THE LATE MIDDLE PALEOLITHIC BLADE TECHNOLOGIES AND THE TRANSITION TO THE UPPER PALEOLITHIC IN SOUTHERN POLAND: TL DATING CONTRIBUTION

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Abstract

Recent investigations at the open-air site of Pickary II, located on a terrace of the Vistula River near Kraków, yielded abundant data concerning the stratigraphy, chronology, technological patterns, and human behavior during the Middle Paleolithic to Upper Paleolithic transition in southern Poland. TL dates on burnt flints from the cultural levels indicate that between 60 and 35/32 ky early blade production was accompanied by Middle Paleolithic technologies and followed by a local Early-Upper Paleolithic and the Aurignacian, ca. 32–31 ky.

INTRODUCTION

One of the basic criteria for recognizing the Upper Paleolithic is the blade technology that is dominant during this period and determines the morphology of the Upper Paleolithic implements. Numerous discoveries have shown that this blade technique appeared in Eurasia and Africa well before the beginning of the Upper Paleolithic. The Upper Paleolithic blade technique, has been documented from the early stages of the Middle Paleolithic (300–120 ky; OIS 8-6), and has been documented elsewhere on several occasions in various parts of Africa, Near East, Europe, and Central Asia. Afterward it vanished and did not become a permanent element in the repertoire of Middle Paleolithic techniques. The appearance of blade techniques – both those stemming from the Levallois tradition and from another independent technique (the latter is often close to the Upper Paleolithic concept of volumetric cores) – was interpreted as the consequence of a parallel development of blade techniques and Middle Paleolithic flake techniques – as separate episodes sometimes interstratified with typical Middle Paleolithic flake technologies.

These techniques were consequently ascribed to different populations, even sometimes to different anthropological types, e.g. to Homo Sapiens and to Neanderthals. Thus the “anthropologically different populations” interpretation was suggested in the case of the blade episodes interstrati-
fied within the Acheuleo-Yabrudian sequence in the Near East (Vishnyatsky, 2000), where the blade episode was mistakenly linked to the evolutionary line leading to the Aurignacian (Bordes, 1977).

A similar model was proposed to explain the parallel evolution of blade, Levallois, and Mousterian techniques in western Europe by the supporters of the theory of the multi-regional origins of modern humans. The Piekary IIa site, where a blade industry with Upper Paleolithic features was found in layers tentatively correlated with the Penultimate Glaciation, has provided another argument in the discussion of the significance of the preleptolithic blade industries for the beginning of the Upper Paleolithic in Europe.

The criticism of multi-regional theories of *Homo Sapiens* evolution and the evidence for the isolation of Europe from Africa in the early phase of the Middle Paleolithic that resulted in the evolution leading to the Neanderthals (an exclusively European phenomenon) call for a review of the models accounting for the parallel occurrence of blade techniques and typical Middle Paleolithic techniques in Europe. Contributing to this review are the most recent investigations at Piekary which yielded dates for the preleptolithic blade episode in the Piekary IIa sequence and made it possible to establish the relationship between blade and non-blade *chaînes opératoires* in the Piekary II sequence.

**HISTORY OF INVESTIGATIONS**

The Piekary complex of Paleolithic sites is located on the northern slope (left bank) of the Vistula River valley (the Vistula River is ca. 203 m a.s.l.), about 12 km upstream from Kraków (southern Poland) at the Tyniec Gate, the narrowest section of the Kraków Gate (Fig. 1). This complex consists of the following sites:

Piekary I: Nad Galoską Cave (Jama Cave), is located on the western slope of the Okrążeż hill (Okrąglik by S. Krukowski, 1939/1948), with the rocky entrance at a height of ca. 219 m a.s.l.;

Piekary II and IIa: Located on and near the top of the Okrążeż hill at 234.5 m a.s.l. Piekary II, on the eastern slopes of the hill represents the “Okrążeż” of S. Krukowski. Piekary IIa is situated on the top and the western slope above the Nad Galoską Cave and Piekary III sites;

Piekary III: Located on the western slope of Okrążeż, under the Nad Galoską Cave. The base of the sediments excavated by S. Krukowski was at 208-210 m a.s.l.;

Piekary IV: Na Gołąbcu Cave, located in the southern wall of another Jurassic hill to the southwest, and;

Piekary V: Located on a rocky ridge 210 m
a.s.l. about 12–15 m south of Piekary III.

The Piekary Paleolithic complex was first excavated in 1879–1880 by G. Ossowski (Piekary I and IV; Ossowski, 1880) and subsequently by (Fig. 2):

- S. Krukowski in 1927 (Piekary II, III), and 1936 (Piekary I, III), see Krukowski, 1938/1948;

SEDIMENTS AND STRATIGRAPHY

For a good understanding and interpretation of the sediments and stratigraphy of Piekary IIa it was necessary to examine all of the trenches (I–XXII), both vertically and horizontally. This was particularly important for the lower part of the profiles below the loess cover.

Description

The bedrock supporting the site consists of Jurassic limestone with a karstic pit at the top (227.6–229.0 m a.s.l.) covered by a 5–7 m thick Quaternary sequence. Three main series of Quaternary sediments could be distinguished from the base:

- fluvial deposits,
- buried pedocomplex deformed by slope processes, and;
- aeolian loess;

TL dating will be explained in a separate paragraph.

Fluvial deposits

Unit 8 contains gravel with sands from a buried erosional accumulation from the Vistula River terrace lying on the bedrock. The material from
unit 8 includes two boulders (0.5 m in diameter) of crystalline rocks at the base of the formation (Sachse-Kozlowska, 1989). These were probably erratic blocks of San glaciation (OIS 16/14, Imbrie et al., 1982) from lag deposits on the erosional level about 25 m above the present river. Similar blocks in the same geological position (in lag deposits on the erosional surface of Miocene clay) were described from the post-San Glaciation loess terrace (Kleczyński, 1964) and the Late Vistulian-Holocene flood plain (Kalicki and Krąpiec, 1991) downstream from Kraków. The thickness of the fluvial channel deposits is small (up to 1 m) with a general thinning upward sequence. Gravels with a sandy bottom distinctly change toward the top to sands and silty sands. Petrographical analysis assigned the gravels to a period younger than the San Glaciation but also as pre-Holocene (Madeyska et al., 1994). Sandy alluvia on the border between sites II and IIa were comprised of the rocks of Fenno-Scandinavian origin from washing-out of the till-deposits, and material resulting from weathering of local Oxfordian limestone (analysis by M. Pawlikowski). B. van Vliet (manuscript) described traces of cryoturbation, solifluction, and local frost wedges with an hexagonal net pattern in in the sands (PHc). These sands were changed by pedological processes evident in the well-developed fine angular blocky structure.

Due to the morphological situation and the elevation above the river level (see Sitlvy et al. 1999a; fig. 10), the alluvia at Piekary are older than fluvial deposits at Ściejowice and Księża Józefa sites. Therefore, the fluvial sequence was probably deposited during the Oder-Warta Glaciation (OIS 8/6).

The pedocomplex

The pedocomplex was interpreted by Van Vliet in 1975, and reinterpreted by Van Vliet-Lanoë in 1986 and 1988.

These are very homogenous silty sands covering the fluvial channel deposits, at the base of which are found carbonate concretions (poupées). B. van Vliet (manuscript) analyzed similar deposits in the profile of trench X (excavated by W. Morawski), situated at the highest top of site IIa (234 m a.s.l.). Three members (PK1, PK2, and PK2a) were identified within a 1 m layer of fossil soils. The lower member (7c), contains yellow-orange sandy silts and silts with clear traces of the pedological processes (PK1) that cover the fluvial channel deposits. The pedocomplex shows a very fine subangular blocky structure that is better developed in the upper part, but less developed with discontinuous clay skins in the lower part. In the upper part of the pedocomplex, the thin clays skins are evident toward the surface but are frequently degraded (B. van Vliet in Madeyska et al., 1994). Some remains of very old paleosols are also incorporated, probably by solifluction. Traces of small hummocks, deformed by solifluction and local frost wedges with a hexagonal net pattern occurred. This material has been further enriched in alluvial clay before the development of a well-developed fine angular blocky structure, related to a deep seasonal frost penetration. This unit had support decalcification and a weak pedogenesis before being stretched by frost creep.

Unit 7b is a strong brown sandy loam, somewhat clayey, up to 1 m thick in profile X, strongly stretched and structured by frost creep. The topmost horizon consists of a light yellowish brown pure loam incorporating a local charcoal concentration (coniferous). To the northeast, it includes stretched tongues of humic pure loam. Remains of clay skins, sometimes organic, are crushed and disturbed by frost creep. This unit represents a polygenetic soil profile. A later slight recarbonation is recorded in the form of pseudomycelium.

Unit 7a in trench X consists of a brownish pure loam, noncalcareous, with humic lenses, also stretched by solifluction. Frost shattered carbonate concretions occur, probably as a result of frost jacking from the base of the pedocomplex truncated by erosion. This part of profile was destroyed by slope processes (members PK3a and PK3b) in profiles IX and XIII. Due to a deformation (gravitational turbation, cryoturbation, lobes with intercalation of underlying and overlying layers, lumps of A1 and A2 horizons, etc.) these sediments were redeposited. This type of deformation reflected a few stages of transport by solifluction, which could have occurred during the Vistulian. B. van Vliet’s micromorphological study of the lumps found in the A-horizon, documented a well-developed fine angular blocky structure (lumps of A2 in the lower part of the soliflucted sediments – PK3a) and a weakly-
developed fine angular blocky structure (lumps of A1 in the upper part of this level – PK3b). The morphological situation caused a degree of transformation in the soil profile and the depth of redeposition. Therefore, locally on the top of the hill (outcrop X) the buried soil profile could be in situ, but on the slope it was partly or fully redeposited (outcrops IX and XIII with TL datings). The TL dating of artifacts is as follows: Unit 7c varied from 61–48 ky B.P.; for unit 7b the date was 38.7–38.9 ky B.P., and; for unit 7a the date was 42–36 ky B.P.

The well-developed soil PK1 and PK2a with a thick B-horizon occurred only during the Eemian interglacial (Nietulisko soil; OIS 5e). This pedocomplex fits the classic preservation of the OIS 5 sensu-lato pedocomplex as is also commonly described at Kraków–Spadzista, Rocourt in Belgium, and Riencourt-les Bapaume in France. The main pedogenesis developed in a loess-like deposit, unit 7b, on pre-existing units.

This break in sedimentation (hiatus) occurred between the last interglacial and the Younger Pleniglacial. The deformations developed during the settling of unit 7b2 below the base of the young loesses. Micromorphological study of the various horizons of these two units show they are similar to those at Rocourt (Van Vliet, 1975) where sedimentary discontinuities are observed between the pedocomplex, the light yellowish brown unit including the charcoals, and the Younger Pleniglacial when denudational processes dominated. In highly truncated sections, Middle Pleniglacial pedocomplex also weather the previous one. In highly truncated sections, the Middle Pleniglacial pedocomplex also weathered the previous one. This type of deformation reflects the transport by solifluction (frost creep) in a few stages, which could have occurred during the Vistulian (OIS 4-early 2) like those observed in western Europe (Van Vliet-Lanoë, 1986, 1988, 1990). Notice that the deformation in vertical and horizontal sections clearly shows the development of mudboils (cryoturbations) stretched in sorted stripes by solifluction (Van Vliet-Lanoë, 1998). This resulted from the higher frost susceptibility of unit 7b compared to unit 7a. Carbonate concretions are frost shattered, and reacted like stones. On the partly eroded surface of unit 7b1 were also found small carbonate-rich frost cracks. Subsequently, solifluction sediments covered this surface: loamy unit 7a, and purely loamy unit 6.

The Younger Loesses

A 3–4 m thick of carbonate-rich (up to 8%) loess layer covers all trenches of the Piekary hill.

Unit 6 is pure loess, light yellowish brown, calcareous and porous including the carbonate concretions. It includes two tundra gley soils that seem to be synchronic with the main occupation at Kraków–Spadzista dated at 23 ky by $^{14}$C. These weakly developed paleosols support a thin massive, light yellowish brown loess followed by an arctic meadow soil, unit 4, as also recorded. This soil is covered by a new loess in which a Limon à doublets develops in unit 5. This sequence ends with remnants of the Late Glacial pedocomplex.

The upper units represent the colDEST and driest part of the record corresponding to the Upper Pleniglacial. The recorded stratigraphy shows a sequence similar to these observed by Van Vliet (1974) at Kraków–Spadzista and at Brzoskwinia (1978). During the excavation by J. Kozlowski at Brzoskwinia, the upper units predated an ice wedge that was filled by massive loess, Magdalenian artifacts, and a Late Glacial pedocomplex. This sequence was interpreted as tundra gley and as Kesselt–Nagelbeek pedocomplex, a 19 ky B.P. interstadial that corresponds to the arctic meadow soil and the 16.5 ky B.P. interstadial Limon à doublets (Lascaux). A recent TL-OSL dating of similar sequences in western Europe (Frechen et al., 2001) matching the Voelker et al. (1998) $^{14}$C calibration, allows us now: 1) to attribute the Kesselt–Nagelbeek pedocomplex to the H3 event; 2) to attribute the humic soil to the stabilization close to the end of the main loess deposition (24–20 ky); 3) to attribute the Limon à doublet interstadial to DO2 immediately after the H2 event from 19–17 ky B.P., and; 4) to attribute the upper loess in which the Late Glacial pedocomplex develops (Van Vliet-Lanoë et al., 1992) to a 14–17 ky B.P. deposition, matching the age of Gravettian in Germany.

Morphological control

The morphological situation induced the periglacial transformation of the compound pedocomplex and controlled the depth of burial of formerly denuded surfaces. Therefore, on the hilltop the
buried soil profile remained mostly *in situ* in places (trench X), but also had been truncated by several erosion surfaces; on the slope, it was partly or fully re-deposited in form of solifluction splay or lobe over the previous units (trenches IX, XIV, and XIII; Figs 3 and 4), probably deriving from a preserved hill resting on the limestone surface (Fig. 5). The base of trench IX and XIII profiles consists of the gravel-sandy alluvia (unit 8), probably from the Oder-Warta stages (OIS 8/6). In the latitudinal section of the slope (trench XIII), in the upper part of these alluvia, a very distinct depression filled by loamy-sandy deposits could be observed (units 7c–7b1). The shape of this depression suggests that it was a karstic sinkhole deforming the Quaternary deposits. This hypothesis is reinforced by the existence of a cave (Piekary I) just below trench XIII. Gravel-sandy alluvia were collapsed in this karstic hole, settling as basal sediments in the cave. The drainage and slope wash were guided by this sinkhole. Therefore in unit 7c, sandy-silty sediments (with small
carbonate concretions) overlying gravels containing a concentration of artifacts. These artifacts were TL-dated to ca. 61–48 ky B.P. (at a depth 3.9–4.35 m in trench XIII) and indicate a period of karstic activity. The same karstic sinkhole was active during the deposition of the subsequent unit 7b2 (trench XIII), which completely filled the karstic sinkhole, levelling the micro-relief of this area. During the deposition of the next unit (7b1) the karstic sinkhole fossilized (ca. 39 ky B.P.). Unit 7b2 was formed by sandy loamy sediments, and in this unit lenses of humic material from horizon A of the Interpleni-glacial soil were present. Unit 7b1 is more homogenous, formed by clayey-loamy material from the re-deposited B-horizon of the fossil soil.
Fig. 5. a) TL glow curves of a typical burnt flint (PY1): natural TL and natural plus artificial TL induced respectively by the added doses of 46, 92, and 138 Gy. Plateau test plots computed from the linear growths of the TL signal as a function of applied dose, and; b) TL growth curves obtained respectively at the first and second heatings in the TL oven.

All data from trenches IX and XIII documented a hiatus in accumulation between gravel (OIS 8/6) and Interpleniaglacial (OIS 3) members. The 7c, 7b2, 7b1, 7a and 6 levels are products of the erosional processes on the Piekary site during more a humid interstadial. The southern exposure of the slope was favorable for repetitive frost creep stretching, slope wash, and some degradation of permafrost. This was confirmed by the reactivation of karstic water activity, probably non-existent during the Lower Pleniaglacial (OIS 4 and some of OIS 3). During the first stages of the degradation of the Interglacial soil (Eemian; OIS 5e) slope washing processes prevailed. After that, the solifluction processes dominated (units 7a, 6).

The slope was gradually stabilized in the colder and drier climatic conditions of the Last Glaciation maximum (OIS 2). Therefore on the top of soliflucted levels, there occurred a traces of cryoturbated initial grassy soil at X outcrop on the top of hill. Here was found the lowest Upper Palaeolithic cultural layer. The concentration of artifacts in this layer indicates that flints were probably not removed by slope processes, but only covered by loess because of the very dry conditions at the site. During most of the Pleniaglacial (Van Vliet-Lanoé and Litsitsyna, 2001), the permafrost was probably rather thick, with a deep active layer, in relation to the morphology and the dryness of the site. The development of frost creep and frost jacking of artifacts, instead of mudflow, are consistent with this dryness. In these conditions, vegetation was probably scattered on the hill (grassy tundra). The site was likely used as a hunting observatory. However, at the foot of the hill, shrub-like to forested tundra may have developed due to its higher humidity and sheltered position, with permafrost and lateral seepage, as today in northern Mongolia and Yakoutia.

During the Younger Pleniaglacial, the cold and dry climate was evident in the uppermost series of carbonate slope loesses that entirely covered Piekary hill. Two to three levels of initial grassy soil and humic soil in the middle of loess cover were discovered (Van Vliet, manuscript) that indicated a break in sedimentation.

The uppermost part of the loess series was eroded and covered in stages by loess deluvia during the Late Glacial and the Holocene. The Holocene soil developed at the top of the profile containing geological units A1, A2, B1, B2, and B3.

**THERMOLUMINESCENCE AGES OF MIDDLE PALEOLITHIC LAYERS (7a–7c)**

**Materials and methods**

Flints in archaeological strata act as dosime-
ters for the natural radiation received from internal and environmental sources during the burial time. From the thermoluminescence measurements of burnt flints one can determine when the flints were last subjected to temperatures in excess of 450°C, in a prehistoric hearth, for example (H. Valladas, 1992). This technique is particularly useful for dating Middle Paleolithic sites beyond the range of radiocarbon methods and has provided age estimates for several important Mousterian sites in Europe and the Near East (H. Valladas et al., 1987, 1988; Mercier et al., 1993, 1995).

The flint specimens discussed in this article were collected from the 1969–1975 excavations in the accessible Middle Paleolithic layers (7a, 7b, and 7c) of sectors PIX/W and PXIII. Of about 20 flints showing signs of having been exposed to fire only 17 were sufficiently heated to be dateable by TL. Of these, 10 specimens came from the upper layer 7a and 2 from 7b in sector PIX/W; the 5 from layer 7c were all found in sector PXIII (Fig. 2).

Each flint was treated according to the procedure described by H. Valladas (1992), and the paleodoses were determined by the additive-dose technique (Mercier et al., 1992), for which a Cs-137 gamma-ray source delivering doses of 1.48 Gy/min was used (G. Valladas, 1978). The automatic apparatus (G. Valladas et al., 1994) used for the TL emission measurements had a heating rate of 5°/sec and was equipped with a Thorn EMI 9635QB photomultiplier and a MTO 380 nm optical filter that selected the blue component of the emission spectrum. Figure 5 shows the TL glow curves (natural TL and natural + artificial) of a typical burnt flint (PY1) alongside the TL growth curves and the values of the accumulated doses deduced as a function of temperature (plateau test). The paleodose was obtained by integrating the 380°C peak from 340°C to 400°C, where the plateau test was satisfied (Aitken, 1985; fig. 5).

Between 1997 and 2000, eight CaSO₄:Dy dosimeters, each planted for one year, measured the environmental dose-rates. Since fill sediments of PIX/W and PXIII sectors were removed during the 1996 excavations, we were unable to measure the dose-rates in the vicinity of the flint findspots. The measurements were performed in the surrounding undisturbed areas, several meters away: three dosimeters were planted in sector XX located to the southeast of sector XIII and five in sector XXI adjacent to the southern limit of sector IX (Fig. 2). We assumed that the environmental dose-rates recorded there were representative of the ones experienced by the dated specimens, as previous excavations in different zones of Piekary indicated a relatively homogeneous sediment throughout. For example, the five dosimeters distributed within sectors XX (z=316 cm) and XXI (z between 250 and 295 cm) of layer 7a recorded dose-rates ranging from 1090 to 1290 μGy/y, with an average of 1201±70 μGy/y. This value is close to the dose-rate of 1327 μGy/y recorded below in layer 7b (z=343 cm) of sector XX. The two dosimeters from layer 7c gave results which were 30% apart: 1261 μGy/y (sector XX, z=385 cm) and 948 μGy/y (sector XXI, z=320 cm), with an average of 1104±221 μGy/y, not that different from the dose-rates recorded in the layers above.

The cited dose-rates include the cosmic components that were measured with a portable multichannel analyzer and found to have values ranging from 145 to 125 μGy/y, depending on the depth (about 3 m and 4 m, respectively). The same apparatus, also used to get the gamma component of the environmental dose-rate in the three layers, yielded results in agreement with those of the dosimeters.

The internal dose-rate of each flint was computed from its U-238, Th-232, and K-40 contents measured by neutron activation analysis at the Pierre Sûre Laboratory, CEN, Saclay (Joron, 1974) and from the specific dose-rates given by Adamiec and Aitken (1998). The chemical heterogeneity of the flints was such that the internal dose-rates ranged from 67±4 to 1019±95 μGy/y, and consequently could account for as little as 5% to as much as 48% of the total dose-rate. Therefore the contribution of the environmental dose-rate varies from 95 to 52%.

Results

All of the age estimates and the data from which they were deduced are presented in Table 1 below. The same dates are plotted as a function of depth in Figure 6.

The 10 specimens from layer 7a yielded ages ranging from ca. 36–42 ky. The small dispersion of the individual ages of these ten flints, for which the contribution of the environmental dose-rate to
the total dose-rate varied from 5 to 50%, supports the assumption of a homogeneous distribution of gamma radiation in this layer.

The two flints from 7b gave very close age estimates of: 38.7±6.6 and 38.9±6.7 ky. The fact that the two dated specimens (12a and 12b) from layer 7b have identical radioisotopic contents and TL properties (alpha sensitivity and paleodose), suggests that they may have come from the same block of raw flint. The agreement between the two independently obtained ages demonstrates the reproducibility of the experimental protocol.

The five specimens from the lower layer 7c were somewhat older, ranging in age from 48 to 61 ky.

Having assumed that flints from a given layer were contemporaneous we computed the mean age of a layer from the weighted averages of individual flints originating in this layer. The statistical and systematic errors of each flint date were treated separately. The mean weighted ages at one sigma level are respectively 38.5±1.9 ky for layer 7a, 38.8±4.9 ky for 7b and 53.0±4.3 ky for layer 7c. The TL results suggest that though the hearths in layers 7a–7c were responsible for the burning of dated flints belong to OIS 3 (Martinson et al., 1987), the flints from layer 7c were burnt several millennia earlier than those from the two layers above.

**MIDDLE PALEOLITHIC INDUSTRIES**

The industry of layer 7c2 of Piekary IIa was stratigraphically identified for the first time in trench XXII during a joint Polish-Belgian expedition (2000 field season). The few retrieved artifacts were found in the orange sands (underlying the yellow sand 7c) and displayed clear Micoquan features. Similar Micoquan industries are known from Piekary I (Piekary Cave; forthcoming), Piekary II, and Piekary III and near Kraków (Ciemna, Wybatne, and other caves) (Kozłowski and Kozłowski, 1996).

The lithic industry from the upper part of the sands (layer 7c) is more representative (about 200 pieces from Morawski’s assemblage and 154 artifacts from the new 1998–2000 excavations). Artifacts were present all over the site but a homogeneous complex was only discovered in sector XIII (ca. 170 pieces). This material was only slightly disturbed (refittings can be made). Prior to this publication, the assemblage from layer 7c had always been regarded as an example of early blade manufacturing in the region (Saalian OIS 8/6), but it remained unpublished. As a whole, the industry is characterized by the coexistence of two independent reduction processes devoted to the production of flakes and blades by means of various methods. Blade production is attested by cores from different stages of reduction (initial stage, full debitage, exhaustion) and by technological products such as various crested blades, preparation flakes, accidental knapping elements, and final blades (Fig. 7). They were produced by two methods: a) direct (i.e., with no preparation of debitage surfaces) non-Levallois uni- and bidirectional blade reduction; b) prepared (i.e., crest installation) non-Levallois uni- and often bidirectional blade reduction. The first technique was applied to voluminous and flat flint blocks, where rather flat preforms were initially prepared from the side(s), bifacially or by lateral flakes, in order to create a central crest (with two slopes). The reduction was often performed on the narrow part of the core, from a single or two opposite platform(s), producing partially turned cores. Platforms were prepared by a single elongated scar or, most often, by several short blows. The second opposite and supplementary platform was often used for the purpose of debitage maintenance (flaking convexity). The lateral convexities were maintained by natural débordant blades or by lateral crests. On rare occasions the re-preparation of
Table 1

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<th>Th (ppm)</th>
<th>K (%)</th>
<th>α-sensitivity (μGy/h 10⁻⁶ ø)</th>
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<th>Equivalent dose (Gy)</th>
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The U, Th and K contents of the dated specimens (column 3 to 5) are given in ppm, ppm and % respectively. The combined statistical and systematic error of ±10% are essentially caused by uncertainties in the reference standard. The α-sensitivity (column 6) was determined by comparing the TL-α and TL-β signals induced by α and β particles from Pu-238 and Y/Sr-90 sources, respectively (Valladas G and Valladas H, 1982).

Gamma (column 9) and cosmic (column 10) dose-rates were deduced from measurements taken in the field by dosimeters and a gamma spectrometer.

The water content of the sediment collected during the most recent excavation is about 20%. During the Pleistocene period the water content was probably higher due to permafrost. Therefore, the gamma dose-rate obtained by the dosimeters were computed by assuming an average water content of 28% (30% during the Pleistocene and 20% during the Holocene: Frechen et al., 2001).

The one dosimeter in layer 7b was planted about 10 m away from the finds of burnt flint specimens. So, an uncertainty of ± 20% was introduced into the external dose calculations to allow for possible spatial variability of the environmental radiation. Following Aitken’s recommendations (Aitken, 1985) the statistical and systematic errors were calculated separately for each flint. Each of the tabulated overall errors represents the mean square average of the two (column 18).

Platforms and flaking surfaces was done by means of crude (facetted) removal of the overhang. Final blades are of medium and small size (even bladelets), often with bidirectional dorsal pattern. Butts are often crudely prepared or faceted. Predominance of well-developed bulbs and open flaking angles attests to the direct use of hard hammerstones. The trapezoidal cross-section of blades attests to a recurrent approach and the intensity of core reduction. However, those blades were seldom transformed into tools, as in many blade episodes during the Middle Paleolithic (e.g., some retouched and truncated blades).

Flake production was mainly based on the Levallois concept (e.g., linear Levallois cores and preferential round and triangular flakes; Fig. 8); it was accompanied by non-Levallois reduction (massive convergent and centripetal débordant flakes with crudely prepared butts). The tool kit is represented by rare retouched flakes, blades, denticolated and notched tools, transversal sidescrapers, and truncated faceted implements. The very few tools (Fig. 9) found in 7c (even in the flint-rich sector XIII) were more often on blades (straight-backed blades, angular-backed blades, or burin) than on flakes (sidescrapers).
The industry from layer 7b is also represented by flake and blade production. The abundant material was slightly disturbed (thermic and technological refittings can be made). If old collections are sometimes difficult to sort out (i.e., layer 7b vs. 7a), new investigations in trenches XX and XXII give us the opportunity to work with an unmixed industry.

Blades (Fig. 10: 2, 6–9) were probably obtained directly or after the preparation of a crest on the narrow reduction surface and from a single prepared platform. The working surface sometimes extends onto the larger part of the core. The working convexities were maintained by the removal of backed cortical blades (Fig. 10: 1). Reduction could begin with the production of rather big blanks and it could end in the production of medium- and small-sized blanks (even bladelets). Most butts were prepared by a long single blow, but could also be faceted (Fig. 10: 5, 7). Hard hammerstones were used. The platform zone was ground to eliminate the overhang (Fig. 10: 2, 3, 6). Blade reduction products were accompanied by products of centripetal non-Levallois methods (flat and conical/biconical cores, massive short and crudely prepared débordant flakes obtained during the secant orientation of the debitage) and especially by Levallois debitage (Fig. 11).

Later, Levallois debitage is well represented, with a high level of butt faceting, some crude and fine preferential flakes, numerous small centripetal recurrent blanks, some blades and laminar flakes, convergent blanks, flakes from the preparation and the re-preparation of the working surface and cores. The core reduction was mainly recurrent, centripetal, and repetitive. In addition, there are examples of the Levallois convergent point method in this collection: cores for short points (Fig. 11: 1), numerous convergent flakes (short and elongated ones), with plain, dihedral or faceted butts (Fig. 11: 3, 6). Only one case of bidirectional distal preparation was found. Levallois convergent recurrent or/and linear method is also attested by final triangular points and their fragments (Fig. 11: 5). Retouched tools are rare (e.g. déjeté scrapers; Fig. 11: 7), but numerous used blanks and slightly modified blanks, showing marginal retouching, differ from other Middle Paleolithic assemblages of Piekary.

The lithic industry of layer 7a is the most abundant of the Middle Paleolithic of Piekary IIa. This layer reflects intensive reduction activity for the production of flakes and blades. From trench to trench, the Piekary sites show differences in the spatial distribution of the industries in the layers. The most striking change in the spatial distribution pattern can be seen in layer 7a. Morawski’s excavations and trench XX (Sitlivy et al., 1999a) show the predominance of blade debitage of Middle Paleolithic type (less Levallois features than in layer 7b) over blade production of Upper Paleolithic type. However, trench XXII-2000 has mostly yielded traces of a blade debitage and its by-products in the same stratigraphic position (i.e., in layer 7a; Fig. 12). All trenches yielded only Middle Paleolithic tools. Several methods of blade production were recognized.

1. A direct, uni- and bidirectional exploitation of voluminous and flat nodules. The preliminary preparation can be seen in the making of platforms (plain and prepared) and in the partial cortex removal. Exploitation continued with no crest installation taking advantage of the natural convexities; maintenance was insured by retrieval of lateral cortical débordant blades, by bidirectional debitage and, finally, by changing the debitage orientation. The cores connected to a direct exploitation are often left in their initial stage; they were abandoned because of numerous hinged fractures.

2. A prepared exploitation with crest installation (central and more often lateral). We can mention large bifacial preforms with a residual cortical surface and a lateral (?) crest, as well as reduced cores with neo-crests. As a matter of fact, crested blades (Fig. 12: 3, 4) are not at all numerous when compared with all blade debitage products or with the much smaller industry from layer 7c.

During debitage, platforms were rejuvenated by retrieving partial tablets, by faceting, and by grinding overhang (Fig. 12: 1). On the whole, blade cores of all types were abandoned without important reduction of their mass and their volume. Large and massive blades are followed by a more representative generation of medium sized blades.

The flake production (mostly from Morawski’s excavations and from trench XX-1998) is attested by numerous convergent and centripetal,
Fig. 7. Middle Paleolithic layer 7c blade production: 1, 3, and 5 are bidirectional cores; 2 and 4 are crested blades. (1 is from trench XXII/2000; 2, 3, and 5 are from trench XIII, and; 4 is from trench IX.)
Fig. 8. Middle Paleolithic layer 7c Levallois flake production: 1 is a Levallois blank; 2 and 3 are Levallois cores. (1 and 3 are from trench XXII/2000, and; 2 is from trench XIII.)
short, and asymmetrical *débordant* flakes of a rather small size (Fig. 13). The Levallois methods (more likely the centripetal recurrent method) are less common than in layer 7b. Decoricated and *débordant* flakes were usually modified or used as tools. However, the tool kit is modest and trivial for the Middle Paleolithic. Blades remain still almost non-retouched.

Thus several production systems can be proposed for Piekary IIa Middle Paleolithic layers 7c, 7b, and 7a (Sitlivy *et al.*, 1999b).

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1. Blade debitage is rather unique and very well represented during the Middle Paleolithic in Piekary: it was first found in layer 7c, and then again more recently during new excavations and analyses in layers 7b and 7a. Systematic blade reduction in the Middle Paleolithic layers has a volumetric concept of core reduction of Upper Paleolithic type as opposed to flat Levallois blade production and it seems to differ only quantitatively from the production of the Upper Paleolithic industries of Piekary. Two main methods are
Fig. 10. Middle Paleolithic layer 7b blade production: 1 and 5 are débordant blades; 4 is a crested blade; 2, 3, 6, 7, 8 and 9 are blades of full debitage (2, 3, and 6 bare traces of elimination of overhang). (All blades in this figure are from trench XXII/2000)
Fig. 11. Middle Paleolithic layer 7b Levallois production: 1 is a point core; 2, 3, 4, and 6 are flakes; 5 is a point; 7 is a déjeté scraper. (All items in this figure are from trench XXII/2000)
involved: a) direct non-Levallois blade method, and; b) prepared (with crest installation) non-Levallois blade method.

Voluminous flint nodules and slabs are the main source for blade production and were exploited without continuous reshaping, due to natural convexities and guide ridges of previous blade removals or with transversal pre-forming in order to create crest(s). Maintenance was achieved by neo-crests, changes in orientation, and platform rejuvenation (tablets, grinding, trimming). All blade debitage elements and reduction stages are present in every layer. Debitage probably started from a single platform. However, the bidirectional model is also well represented, especially in layers 7a and 7c. Flaking surfaces were located on wide and narrow sides and were expanded to the lateral edges resulting in partially turned (or rare fully-turned cores). At first glance, the principal difference between blade methods in the Middle and Upper Paleolithic layers of Piekary Ila lies in the technique of blank production: the use of soft hammer was standard during the Upper Paleolithic.

2. Levallois linear method for medium and small single preferential flakes with “simple” and more regular centripetal or orthogonal preparation. This method was seldomly used in the Piekary Middle Paleolithic complexes. It could be linked to the recurrent Levallois flake technology.

3. Levallois recurrent repetitive centripetal method for production of several generations of flakes (i.e., several flakes per working surface and several flake generations per core blank).

4. Levallois convergent method for short wide points. Some blades from layer 7b could be linked to this method (by-products).

5. Centripetal recurrent conical/biconical method with secant flake production is attested in all Middle Paleolithic layers. The difference from the previous centripetal methods is linked to non-flat, secant, alternating (if biconical) core exploitation.

The preliminary study of Morawski’s assemblages and samples from the 1998–2000 excavations (Sitlivy et al., 1999b, 2001) shows a systematic blade production of Upper Paleolithic type accompanied (in various proportions) by a series of Middle Paleolithic flake methods. During the Middle Paleolithic, the Piekary blade manufac-

ture was not linked to – and differs significantly from – Levallois technology, which had a clear non-elongated character. The Upper Paleolithic volumetric concept of blade production first appears in Middle Paleolithic layer 7c, coexisting with several flat core flake methods during the Later Middle Paleolithic (layers 7b and 7a) and re-appeared and developed into a unique standardized blade production in the Early Upper Paleolithic (layer 6), which belongs to different cultural, chronological, and functional traditions.

**EARLY UPPER PALEOLITHIC LAYERS**

**Layer 6**

The beginning of the Upper Paleolithic at Piekary II is represented by three different assemblages, all of which occur within a loess intercalation directly overlying weathered clays, or re-worked in a series of soliflucted sediments. In the central portion of the loess intercalation, S. Krukowski (1939/1948) discovered a small concentration of Upper Paleolithic finds that he described as the “Naskalanski” industry. This industry is characterized by the presence of double-platform cores devoted to the production of relatively narrow and regular blade blanks; the only tools are simple blade endscrapers. The industry was located near a washed out hearth. The charcoal (mostly from Juniperus) found in this hearth was dated to 31,100±1,100 B.P. (OXA-7347). Another industry, still undated, was present in the top portion of the loess intercalation itself and in its interface with the Upper Loess of Pleniglacial II (Last Glacial Maximum): the “Okraglicki” industry, with broader blade blanks obtained from single-platform cores. This industry contained tools such as endscrapers (among them nosed and carinated examples), truncation burins, dished déjeté burins, and retouched blades (Fig. 14). It exhibits characteristic features for the Central European typical Aurignacian and it is posterior to the “Naskalanski” industry. Blade workshops are also found at other spots of Piekary II and Ila, within solifluction sediments, and underneath the Pleniglacial II loess. The blades were obtained from single-platform cores that are similar to those of the Piekary II Aurignacian.

Thus, we may suggest the existence of two
Fig. 12. Middle Paleolithic layer 7a blade production: 1 and 2 are bidirectional blade cores; 3 and 4 are crested blades. (All items in this figure are from trench XXII/2000)
Fig. 13. Middle Paleolithic layer 7a Trench XX/1998. Centripetal non-Levallois and Levallois recurrent flake debitage (after Sitlivy et al., 1999a)
different technological traditions at the end of the Interpleniglacial: 1) an earlier industry linked to the older preleptolithic local industries characterized by a technology of volumetric double-platform cores and unspecific Upper Paleolithic tools, i.e., Piekary II ca. 31 ky B.P. (unit Py/II 3, from S. Krukowski), and Piekary IIa ca. 25,840 ky B.P. (the youngest AMS date B-2562 was obtained by H. J. Müller-Beck on charcoal from unit 6 excavated by W. Morawski), and 2) a later industry, with typical Aurignacian tools, representing a new allochthonous technological tradition.

Technological analysis of layer 6, Piekary IIa (1998–2000)

The lithic industry of Layer 6 was discovered in all parts of Piekary IIa. Morawski attributed this industry to an Aurignacian workshop, with medium-size blades detached from volumetric unidirectional cores. However, sectors XX-1998 and XXII-2000 yielded a few tools on flakes and on blades (endscrapers, and nosed implements: core or tool preform, several burins and burin spells, denticulated and notched tools, sidescrapers, backed knives, retouched and used blades and flakes), as well as an artistic production (two engraved pieces of hematite; Sitlivy et al., 2001). Moreover, the exclusive blade debitage does not fit well with the classical Aurignacian technology (e.g., bidirectional prepared blade cores) but resembles rather the “Naskalański” industry from Krukowski’s excavations in Piekary II. We are probably dealing with a spatial clustering of cultural groups or with a unique Early Upper Paleolithic complex which occurs in various forms in Central Europe and especially in the Carpathian region (e.g., Korolevo I and II, layers Ia and II). To summarize, the layer 6 complex reflects exclusive blade and some bladelet production based on volumetric core reduction, with crest installation or direct and partially-turned debitage extension (Sitlivy et al., 1999b). The use of the soft hammerstone percussion is well documented. There are no Middle Paleolithic elements in this industry. Several modes of blade core exploitation have been identified:

1. prepared unidirectional exploitation (following an initial bidirectional exploitation) with a debitage orientation from the narrow working surface to the large side;

2. prepared unidirectional exploitation, from the large side to the narrow working surface;

3. prepared bidirectional exploitation, with two opposing work surfaces located on the large part of the core and which could extend to the side(s), (Fig. 15: 1, 2), and;

4. direct (?) unidirectional reduction of almost the whole perimeter of a sub-conical core (Fig. 15: 3).

DISCUSSION

Blade technique occurred early in western Europe, particularly in northern France, Belgium, and Germany, and is dated to late phase of OIS 5. The stratigraphic position of the blade industry at Piekary is consistent although younger than those observed to the west. At Riencourt (Tuffreau and Van Vliet-Lanoë, 1993; Van Vliet-Lanoë et al., 1993), we suggest that these populations were migrating seasonally, wintering in valley shelters, and then following the summer migration of heard of horses and Bos to grassy tundra zones (as documented in modern migrations of reindeer from the north and west to the emerged epicontinental seas).

CONCLUSIONS

The re-analyzed stratigraphy and TL dates for the Middle Paleolithic layers (7a–7c) of the sequence of Piekary II and IIa, as well as new excavations and lithic analyses indicate that the blade technology during OIS 3 (60–35/32 ky B.P.) was present in all Late Middle Paleolithic industries (together with flake debitage) and was not produced by different populations but by the same Late Neanderthals as was the local Mousterian- Levalloisian. The blade chaînes opératoires were aimed at different tasks, which needed special blanks. These blanks were used mostly unmodified on the site or were exported away from the site.

These data show that blade technologies were not confined to Modern Humans, but could be the result of independent development of Late Middle Paleolithic units. These units persisted in southern Poland during the Late Interpleniglacial, parallel to the “transitional units” such as the Szeletian, Jerzmanowicjan, and Bohunician.

Only after 32/31 ky B.P. do new Upper Paleolithic units appear, stemming from the local
Fig. 14. Aurignacian industry of Piekary II layer 6 (after Sachse-Kozłowska, 1978)
Fig. 15. Early Upper Paleolithic layer 6 blade cores from trenches XX/1998 and XXII/2000
Late Middle Paleolithic as well as the allogenic Aurignacian characterized by the complete “Upper Paleolithic package”.

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