1.4*
	Bidirectional	5	*3.5*
	Narrow-sided	8	*5.7*
	Narrow-sided fragment	2	*1.4*
	Wide-face flat	2	*1.4*
	Wide-face flat fragment	1	*0.7*
	Multi-platform	6	*4.3*
	Undetermined fragment	18	*12.8*
Bladelet core	Unidirectional	3	*2.1*
	Unidirectional fragment	1	*0.7*
	Triangular convergent	1	*0.7*
	Narrow-sided	6	*4.3*
	Narrow-sided fragment	1	*0.7*
	Multi-platform fragment	2	*1.4*
	Carinated burin	26	*18.4*
	Double carinated burin	1	*0.7*
	Carinated endscraper	11	*7.8*
	Carinated core	4	*2.8*
	Carinated core fragment	2	*1.4*
	Core-on-flake	7	*5*
	Undetermined fragment	6	*4.3*
Total		141	*100*

Table 3 Total number and percentage of the knapping by-products at Kraków-Zwierzyniec 1 trench 3

	N	%
Cortical blade	3	*0.6*
Cortical blade fragment	7	*1.5*
Semi-cortical blade	5	*1.1*
Semi-cortical blade fragment	30	*6.4*
Crested blade	1	*0.2*
Core–edge removal blade	3	*0.6*
Blade	21	*4.4*
Blade fragment	197	*41.7*
Semi-cortical bladelet	1	*0.2*
Semi-cortical bladelet fragment	1	*0.2*
Bladelet	28	*5.9*
Core–edge removal bladelet	1	*0.2*
Burin spall	1	*0.2*
Bladelet fragment	89	*18.9*
Semi-cortical microblade fragment	3	*0.6*
Microblade	14	*3.0*
Core–edge removal microblade	1	*0.2*
Microblade fragment	30	*6.4*
Burin spall	2	*0.4*
Rejuvenation flaking surface	10	*2.1*
Flank	3	*0.6*
Tablette	6	*1.3*
Tablette fragment	9	*1.9*
Knapping accident	6	*1.3*
Total	472	*100*

flaking surfaces are configured by the removals of a few cortical blades or by the creation of a longitudinal crest. All pre-cores retain most of the cortical surface and are largely unexploited.

Once the striking platform and the flaking surface were prepared, the laminar reductions branch out in different categories of core (Table 2). The category most common is unidirectional in which cores are exploited by a semi-rotating (*demi-tournant*) method (Fig. 2 no. 1). These artifacts are characterized by the unidirectional reduction from one striking platform along the longitudinal axis of the pebble. The morphology of the cores is sub-prismatic ($n=7$) and sub-pyramidal ($n=5$). The striking platforms are generally flat and re-shaped by few unidirectional or centripetal detachments. The surfaces opposed to the flaking surfaces are often cortical or thinned by removing some invasive flakes. The lateral convexities are cortical, taking advantage of the natural morphology of the block, or created and maintained through the opportunistic detachment of flakes from the striking platform or the débitage surface. The exploitation of a large part of

Table 4 Total number and percentage of the retouched tools at Kraków-Zwierzyniec 1 trench 3 (* the number of carinated burins was counted also in Table 2)

	N	%
Aurignacian blade	3	*2.8*
Retouched blade	14	*13*
Dufour bladelet fragment	1	*0.9*
Marginally retouch bladelet	1	*0.9*
Endscraper	31	*28.7*
Scraper	3	*2.8*
Axial burin	1	*0.9*
Axial burin dihedral	2	*1.9*
Axial burin dihedral *dejete*	1	*0.9*
Axial burin on a transverse break	1	*0.9*
Axial burin on transverse burin facet	1	*0.9*
Angle burin simple	1	*0.9*
Angle burin on transversal break	6	*5.6*
Angle burin on truncation	2	*1.9*
Angle burin on endscraper	1	*0.9*
Dihedral burin	7	*6.5*
Dihedral burin *dejete*	1	*0.9*
Dihedral burin on a retouch blade	1	*0.9*
Dihedral burin on a transverse break	1	*0.9*
Carinated burin*	26	*24.1*
Double carinated burin*	1	*0.9*
Multiple burin	1	*0.9*
Fragment	1	*0.9*
Total	108	*100*

the block is aimed at the production of large blades although in three cores some bladelets were also produced.

In five cores, the semi-rotating method is carried out by using two opposite striking platforms (Table 2, Fig. 2 nos. 3–4). In four examples, the production is bidirectional whereas, in the last core, the second striking platform is used for continuing with the reduction instead of reconfiguring the convexity of the flaking surface. The technical expedients of preparing the striking platform and maintaining the lateral convexity are very similar to those used for the unidirectional method. However, the morphology of three cores is sub-cylindrical, due to the broadening of the débitage surface, whereas the other two artifacts have a sub-prismatic shape. In one core, blades and bladelets were produced simultaneously.

At times, when the maximal convexity of the flaking surface is reached and the removal of a plunging blade would be necessary for reconfiguring the débitage area, the knappers rotated the cores of 90° or 180° and exploited the volume from other independent striking platforms. In this category of multi-platform cores (Table 2), the flanks are generally used as new flaking surfaces shaping the artifacts in a sub-prismatic morphology.

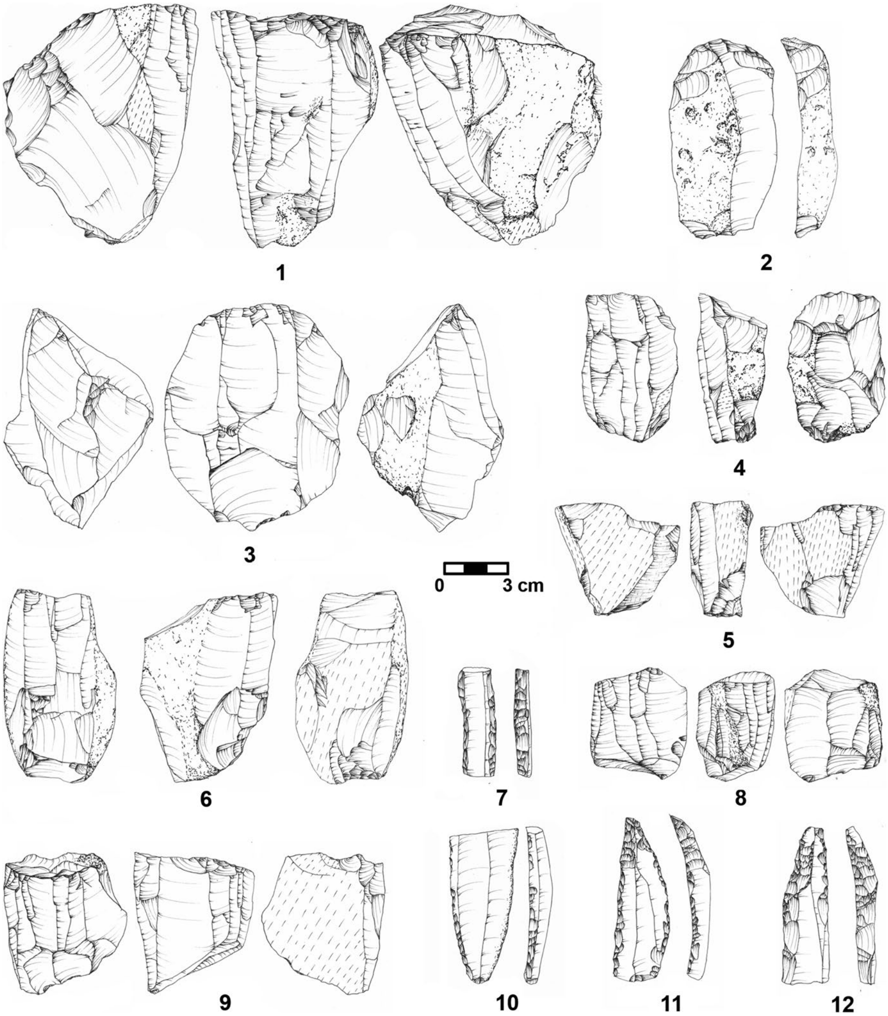

Fig. 2 Kraków-Zwierzyniec 1 trench 3: 1 unidirectional semi-rotating blade core; 2 endscraper; 3–4 bidirectional blade core; 5 unidirectional narrow-sided bladelet core; 6 unidirectional narrow-sided blade core; 7, 12 Aurignacian retouched blade; 8 unidirectional semi-rotating bladelet core; 9 unidirectional multiplatform blade/bladelet core; 10–11 retouched blade

The second most common category is the narrow-sided cores in which the production is restricted only to one narrow side of the block along the longitudinal axis (Table 2, Fig. 2 no. 6). Generally, the shape of the flaking surface is triangular, and the lateral convexities are maintained by using the natural morphologies of the pebble or by detaching unidirectional flakes from the main striking platform or from the backside. Five cores show striking platforms created by few lateral or centripetal removals and the scar negatives on the flaking surfaces indicate the production of blades of midsize. The other three narrow-sided cores were made on thick flakes exploiting one lateral edge of the blanks. The striking platforms are prepared with a few small detachments, and the lateral convexities are maintained through the thinning of the dorsal surfaces. In two cores, the reduction is aimed at producing blades whereas in the other six examples blades and bladelets were detached at the same time. The secondary operative chain includes wide-face flat cores (Table 2) characterized by the absence of at least one of the flanks due to the advanced stage of reduction.

In the assemblage, different categories of bladelet cores are also documented (Table 2). The most numerous group is composed of artifacts in which the flaking surface is limited to a small side of the core including narrow-sided and carinated burins artefacts. Narrow-sided cores are made on large flakes or chunks, and their striking platforms are flat, created by the removal of one or two small flakes or by using a plain fracture (Fig. 2 no. 5). Generally, one flank is associated with the ventral surface whereas the other flank is prepared through the detachment of few small flakes shaping the cores in sub-pyramidal ($n=4$) and sub-prismatic ($n=2$) morphology. In the same group, carinated burins are also included (Fig. 3 no. 2). Morphologically, these artifacts are very similar to the previous ones and differ in the width of the flaking surface which is smaller than 1 cm. The blanks used for shaping these burin-like cores are generally flakes and flake fragments whereas very few were made on blades. The aim of the reduction was the production of straight/slightly curved bladelets and microblades. Although three carinated burins were made on retouched blades, *busqué* burins were not found.

Lamellar production is also carried out with carinated endscrapers and with carinated cores (Table 2, Fig. 3 no. 1, 3–4). Although both categories share similar features such as flat striking platforms and broad fronts, the main difference between them is recorded in the length of the flaking surface that in carinated cores is longer than the width of the striking platform. In three carinated endscrapers, the front

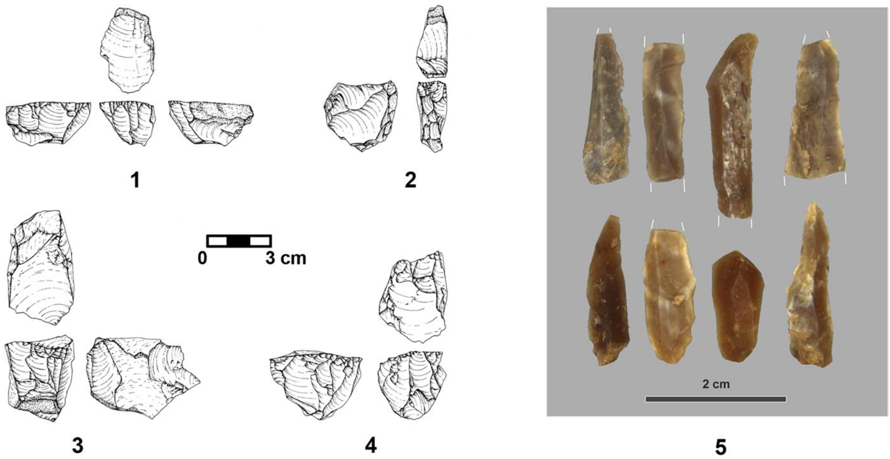

Fig. 3 Kraków-Zwierzyniec 1 trench 3: 1 carinated endscraper; 2 carinated burin; 3 bladelet core; 4 carinated bladelet core; 5 bladelets

width is bigger than 25 mm (width: 33.1 ± 6 mm). Typologically, nosed endscrapers are absent. In one example, the rejuvenation of the flaking surface removed a lateral portion of the blank creating a notch. However, this knapping accident is posterior to the bladelet production, and it did not aid in restricting the flaking surface.

In the assemblage, it is worth noting the presence of unidirectional bladelet cores with sub-prismatic morphologies (Table 2, Fig. 2 nos. 8–9, Fig. 3 no. 3). In this group, a broken carinated endscraper is characterized by the use of the fracture as a new striking platform for the production of straight bladelets. Other secondary operative chains are core-on-flakes (Table 2), typified by the exploitation of the ventral surfaces for the production of up to three small flakes or bladelets, and a triangular bladelet core with convergent unidirectional scar removals and a sub-pyramidal shape. This latter core is atypical in the Aurignacian and shares several features with the Proto-Aurignacian.

The stage of the nodules' decortication is underrepresented (Table 3) suggesting that in the early phases of reduction flakes were produced more commonly than blades. Furthermore, artifacts related to the preparation of the core lateral convexities and rejuvenation of the striking platforms and flaking surfaces are few (Table 3). The number of complete blades and bladelets is limited, and most of them are fragmented (Table 3, Fig. 3 no. 5). Although large cores are recorded at the site, the length of unbroken blades is midsize ($n = 21$, length = 42.7 ± 17.2 mm). Generally, these blanks have a straight and slightly curved profile whereas the platforms are mostly flat and lineal. The number of unbroken bladelets and microblades is also limited (Table 3), and their length is rather small (bladelet length = 20.8 ± 5.4 mm; microblade length = 16.1 ± 4.2 mm). Bladelets have generally linear and punctiform platforms whereas the profile is mostly straight and curved although some twisted examples are documented. Similarly, microblades have generally lineal platforms and twisted or straight profiles.

In the retouched tools assemblage, burins are found in higher frequencies followed by endscrapers and retouched blades (Table 4, Fig. 2 no. 2, 7, 10–12). Within carinated artifacts, axial, dihedral, and angle burins are common, whereas in the category of endscrapers, a third of the total number is flat. Retouched and Aurignacian blades are mostly broken, and only one Aurignacian blade shows a strangled pattern (Fig. 2 no. 12). The group of retouched bladelets includes a proximal fragment of *Dufour* bladelet subtype *Dufour* and a fragment of a marginally retouch bladelet.

Kraków-Spadzista Street (Kraków-Zwierzyniec 4)

The Kraków-Spadzista Street site is located in the eastern part of the Tenczynski Hump on the northern slope of the Saint Bronisława Hill (Fig. 1). Since 1968, the site was investigated in several trenches (A, B + B1, B III-IV-V, E, E1, F, C, C2) yielding archaeological evidence from the Aurignacian, Gravettian, and Epigravettian (Drobniewicz et al., 1974; Kozłowski, 1969; Kozłowski & Sobczyk, 1987; Kozłowski et al., 1974; Wilczyński et al., 2015). The stratigraphic sequence is similar to the sedimentary succession of the nearby site of Kraków-Zwierzyniec 1. At the bottom is recorded unit V, a silty-clayed paleosoil dated to the Eemian overlaid by a loess layer of a variable thickness of 0.3–1.3 m and associated with the MIS 4.

Above unit IV, is located unit III, an interpleniglacial soil complex dated to the MIS 3 and composed of silty material (Łanczont et al., 2015b). This unit was conventionally divided into two superimposed weakly developed gley soils. The older soil is composed of silty-clay sediments of ~ 10–50 cm thickness, truncated by erosional processes in some sectors. This soil is associated with the Aurignacian level 7 and is dated by the IRSL method between 38.4 ± 3.4 ka and 32.5 ± 2.8 ka (Łanczont et al., 2015b). The younger soil is characterized by a light grey silt sediment disturbed by solifluction. This soil is attributed to the Gravettian and is dated by the IRSL method between 32.5 ± 2.8 ka and 28.2 ± 1.9 ka (Łanczont et al., 2015b). This chronology is in accordance with the ranges inferred from the samples dated by the radiocarbon method (29.6–24 ka BP). Above unit III lays unit II, an accumulation of loess of slope facies, and unit 1, characterized by Late Glacial–Holocene soils divided into 3 sub-horizons. In unit II of trenches B (III–IV–V) and B + B1 were found the archaeological level 5, attributed to the Epigravettian (Wilczyński et al., 2015).

In comparison with the neighboring site of Kraków-Zwierzyniec 1, the number of Aurignacian artefacts is smaller and their densities vary between the different trenches suggesting short stopovers in this area of the Saint Bronisława Hill (Drobniewicz et al., 1974; Kozłowski & Sobczyk, 1987; Sachse-Kozłowska, 1978; Sobczyk, 1996; Wilczyński et al., 2015) (Table 5). Trench A is the location with the lowest number of finds (Table 5) that comprises an exhausted carinated endscraper and a scraper (Kozłowski, 1969). In trench B, the single semi-rotating bladelet core found is characterized by a flat striking platform and a lateral convexity maintained by the detachment of flakes from the opposed keel area (Drobniewicz et al., 1974). Conversely in trench B1, a study devoted to the typological and functional analysis of burins revealed the presence of a dozen carinated elements which were reclassified in this paper into cores, endscrapers and burins (Table 5) (Stefański, 2004, 2013). In the assemblage were discovered two narrow-sided bladelet cores, characterized by a triangular flaking surface and flat striking platforms, and two semi-rotating bladelet cores (Table 5). The other cores include carinated endscrapers, nosed endscrapers, carinated burins, and one Vachons burin (Table 5). In trench C, lamellar cores are recorded in higher frequencies with the discovery of carinated endscrapers and carinated burins whereas the production of blades is limited to two narrow-sided and one multiplatform core (Table 5) (Sachse-Kozłowska, 1978). In this location, the frequencies of burins are bigger than in the other trenches including dihedral and angle types. It is worth noting also the discovery of some nosed endscrapers, a fragment of *Dufour* bladelet subtype *Dufour*, and two fragments of marginally retouched bladelets (Table 5) (Sachse-Kozłowska, 1982b). In trench C2, the core assemblage includes some flake cores, a unidirectional semi-rotating blade core, and some carinated burins (Table 5, Fig. 6 no. 1–7). The number of unbroken blades is scanty whereas most of the laminar blanks are fragmented. In this latter collection, some crested blades ($n = 5$) and secondary crested blades ($n = 5$) are documented (Wilczyński et al., 2015). Other Aurignacian artifacts include endscrapers, fragments of Aurignacian blades ($n = 3$), and two dihedral burins (Table 5) (Wilczyński et al., 2015). In trench D, a single unidirectional bladelet core was found whereas the bulk of the assemblages is composed of débitage byproducts (e.g., flakes, blades, and fragments) (Table 5). The collection of retouched tools includes retouched

Table 5 Total numbers and percentages of the lithic assemblages of the different trenches of Kraków-Spadzista Street (data from Kozłowski, 1969; Drobniewicz et al., 1974; Sachse-Kozłowska, 1978; Stefański, 2004; Wilczyński, 2015; Wilczyński et al., 2015)

		A (1967)		B (1970–1973) + B1 (1989–1994)		C (1970–1973)		C2 (1980–2012)		D (1986–1988)		E1 (2012)			
		N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	Total	%
Blade core	Unidirectional							1	*0.3*			1	*4.5*	2	*0.3*
	Narrow-sided					2	*3.8*							2	*0.3*
	Multi-platform					1	*1.9*							1	*0.1*
Bladelet core	Unidirectional			3	*9.1*					1	*0.3*			4	*0.5*
	Narrow-sided			2	*6.1*									2	*0.3*
	Carinated endscraper	1	*50*	6	*18.2*	9	*17.3*					1	*4.5*	17	*2.3*
	Carinated endscraper fragment					1	*1.9*							1	*0.1*
	Nosed endscraper			7	*21.2*	3	*5.8*							10	*1.3*
	Nosed endscraper fragment			1	*3*									1	*0.1*
	Carinated burins			10	*30.3*	5	*9.6*	6	*2.1*					20	*2.7*
	Vachons burin			1	*3*									2	*0.3*
Flake core	Unidirectional							1	*0.3*					1	*0.1*
	Discoid							3	*1.0*					3	*0.4*
	Core fragment			1	*3*	2	*3.8*	2	*0.7*					5	*0.7*
Débitage	Flakes							71	*24.7*	83	*23.9*	5	*22.7*	159	*21.3*
	Flake fragment			1	*3*			97	*33.7*	154	*44.3*	7	*31.8*	259	*34.7*
	Blade							4	*1.4*	8	*2.3*			12	*1.6*
	Blade fragment			1	*3*			81	*28.1*	81	*23.3*	6	*27.3*	169	*22.7*

Table 5 (continued)

		A (1967)		B (1970–1973) + B1 (1989–1994)		C (1970–1973)		C2 (1980–2012)		D (1986–1988)		E1 (2012)			
		N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	Total	%
Retouched tools	Retouched flakes					3	*5.8*	7	*2.4*	5	*1.4*			15	*2.0*
	Retouched blade					4	*7.7*	5	*1.7*	3	*0.9*	1	*4.5*	13	*1.7*
	Truncated blade							1	*0.3*					1	*0.1*
	Dufour bladelet					1	*1.9*			1				2	*0.3*
	Marginally retouched bladelet					2	*3.8*							2	*0.3*
	Endscraper					4	*7.7*	3	*1*	3	*0.9*			10	*1.3*
	Scraper	1	*50*			3	*5.8*	4	*1.4*	1	*0.3*			9	*1.2*
	Axial burin dihedral					1	*1.9*							1	*0.1*
	Angle burin on truncation					4	*7.7*			1	*0.3*			5	*0.7*
	Dihedral burin					4	*7.7*	2	*0.7*	3	*0.9*			9	*1.2*
	Double dihedral burin					1	*1.9*							1	*0.1*
	Dihedral burin on a transverse break					2	*3.8*					1	*4.5*	3	*0.4*
	Double burin									3	*0.9*			3	*0.4*
	Piece esquillée									1	*0.3*			1	*0.1*
	Notched tool + bec									1	*0.3*			1	*0.1*
Total		2	*100*	33	*100*	52	*100*	288	*100*	349	*100*	22	*100*	746	*100*

blades, endscrapers, few burins, and a proximal fragment of *Dufour* bladelet subtype Dufour (Table 5) (Sobczyk, 1996). In trench E1, the laminar/lamellar production is attested to by a unidirectional semi-rotating core and a carinated endscraper (Table 5). The débitage is mostly fragmented while the stone tools are represented by a single burin on a break made on a flake and a mesial fragment of a retouched blade (Wilczyński, 2015).

Even if wet sieving was carried out at the site during the excavations, the amount of bladelets is very small, and only 1 *Dufour* bladelet in sector C (Sachse-Kozłowska, 1978) and 1 in sector D were discovered (Sobczyk, 1996). In addition, although burins are more numerous than endscrapers, the category *busqués* is absent (Table 5).

Kraków-Księcia Józefa Street (Kraków-Zwierzyniec 16)

The open-air site of Kraków-Księcia Józefa Street is located in the Zwierzyniec district of Kraków, on the northern slope of the Vistula valley (Fig. 1). The archaeological excavations were carried out between 1998 and 2002 investigating an area of more than 100 m^2 (Sitlivy et al., 2009; Zieba et al., 2008). The stratigraphic sequence of the site is composed 3.5-m-thick sand deposit accumulated during periglacial period (series IV) followed by two units of silty sands (series III), respectively with a thickness of about 1.5–2.0 m (member III-1) and 0.7–1.0 m (member III-2), accumulated during alluvial deposition. After this the sedimentary succession includes stratified silty muds of a thickness of about 1.0–1.5 m (series II), disturbed at the top by cryoturbations, and covered by eolian loess sediments of 2.5 m (series I). The archaeological horizons include layer III, attributed to the Middle Paleolithic, and layers II and I, associated with the Upper Paleolithic. The chronology of the site is limited to two radiocarbon dates (Sitlivy et al., 2009). One charcoal from Layer III yielded a range of 49.071–46.475 cal BP (68.2%) whereas another charcoal from layer II yielded a range of 44.789–43.193 cal BP (68.2%) (Table 1).

The lithic assemblage of Layer II was found in the silty-sands of Member III-1, confined to a small area of about 6 m^2, and includes 618 items and 1571 small chips (Sitlivy et al., 2009). The core collection comprises 12 cores and a fragment. The main blade reduction strategy used at the site is the bidirectional semi-rotating (*demi-tournant*) method (Table 6, Fig. 4 no. 4, 6). The striking platforms are created with few unidirectional detachments from the flaking surfaces and generally, the second striking platform is used after the first round of blade production, a technical expedient for maintaining the convexity of the débitage area. The cores have a sub-prismatic morphology and, only in one example, the semi-rotating exploitation shapes the artifact in sub-cylindrical (Fig. 4 no. 4, 6).

In the other three cores, the bidirectional blade production is restricted to a narrow side of the blank (Table 6, Fig. 4 no. 2, 5). In the first core, the striking platforms are prepared with centripetal (top) and unidirectional removals (bottom) whereas, on the left, the lateral convexity is maintained through the bidirectional detachments of elongated flakes and blades (Fig. 4 no. 2). The débitage surface is exploited by using two striking platforms, one after the other as in the semi-rotating method. The core is discarded after the flaking surface is disarranged by few preparatory removals for

Table 6 Total numbers and percentages of the lithic assemblages of the levels II and I of Kraków-Księcia Józefa Street (data from Sitlivy et al., 2009)

		Level II		Level I	
		N	%	*N*	%
Blade core	Unidirectional	3	*0.1*	1	*1.5*
	Unidirectional fragment			1	*1.5*
	Bidirectional	4	*0.2*		
	Narrow-sided	4	*0.2*		
	Undetermined fragment	1	*0.05*		
Bladelet core	Narrow-sided	1	*0.05*		
Débitage	Cortical blade	5	*0.2*		
	Semi-cortical blade	22	*1*		
	Semi-cortical blade fragment	57	*2.6*		
	Blade	2	*0.1*		
	Blade fragment	189	*8.8*		
	Semi-cortical bladelet	3	*0.1*		
	Semi-cortical bladelet fragment	2	*0.1*		
	Bladelet	2	*0.1*		
	Bladelet fragment	42	*1.9*	15	*23.1*
	Cortical flake	20	*0.9*		
	Semi-cortical flake	27	*1.3*	1	*1.5*
	Semi-cortical flake fragment	41	*1.9*		
	Flake	108	*5*	26	*40*
	Flake fragment	45	*2.1*	8	*12.3*
	Chips	1571	*72.9*	11	*16.9*
Retouched tools	Retouched blade	1	*0.05*		
	Retouched flake	1	*0.05*		
	Retouched flake fragment	1	*0.05*		
	Scraper	1	*0.05*		
	Borer	1	*0.05*		
	Notched tool	1	*0.05*	2	*3.1*
	Total	2155	*100*	65	*100*

the production of an invasive flake that removed a large portion of the right flank. The second core is a chunk in which the lateral convexities are cortical, and the striking platforms are prepared by few unidirectional removals. Although the production was bidirectional, the knapper was not able to keep the convexity of the flaking surface and the retreatment of the upper striking platform caused the hinged terminations of the production of the last blades. The last bidirectional core was made on a large flake. The original platform was removed and a new striking platform was created by two unidirectional detachments (Fig. 4 no. 5). The refitting of some blades and bladelets indicates that the flaking surface was created by the preparation of a crest. Then, the bidirectional exploitation enlarged the surface of production

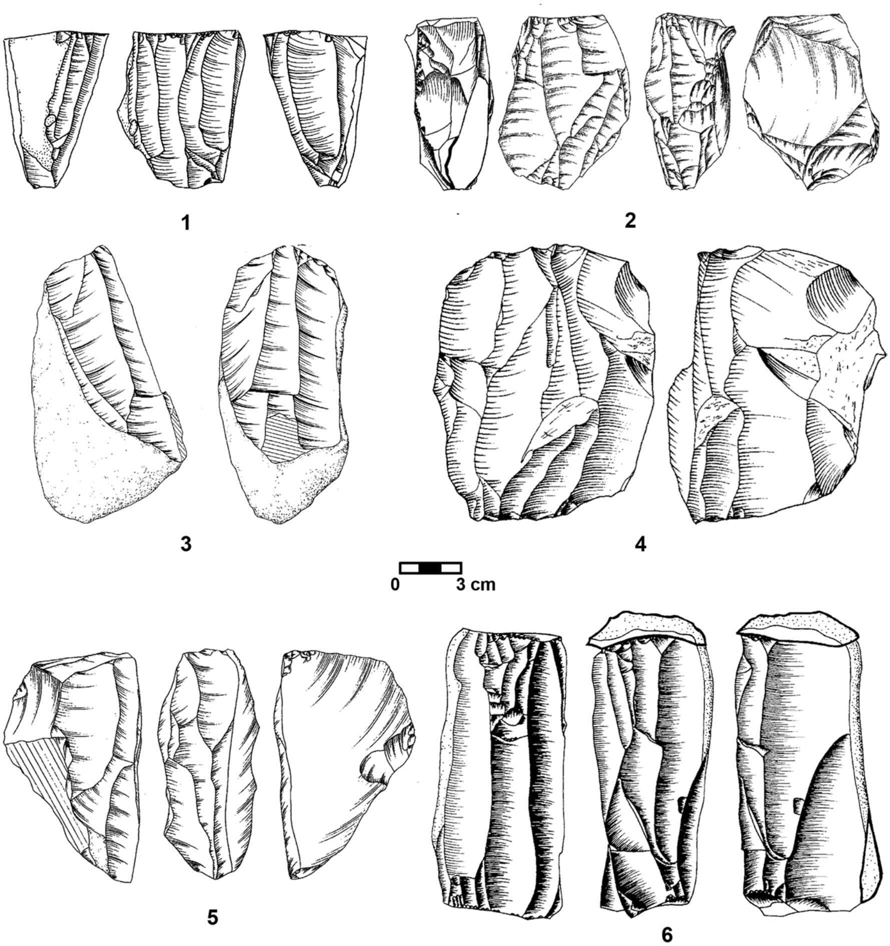

Fig. 4 Kraków-Księcia Józefa Street layer II: 1 blade/bladelet unidirectional core semi-rotating, 2, 5 bidirectional narrow-sided blade core, 3 unidirectional semi-rotating blade core; 4, 6 bidirectional semi-rotating blade core (modified from Sitlivy et al., 2009)

removing some volume from the ventral and dorsal sides. One more time, the use of the striking platforms is not alternating, and the core is turned only when the first round of blades and bladelets is produced.

Another operative chain includes the unidirectional semi-rotating method (Table 6, Fig. 4 no. 1, 3). These cores have a sub-prismatic ($n = 2$) and sub-pyramidal morphology ($n = 1$), and all of them retain some cortical portion on the lateral or backside. Two other cores are categorized as narrow-sided (Table 6). The first one is made on a large chunk in which the backside is cortical whereas invasive removals create a narrow triangular surface that was used as a flaking area. The striking platform is mostly cortical, and only two small preparatory flakes were detached. The other sample is an exhausted core-on-flake with the striking platform created by one unidirectional removal and a narrow flaking surface used for the production of bladelets.

The *débitage* assemblage is composed of blades and flakes whereas the number of bladelets is limited (Table 6). Most of the flakes were produced during the phase of decortication and configuration of the core's convexity. Blades and bladelets have midrange sizes and straight or curve profiles. Twisted bladelets are very few ($n=6$). The assemblage of retouched tools is small and comprises a scraper, a retouched blade, a retouched flake, a fragment of retouched flake, a borer, and a notch (Sitlivy et al., 2009).

The lithic assemblage of layer I was discovered in the lower and middle parts of the silty muds of series II and comprises 55 artifacts and 10 little chips (Table 6) (Sitlivy et al., 2009). The few and scattered distribution of the items over a surface of 80 m^2 suggest that the archaeological layer is a palimpsest of repeated short-term occupations. The assemblage includes a core and a core fragment exploited by using the semi-rotating unidirectional method. In this latter, the striking platform is prepared by a few centripetal removals, and the lateral convexity is maintained through the production of unidirectional blades. The flaking surface is characterized by unidirectional convergent removals. The débitage assemblage is undiagnostic and comprises 27 flakes, 8 flake fragments, and 13 blade fragments. Retouched tools include only two notched tools.

Piekary II

The complex of Piekary is located on the left bank of the Vistula River valley at the narrow east section of the Krákow Gate, about 12 km upstream from the current city of Kraków (Fig. 1). Since the end of the nineteenth century, the area underwent intense archaeological investigations that resulted in several localities, characterized by Middle and Upper Paleolithic occupations: Piekary I (Jama Cave), Piekary II and IIa, Piekary III, Piekary IV (Na Gołąbcu Cave), and Piekary V (Krukowski, 1939; Morawski, 1975; Ossowski, 1880; Sawicki, 1956, 1957, 1959; Sitlivy et al., 2008). The last fieldworks were carried out between 1998 and 2000 at the location Piekary IIa in the trenches XX, XXI, and XXII (Sitlivy et al., 2008) whereas the archaeological materials of the previous excavations were revised in Sachse-Kozłowska and Kozłowski (2004). The stratigraphic sequence comprises a Jurassic limestone with a karstic pit at the top covered by 5–7 m of fluvial deposits, buried pedocomplex deformed by slope processes, and eolian loess (Sitlivy et al., 2008; Valladas et al., 2003). At the base, layer 8 lies on Oxfordian limestone bedrock and is composed of a fluvial deposit of gravel with sands accumulated probably during late MIS 9. Above, layer 7c consists of yellow-orange sandy silts and silts with traces of pedological processes. Layer 7b is composed of brown sandy loam, up to 1 m thick, strongly stretched, and deformed by frost creep, and an uppermost horizon of light yellowish-brown pure loam. Successively, layer 7a consists of brownish pure loam also stretched by solifluction. Due to the solifluction process, this layer is probably in situ at the top of the hill whereas it is partly or fully redeposited along the slope. The upper part of the sequence consists of a 3–4-m-thick loess. Layer 6 is a light yellowish-brown loess that includes two tundra gley soils, covered by the loess soil of layer 5 and an arctic meadow soil of layer 4. Then, the sequence ends with remnants of the Late Glacial pedocomplex (Sitlivy et al., 2008; Valladas et al., 2003).

During the last excavation, a thermoluminescence (TL) dating program on burned flint was carried out for understanding the chronology of the Paleolithic occupations at the site (Sitlivy et al., 2008; Valladas et al., 2003). The 5 samples from layer 7c yielded an age between 61,000 and 48,000 years BP, two samples from layer 7b gave a similar result of ~ 39,000 years BP, and 10 samples from layer 7a yielded a range between 46,000 and 33,000 (Sitlivy et al., 2008). The discrepancy in the chronological order of the TL samples has been interpreted to be the result of the solifluction process. Thus, an arithmetic mean instead of a weighted one was preferred yielding results at one sigma of 55,000 ± 6500 years for layer 7c, 39,000 ± 5000 years for layer 7b, and 39,000 ± 4000 years for layer 7a (Sitlivy et al., 2008; Valladas et al., 2003). Some charcoals were also sent for radiocarbon dating to different facilities for complementing the TL results. One charcoal from layer 7a was divided into two pieces and sent to the AMS Tandetron in Gif-sur-Yvette (France) and to the Heavy Ion Accelerator Facility in Canberra (Australia). The samples were dated 43,300 ± 1000 year ^{14}C BP (GifA 102,397) and 45,200 ± 2400 years ^{14}C BP (ANUA-GifA-31512) yielding respectively ranges of 46,700–44,876 cal BP (68.3%) and > 50,000–45,444 cal BP (68.3%) (Table 1). In layer 6, a *Juniperus* charcoal, found during Krukowski's excavation in unit Py/II 3 at Piekary IIE yielded a range of 36,551–34,480 cal BP (68.3%) while another charcoal found in 2000 in Trench XIII yielded a range of 33,082–28,376 cal BP (68.3%) (Table 1).

Layer 6 comprises at least two Aurignacian occupations as corroborated also by the radiocarbon dates. In the excavation carried out by Krukowski (1939) in trench IIE, the oldest horizon is a small concentration of artifacts dispersed around a washed-out fireplace, found in unit Py/II 3. The lithic assemblage, called *Naskalanski*, was associated to the Early Upper Paleolithic (Krukowski, 1939), and successively categorized as lower Aurignacian (Sachse-Kozłowska & Kozłowski, 2004). In this assemblage, three cores are documented. The first is a sub-prismatic bidirectional core for the production of blades. The striking platforms were prepared with unidirectional detachments whereas the lateral convexities are maintained through orthogonal removals from the flaking surface. The second core is a narrow-sided core of sub-pyramidal morphology. The backside of the core is cortical, the striking platform is prepared by few unidirectional detachments, and the lateral convexity is maintained by the removal of invasive unidirectional blades from the same striking platform. The flaking surface shows a pattern of blade unidirectional convergent production. The last core is a broken bidirectional narrow-sided core. The *débitage* assemblage is composed of few blades and bladelets, a notched tool, and an end-scraper (Sachse-Kozłowska & Kozłowski, 2004).

The second occupation of unit Py/II 3 was named *Okraglicki* by Krukowski (1939) and subsequently classified as upper Aurignacian (Sachse-Kozłowska & Kozłowski, 2004). The blade core assemblage is composed of unidirectional cores (n = 19) and a narrow-sided core whereas the bladelet production is performed by using carinated scrapers (n = 3), nosed carinated cores (n = 2), and a carinated burin. Blades are longer than in the older occupation ranging between 20 and 50 mm whereas in the lower horizon the blade length spans between 10 and 30 mm (Sachse-Kozłowska & Kozłowski, 2004). In the stone tools assemblage, retouched blades, endscrapers, and burins (carinated, dihedral, and on truncated blade) are found (Sachse-Kozłowska & Kozłowski, 2004).

In the excavations carried out by Sawicki (1957) in Piekary IIE, adjacent to the trench of Krukowski, the two Aurignacian and the Middle Paleolithic archaeological horizons are deposited closer in the sedimentary sequence due to erosional processes and low sedimentation rates during the MIS 3. In the revision of the lithic materials, Sachse-Kozłowska and Kozłowski (2004) identified several Aurignacian artifacts in the lower loess layer (level 5), attributed to the Micoquian, that gradually increase in number at the layer of contact between the lower and the upper loess (level 5/6), and in the upper loess layer (level 6) (Table 7). In level 5, cores are not diagnostic of the Aurignacian whereas, within retouched tools, an endscraper and two nosed endscrapers were found (Table 7). In level 5/6, the core collection is composed of large wide-face and unidirectional cores whereas narrow-side, carinated and bidirectional cores are rare (Table 7). Complete laminar blanks are few and their sizes range midrange. Similarly in level 6, the core assemblage is dominated by pre-cores ($n=23$), unidirectional, bidirectional, narrow-sided, and carinated artifacts (Table 7). Within retouched tools, an endscraper, a nosed endscraper, angle burins, retouched blades are listed (Sachse-Kozłowska & Kozłowski, 2004).

In the new excavation of Sitlivy et al. (2008) in trench IIA, the lithic assemblage is smaller but shares similar technological features with the older collections (Table 7). Two unidirectional cores were reduced by using the semi-rotating method (Fig. 5 no. 1, 2). These artifacts are characterized by flat striking platforms, created by the removal of an invasive flake or *tablette*, and a cortical portion on the backside. The cores have respectively a sub-pyramidal and a sub-prismatic morphology. In the former, the production is unidirectional convergent (Fig. 5 no. 5). In two other artifacts, the cores are rotated at 180° during the semi-rotating exploitation, and the flaking surfaces are exploited bi-directionally (Fig. 5 no. 3). The cores have a sub-prismatic shape and the striking platforms are prepared by few detachments and removing the overhang by faceting and abrasion. In both artifacts, blades and bladelets were produced during the reduction.

Within the assemblage, two narrow-sided cores were also discovered (Table 7). The first core was probably made on a chunk and turned opportunistically for the production of blades. The striking platform is created by several removals from the right flank whereas the lateral convexities are maintained by some lateral detachments. During the production, the last blade is hinged and the core is discarded. The second artifact is made on a proximal end of a large cortical-backed flake (Fig. 5 no. 6). The striking platform is created by three small detachments and the production is aimed to small blades/bladelets. Within these cores, a double carinated burin on flake is also documented (Table 7, Fig. 5 no. 7).

The débitage assemblage is small and comprises blades, bladelets, and flake fragments (Table 7). The semi-rotating method produced blades with mostly straight and convex profiles (Sitlivy et al., 2008). Conversely, bladelets have twisted, straight and curved profiles (Sitlivy et al., 2008). The group of retouched tools includes fragmented retouched blades, dihedral burins on flakes, endscrapers, some retouched

Table 7 Total numbers and percentages of the lithic assemblages of the trenches IIE and IIA of Piekary (data from Sachse-Kozłowska & Kozłowski, 2004; Sitlivy et al., 2008)

		IIE						IIA		Total	
		IIE level 5		IIE level 5/6		IIE level 6		IIA level 6			
		N	%	*N*	%	*N*	%	*N*	%	*N*	%
Preforms	Pre-core	1	*0.2*	4	*0.5*	4	*0.1*	1	*0.1*	10	*0.2*
Blade core	Unidirectional	3	*0.5*	17	*2.1*	22	*0.8*	2	*0.1*	44	*0.8*
	Bidirectional			2	*0.2*	5	*0.2*	2	*0.1*	9	*0.2*
	Narrow-sided			1	*0.1*	4	*0.1*	2	*0.1*	7	*0.1*
	Wide-face flat	1	*0.2*	22	*2.7*	23	*0.8*			46	*0.8*
Bladelet core	Carinated endscraper			1	*0.1*	3	*0.1*			4	*0.1*
	Nosed endscraper	2	*0.3*			1	*0.04*	1	*0.1*	4	*0.1*
	Double carinated burin							1	*0.1*	1	*0.02*
Débitage	Cortical blade							3	*0.2*	3	*0.1*
	Semi-cortical blade							17	*1.2*	17	*0.3*
	Cortical fragment							41	*3*	41	*0.7*
	Blade	2	*0.3*	8	*1.0*	20	*0.7*	17	*1.2*	47	*0.8*
	Crested blade	25	*4.3*	9	*1.1*	53	*1.9*			87	*1.6*
	Blade fragment	129	*22.1*	124	*15.5*	234	*8.3*	244	*17.6*	731	*13.1*
	Bladelet							12	*0.9*	12	*0.2*
	Bladelet fragment							51	*3.7*	51	*0.9*
	Cortical flake	51	*8.7*	96	*12.0*	608	*21.7*	19	*1.4*	774	*13.9*
	Semi-cortical flake	86	*14.8*	119	*14.8*	597	*21.3*	14	*1*	816	*14.6*
	Cortical fragment							58	*4.2*	58	*1*
	Flake	155	*26.6*	193	*24.1*	757	*27.0*	195	*14.1*	1300	*23.3*
	Crested flake	1	*0.2*			11	*0.4*			12	*0.2*
	Flake fragment	126	*21.6*	206	*25.7*	454	*16.2*	126	*9.1*	912	*16.3*
	Chips							561	*40.5*	561	*10.1*
Retouched tools	Aurignacian blade					1	*0.04*			1	*0.02*
	Retouched blade					1	*0.04*			1	*0.02*
	Retouched blade fragment							7	*0.5*	7	*0.1*
	Retouched flake							6	*0.4*	6	*0.1*
	Backed blade fragment							1	*0.1*	1	*0.02*
	Backed bladelet fragment							1	*0.1*	1	*0.02*
	Endscraper	1	*0.2*			1	*0.04*	1	*0.1*	3	*0.1*
	Angle burin simple					4	*0.1*			4	*0.1*
	Dihedral burin							2	*0.1*	2	*0.04*
	Burin spall							6	*0.4*	6	*0.1*
	Scraper							2	*0.1*	2	*0.04*
Total		583	*100*	802	*100*	2803	*100*	1392	*100*	5580	*100*

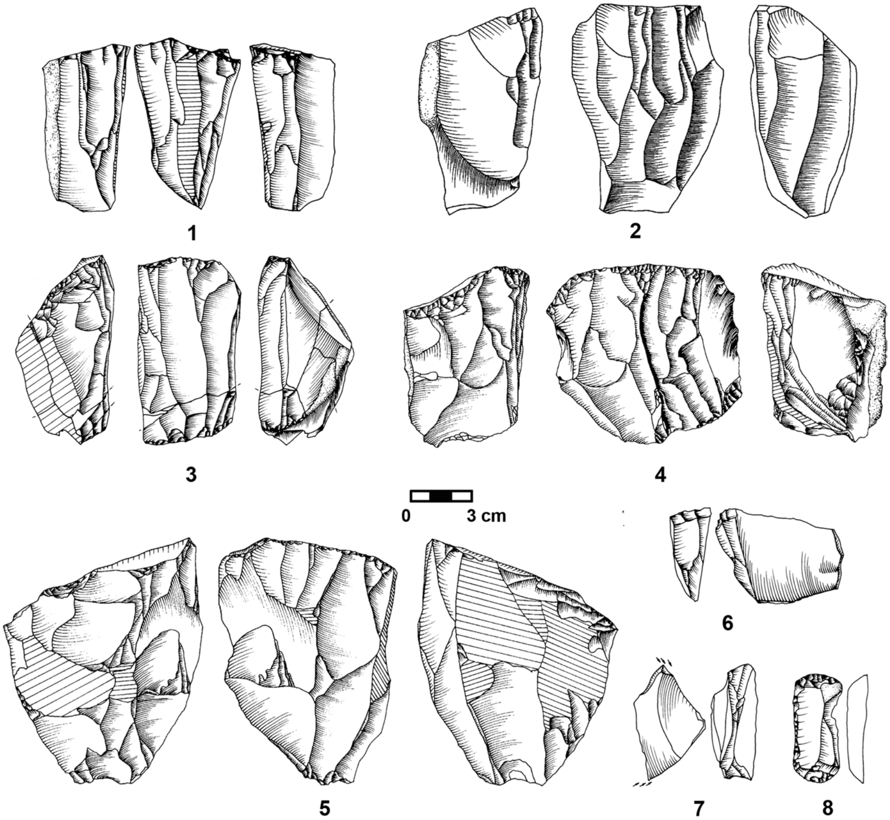

Fig. 5 Piekary IIa level 6: 1, 2 unidirectional semi-rotating blade core; 3 bidirectional semi-rotating blade/bladelet core; 6 unidirectional narrow-sided blade/bladelt core; 7 double carinated burin; 8 end-scraper; Piekary IIa level 7a/6: 4, bidirectional semi-rotaing blade/bladelet core; 5 unidirectional semi-rotating blade core (modified from Sitlivy et al., 2008)

flakes, a sidescraper, and a denticulate (Table 7). It is worth noting the presence of a fragment of a backed bladelet (Table 8).

At the intersection between layer 7a and layer 6, two other cores were found (Sitlivy et al., 2008). The first one is a bidirectional semi-rotating core with a flat upper striking platform created by an orthogonal detachment and prepared by small retouch (Fig. 5 no. 4). The two lateral flanks are configured by bidirectional removals on the right and by an invasive flake orthogonal to the direction of flaking on the left. The débitage is aimed at the production of blades but during the reduction a knapping error removed a large portion of the flaking surface. In this area, few blades and bladelets are detached, and then, the core is discarded. The other one is a unidirectional semi-rotating core with a flat striking platform created by removal from the backside (Fig. 5 no. 5). The left flank is semi-cortical whereas the right flank is created by several bidirectional removals. After, the configuration and the detachment of three bladelets and a blade, the core is discarded.

Table 8 Total numbers and percentages of the lithic assemblages of Mamutowa Cave, Deszczowa Cave, and Obłazowa Cave (data from Cyrek et al., 2000; Kowalski, 2006; *preliminary counting)

		Mamutova		Deszczowa		Obłazowa layer VIII		Obłazowa layer XXII	
		N	%	*N*	%	*N*	%	*N*	%
Bladelet core	Narrow-sided					1	*20*	1	*9.1*
	Carinated endscraper	2	*33.3*					1	*9.1*
	Carinated endscraper fragment							1	*9.1*
	Nosed endscraper	2	*33.3*						
Débitage	Blade							1	*9.1*
	Blade fragment							2	*18.2*
	Bladelet fragment					2	*40*		
	Retouched blade	2	*33.3*	4	*28.6*				
	Retouched blade fragment							1	*9.1*
	Chips			7	*50.0*				
Retouched tools	Scraper			1	*7.1*			1	*9.1*
	Endscraper					2	*40*	3	*27.3*
	Axial burin dihedral								
	Angle burin on truncation			1	*7.1*				
	Double burin			1	*7.1*				
Total		6*	*100*	14	*100*	5	*100*	11	*100*

Kraków-Częstochowa Upland (Polish Jura)

The Kraków-Częstochowa Upland is part of the Jurassic system of south-central Poland and is divided into two main areas: a southern region, the Olkusz Upland (also called Ojców Plateau), and a northern region, the Częstochowa Upland. Since the beginning of the nineteenth century, more than 200 karst systems and caves have been explored, many of which attest to archaeological occupation during the Late Pleistocene (Kowalski, 1967a, b; Kozłowski & Kozłowski, 1996; Krukowski, 1939). Although many publications corroborate the human settlements in this territory from the Middle Paleolithic to the Magdalenian (Cyrek et al., 2014; Kot et al., 2021; Kozłowski, 2006; Kozłowski & Kozłowski, 1996; Picin et al., 2020; Sachse-Kozłowska, 1982b; Valde-Nowak et al., 2014; Wiśniewski et al., 2017), information on the chronologies and the lithic assemblages attributed to the Aurignacian is still fragmentary and largely unpublished.

An important Aurignacian site in this area is Stajnia Cave located between the villages of Mirów and Bobolice on the northern side of the Mirów Elevation (Fig. 1). Archaeological fieldwork at the site was carried out between 2007 and 2010 unearthing several human occupations spanning from the Middle Paleolithic (MIS 5a) to the Magdalenian (Nowaczewska et al. 2021; Picin et al., 2020; Talamo et al., 2021a). The lithic assemblage is small and includes mostly ordinary blades and bladelets and three lamellar cores. Within the retouched tool assemblage, an endscraper, a dihedral burin on a core–edge blade and a probable dihedral burin on a blade were found. Although lithic *fossile directeurs* are absent, Aurignacian settlements are inferred by the ages of a decorated ivory pendant and a bone awl, directly dated respectively to 41,730–41,340 cal BP (68.3%) and 42,270–42,070 cal BP (68.3%) (Table 1). Furthermore, animal bone samples from layer C19 yielded a range of *c*. 42–37 ka BP (Talamo et al., 2021a). The small dimension of the natural shelter and the few artifacts discovered indicates ephemeral visits to the site probably during foraging activities in the area.

An additional Aurignacian site in the Polish Jura is Mamutowa Cave (Wierzchowie 1) in Olkusz Upland, located in the Kluczwoda valley at ~ 20 upstream of the Rudawa River from Kraków-Zwierzyniec 1 (Fig. 1). The natural shelter was investigated firstly by Zawisza (1878) between 1873 and 1881, by Kozłowski (1922) in 1913, and by Kowalski (1967b) between 1957 and 1974. Although some stratigraphic discrepancies are documented between the cave interior and the entrance, the fieldwork unearthed a rich sequence of Middle Paleolithic, Szeletian, Jerzmanowician, Aurignacian, and Gravettian (Kowalski, 2006). Thus far, information on the lithic assemblages is still incomplete, and the collections are currently under study. However, the Aurignacian presence is attested by several artifacts, and in particular by carinated endscrapers, nosed endscrapers, and Aurignacian blades (Fig. 6 nos. 8–11) (Kowalski, 2006). The assemblage of bone tools includes one split-base point, and eleven massive base points (type Mladeč) (Fig. 6 nos. 12–16). Two Mladeč points were directly radiocarbon dated yielding respectively a range of 39,177–38,178 years cal BP (68.3%), and 36,836–36,347 years cal BP (68.3%) (Table 1) (Davies et al., 2015).

Another Aurignacian occupation is reported at Deszczowa Cave level VII in the Częstochowa Upland (Cyrek et al., 2000) (Fig. 1). The stratigraphic sequence includes Middle Paleolithic, Aurignacian, and Epigravettian layers. The site was probably visited for short stopovers during the forays. In the Aurignacian archaeological floor, bones, and stone tools were found around a fireplace near the cave wall and scattered on a surface of *c*. 10 m^2. The lithic assemblage is composed of retouched blades ($n=4$), an endscraper, a burin on truncation, a double burin, and few flake/blade fragments. In the assemblage also a fragment of a reindeer antler, two bear canine pendants, an awl and two polished bone tools are documented (Cyrek et al., 2000). Diagnostic cores and stone tools are absent, but a single radiocarbon date places the settlement during the Late Aurignacian at *c*. 35–34 ka BP (Lorenc, 2013) (Table 1).

Orawa-Podhale Basin (Western Carpathian Mountains)

Obłazowa Cave (Nowa Biała 2)

Obłazowa Cave is located near the village of Nowa Biała in the Western Carpathian Mountains (Valde-Nowak et al., 2003) (Fig. 1). The cave is found in the Obłazowa Rock, situated approximately 7 m above the bank of the Białka River, a tributary of Dunajec River, in the Orawa-Nowy Targ (Podhale) Basin. The chamber formed in-between the layers of white crinoid Jurassic limestone and red limestone of ammonitico rosso facies. The earliest works at the site started in 1985–1995 exposing a ~ 4 m

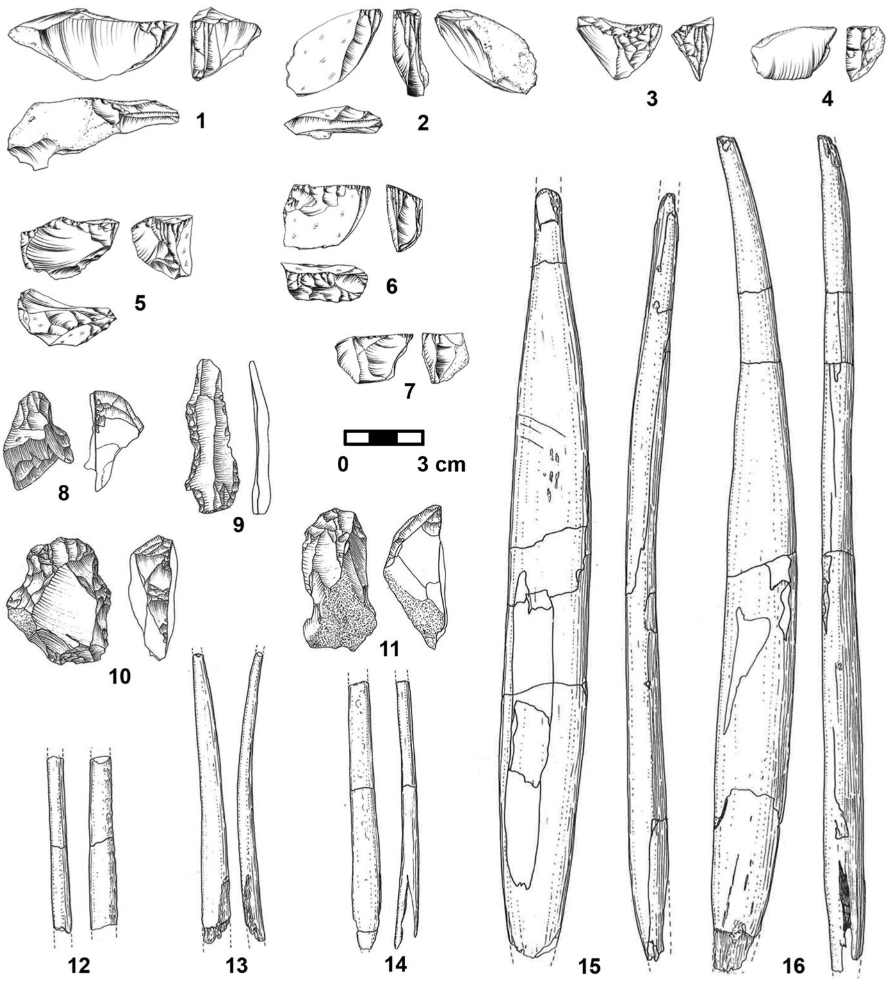

Fig. 6 Krakow-Spadzista Street trench C2 excavations 1980–2012: 1–7 carinated burins (modified with permission from Wilczyński et al., 2015); Mamutowa Cave: 9 retouched blade; 8, 10–11 nosed-endscraper; 12–13 bone point fragments; 14 split-based point; 15–16 Mladeč points (modified from Hahn, 1977)

sedimentary sequence and unearthing a phalanx of *Homo sapiens* (Table 1) and a boomerang made in ivory tusk (Trinkaus et al., 2014; Valde-Nowak et al., 1987). In 2008–2009 and 2012–2018, fieldwork restarted at the site reaching the bedrock and expanding the excavation in extension (Valde-Nowak & Nadachowski, 2014).

The stratigraphic sequence is composed of 21 lithostratigraphic units and 10 archaeological layers (Madeyska, 2003). Layer XXb, XIX, XVIIIb, XVII, XVI, XVb, and XIII are dated to the Middle Paleolithic whereas layer XI is associated with the Szeletian. The Aurignacian occupation is found in layer VIII and, in a secondary position, in the so-called pit (layer XXII). In previous works (Alex et al., 2017; Valde-Nowak & Nadachowski, 2014; Valde-Nowak et al., 2003), layer VIII was related to the early Gravettian (Pavlovian), and those groups were thought to have removed some sediments for enlarging the interior space of the cave chamber. This hypothesis was supported by the discovery of a polished and artificially incised *Conus* shell, a fossil shell common during the Pavlovian in Moravia and Lower Austria, at the bottom of the pit (Valde-Nowak, 2015), and a horn wedge, decorated with multiplied parallel engraved lines and interpreted as a mining tool (Valde-Nowak et al., 2003). The curvilinear theme of this latter artifact closely corresponds to the style of bone representations found in Předmosti, Dolní Věstonice and Pavlov, as well as in other bone artifacts (d'Errico et al., 2011).

During the early fieldwork, several Aurignacian artifacts were found on the top fill of the pit in a secondary position making any stratigraphic association difficult. The following investigations of the sedimentary sequence allowed to circumscribe the anthropogenic disturbance that removed almost vertically some portions of the original Middle and Upper Paleolithic layers, reaching the coarse gravel horizon (layer XXI and XX) whereas in the ceiling area cut *c*. 3 m deep into the cave, counting from the entrance opening. During the last cycle of excavations in the inner part of the cave, Aurignacian artifacts were found in situ in layer VIII whereas some Pavlovian elements were discovered on top of them in a thin palimpsest difficult to separate in some squares. This new discovery consented to updating the stratigraphic association of the EUP layers and modifying the previous interpretation.

The radiocarbon dates made on the human fossil and the organic artifacts found in layer VIII set the Aurignacian occupation between ~ 37 and 34 ka BP (Table 1). Here, the lithic analysis is carried out by combining the assemblage from layer VIII and the pit (layer XXII). At present, the Aurignacian assemblage from Obłazowa Cave consists of 16 lithic artifacts and 3 fragments of cylindrical ivory bone point (Fig. 7). The analysis of the raw materials reveals the use of local radiolarite and the import of artifacts from exogenous outcrops such as the Jurassic flint from the Kraków area, radiolarite from the Carpathian Basin, and Volhynian flint from West Ukraine. The core assemblage comprises two narrow-sided bladelet cores and one carinated endscraper. The first narrow-sided bladelet core is made on a flat pebble of Carpathian radiolarite (Fig. 7 no. 1). The striking platform is created by two small orthogonal removals. The lateral convexities are shaped minimally by using the natural morphology of the pebble and by detaching cortical flakes on the right flank. The distal convexity is not prepared and the bladelet production is overshot. The second narrow-sided bladelet core is made on a local radiolarite cobble (Fig. 7 no. 2). The striking platform is prepared with the detachment of two elongated blanks. The core's back is cortical whereas the lateral convexities are prepared with few flake removals. The production surface is characterized by convergent bladelet production. The carinated end-scraper is made on a thick flake of Jurassic flint (Fig. 7 no. 3), and the bladelet production was performed on the whole blank outline. The artifact was then discarded after reaching the maximum knapping convexity. The débitage byproducts are few and include two blade fragments and two bladelet fragments in Jurassic flint, and a blade fragment in Volhynian flint. The stone tools assemblage comprises a fragment of carinated endscraper, a scraper, and two endscrapers in Jurassic flint, an endscraper and a retouched blade fragment in Volhynian flint, and an endscraper in green radiolarite (Fig. 7 nos. 4–9).

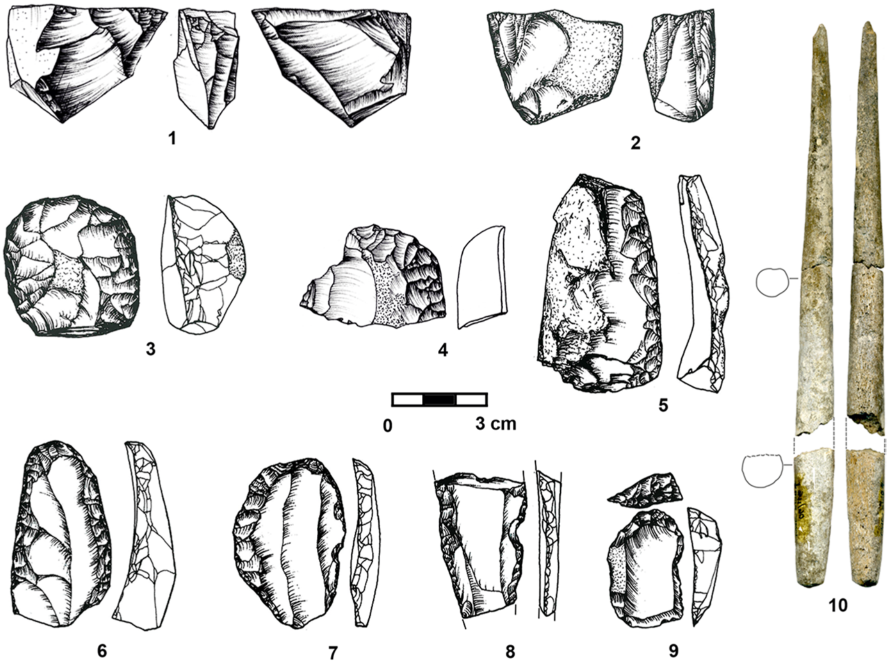

Fig. 7 Obłazowa Cave layer VII: 1–2 bladelet core; 3 carinated endscraper; 4, 6, 7, and 9 endscraper; 5 scraper; 8 retouched blade fragment; 10 ivory point

Discussion

Previous works on the emergence of EUP in Poland outlined a complex scenario with the development of different toolkits and the chronological overlapping of several Aurignacian variants (Kozłowski, 1983, 2002; Sachse-Kozłowska, 1982b; Sitlivy, 2016; Sitlivy et al., 2008, 2009). The current hypotheses of elaboration of laminar/lamellar technologies from the forgoing Middle Paleolithic (Sitlivy, 2016), and the contemporaneity of different Aurignacian facies (e.g., Zwierzyniec Type, Piekary Type, Góra Puławska Type) (Jarosińska, 2006b; Kozłowski, 2002; Sachse-Kozłowska, 1982b) is incongruous with the neighboring regions where these innovations were introduced by groups of *Homo sapiens* and techno-typological changes are documented over time (Bar-Yosef & Zilhão, 2006; Benazzi et al., 2015; Picin et al., 2021; Zilhão, 2011). This inconsistency raises to question if this evidence is a taphonomic byproduct, generated by complex post-depositional histories of the archaeological sites, or if Poland followed a different technological trajectory during the EUP.

The analyses of the lithic assemblages of the sites, examined in this study, reveal technological features typical of the European Aurignacian (Tables 2, 3, and 5). Laminar and lamellar production is characterized by two independent knapping strategies. Large and robust blades were detached using unidirectional semi-rotating and wide-face flat cores while narrow-sided and multiplatform cores produced smaller laminar blanks. Even if only one fragment shows a lateral constriction (Fig. 2 no. 12), Aurignacian retouched blades are present (Tables 4 and 6). Bladelets were produced using carinated endscrapers and carinated burins (Tables 2, 3, 4, and 5). The profile of complete bladelets is straight and curved whereas microblades are generally twisted. The number of *Dufour* bladelets is limited and associated with the subtype Dufour (Tables 4 and 5). At Kraków-Zwierzyniec 1, burins outnumber endscrapers but none of them is recorded as nosed endscraper. Busqué burins, Caminade bladelets, and Vachons burins are missing. Previous studies point out they are also absent in the other trenches of Kraków-Zwierzyniec 1 (Jarosińska, 2006b; Sachse-Kozłowska, 1978, 1982b). Conversely, at Kraków-Spadzista Street nosed endscrapers and a Vachons burin were recorded in trench B1 and C (Sachse-Kozłowska, 1978; Stefański, 2003, 2013).

Unfortunately, the resolution of the radiometric data is low, and the chronological information could give only a rough estimation of the time of the Aurignacian settlement in Poland (Table 1). However, the radiocarbon dates indicates dispersals of *Homo sapiens* also before 35 ka BP. At Kraków-Zwierzyniec 1, the interpleniglacial soil, which includes the Aurignacian layer, is embedded between two loess layers dated respectively 55.6 ± 5.2 ka and 36 ± 4.7 ka (Table 1). At Mamutowa Cave, located at ~ 20 upstream of the Rudawa River from Kraków-Zwierzyniec 1, the direct radiocarbon dates on two Mladeč points yielded a range of 39–36 ka BP (Table 1). At Kraków-Spadzista Street, radiocarbon and TL dates place the formation of Aurignacian layer 7 at 38–31 ka BP whereas, at Piekary II, at least two occupations are documented (~ 36–34 ka BP and ~ 33–28 ka BP) (Table 1). At Stajnia Cave, the direct radiocarbon dates on the ivory pendant and the bone awl indicate an Aurignacian dispersal at least at 41.5 ka BP (Table 1). At Obłazowa Cave layer VIII, the Aurignacian is dated ~ 37–34 ka BP while at Deszczowa Cave level VII it occurred at *c*. 35–34 ka BP (Table 1). These results indicate that *Homo sapiens* visited recurrently southern Poland during the EUP as well the other northern European regions. Similar evidence is recorded at the Meuse Basin (Belgium) where the technological reassessment of the lithic industries pointed out possible ephemeral occupations during the Proto-Aurignacian and the Early Aurignacian (Flas, 2015). The small amount of Aurignacian finds in Poland could be related as well to short-term visits of groups of *Homo sapiens* that moved to the areas north of the Carpathians during recurrent forays.

In this chronological context, it is puzzling the association of the laminar/lamellar evidence of Kraków-Księcia Józefa Street layer II to *c*. 44–42 ka BP (Table 1) (Sitlivy et al., 2009). Although spatial and refitting studies indicated that the lithic scatter was in situ (Sitlivy et al., 2014c), the assemblage was generally dated to a younger age of ~ 40 ka and included with Piekary IIa layer 6 in a local EUP group disconnected from the other European chrono-cultural facies (Sitlivy, 2016; Sitlivy et al., 2008, 2009). The absence of carinated elements or typical Aurignacian stone tools was used as the main argument for supporting the local development from the preceding Middle Paleolithic substrate. However, the crested blades from Kraków-Księcia Józefa Street layer III and Piekary IIa layer 7b–7a (Sitlivy, 2016; Sitlivy et al., 2008, 2009) are most likely flakes of translation of the striking platforms of discoid cores, as it has been demonstrated also by refittings (Sitlivy et al., 2014c).

This technical expedient is common during the Middle Paleolithic for creating a new striking platform when the overall convexity was achieved (Picin & Vaquero, 2016; Slimak, 2003). Furthermore, the production of elongated flakes/blades by unidirectional methods is as well a common feature of the Middle Paleolithic of Central Europe since the late MIS 8 (Hérisson et al., 2016; Picin, 2018, 2020; Picin et al., 2020; Wiśniewski, 2014). The features of the lithic assemblage of Kraków-Księcia Józefa layer II are very different from those of the Central European Micoquian and Levallois-Mousterian (Conard et al., 2019; Neruda, 2011; Picin, 2016; Picin et al., 2020; Wiśniewski et al., 2013) ruling out its possible association with the Middle Paleolithic. The age of the radiocarbon date could place Kraków-Księcia Józefa layer II within the transitional industries of Zwierzyniecian (Stefański, 2018) or Jerzmanowician (Krajcarz et al., 2018) but the absence of Zwierzyniecian backed artifacts and Jerzmanowice points make this hypothesis difficult to support. On the other hand, the core and débitage assemblages show several similarities with the artifacts documented at the nearby site of Kraków-Zwierzyniec 1. Therefore, the most parsimonious explanation is that the dated charcoal was not associated with the lithic assemblage and the human occupation occurred only successively when *Homo sapiens* visited the Kraków Gate during the EUP.

Even though these Polish lithic assemblages have been published previously as a whole (Kozłowski, 2002; Sachse-Kozłowska, 1978, 1982b; Sachse-Kozłowska & Kozłowski, 2004), our study reveals the occurrence of cores and stone tools representative of different stages of the Aurignacian suggesting that palimpsests of different occupations were combined. In this context, the lithic assemblage of Kraków-Zwierzyniec 1 would not correspond to a “unique” local facies but most likely to a mixed collection. The occurrence of a convergent unidirectional bladelet core and some straight bladelets could attest to an incursion in the area during the Proto-Aurignacian. For the moment, it would be hasty to propose this hypothesis based on of these few artifacts but the recent discoveries in Transcarpathia (Demidenko et al., 2020; Gerasimenko et al., 2019), at Kostenki 17 layer II and Kostenki 14 layer IVw (Anikovich et al., 2007; Dinnis et al., 2019b), and the *Dufour* bladelets from Góra Puławska I (Krukowski, 1939) could support a possible expansion of the boundaries of the Proto-Aurignacian. Then, the presence of Aurignacian blades and wide-front carinated cores corroborates forays along the Vistula river during the Early Aurignacian whereas the finding of narrow-fronted carinated cores together with burins and carinated burins implies a Late Aurignacian attribution. The few dates available make it difficult to constrain the chronology of the Aurignacian at Kraków-Zwierzyniec 1, but the absence of *busqué* burins and Vachons burins in trench III could confirm several dispersals between ~ 42 and 36 ka BP. A similar hypothesis could be proposed for layer 7 of Kraków-Spadzista Street where the co-occurrence of a wide-front carinated endscraper with carinated burins and nosed endscrapers demonstrates again the mixing of artifacts from the Early Aurignacian and Late Aurignacian (Table 5). The lower density of finds indicates sporadic visits on this side of the Sowiniec horst probably due to a steeper slope in comparison with Kraków-Zwierzyniec 1.

The cultural facies Piekary (Sachse-Kozłowska, 1978; Sachse-Kozłowska & Kozłowski, 2004) could be considered as well a taphonomic byproduct. At Piekary

IIE, previous studies already showed that post-depositional processes moved the Aurignacian artifacts from their original location (Sachse-Kozłowska & Kozłowski, 2004). Therefore, it is unlikely that two independent facies (Piekary and Zwierzyniec) developed roughly at the same time within a radius of 10 km. From a technological perspective, no differences are recorded in terms of core configurations and reduction with the other sites of the Sowiniec horst. The differences documented in the frequencies of burins and endscrapers between the two locations could be related to the site function and the duration of the occupations. In a similar vein, the absence of typical Aurignacian artifacts in level 6 of Piekary IIA could be considered as well the result of temporary forays in the area.

The hypothesis of recurrent short-term incursions in the neighborhood of Kraków during the initial phases of the EUP is observed also at Mamutowa Cave. The revision of lithic assemblage is currently in progress, but the published material shows the presence of Early Aurignacian artifacts including Aurignacian blades and a split-based point (Fig. 5 no. 9, 13). Although the strict association of a split-based point with the Early Aurignacian is still debated because it could appear also in the Proto-Aurignacian (Ortega Cobos et al., 2005) or Late Aurignacian (Kitagawa & Conard, 2020), when homogenous assemblages are considered, this type of organic projectile is not documented in contexts younger than the Early Aurignacian (Flas, 2015; Tartar & White, 2013). In this perspective, the split-based point should be older or contemporaneous with the two Mladeč points found at Mamutowa and directly radiocarbon dated to 39–36 ka BP (Table 1). The remaining stone tools such as nosed-endscrapers and a carinated burin attest occupations during the Late Aurignacian.

Information on other EUP sites in the Kraków-Częstochowa Upland is largely fragmentary and incomplete. Beyond the ephemeral occupations identified at Deszczowa Cave (Cyrek et al., 2000) and at Stajnia Cave (Talamo et al., 2021a), no evidence is available for the other multi-layered sites. Aurignacian artifacts were possibly discovered in the cultural layer II of Ciemna Cave (Valde-Nowak et al., 2014) while they are missing at Nietoperzowa Cave and Koziarnia Cave where the Gravettian lies on top of the Jerzmanowician (Kot et al., 2021; Krajcarz et al., 2018). In the western Carpathians, the lithic assemblage of Obłazowa Cave reveals recurrent short-term visits from the Kraków uplands, Slovakia, and western Ukraine (Valde-Nowak et al., 2003). This data indicates that the site was an important location on the way to farther areas.

The Polish Aurignacian in a Broader Context

The technological reassessment of EUP lithic assemblages from several key sites in southern Poland points out the presence of artifacts characteristic of different stages of the Aurignacian. This evidence indicates that groups of *Homo sapiens* recurrently dispersed in the tundra environments above 49° N for chasing herds of cold-adapted species or exploiting seasonal resources (Cyrek et al., 2000; Nadachowski, 1976; Nadachowski et al., 2009). These periodic forays into the southern Polish territories should have occurred crossing the Moravian Gate, circumventing the Sudeten, or moving north across the Dniester or Prut basins. In the last decades, connections with the northern Carpathian Basin have been proposed by studies on raw material sourcing and transport. Artifacts made in Polish erratic and chocolate flint are discovered in eastern Slovakia (Kaminská et al., 2000) and northern Hungary (Adams, 2007; Kozłowski et al., 2009; Lengyel et al., 2006; Markó, 2009; Péntek, 2018). The highest proportion of Polish flint is found in the Aurignacian levels of Istállóskő Cave (Hungary) (Adams, 2007 but see Markó, 2015) whereas few artifacts are retrieved in the open-air sites of northern Hungary and Slovakia (Kaminská et al., 2000; Kozłowski et al., 2009; Lengyel et al., 2006; Markó, 2009; Péntek, 2018). Slovakian radiolarite is also found in Poland and documented by a core and few fragments at Kraków-Zwierzyniec 1 (Kozłowski & Sachse-Kozłowska, 1981). Unfortunately, most of these Aurignacian open-air sites in the northern Carpathian basin are still undated impeding a deeper chronological understanding of these movements.

Thus far, the expansion of the Aurignacian in Hungary is based on few and disputed data. In the Büuk Mountains, the key Aurignacian sites of Istállóskó Cave and Peskő Cave were excavated at the beginning of the twentieth century, and the stratigraphic and cultural associations of the finds are still a matter of debate (Chu et al., 2020; Davies & Hedges, 2008; Markó, 2015; Patou-Mathis et al., 2016). However, although some laminar byproducts are undiagnostic (Markó, 2015; Svoboda & Simán, 1989), the Aurignacian occupations are confirmed by a large collection of bone tools (Davies & Hedges, 2008; Markó, 2017). At Istállóskó Cave, direct radiocarbon dates on split-based and Mladeč points corroborate ephemeral occupations during the Early Aurignacian (*c*. 39–37 ka BP) and Late Aurignacian (*c*. 33–30 ka BP) (Davies & Hedges, 2008; Patou-Mathis et al., 2016). At Peskő Cave, the direct radiocarbon date of a splintered point instead hints a possible earlier incursion at *c*. 42–40 ka BP (Davies et al., 2015). The other Aurignacian evidence is based on unstratified and undated open-air sites where the operative chains of the lithic assemblages are highly fragmented, and composed of blades, endscrapers, burins, and few cores making difficult a chrono-cultural attribution (Dobosi, 2008; Kozłowski et al., 2009; Lengyel et al., 2006; Péntek, 2018).

In eastern Slovakia, the Aurignacian settlement is as well characterized by recurrent repopulations events. At Dzeravá Skala Cave, a large collection of osseous projectiles was found with a split-based point, possibly associated with the Early Aurignacian, while two other Mladeč points, directly radiocarbon dated, yielded a range of 39–32 ka BP (Kaminská et al., 2005; Markó, 2013). Other Aurignacian evidence is attested by the direct radiocarbon dates on the human occipital bone from Görömnöly-Tapolca (35–34 ka BP) (Davies & Hedges, 2008). At the open-air sites of Košice-Barca (I, II, and III), Seňa I, and Tibava, dated after 34 ka BP (Chu et al., 2020), habitation structures and storage pits have been claimed (although still debated) (Bánesz, 1968; Kaminská, 2014) suggesting seasonal settlements on a semi-regular basis. At Košice-Barca I, forays in the outer northern Carpathians territories are proven by few artifacts made on the Polish Wieliczka flint (Kozłowski, 1958).

In the Czech Republic, the information on the dispersal of the Aurignacian is thus far fragmentary and debatable (Neruda & Nerudová, 2013). However, the OSL age of 37.3 ± 2.5 ka is the minimum age for the Aurignacian industry at Vedrovice Ia (Nejman et al., 2011) which is in agreement with the direct radiocarbon dates on a human fossil from Mladeč (36–34 ka BP) (Wild et al., 2005). Short-term occupations in a high mobility context are found at Pod Hradem Cave for the period between 40 and 38 ka BP (Nejman et al., 2017) whereas, at Hradsko, the mixing of the assemblage and the absence of the diagnostic stone tools make the Aurignacian presence difficult to estimate (Neruda & Nerudová, 2000).

In eastern Europe, the evidence of Aurignacian is fewer and scattered over a larger area. At Kostenki-Borshchevo (Russia), the oldest EUP occupation is documented at Kostenki 14 layer IVb, dated at ~ 45–42 ka BP (Anikovich et al., 2007). Successively, at Kostenki 17 layer II and Kostenki 14 layer IVw, the laminar/lamellar production, named Spitsynian, is dated ~ 42–41 ka BP and interpreted as a variant of the western Proto-Aurignacian (Dinnis et al., 2019b; Hoffecker, 2011 but see Bataille et al., 2020). Then, at Kostenki 14 (Markina Gora) and at Kostenki 1 layer III, diagnostic Aurignacian artifacts are dated 38–36 ka BP (Anikovich et al., 2007; Hoffecker et al., 2016). Thus far it is unclear whether the diffusion of these EUP variants at Kostenki-Borshchevo is the result of an expansion of groups of *Homo sapiens* from western Europe or western Asia. However, further south, lithic assemblages similar to the western Proto-Aurignacian *Krems-Dufour* facies are found at Chulek at the mouth of the Don River (Demidenko, 2009), at Siuren I units H/G (Demidenko & Noiret, 2012) in Crimea, and at Shirokii Mys and Kamennomostskaya Cave in Northern Caucasus (Demidenko, 2009). Unfortunately, radiocarbon dates are still unavailable for most of these sites while the chronology of Siuren I units H/G (~ 30 ka BP) is too young probably due to the failure of removing the contamination from the bone samples (Demidenko, 2014).

In the Prut basin, recurrent Aurignacian settlements are documented at Mitoc-Malu Galben (Moldavia) (Nigst et al., 2021; Otte et al., 2007). Although a radiocarbon date on charcoal yielded a range between 37 and 36 ka BP for the lowest Aurignacian level 12b (Haesaerts et al., 2010), the lithic artifacts are typical of the Late Aurignacian (Noiret, 2009). At Ripecini Izvor open-air site (Romania), the Aurignacian collections are mixed with flakes and bifacial artifacts displaced from the previous Middle Paleolithic occupations (Noiret, 2009; Paunescu, 1993). The absence of the diagnostic lithic pieces makes difficult the cultural attribution and several criticisms on the accuracy of the Aurignacian presence have been advanced (see reference in Noiret, 2009). Conversely, at Corpaci–Mâs, a Late Aurignacian chronology is suggested after the discovery of two Mladeč points (Noiret, 2009).

Thus far, even if the raw material transport reveals a connection between southern Poland and the northern areas of the Carpathian Basin, the settlement dynamics in the latter during the Aurignacian are ephemeral, and characterized by high mobility patterns (Kaminská et al., 2005; Neruda & Nerudová, 2013; Škrdla, 2017). Moreover, most of the Aurignacian evidence in Moravia is dated after 38 ka BP (Neruda & Nerudová, 2013; Škrdla, 2017) and in Slovakia after 35 ka BP (Chu et al., 2020; Kaminská, 2014). The only region in Central Europe that shows a continuous settlement is the Swabian Jura with several sites with long sedimentary sequences spanning from the Early to the Final Aurignacian (Conard & Bolus, 2003). From a technological perspective, the lithic assemblages of Kraków-Zwierzyniec 1 and Piekary IIE share some features with the technical behaviors used in this area. Big semi-rotating unidirectional blade cores are found at Geißenklösterle AH III, Hole Fels AH IV, and Sirgenstein AH V (Conard & Bolus, 2003, 2006b; Teyssandier & Liolios, 2003). Moreover, burins and carinated burins occur during the Early Aurignacian at Geißenklösterle AH III and Hole Fels AH IV (Conard & Bolus, 2006b; Teyssandier & Liolios, 2003). In this perspective, Poland could have been an interconnected region with the Carpathian Basin and southern Germany.

Conclusions

Our up-to-date revision of the EUP in Poland provides new information on the dispersal of *Homo sapiens* in the territories of the outer northern Carpathians. Conversely to the current hypotheses that support the development of some laminar/lamellar technologies from the forgoing Middle Paleolithic and the contemporaneity of different Aurignacian facies, our chronological and technological reassessment points out a scenario in agreement with the European chrono-cultural succession. The distinctive techno-typological features of the Zwierzyniec type are in all probability the result of the mixing of stone tools from different chronologies. Although the chronological resolution is low, the comparison with the technological characteristics of the neighboring archaeological sites corroborates the hypothesis of multiple dispersals of *Homo sapiens* in the territories north of the Carpathians since the Early Aurignacian. Due to the climatic deterioration in Central Europe after 42 ka BP (Fletcher et al., 2010), the cold steppe environment above 49°N latitude could have been too harsh for continuous settlements. In this perspective, Poland could be interpreted as a satellite area in the Aurignacian settlement system. Studies on raw material transport document recurrent movements from Poland to Moravia and the inner Carpathian basin whereas the technological features of the Polish lithic assemblages reveal similarities with the Swabian Jura. These two locations could have been interconnected core areas of a broad ethno-linguistic macro-region (Schmidt & Zimmermann, 2019; Vanhaeren & d'Errico, 2006) from where seasonal expeditions to satellite territories were carried out.

Future studies using high-resolution chronometric (Fewlass et al., 2017; Sponheimer et al., 2019; Talamo et al., 2021b, 2023) and prey mortality (Rendu, 2010; Sánchez-Hernández et al., 2016) analyses will unveil the precise timing and seasonality of the Aurignacian dispersals in the Polish territories.

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Declarations

Conflict of Interest The authors declare no competing interests.

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