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УДК 903.4(477.64)”632” DOI: 10.37445/adiu.2026.01.08

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LAYER I OF THE MIRA SITE: FLAKE TOOL TRANSFORMATION AS A KEY TO UNDERSTANDING KNAPPING STRATEGIES

A pilot study of Layer I at the Mira site applies diacritical analysis to reconstruct flake-tool transformation under severe flint scarcity. The apparently «flake-like» character proves largely secondary: initial blanks were often blades or bladey flakes, while reworking and fragmentation generated secondary blanks with flake proportions. Directional elaboration is reflected in increased linear and angular edges, more combined tools, and more frequent scaled thinning, probably linked to producing small blanks for microliths.

Keywords: *Upper Palaeolithic, diacritical analysis, stages of flake tool modification.*

1. Introduction. Under certain conditions, lithic assemblages allow the reconstruction of an artefact’s individual history (sensu Schild 1980), that is, the transformation history of a retouched or otherwise modified piece. Evidence of such transformations is particularly abundant and at the same time readily identifiable in contexts of relatively short-term occupation accompanied by intensive subsistence activities, carried out under conditions of lithic raw-material scarcity and the absence of opportunities for replenishing limited reserves. In such circumstances, the available stock of flint, largely represented by finished artefacts, effectively assumes the role of a secondary raw-material source. Intensive use and repeated reuse of a restricted number of artefacts inevitably lead to a marked distortion of the assemblage’s appearance when compared with its original state.

Under these conditions, the reconstruction of the initial configuration of a lithic industry and its principal techno-morphological and typological characteristics requires detailed diacritical analysis (Baena Preysler, Cuartero 2006). In certain cases, such analysis allows the sequence of transformation stages affecting individual artefacts to be established, thereby enabling the reconstruction of their individual biographies. This approach further makes it possible to identify the most significant original techno-morphological parameters of the industry as a whole, which in turn permits a more precise assessment of its position among synchronous industries within the region (e. g. García-Franco, Morgado 2016). Reconstructing these individual transformation histories also allows insights into the knapping strategies employed under conditions of raw-material scarcity.

This paper focuses on the reconstruction of individual transformation histories of 40 flake tools from the upper layer of the Mira site. The site is interpreted as a short-term winter occupation and is located in an area entirely lacking knappable flint outcrops, that is, under conditions of severe lithic raw-material constraint. The main aim of the study is to evaluate the extent to which these conditions shaped the industry’s present techno-morphological characteristics and overall appearance.

1.1. Archaeological context. The Mira site, located on the left bank of the modern Dnipro channel near the village of Kanivske, Zaporizhzhia District, Zaporizhzhia Region, was discovered in 1995. Systematic investigations began in 1997 and were conducted intermittently until 2012 (Stepanchuk, Cohen, Pisaryev 1998; Степанчук 2013; Степанчук та ін. 2013). Two occupation horizons were identified, as well as an intermediate level containing traces of an anthropogenic (?) fire. A series of ten radiocarbon dates places

all layers within the range of 33—31 ka cal BP (Степанчук 2013; Hoffecker et al. 2014), allowing correlation with the cool episode GS-5 recorded in the Greenland ice-core sequence. According to the Ukrainian stratigraphic scheme, the deposits are associated with the Vytachiv Horizon (ed. Веклич 1993). It is assumed that different stages of occupation of the locality may have been separated by intervals not exceeding 100—200 years (Герасименко, Эзартс 2013). The proposed absolute and relative chronological positions are consistent with geostratigraphic, lithostratigraphic, palynological, and biostratigraphic evidence (Журавлев, Пучков 2001—2003; Рековець 2004; Степанчук та ін. 2004; Герасименко, Эзартс 2013; Матвіїшина, Кармазиненко 2013; Haesaerts et al. 2014; Hoffecker et al. 2014; Журавлев 2015; Герасименко та ін. 2022).

The site is located in an area almost completely devoid of flint outcrops (ed. Бондарчук 1960; Сивий, Паранько, Іванов 2013; Нікітенко 2022), while at the same time lying within a zone rich in biological resources (Степанчук 2025). To date, Mira remains a unique site within the Middle Dnipro region, distinguished by its well-defined stratigraphy and the high degree of preservation of the archaeological layers (Смирнов 1973; Нужний 1994; Тубольцев, Бусел 2001).

The site exhibits exceptional taphonomic characteristics, as shortly after the accumulation of cultural remains they were sealed by thick alluvial sandy deposits. This rapid burial significantly contributed to the preservation of the Palaeolithic occupation remains after the final transition of the locality to subaerial conditions. Given the absence of natural stone clasts in the culture-bearing sediment and adjacent deposits, a geogenic explanation for the extensive trampling and associated damage is improbable.

The lithic industry of the Upper Palaeolithic layer combines typological traits characteristic of both the Middle and Upper Palaeolithic (Степанчук 2013), including non-geometric microliths, and shows clear analogies with the Crimean Micoquian and the Gorodtsovian Upper Palaeolithic (Бонч-Осмоловский 1940; Аникович, Анисюткин, Вишняцкий 2007; Аникович, Попов, Платонова 2008; Степанчук 2013; Sinitsyn 2015). This combination initially suggested attribution of the upper layer of the Mira site to transitional industries between the Middle and Upper Palaeolithic (Коен, Степанчук 2000). It has also been suggested that the archaic features in typological appearance of the assemblage may reflect a highly mobile subsistence strategy in steppe environments, particularly the prevalence of expedient tools (Hoffecker 2011; Hoffecker et al. 2017). The apparently archaic character of the industry may therefore reflect not a cultural «backwardness» but intensive exploitation of a strictly limited lithic supply (Stepanchuk 2013). In this context, the continued need for functional implements could have promoted production of very small tools, expressed here in the emergence of distinctive non-geometric microliths (Ryzhov, Stepanchuk 2025). Technological analysis of the industry is significantly hampered by the near absence of cores and of debitage unaffected by subsequent transformations. Despite the generally flake-based appearance of the assemblage, it can hardly be regarded as a flake-oriented production system *sensu stricto*.

2. Methods.

2.1. Reconstruction of the sequence of manufacturing stages in flake tools. Due to the morphological characteristics of secondarily modified artefacts, it is sometimes possible — though with varying degrees of confidence — to reconstruct the order of stages in their manufacture and subsequent modification. Relative sequencing can be inferred from a range of indicators, including the superimposition of retouch, the truncation of a retouched edge by a fracture plane or a deliberately produced fragmentation surface, shifts in modification technique, and small diagnostic features along flake-scar margins that allow the relative chronology of removals to be established.

Refitting and diacritical analysis pursue a common aim — reconstructing reduction and transformation histories — but operate at different analytical levels. Refitting physically reassembles fragments and detached removals, whereas diacritical analysis reconstructs sequences virtually by reading scar patterns (negative removals) on individual pieces.

Most of the indicators used for such sequencing are readily recognisable, and well known to Palaeolithic researchers, and form the basis of the so-called diacritic method of lithic analysis (Baena Preysler, Cuartero 2006). Diacritic analysis is grounded in the concept of the reduction sequence, i. e. the *chaîne opératoire* (Geneste 1985; Boëda et al. 1990), that is, the reconstruction of the chronological succession of flake removals. In its early applications, it focused chiefly on reconstructing the predetermined products targeted as the main outcome of core reduction (Sellet 1993), and later was widely applied to the analysis of manufacturing stages of bifacial tools (e. g. Richter 1997; Kot 2014; Herzlinger et al. 2021), whereas its application to flakes and flake tools has remained comparatively less common (see, however, Baena et al. 2010; Capellari et al. 2021). In the present study, this methodological framework, most fully and systematically developed in Baena Preysler and Cuartero (2006), is consistently applied to the analysis of a sample of flake tools. The principal elements of the approach used here to reconstruct the life histories of individual flake tools are outlined in Степанчук (2003).

Flake tools from the 1995 and 2000 collections were subjected to analysis. The selection was largely random; however, several mandatory criteria were applied, including identification

as flake tools, the presence of clear evidence of modification, and the potential for reconstructing stages of reshaping.

The majority of the analysed artefacts were examined petrographically by Dr. V. F. Petrougne (Петрунь 2001—2003; Степанчук та ін. 2004; Stepanchuk, Petrougne 2005) through the study of immersion preparations under a polarising microscope.

The assemblage from Layer I exhibits considerable raw material diversity, with more than twenty lithic varieties identified, including thirteen distinct types of flint (Петрунь 2001—2003; Stepanchuk, Petrougne 2005). The analysed sample consists predominantly of flints of East Carpathian provenance (Raw Material Units Ia1, Ia3, Ia4), originating from the area between the middle reaches of the Prut and Dniester rivers (RMU Ia—b (A)), the middle Dniester region (RMU Ia—b (B)), and the Lower Bug basin (RMU Ia—b (V)). The provenance of most flint raw materials is remote, located up to c. 700—750 km west of the site. A portion of the non-flint raw materials (including actinolitite, zeolite, amphibolite, etc.) exhibits paragenetic associations and likewise indicates a distant East Carpathian origin (Петрунь 2001—2003; Stepanchuk, Petrougne 2005; Nikitenko et al. 2022).

2.2. Flake tools with linear and angular edge configurations. In reconstructing the individual modification histories of flake tools, traits commonly relied upon for typological attribution — such as the number and outline of tool edges and the character and distribution of retouch (Demars, Laurent 1989; Debénath, Dibble 1994; Andrefsky 2005) — are only weakly diagnostic, since extreme fragmentation preserves only restricted portions of the original morphology. Instead, the present study employs a conceptual distinction between so-called *linearly* and *angularly configured edge tools*. Within this framework, flake tools are subdivided into three morphological categories: (1) tools with linear edge geometry, (2) tools with angular edge geometry, and (3) tools with mixed (or combined) edge geometry.

Flake tools with linear edge geometry are characterised by the presence of one or more working edges. Points of edge convergence, deliberately shaped by secondary modification, may either be present or absent; where they do occur, the transitions between adjacent edges — that is, the zones of their junction — are smooth or rounded in character (as on fig. 2: 3: I).

By contrast, flake tools with angular edge geometry invariably possess two or more working edges. Transitions between these linear edges are marked by a distinctly angular configuration (as on fig. 2: 7), and their junction forms a clearly expressed tip, a so-called angular element.

Flake tools with mixed (or combined) edge geometry are characterised by the presence of multiple working edges and combine clearly distinguishable linear and angular elements within a single implement.

The angles of edge convergence on tools with linear and angular geometries may vary considerably and partly overlap in their values. Accordingly, the decisive criterion for distinguishing between linear and angular forms is not the angle of edge convergence per se, but the morphological characteristics of the immediate zone of edge junction — namely, whether the transition is smooth and rounded or sharp and angular. This distinction partly reflects differences in functional constraints. Potential modes of use are inferred exclusively from edge geometry and the nature of edge junctions and do not imply the determination of actual function. Thus, a linear edge combined with a smooth, rounded junction is morphologically better suited to cutting and scraping operations, whereas an angular configuration of the edge junction allows for effective piercing, splitting, incising, or scratching.

A further distinction can be made between simple and complex implements. Simple implements comprise tools with either linear or angular edge geometry, whereas complex implements combine linear and angular elements within a single artefact. Independently of this, an additional key indicator of conceptual elaboration is the application of modification techniques that differ fundamentally in both the geometry of their action and their mode of execution — for example, the combination of retouch, a burin blows, and thinning on the same piece.

The application of this analytical approach is motivated by the fact that successive stages of modification of individual flake tools within the studied assemblage are in some cases sufficiently clearly distinguishable. This makes it possible to trace potential continuity between consecutive phases of modification, to assess whether the original morphological type of an implement was maintained, and to identify instances of substantial or radical reworking.

2.3. Modification of the edge zone of flake tool. Within this approach, it is important to distinguish distinct working edges; in addition to their topographical setting, a change in the operational scheme of flake-edge modification may be used as a criterion. Modification of the edge zone of a flake may be undertaken in order to alter its edge angle by reducing or increasing its massiveness. Such changes can be achieved through retouch, thinning, burin blows, or bipolar trimming. What all these operations have in common is that the modification is effected by a concentrated percussive impulse, characterised by a point of application, a directional vector, and a plane of propagation.

In the case of retouch, the impulse is delivered tangentially to the edge of the artefact, within a plane inclined at an angle to the principal plane

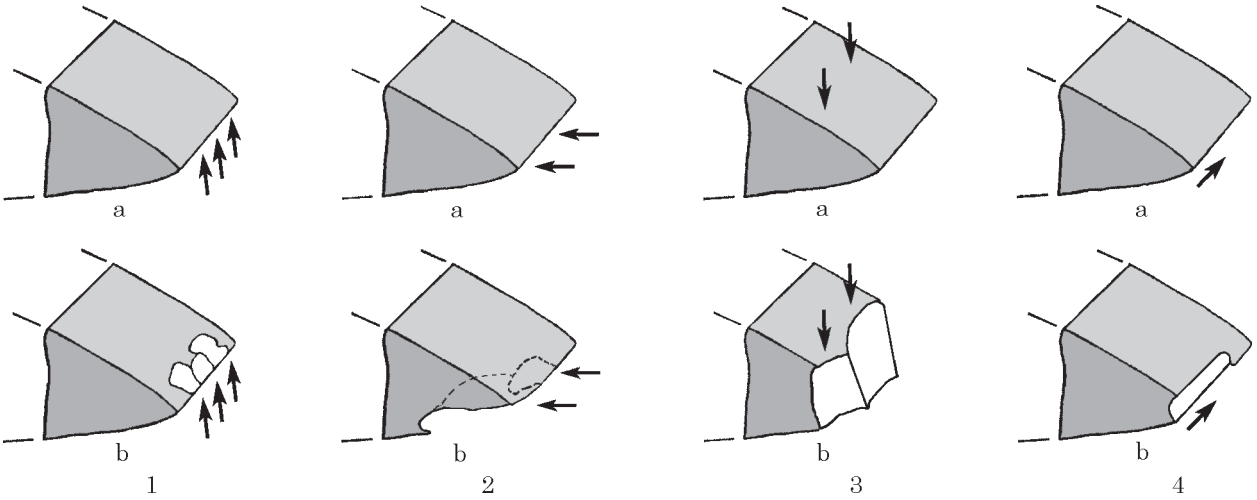

Fig. 1. Variants of modification of the edge zone of a flake tool: 1 — retouching, 2 — thinning, 3 — bipolar trimming, 4 — burin blow; a — before modification, b — after modification

Рис. 1. Варіанти модифікації крайової зони знаряддя на сколі: 1 — ретушування, 2 — потоншення, 3 — біполярний тримінг, 4 — різцевий скол; a — до модифікації, b — після модифікації

of the flake (fig. 1: 1). In thinning, the impulse is directed from the edge into the body of the artefact, within a plane that is roughly parallel to the main plane of the flake (fig. 1: 2). In contrast, during a burin blow the impulse is directed along the edge, within a plane that is roughly perpendicular to the principal plane of the flake (fig. 1: 4).

A further type of percussive modification of the flake edge zone is trimming on an anvil (fig. 1: 3). Like the burin blow, this technique results in a sharp increase in the massiveness of the edge zone. Its application, however, has not been documented in the assemblage from Mira. In certain respects — for example, in the removal of flakes struck at some distance from the edge — the trimming technique is comparable to the so-called Clactonian notch technique (Inizian et al. 1999).

The distinction between these operations implies differences in the manner in which the artefact is held, in the spatial relationship between the object being modified and the percussive implement, and in the geometry of impulse application and propagation. Thus, from a formal perspective, a change in the operational scheme of flake modification may be regarded as a significant criterion for distinguishing individual retouched edges.

2.4. Operational definition and identification of edges. In the context of the present study, an edge is defined as a morphologically and technologically individualised working margin of an artefact, characterised by homogeneity of secondary modification, consistent geometry, continuity and extent, and the presence of clearly identifiable boundaries, defined either by a change in the character of modification or by intersection with another edge.

The number of edges on a single artefact was determined through diacritic analysis, based on the identification of: (i) discrete segments of linear edges separated by topographically, morphologically, and technologically meaningful boundaries; (ii) differences in edge orientation, geometry, and modes of modification; and (iii) evidence for shifts in the operational scheme of flake-edge modification, indicating the independent formation of individual edges. Accordingly, the identification and counting of edges are grounded in the reconstruction of the sequence of technological actions, as recorded in the diacritic relationships among surface elements of the artefact.

2.5. Evidence for establishing the sequence of artefact modification stages. The main types of evidence used to establish the sequence of stages in the reworking of flake artefacts (Степанчук 2003) are as follows.

* *Rejuvenation and renewal of retouch along the entire extent of the original retouched edge* can be identified by the presence of distal portions of the scars of earlier retouch, together with a clear mismatch between the angles of inclination of the earlier and the subsequent retouch. These features are equally characteristic of retouched artefacts made on flakes (fig. 2: 1: I) and of artefacts produced on a bifacially shaped blank (fig. 2: 2).

* *Rejuvenation of retouch on a discrete segment of the original retouched edge* can be identified through a combination of the following attributes: (1) superimposition of the scars of the subsequent retouch over those of the earlier retouch; (2) a mismatch between the angles of inclination of the earlier and subsequent retouch; and (3) disruption of the edge line in plan-view within the zone of subsequent retouch (fig. 2: 1: II).

* *The sequence of shaping of adjoining retouched edges* can be established from the relative position (overlap) of marginal retouch scars in the area where the retouched edges meet. Figure 2: 3: I illustrates a configuration of two edges meeting at an angle exceeding 90°.

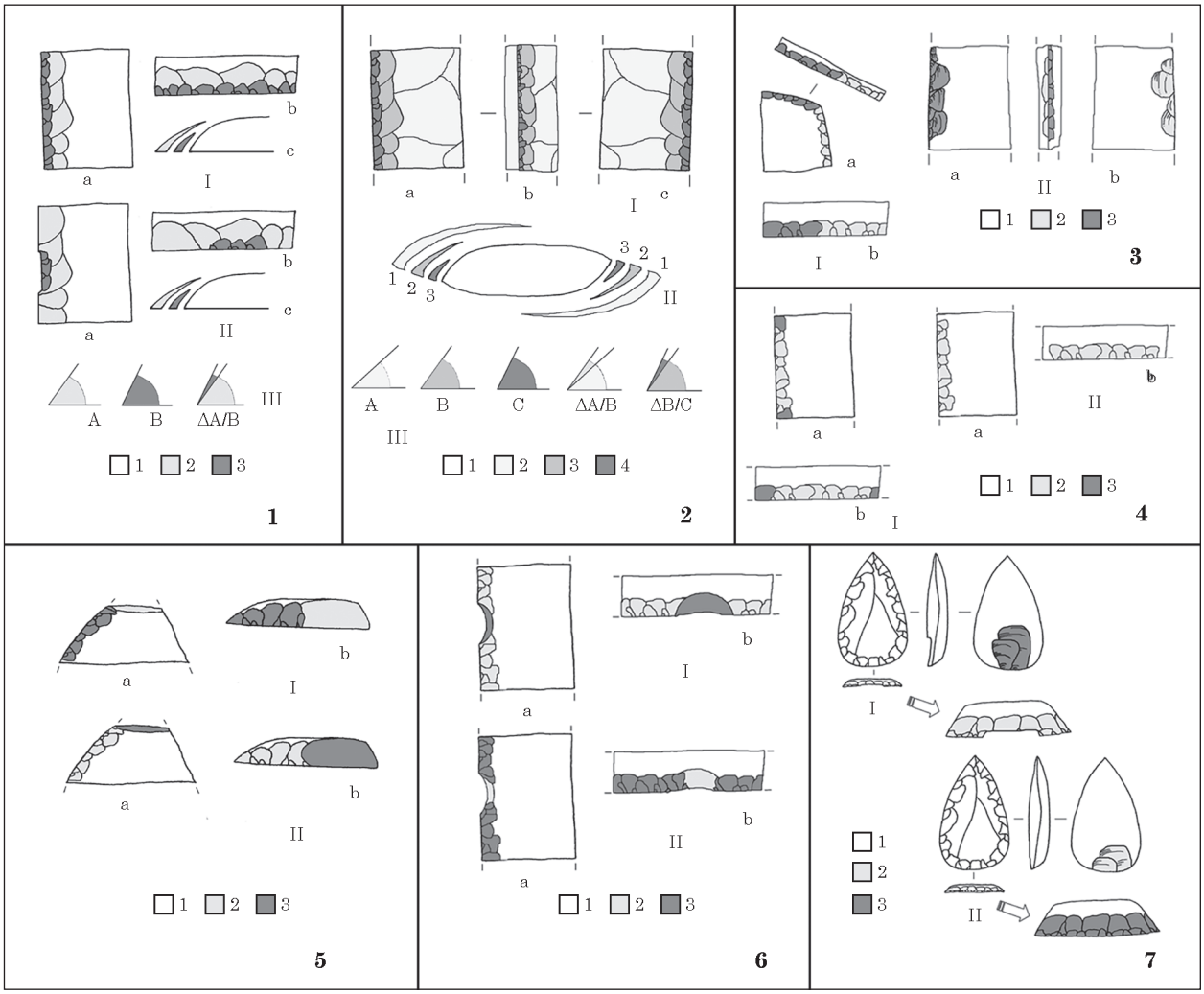

Fig. 2. Tracing transformation sequences in flake tools: retouching, fragmentation, and thinning (after Stepanchuk 2003) See the explanation below and on p. 172:

Рис. 2. Відстеження послідовності трансформації знарядь на сколах: ретушування, фрагментація та потоншення (за: Степанчук 2003). Пояснення див. нижче та на с. 172:

Box 1.

I. *Rejuvenation and renewal of retouch along the entire length of an initially retouched edge*. Flake product with two overlapping retouched edges. a — artefact in plan view; b — retouched edge, en face; c — cross-section of the artefact showing scars from earlier and later phases of retouch.

II. *Rejuvenation of retouch on a limited area of an initially retouched edge*. Flake product with a later, smaller retouched area overlapping the earlier edge.

a — artefact in plan view; b — retouched edge, en face; c — cross-section of the artefact showing scars from earlier and later phases of retouch.

III. A — angle of retouch of the earlier phase; B — angle of retouch of the later phase; ΔA/B — difference between the angles of earlier and later retouch phases.

1 — body of the artefact; 2 — scars from the earlier series of retouch; 3 — scars from the later series of retouch.

Box 2.

I. *Rejuvenation of retouch along the entire length of initially retouched edges on a bifacially prepared blank*. Bifacial artefact with alternating retouched edges representing two chronologically distinct episodes.

Блок 1.

I. *Відновлення ретуші по всій довжині початкового ретушованого леза*. Виріб на сколі з двома накладеними ретушованими лезами. a — виріб у плані; b — ретушоване лезо, анфас; c — поперечний переріз виробу з негативами раннього та пізнішого рядів ретуші.

II. *Відновлення ретуші на обмеженій ділянці початкового ретушованого леза*. Виріб на сколі з пізнішою, невеликою ретушованою ділянкою, що перекриває раннє лезо. a — виріб у плані; b — ретушоване лезо, анфас; c — поперечний переріз виробу з негативами ранньої та пізнішої фаз ретушування.

III. A — кут ретуші ранньої фази; B — кут ретуші пізнішої фази; ΔA/B — різниця між кутами ранньої та пізнішої фаз ретушування. 1 — корпус виробу; 2 — негативи ранньої серії ретуші; 3 — негативи пізнішої серії ретуші.

Блок 2.

I. *Відновлення ретуші по всій довжині початкового ретушованого леза на двобічно оббитій заготовці*. Двобічний виріб з альтернативно розташованими ретушованими лезами, що відображають два хронологічно різні епізоди. a — виріб у плані, поверхня a; b — виріб, профіль; c — виріб у плані, поверхня b.

a — artefact in plan, surface a; b — artefact in profile; c — artefact in plan, surface b.

II. Cross-section of the artefact. 1 — rough shaping of the bifacial blank; 2 — early series of retouch; 3 — later series of retouch.

III. A — angle of rough shaping; B — angle of retouch, early series; C — angle of retouch, later series; ΔA/B — difference between angles of rough shaping and early retouch; ΔB/C — difference between angles of early and later retouch series.

1 — body of the artefact; 2 — surface of rough shaping, forming the bifacial blank; 3 — scars from early retouch; 4 — scars from later retouch.

Box 3.

I. *Sequence of formation of joined retouched edges*. Canted, two-edged flake artefact: the longitudinal edge was retouched first, followed by the transverse edge. a — artefact in plan; b — contact of the two retouched edges, en face.

II. *Sequence of formation of a bifacially retouched edge or alternately arranged retouched areas on the same edge*. Flake artefact with partially bifacial retouched edge: surface b retouched first, then surface a.

1 — body of artefact; 2 — scars from early retouch; 3 — scars from later retouch.

Box 4.

I. *Sequence of retouching and fragmentation*. One-edged artefact: retouched first, then fragmented. a — artefact in plan; b — retouched edge, en face.

II. *Sequence of retouching and fragmentation*. One-edged artefact: fragmented first, then retouched. a — artefact in plan; b — retouched edge, en face.

1 — body of artefact; 2 — retouch scars unaffected by fracture surface; 3 — retouch scars truncated by fracture surface.

Box 5.

I. *Sequence of retouching and fragmentation*. One-edged artefact: fragmented first, then retouched. a — artefact in plan; b — distal fracture area, profile.

II. *Sequence of retouching and fragmentation*. One-edged artefact: retouched first, then fragmented. a — artefact in plan; b — distal fracture area, profile.

1 — body of artefact; 2 — early-stage transformation; 3 — late-stage transformation.

Box 6.

I. *Sequence of retouching and fragmentation*. One-edged artefact: retouched first, then local edge fracture. a — artefact in plan; b — retouched edge, en face.

II. *Sequence of retouching and fragmentation*. One-edged artefact: local edge fracture first, then retouched. a — artefact in plan; b — retouched edge, en face.

1 — body of artefact; 2 — early-stage transformation; 3 — late-stage transformation.

Box 7.

I. *Sequence of retouching and thinning*. Multi-edged point on flake with ventrally thinned base: retouching followed by thinning. a — four aspects of artefact; b — retouched-then-thinned area, en face.

II. *Sequence of retouching and thinning*. Multi-edged point on flake with ventrally thinned base: thinning followed by retouching. a — four aspects of artefact; b — thinned-then-retouched area, en face.

1 — body of artefact; 2 — early-stage transformation; 3 — late-stage transformation.

II. Поперечний переріз виробу. 1 — грубе формування (оббивка) двобічної заготовки; 2 — рання серія ретуші; 3 — пізніша серія ретуші. III. A — кут оббивки; B — кут ретуші (рання серія); C — кут ретуші (пізніша серія); ΔA/B — різниця між кутами оббивки та ранньої ретуші; ΔB/C — різниця між кутами ранньої та пізнішої серій ретуші.
1 — корпус виробу; 2 — поверхня грубого формування, що утворює двобічну заготовку; 3 — негативи ранньої ретуші; 4 — негативи пізнішої ретуші.

Блок 3.
I. *Послідовність виготовлення ретушованих лез, що сполучаються*. Кутастий дволезовий виріб на сколі: спочатку ретушовано поздовжнє лезо, потім — поперечне. a — виріб у плані; b — контакт двох ретушованих лез, анфас.
II. *Послідовність оформлення двобічно ретушованого леза або альтернативно розташованих ретушованих ділянок на одному лезі*. Виріб на сколі з частково двобічно ретушованим лезом: спочатку ретушовано поверхню b, потім — поверхню a.

1 — корпус виробу; 2 — негативи ранньої ретуші; 3 — негативи пізнішої ретуші.

Блок 4.
I. *Послідовність ретушування та фрагментації*. Однолезовий виріб: спочатку ретушований, потім фрагментований. a — виріб у плані; b — ретушована кромка, анфас.
II. *Послідовність ретушування та фрагментації*. Однолезовий виріб: спочатку фрагментований, потім ретушований. a — виріб у плані; b — ретушована кромка, анфас.
1 — корпус виробу; 2 — негативи ретуші, не порушені поверхнею зламу; 3 — негативи ретуші, зрізані поверхнею зламу.

Блок 5.
I. *Послідовність ретушування та фрагментації*. Однолезовий виріб: спочатку фрагментований, потім ретушований. a — виріб у плані; b — дистальна зона зламу, профіль.
II. *Послідовність ретушування та фрагментації*. Однолезовий виріб: спочатку ретушований, потім фрагментований. a — виріб у плані; b — дистальна зона зламу, профіль.
1 — корпус виробу; 2 — трансформація ранньої стадії; 3 — трансформація пізньої стадії.

Блок 6.
I. *Послідовність ретушування та фрагментації*. Однолезовий виріб: спочатку ретушований, потім відбувся локальний вилом леза. a — виріб у плані; b — ретушоване лезо, анфас.
II. *Послідовність ретушування та фрагментації*. Однолезовий виріб: спочатку локальний вилом леза, потім ретушований. a — виріб у плані; b — ретушоване лезо, анфас.
1 — корпус виробу; 2 — трансформація ранньої стадії; 3 — трансформація пізньої стадії.

Блок 7.
I. *Послідовність ретушування та потоншення*. Багатолезове вістря на сколі з вентрально потоншеною базою: спочатку ретушування, потім потоншення. a — чотири проекції виробу; b — ділянка ретушованого, потім потоншеного леза, анфас.
II. *Послідовність ретушування та потоншення*. Багатолезове вістря на сколі з вентрально потоншеною базою: спочатку потоншення, потім ретушування. a — чотири проекції виробу; b — ділянка потоншеного, потім ретушованого леза, анфас.
1 — корпус виробу; 2 — трансформація ранньої стадії; 3 — трансформація пізньої стадії.

* *The sequence of shaping bifacial edges, or alternatively positioned retouched zones on a single edge*, can be established on the basis of the absence of basal portions of scars (fig. 2: 3: II). The diagram in fig. 2: 3: II shows an artefact in which the retouched edge on surface (a) was produced after the retouched segment on surface (b).

* *The chronological relationship between edge retouch and fragmentation of an artefact* can be determined from the relative position (overlap) of marginal retouch scars and the fracture surface in the zone of their contact (fig. 2: 4: I, II; 2: 5: I, II; 2: 6: I, II). Figure 2: 4: I; 2: 5: II and 2: 6: I depict artefacts that were first retouched and then broken: the marginal retouch scars are truncated by later fracture surfaces. Figure 2: 4: II; 2: 5: I and 2: 6: II depict artefacts that were first broken and subsequently retouched.

* *The chronological relationship between edge retouch and thinning of the artefact's body* can be established from a combination of attributes, including: (1) the integrity of the thinning-scar negatives; and (2) disruption of the edge line in profile within the thinned zone (fig. 2: 7: I, II).

* *The chronological relationship between edge retouch and a burin blow* can be determined from the relative position (overlap) of the marginal retouch facets and the negative of the burin spall in the area where they intersect. The principle for establishing event order here is the same as that described for the fracture / retouch case.

3. Results. These data provided the basis for reconstructing the transformation sequences of a subset of flake tools from Layer I of the Mira site, predominantly excavated in 2000. The analysed series of artefacts considers both stable parameters, such as raw material type, and variable parameters, including initial blank type, completeness, formal type of the blank after fragmentation (so-called secondary blank), number of retouched edges, type of modification, and the initial and final tool type. In this way, key technological and morphological indicators are taken into account. Metrical parameters provide a key criterion for blank classification: B blanks have a length at least three times their width, BF blanks are two to three times longer than wide, whereas F blanks have shortened proportions.

Depending on the confidence with which stages could be established, the sequence of presumed transformations is described using strict (1, 2, 3, etc.), semi-strict (1/2, 2/1, 1a, 1b, etc.), or probabilistic (3?, 4?, etc.) notation. The attribution of all operations creating the original tool form to Stage 1 is largely conventional, as is the assumption of their contemporaneity.

It is assumed that the so-called secondary blank was perceived by the knapper as a distinct unit of raw material for producing a new artefact. Remnants of previously retouched edges or other secondary modifications are considered morphologically significant for determining the type of the final artefact only if they are incorporated into the system of the new shaping. Additional support may be drawn from the presence of analogous types among complete or apparently unmodified tools within the same industry.

3.1. Artefact-by-artefact analysis of flake tools from layer I of Mira site.

3.3.1. Multi-edge flake tool М0023ЖІ/601 (fig. 3: 1; Степанчук 2013, fig. 40: 11), blank of type F, incomplete, with current form proportions corresponding to type F, with three secondarily modified edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, combining three linear and one angular element. Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 23 Ж. Database number: 601. Raw material: flint variety Ia—б (A). Dimensions L × W × T: 30 × 23 × 4 mm.

Stages of the tool's proposed individual history (fig. 4: 1):

0 — original blank: (semi-)cortical flake;

1 — retouching of two longitudinal edges and one transverse edge, *forming an end-scraper with two retouched lateral edges or an end-scraper combined with a point*;

2 — breakage or deliberate fragmentation of the proximal part, producing a secondary blank (distal fragment of the original tool);

3 — modification of the surface of fracture with oppositely directed (counterblow?) retouch, forming a possible perforator / awl;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper with two retouched lateral edges combined with an awl.*

3.3.2. Multi-edge flake tool М0022ЖІ/655 (fig. 3: 2; Степанчук 2013, рис. 39: 6), blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, combining linear elements and a scaled thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 22 Ж. Database number: 655 (associated bone 754). Raw material: flint, variety Ia1. Dimensions L × W × T: 37 × 27 × 10 mm.

Stages of the tool's proposed individual history (fig. 4: 2):

0 — Initial blank: large flake or bladey flake;

1 — Creation of a longitudinal retouched edge on the ventral surface of the blank, forming a simple scraper;

2 — Possible deliberate fragmentation — removal of the distal part of the tool, producing a secondary blank (proximal fragment of the original tool);

3 — Shaping a convex edge on the distal extremity of the fragment (on the butt of the preceding artefact), forming an end-scraper;

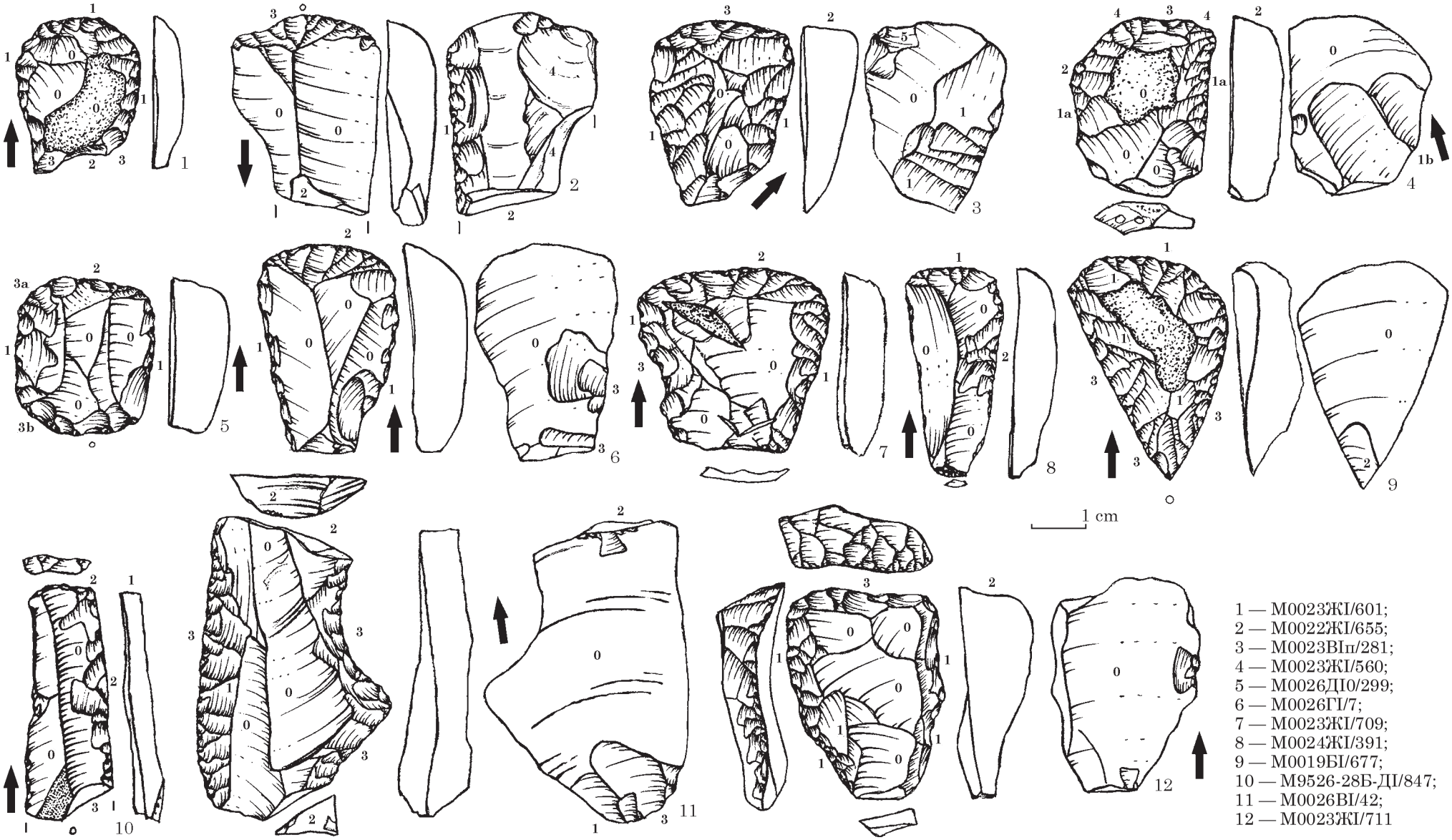

Fig. 3. Grayscale drawings of flake artefacts from Layer I of the Mira site (after Stepanchuk 2013). Arrows indicate the direction of blank removal. Numbers show the sequence of transformation stages established through diacritical analysis

Рис. 3. Чорно-білі рисунки артефактів на сколах із шару I стоянки Міра (за: Степанчук 2013). Стрілками позначено напрям зняття заготовки. Цифри відображають послідовність стадій трансформації, встановлену за результатами діакритичного аналізу

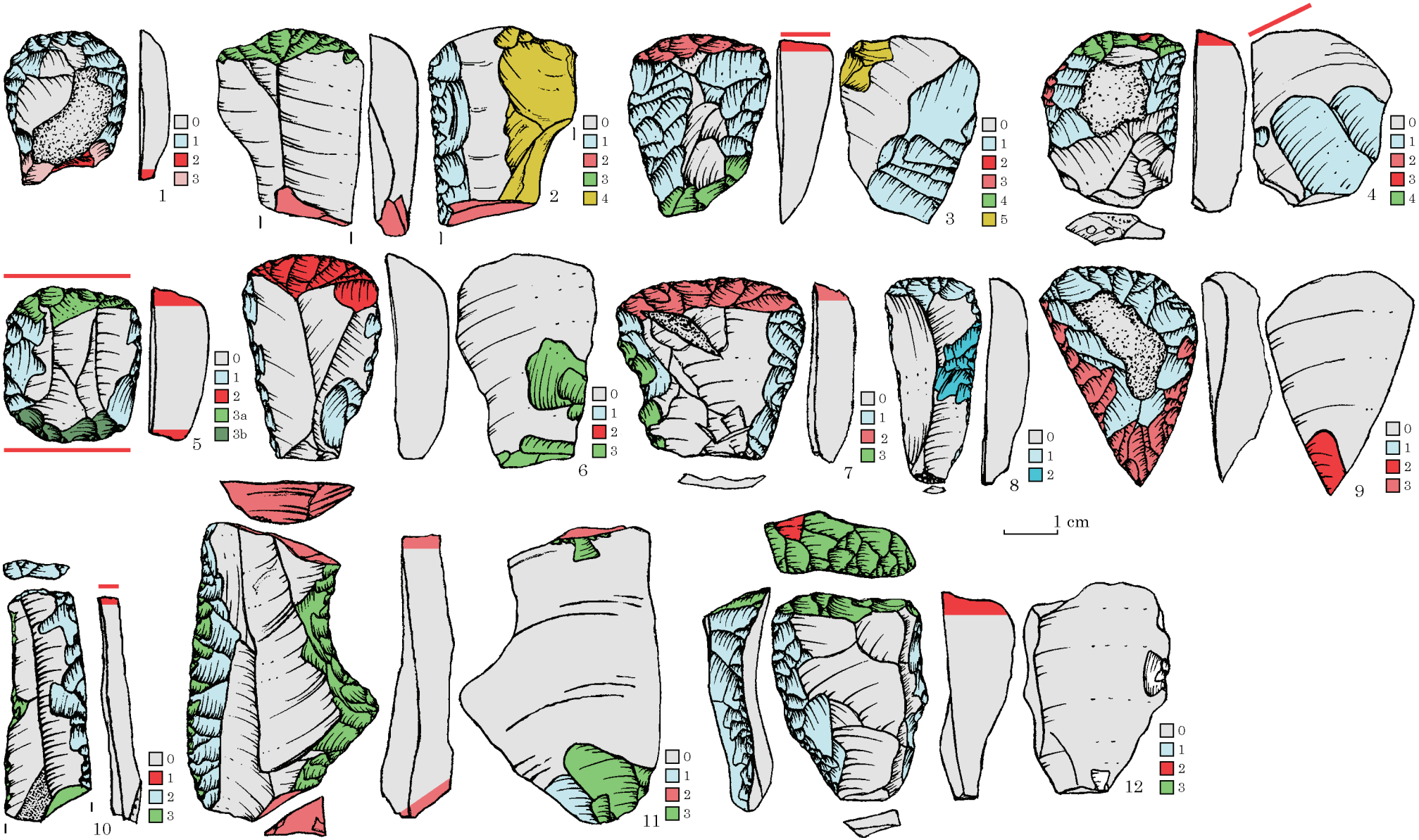

Fig. 4. Color representation of the results of diacritical analysis indicating the sequence of transformation stages for the artefacts shown in the previous figure (see at fig. 3)

Рис. 4. Кольорова візуалізація результатів діакритичного аналізу, що відображає послідовність стадій трансформації артефактів, представлених на попередньому рисунку (див. рис. 3)

4 — Use of the working edge of end-scraper either as a chisel, causing terminal-ventral thinning, or as a platform for flake removals, resulting in a chisel or core-like artefact;

ΣΣ — Typological characterisation of the item as a complete finished product: *a side-scraper combined with an end-scraper and either a chisel or core.*

3.3.3. Multi-edge flake tool М0023ВІп/281 (fig. 3: 3; Степанчук 2013, рис. 40: 6), blank of type F (or BF), incomplete, with current form proportions also corresponding to type F, with five secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, combining linear and angular elements, and two areas of scaled thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 23 B. Database number: 281. Raw material: flint, variety Ia1. Dimensions L × W × T: 35 × 26 × 10 mm.

Stages of the tool's proposed individual history (fig. 4: 3):

0 — Initial blank: large flake;

1 — Apparently, simultaneous or sequential retouching of longitudinal and transverse edges, combined with extensive ventral truncation, forming a multi-edged (?) tool;

2 — Breakage or deliberate removal of the distal part, producing a secondary blank (proximal fragment of the original tool);

3 — Retouching of the broken edge, forming an end-scraper;

4 — Retouching of the longitudinal edges, forming a point;

5 — Scaled thinning on the ventral surface at the junction of the transverse and longitudinal edges, possibly forming a chisel;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper combined with a point.*

3.3.4. Multi-edge flake tool М0023ЖІ/560 (fig. 3: 4; Степанчук 2013, рис. 39: 8), blank of type BF, incomplete, with current form proportions corresponding to type F, with four secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, combining linear and angular elements, and scaled thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 23 B. Database number: 560. Raw material: flint, variety Ia—b (B). Dimensions L × W × T: 32 × 24 × 10 mm.

Stages of the tool's proposed individual history (fig. 4: 4):

0 — Initial blank: (semi-)cortical flake;

1a — Retouching of the longitudinal edges, forming a double-edged tool (a point?);

1b — Ventral thinning of the base, thinning the tool body (?);

2 — Sharpening of at least the left longitudinal edge in a specific area, edge adjustment;

3? — Removal (?) or breakage (?) of the distal part, emerging a secondary blank (proximal fragment of the original tool);

4 — Creation of a transverse scraping edge, forming an end-scraper;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper with two lateral edges.*

3.3.5. Multi-edge flake tool М0026ДІ0/299 (fig. 3: 5; Степанчук 2013, рис. 40: 15), blank of type B, incomplete, current form as F, with four secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with several linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: 0. Feature: n/d. Unit: 26 Д. Database number: 299. Raw material: flint, variety Ia3. Dimensions L × W × T: 28 × 25 × 10 mm.

Stages of the tool's proposed individual history (fig. 4: 5):

0 — Initial blank: bladey flake or blade;

1 — Retouching of the edges, forming possible double-edged tool;

2 — Breakage or deliberate fragmentation — removal of distal and proximal parts, producing a secondary blank (medial fragment of the original tool);

3a — Retouching of the transverse broken edge at the distal end of the tool, forming an end-scraper;

3b — Retouching of the transverse broken edge at the basal end of the tool, forming an end-scraper;

ΣΣ — Typological characterisation of the item as a complete finished product: *double end-scraper.*

3.3.6. Multi-edge flake tool М0026ГІ/7 (fig. 3: 6; Степанчук 2013, рис. 39: 5), blank of type B, incomplete, with current form proportions corresponding to type F, with four secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, featuring three linear elements and ventral thinning.

Site: Mira, excavations 2000. Horizon: main level. Feature: pit 2. Unit: 26 Г. Database number: 7. Raw material: flint, variety Ia1. Dimensions L × W × T: 38 × 25 × 11 mm.

Stages of the tool's proposed individual history (fig. 4: 6):

0 — Initial blank: large blade (or bladey flake);

1 — Creation of two retouched edges, producing a tool with retouched lateral edges;

2 — Fragmentation (areas of the presumed break not preserved) retouching of the transverse edge, forming an end-scraper with retouched lateral edges;

3 — Ventral thinning of the basal part and the left edge, possibly resulting in thinning of the tool body or core-like knapping;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper with two converging lateral edges, showing signs of core-like knapping*.

3.3.7. Multi-edge flake tool М0023ЖІ/709 (fig. 3: 7; Степанчук 2013, рис. 39: 3), blank of type BF, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with several linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: associated with bone 790. Unit: 23 Ж. Database number: 709. Raw material: flint, variety Ia1. Dimensions L × W × T: 35 × 30 × 8 mm.

Stages of the tool's proposed individual history (fig. 4: 7):

0 — Initial blank: bladey flake (?);

1a — Retouching of two longitudinal edges and, presumably, a transverse edge, forming an end-scraper (?) or simple scraper (?);

1b — Ventral thinning of the basal part of the tool on the side of the left edge, thinning the tool body (?);

2 — Breakage or deliberate fragmentation — removal of the distal part, producing a secondary blank (proximal fragment of the original tool);

3a — Creation of a transverse scraping edge, forming an end-scraper; 3b — Renewal of the retouch on the left longitudinal edge, edge adjustment;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper with two lateral edges*.

3.3.8. Multi-edge flake tool М0024ЖІ/391 (fig. 3: 8; Степанчук 2013, рис. 40: 16), blank of type B, with current form proportions corresponding to type BF, with three secondarily retouched edges. Simple implement; conceptually, a flake tool with linear edge geometry, with three linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 24 Ж. Database number: 391. Raw material: flint, variety Ia1. Dimensions L × W × T: 38 × 18 × 7 mm.

Stages of the tool's proposed individual history (fig. 4: 8):

0 — Initial blank: blade or bladey flake;

1 — Retouching of the transverse edge and minor adjustment of the two longitudinal edges (possibly also use retouch), forming an end-scraper;

2 — Sharpening of the right edge, section, edge adjustment;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper scraper with two lateral edges*.

3.3.9. Multi-edge flake tool М0019БІ/677 (fig. 3: 9; Степанчук 2013, рис. 40: 2), blank of type F, complete, with current form proportions still corresponding to type F, with three secondarily retouched edges. Complex implement; conceptually, a flake tool with combined edge geometry, combining linear and angular elements and, possibly, scaled thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 19 Б. Database number: 677. Raw material: flint, variety Ia1. Dimensions L × W × T: 38 × 28 × 10 mm.

Stages of the tool's proposed individual history (fig. 4: 9):

0 — Initial blank: (semi-)cortical flake;

1 — Retouching of several edges, forming an end-scraper with two (?) lateral edges;

2 — Ventral thinning of the basal part — thinning of the tool body (?);

3 — Reworking of the longitudinal edges, creation of a piercing tip, forming a point;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper combined with a point, with elements of ventral thinning*.

3.3.10. Multi-edge flake tool М9526-28Б-ДІ/847 (fig. 3: 10; Степанчук 2013, рис. 42: 7), blank of type B, incomplete, with current form proportions still corresponding to type B, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with several linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 26—28 БВГД. Database number: 847. Raw material: flint, variety Ia1. Dimensions L × W × T: 43 × 14 × 5 mm.

Stages of the tool's proposed individual history (fig. 4: 10):

0 — Initial blank: blade;

1 — Accidental breakage or deliberate fragmentation — removal of the proximal part, producing a secondary blank (distal fragment of the original flake);

2 — Retouching of the transverse and right longitudinal edges, forming a truncated and retouched blade;

3a — Tool use, utilization retouch along the left edge and fracture of the basal part of the tool;

ΣΣ — Typological characterisation of the item as a complete finished product: *bilaterally retouched truncated blade*.

3.3.11. Multi-edge flake tool М0026ВІ/42 (fig. 3: 11; Степанчук 2013, рис. 42: 9), blank of type B, incomplete, with current form proportions corresponding to type F, with four secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, combining linear and angular elements and possibly scaled thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 26 В. Database number: 42. Raw material: flint, variety Ia1. Dimensions L × W × T: 58 × 37 × 10 mm.

Stages of the tool's proposed individual history (fig. 4: 11):

0 — Initial blank: large blade or bladey flake;

1 — Retouching of the left longitudinal edge and ventral thinning of the base, forming a simple side-scraper;

2 — Deliberate bi-terminal fragmentation — removal of distal and proximal parts, producing a secondary blank (medial fragment of the original tool);

3a — Shaping of the right edge using strongly concave and straight retouched sections, forming a convergent pointed element (a point);

3b — Re-sharpening of the left longitudinal edge, edge adjustment;

3c — Dorsal thinning of the base and attempted ventral flattening of the transverse basal break, possible thinning of the tool body;

ΣΣ — Typological characterisation of the item as a complete finished product: *a side-scraper combined with a point, with elements of dorsal-ventral thinning*.

3.3.12. Multi-edge flake tool М0023ЖІ/711 (fig. 3: 12; Степанчук 2013, рис. 39: 10), blank of type BF, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, combined several linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 23 Ж. Database number: 711. Raw material: flint, variety Ia1. Dimensions L × W × T: 36 × 28 × 9 mm.

Stages of the tool's proposed individual history (fig. 4: 12):

0 — Initial blank: bladey flake;

1 — Retouching of the longitudinal edges, likely forming a possible double side-scraper;

2 — Breakage or deliberate removal of the distal part, producing a secondary blank (proximal fragment of the original tool);

3 Creation of a transverse edge, forming an end-scraper;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper with two lateral edges*.

3.3.13. Multi-edge flake tool М0028ВІ/2 (fig. 5: 1; Степанчук 2013, рис. 41: 13), blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with angular edge geometry, featuring several elements. Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 28 В. Database number: 2. Raw material: flint, variety Ia1. Dimensions L × W × T: 24 × 20 × 8 mm.

Stages of the tool's proposed individual history (fig. 6: 1):

0 — Initial blank: bladey flake;

1 — Retouching of one (?) longitudinal edge (right) with fine denticulate retouch, forming a retouched blade;

2 — Deliberate fragmentation — removal of the proximal part, producing a secondary blank (distal fragment of the original tool);

3 — Attempt to create a scraping (?) edge on the broken surface, emerging of unfinished end-scraper;

4 — Detachment of the terminal part with the unfinished scraping edge using a transverse burin blow, producing a secondary blank (distal fragment of the original tool);

5 — Adjustment of the burin edge with small additional flat burin removals and marginal retouch, forming a burin;

ΣΣ — Typological characterisation of the item as a complete finished product: *transverse burin plus either unfinished end-scraper or truncation.*

3.3.14. Multi-edge flake tool М0024ДІ/687 (fig. 5: 2; Степанчук 2013, рис. 41: 8), blank of type BF, incomplete, with current form proportions corresponding to type F, with two secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with linear edge geometry, with two linear elements and two thinnings.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 24 Д. Database number: 687. Raw material: flint, variety Ia1. Dimensions L × W × T: 23 × 27 × 7 mm.

Stages of the tool's proposed individual history (fig. 6: 2):

0 — Initial blank: likely a bladey flake;

1 — Retouching of the longitudinal and transverse edge, on the proximal part of the original blank, forming an end-scraper;

2 — Breakage or deliberate fragmentation — removal of the distal part, producing a secondary blank (proximal fragment of the original tool);

3 — Intensive ventral thinning along the transverse edge and dorsal thinning at the fracture, forming either a chisel or indicating core-like knapping;

ΣΣ — Typological characterisation of the item as a complete finished product: *either a chisel or a core.*

3.3.15. Multi-edge flake tool М9526-28Б-ДІ/848 (fig. 5: 3; Степанчук 2013, рис. 37: 6), blank of type B, incomplete, with current form proportions corresponding to type BF, with four secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, with two angular and two linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 26—28 БВГД. Database number: 848. Raw material: flint, variety Ia1. Dimensions L × W × T: 36 × 18 × 6 mm.

Stages of the tool's proposed individual history (fig. 6: 3):

0 — Initial blank: probably a bladey flake;

1/2 — Breakage or deliberate fragmentation — removal of proximal and distal parts, producing a secondary blank (medial fragment of the original flake);

2/1 — Probable retouching of the longitudinal edges, forming a double-edged tool;

3 — Reshaping, forming a double convergent side-scraper;

ΣΣ — Typological characterisation of the item as a complete finished product: *limace (double convergent side-scraper).*

3.3.16. Multi-edge flake tool М0025ГІ/708 (fig. 5: 4; Степанчук 2013, рис. 42: 1), blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily modified edges and fragmentation. Complex implement; conceptually, a flake tool with linear edge geometry, with two linear elements and thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 25 Г. Database number: 708. Raw material: flint, variety Ia1. Dimensions L × W × T: 28 × 29 × 8 mm.

Stages of the tool's proposed individual history (fig. 6: 4):

0 — Initial blank: bladey flake;

1a — Retouching of two longitudinal edges, forming a retouched blade;

1b/2b — Dorsal thinning of the terminal part (on the looped end), thinning of the tool body or attempted core-like knapping;

2 — Deliberate fragmentation — removal of the proximal part, producing a secondary blank (?) (distal fragment of the original tool);

ΣΣ — Typological characterisation of the item as a complete finished product: *retouched blade (showing signs of core-like knapping).*

3.3.17. Multi-edge flake tool М0028ГІ/414 (fig. 5: 5; Степанчук 2013, рис. 41: 10), blank of type BfcWF, incomplete, with current form proportions corresponding to type F. with five secondarily edge modifications and fragmentation. Complex implement; conceptually, a flake tool with angular edge geometry, featuring two linear edges arranged convergently, an angular element, and scaled ventral thinning along three adjacent directions.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 28 Г. Database number: 414. Raw material: flint, variety Ia1. Dimensions L × W × T: 27 × 27 × 9 mm.

Stages of the tool's proposed individual history (fig. 6: 5):

0 — Initial blank: presumably a flake from the fragment of a large biface;

1 — Retouching of the transverse and longitudinal (ventral) edges, forming a canted side-scraper with alternately arranged edges;

2 — Fragmentation — removal of the proximal part, producing a secondary blank (distal part of the original tool);

3 — Ventral scaled thinning from three directions, forming either a chisel or exhibiting core-like knapping;

ΣΣ — Typological characterisation of the item as a complete finished product: *a side-scraper combined with a chisel (or core-like evidence*).

3.3.18. Multi-edge flake tool М0022ЖІ/502 (fig. 5: 6), blank of type BF, incomplete, with current form proportions corresponding to type F, with five secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with linear edge geometry, combining two linear elements and scaled thinning on three adjacent directions. Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 22 Ж. Database number: 502. Raw material: flint, variety Ia1. Dimensions L × W × T: 21 × 19 × 6 mm.

Stages of the tool's proposed individual history (fig. 6: 6):

0 — Initial blank: bladey flake (?);

1 — Retouching of one (?) longitudinal edge, forming a probable single-edged tool;

2 — Ventrally lateral thinning, thinning of the tool body (?);

3 — Deliberate (?) fragmentation — removal of distal and proximal parts, producing a secondary blank (medial fragment of the original tool);

4 — Dorsal-ventral thinning of the breakage areas on the proximal and distal-lateral parts, thinning of the tool body or core-like knapping evidence;

ΣΣ — Typological characterisation of the item as a complete finished product: *a side-scraper combined with a chisel (or core-like evidence).*

3.3.19. Multi-edge flake tool М0021ГІп/112 (fig. 5: 7; Степанчук 2013, рис. 41: 2), blank of type B?, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, with linear and angular elements.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 21 Г. Database number: 112. Raw material: flint, variety Ia1. Dimensions L × W × T: 19 × 10 × 4 mm.

Stages of the tool's proposed individual history (fig. 6: 7):

0 — Initial blank: (bladey) flake;

1 — Retouching of edges, forming a double-edged tool, possibly a point (?) or end-scraper with two retouched lateral edges;

2 — Breakage or deliberate fragmentation — removal of the proximal part, producing a secondary blank (distal fragment of the original tool);

3 — Retouching of the transverse edge on the basal end, forming an end-scraper;

3b — Rejuvenation of longitudinal edges and tip, forming a point;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper combined with a point.*

3.3.20. Multi-edge flake tool М0021ДІп/93 (fig. 5: 8; Степанчук 2013, рис. 40: 4), blank of type B, incomplete, with current form proportions corresponding to type BF, with five secon-

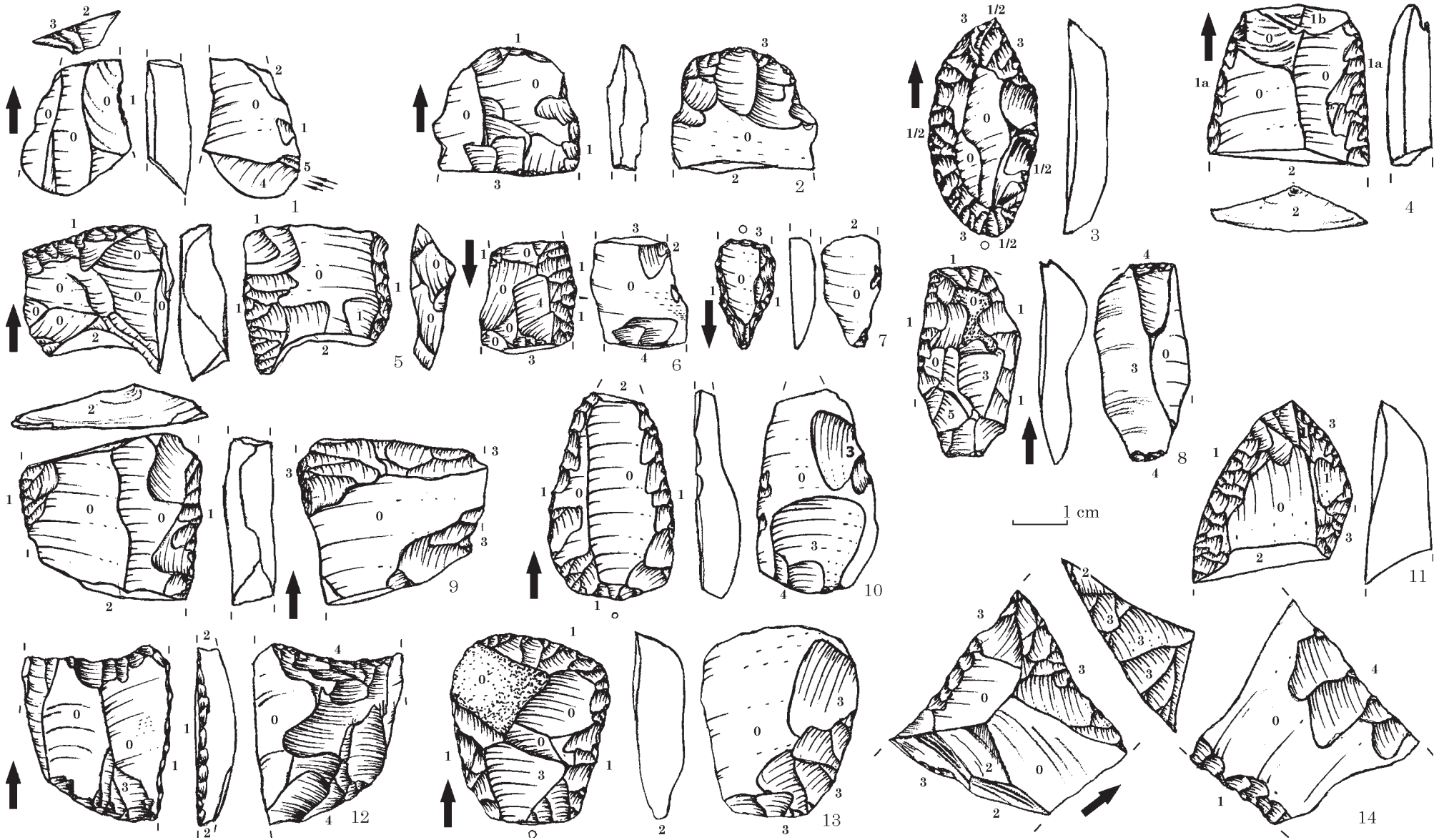

Fig. 5. Grayscale drawings of flake artefacts from Layer I of the Mira site (after Stepanchuk 2013). Arrows indicate the direction of blank removal. Numbers show the sequence of transformation stages established through diacritical analysis

Рис. 5. Чорно-білі рисунки артефактів на сколах із шару I стоянки Міра (за: Степанчук 2013). Стрілками позначено напрям зняття заготовки. Цифри відображають послідовність стадій трансформації, встановлену за результатами діакритичного аналізу

1 — M0028BI/2; 2. M0024ДI/687; 3 — M9526-28Б-ДI/848; 4 — M0025ГI/708; 5 — M0028ГI/414; 6 — M0022ЖI/502; 7 — M0021ГIп/112; 8 — M0021ДIп/93; 9 — M0023BIп/664; 10 — M0025БI/15; 11 — M0022EIп/176; 12 — M0023EI/541; 13 — M0021ДIп/216; 14 — M0027ГI/322

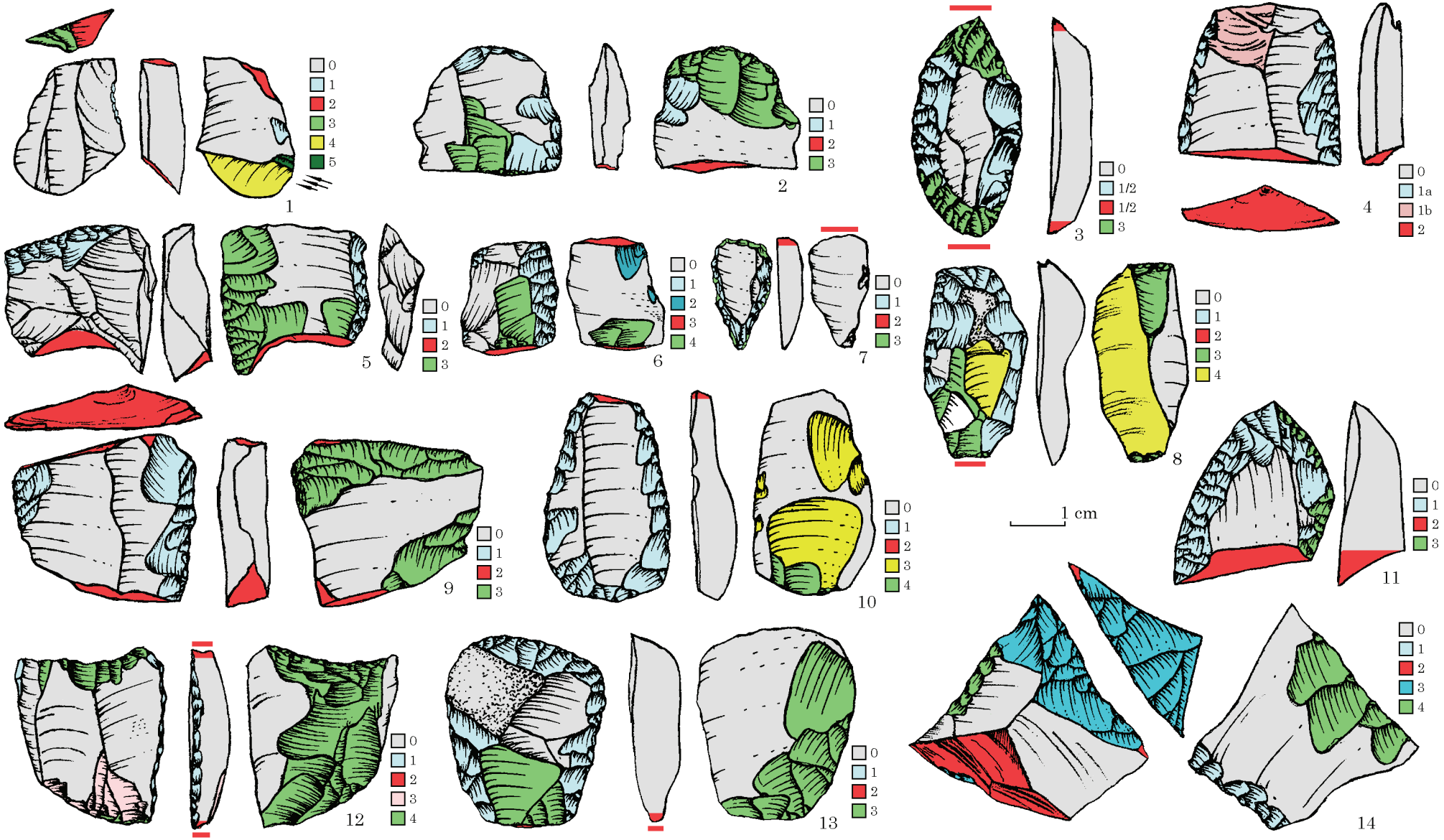

Fig. 6. Color representation of the results of diacritical analysis indicating the sequence of transformation stages for the artefacts shown in the previous figure (see at fig. 5)

Рис. 6. Кольорова візуалізація результатів діакритичного аналізу, що відображає послідовність стадій трансформації артефактів, представлених на попередньому рисунку (див. рис. 5)

darily worked edges and fragmentation. Complex implement; conceptually, a flake tool with linear edge geometry, with three linear elements and scaled thinning (two areas).

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 21 Д. Database number: 93. Raw material: flint, variety Ia4. Dimensions L × W × T: 36 × 18 × 8 mm.

Stages of the tool's proposed individual history (fig. 6: 8):

0 — Initial blank: blade or bladey (?) (semi-)cortical flake;

1 — Retouching of the transverse and two longitudinal edges, forming an end-scraper with lateral edges; not subdivided into stages;

2 — Breakage or deliberate fragmentation — removal of the proximal part, producing a secondary blank (distal fragment of the original form);

3 — Vertical fragmentation (similar to a bipolar core knapping);

4 — Ventral-dorsal damage from likely use as a chisel;

5 — Recent damage;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper combined with a chisel (or a core).*

3.3.21. Multi-edge flake tool M0023BIп/664 (fig. 5: 9; Степанчук 2013, рис. 41: 11), blank of type B, incomplete, with current form proportions corresponding to type F, with four secondarily nransformed edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with two linear elements and ventral opposed scaled thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 23 В. Database number: 664. Raw material: flint, variety Ia4. Dimensions L × W × T: 30 × 33 × 9 mm.

Stages of the tool's proposed individual history (fig. 6: 9):

0 — Initial blank: large massive blade or bladey flake;

1 — Retouching of both longitudinal edges, forming a two-edged tool (retouched blade);

2 — Deliberate biterminal fragmentation — removal of proximal and distal parts, producing a secondary blank (medial fragment of the original tool);

3 — Ventral thinning of the longitudinal edges (opposed ventral thinning of the terminal part + ventral retouch of the basal part), forming a chisel;

ΣΣ — Typological characterisation of the item as a complete finished product: *a chisel (or a core).*

3.3.22. Multi-edge flake tool M0025БІ/15 (fig. 5: 10; Степанчук 2013, рис. 38: 1), blank of type B, incomplete, with current form proportions corresponding to type F, with five secondarily modified edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with three linear elements and two ventral thinnings.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 25 Б. Database number: 15. Raw material: flint, variety Ia1. Dimensions L × W × T: 35 × 30 × 8 mm.

Stages of the tool's proposed individual history (fig. 6: 10):

0 — Initial blank: bladey flake or blade;

1 — Retouching of two longitudinal edges and the transverse (basal) edge, forming an end-scraper or end-scraper combined with a point;

2 — Breakage or deliberate fragmentation — removal of the distal part, producing a secondary blank (proximal fragment of the original tool);

3a — Ventral thinning of the basal part, as result of intentional action or damage, thinning of the tool body;

3b — Thinning of the ventral surface on the side of the left edge, thinning of the tool body;

4 — Formation of a second layer of ventral scar retouch on the basal part, forming a chisel;

ΣΣ — Typological characterisation of the item as a complete finished product: *side-scraper combined with a chisel (or core).*

3.3.23. Multi-edge flake tool M0022EIп/176 (fig. 5: 11; Степанчук 2013, рис. 37: 4), blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, with three linear and one angular element.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 22 Е. Database number: 176. Raw material: flint, variety Ia1. Dimensions L × W × T: 29 × 27 × 7 mm.

Stages of the tool's proposed individual history (fig. 6: 11):

0 — Initial blank: large bladey flake (?);

1 — Retouching of the longitudinal convergent edges, forming a tool with converging edges (point? convergent side-scraper? limace?);

2 — Breakage of the tool at the haft (?); bend of the break propagates along the dorsal side, producing a secondary blank (distal fragment of the original tool);

3 — Reworking of the right edge at its terminal parts and pronounced rounding of the edge, refreshing the edge;

ΣΣ — Typological characterisation of the item as a complete finished product: *a point or convergent side-scraper*.

3.3.24. Multi-edge flake tool M0023EI/541 (fig. 5: 12; Степанчук 2013, рис. 41: 7), blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with one linear element and two thinnings.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 23 E. Database number: 541. Raw material: flint, variety Ia1. Dimensions L × W × T: 31 × 27 × 7 mm.

Stages of the tool's proposed individual history (fig. 6: 12):

0 — Initial blank: bladey flake or blade;

1 — Retouch on at least one longitudinal edge, forming a retouched blade;

2 — Deliberate (?) fragmentation — removal of distal and proximal parts, producing a secondary blank (representing the medial fragment of the original tool);

3 — Formation of a transverse edge, forming an end-scraper or technological platform;

4 — Dorsal-ventral thinning of both transverse edges, forming a double chisel or core-like splitting;

ΣΣ — Typological characterisation of the item as a complete finished product: *chisel (or core)*.

3.3.25. Multi-edge flake tool М0021ДІп/216 (fig. 5: 13; Степанчук 2013, рис. 39: 4), blank of type F, complete, with five secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with three linear elements and two thinning areas.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 21 Д. Database number: 216. Raw material: flint, variety Ia1. Dimensions L × W × T: 33 × 27 × 8 mm.

Stages of the tool's proposed individual history (fig. 6: 13):

0 — Initial blank: (semi-)cortical flake;

1 — Retouching of the longitudinal and transverse edges, forming a three-edged end-scraper with retouched laterals converging toward the base;

2 — Breakage or deliberate fragmentation — removal of the proximal part, producing a secondary blank (distal fragment of the original tool);

3 — Dorsal-ventral thinning of the basal part and ventral thinning of the left lateral part, thinning of the tool body or forming a chisel/core-like splitting;

ΣΣ — Typological characterisation of the item as a complete finished product: an end-scraper with two lateral edges or an end-scraper combined with a chisel (either core-like knapping).

3.3.26. Multi-edge flake tool М0027ГІ/322 (fig. 5: 14; Степанчук 2013, рис. 37: 7), blank of type B, incomplete, with current form proportions corresponding to type F, with five secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, with three linear and one angular elements and one thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 27 Г. Database number: 322. Raw material: flint, variety Ia3. Dimensions L × W × T: 37 × 35 × 13 mm.

Stages of the tool's proposed individual history (fig. 6: 14):

0 — Initial blank: large massive blade or bladey flake;

1 — Retouching of one longitudinal edge on the ventral surface, forming a single-edged tool;

2 — Deliberate fragmentation — removal of proximal and terminal parts, producing a secondary blank (medial fragment of the original tool);

3a — Retouching of the distal part with high lamellar retouch, forming either an accommodation edge or a blade;

3b — Partial retouching of the basal part with several blows and an attempt to remove remnants of the fracture surface, forming an accommodation edge;

4 — Dorsal retouching of the left lateral edge followed by the ventral scaled thinning this edge, thinning of the tool body or core-like knapping;

ΣΣ — Typological characterisation of the item as a complete finished product: *thinned point or a point with features of core-like knapping*.

3.3.27. Multi-edge flake tool М0021ДІп/90, blank of type B, incomplete, with current form proportions corresponding to type BF, with four secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed edge geometry, with three linear and one angular elements and one thinning.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 21 Д. Database number: 90. Raw material: flint, variety Ia3. Dimensions L × W × T: 45 × 18 × 8 mm.

Stages of the tool's proposed individual history:

0 — Initial blank: blade;

1 — Retouching of two longitudinal edges and (possibly) the transverse edge, forming a retouched blade or an end-scraper with two lateral edges;

2 — Breakage or deliberate fragmentation — removal of the distal part, producing a secondary blank (proximal fragment of the original tool);

3a — Retouching of the fracture area, forming a transverse scraping edge, i. e., an end-scraper;

3b — Ventral scaled thinning along the left edge, thinning of the tool body or core-like knapping;

4 — Possible use of the tool as a retoucher;

ΣΣ — Typological characterisation of the item as a complete finished product: *pointed end-scraper with two lateral edges / pointed end-scraper with signs of core-like knapping*.

3.3.28. Multi-edge flake tool М0021ЕІп/713, blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with angular edge geometry, featuring two convergent linear elements, one angular element, and one thinning area.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 21 E. Database number: 713. Raw material: flint, variety Ia1. Dimensions L × W × T: 28 × 22 × 7 mm.

Stages of the tool's proposed individual history:

0 — Initial blank: blade or bladey flake;

1 — Retouching of two convergent edges and ventral thinning along the left edge, forming a retouched blade or a convergent side-scraper with edges converging on the proximal part of the initial blank;

2 — Deliberate fragmentation or breakage of the distal part, producing a secondary blank (distal fragment of the original tool);

3 — Refinement of the right edge with flat retouch, edge adjustment;

ΣΣ — Typological characterisation of the item as a complete finished product: *retouched flake*.

3.3.29. Multi-edge flake tool M0024ЖІ/392, blank of type B, incomplete, with current form proportions corresponding to type BF, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with angular edge geometry, featuring two convergent linear elements, one angular element, and one thinning area.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 24 Ж. Database number: 392. Raw material: flint, variety Ia1. Dimensions L × W × T: 39 × 18 × 6 mm.

Stages of the tool's proposed individual history:

0 — Initial blank: blade;

1 — Retouching of both longitudinal edges, forming a point;

2 — Breakage (?) or deliberate fragmentation of the proximal part, producing a secondary blank (distal fragment of the original tool), with micro-truncation of the distal part;

3 — Ventral thinning of the broken edge, possibly reflecting either the formation of a chisel or core-like knapping;

ΣΣ — Typological characterisation of the item as a complete finished product: *a point combined with a chisel (or a core-like product)*.

3.3.30. Multi-edge flake tool M0021ДІп/87 (fig. 7: B: 5; Stepanchuk 2021, fig. 13: A), blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges. Complex implement; conceptually, a flake tool with likely mixed edge geometry, with several linear elements and one probable angular element.

Site: Mira, excavations 2000. Layer: I. Horizon: the basal part of the main level. Feature: n/d. Unit: 24 Ж. Database number: 87. Raw material: flint, variety Ia1. Dimensions L × W × T: 41 × 23 × 8 mm (fig.7: C, 5).

Stages of the tool's proposed individual history:

0 — Initial blank: blade;

(1) — Deliberate fragmentation into several fragments — producing a secondary blank (medial fragment of the initial blank). This phase is established solely through refitting (Stepanchuk 2021, fig. 13: A). The contact zone with other fragment on M0021ДІп/87 is preserved but is too small to be recognised during assessment of the individual artefact;

1 — Retouching of both longitudinal and transverse edges, forming a combined tool: an end-scraper combined with a point or an end-scraper combined with a convergent side-scraper;

2 — Renewal of all retouched edges, with slight reduction of the tool but preservation of its morphology, resulting in a combined tool;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper combined with a point or an end-scraper combined with a convergent side-scrape*.

3.3.31. Single-edge flake tool M0025EI/754, blank of type B, incomplete, with current form proportions corresponding to type BF, with one secondarily retouched edge and fragmentation. Simple implement; conceptually, a flake with linear edge geometry, with a longitudinal linear element.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 25 E. Database number: 754. Raw material: flint, variety Ia3. Dimensions L × W × T: 22 × 18 × 5 mm.

Stages of the tool's proposed individual history:

0 — Initial blank: bladey flake;

1 — Deliberate (?) biterminal fragmentation — removal of distal and proximal parts — producing a secondary blank (representing the medial fragment of the initial blank);

2 — Retouching of one longitudinal edge — forming a single-edge tool;

ΣΣ — Typological characterisation of the item as a complete finished product: retouched flake.

3.3.32. Multi-edge flake tool M0024EI/381, blank of type B, incomplete, with current form proportions corresponding to type F, with four secondarily retouched edges and fragmentation. Complex implement; conceptually, a flake tool with mixed (or combined) edge geometry, with four longitudinal and one angular element, as well as an edge with a transverse burin spall.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 24 E. Database number: 381. Raw material: flint, variety Ia1. Dimensions L × W × T: 29 × 37 × 12 mm.

Stages of the tool's proposed individual history:

0 — Initial blank: bladey flake;

1 — Retouching of longitudinal edges, forming a double-edged, side-scraper-like (?) tool;

2 — Breakage or possible deliberate fragmentation/removal of the proximal part, combined with deliberate distal truncation, producing a

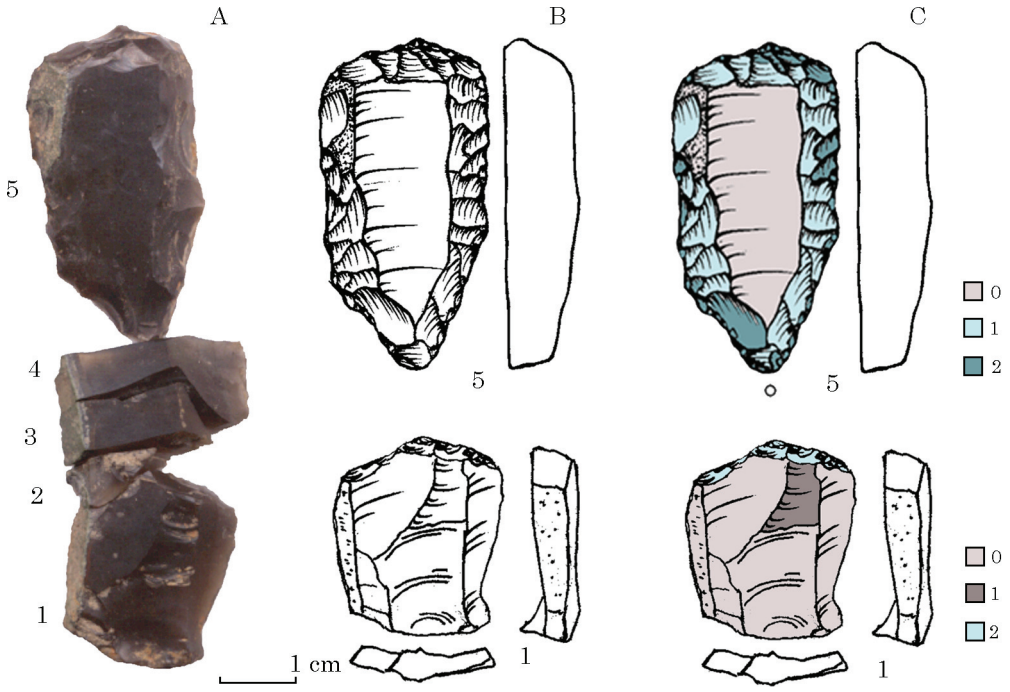

Fig. 7. Mira, Layer I. Example of intentional fragmentation and subsequent transformation. Five-element refitting of the proximal and medial portions of a large blade. The blade was initially used without retouch and then intentionally fragmented on an anvil. Elements 1 and 5 were subsequently transformed into end-scrapers; element 2 is most likely a retouch spall; elements 3—4 represent the medial fragments. Photo (A) and grayscale drawings (B) after Stepanchuk (2021). Color representation (C) of the results of diacritical analysis indicating the sequence of transformation stages

Рис. 7. Міра, шар I. Приклад навмисної фрагментації та подальшої трансформації. П'ятиелементне з'єднання проксимальної та медіальної частин великої пластини. Пластину спочатку використовували без ретуші, після чого її навмисно фрагментували на ковадлі. Елементи 1 і 5 згодом перетворено на кінцеві скребки; елемент 2, найімовірніше, є сколом-відходом ретушування; елементи 3—4 є медіальними фрагментами. Фото (A) та чорно-білі рисунки (B) — за: Stepanchuk (2021). Кольорова візуалізація результатів діакритичного аналізу (C) відображає послідовність стадій трансформації

1 — M0519BI/7; 2 — M0021ГІ/1210a; 3 — M0021ГІ/1227; 4 — M0520ГІ/17; 5 — M0021ДІ/87

secondary blank (representing the medial fragment of the original tool);

3 — Retouching of an edge on the basal part of the item, resulting in the formation of a convergent side-scraper;

4 — Possible deliberate production of a transverse burin blow on the fracture surface of the distal part of the item, resulting in a burin (?);

ΣΣ — Typological characterisation of the item as a complete finished product: convergent side-scraper (possibly combined with a burin).

3.3.33. Multi-edge flake tool M0022ГІ/756, blank of type F, incomplete, with current form proportions still corresponding to type F, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with three linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 22 Г. Database number: 756. Raw material: flint, variety n/d. Dimensions L × W × T: 12 × 10 × 4 mm.

Stages of the tool's proposed individual history:

0 — Initial blank — (?) flake;

1 — Retouching of at least two longitudinal edges, forming a point;

2 — Either breakage through use or resharpening, or possible deliberate fragmentation / removal of the proximal part, producing a secondary blank (representing the distal fragment of the original tool);

3 — Retouching along the sharp edge at the separation of the terminal part of the previous tool, forming a new working edge;

ΣΣ — Typological characterisation of the item as a complete finished product: *flake with retouch*.

3.3.34. Multi-edge flake tool M0022EI/757, blank of type F, incomplete, with current form proportions still corresponding to type F, with three secondarily retouched edges. Complex implement; conceptually, a flake tool with mixed edge geometry combining one angular and three linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: beneath bone 370 (giant deer horn) near pit 10. Unit: 22 E. Database number: 757. Raw material: flint, variety Ia1. Dimensions L × W × T: 26 × 18 × 7 mm.

Stages of the tool's proposed individual history:

0 — Initial blank — (?) flake;

1 — Retouching of two longitudinal and one transverse edges (at the basal part), forming an end-scraper combined with a point;

2 — Renewal of all retouched edges, resulting in a reduction of the tool's size while preserving its morphology, forming a combined tool: an end-scraper-point;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper combined with a point*.

3.3.35. Multi-edge flake tool M0022EI/126, blank of type F, incomplete, with current form proportions still corresponding to type F, with four secondarily transformed edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry comprising thinning and linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: pit 5. Unit: 22 E. Database number: 126. Raw material: flint, variety Ia1. Dimensions L × W × T: 30 × 23 × 4 mm.

Stages of the tool's proposed individual history:

0 — Initial blank —— likely flake;

1 — Retouching of edges, forming a possible double-edged tool;

2 — Breakage or intentional fragmentation / sectioning of the distal part, producing a secondary blank (proximal fragment of the original tool);

3 — Intensive bifacial scaled thinning along 2/3 of the perimeter, forming a chisel;

ΣΣ — Typological characterisation of the item as a complete finished product: *a chisel*.

3.3.36. Multi-edge flake tool M0023BI/782, blank of type F, incomplete, with current form proportions also corresponding to type F, with one secondarily retouched edge and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with one linear element.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 23 B. Database number: 782. Raw material: n/d. Dimensions L × W × T: 8 × 11 × 3 mm.

Stages of the tool's proposed individual history:

0 — Initial blank — cortical flake;

1 — No direct evidence, but retouching of the edge is possible, tool formation (?);

2 — Breakage or intentional fragmentation/ sectioning of the distal part, producing a secondary blank (proximal fragment of the original tool);

3 — Retouching of the transverse edge of the break on the basal end, forming an end-scraper;

4 — Breakage of the terminal part, possible tool destruction during use;

ΣΣ — Typological characterisation of the item as a complete finished product: *fragment of an end-scraper*.

3.3.37. Multi-edge flake tool M0021ЖI/416, blank of type B, incomplete, with current form proportions corresponding to type F, with three secondarily retouched edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry comprising three thinnings.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 21 Ж. Database number: 416. Raw material: flint, variety Ia—б (B). Dimensions L × W × T: 15 × 17 × 57 mm.

Stages of the tool's proposed individual history:

0 — Initial blank — bladey flake;

1 — Production of at least one edge by bifacial thinning at the basal part, forming a chisel;

2 — Breakage or intentional fragmentation of the distal part, producing a secondary blank (proximal fragment of the original tool);

3 — Ventral scaled thinning of the left edge, chisel formation;

ΣΣ — Typological characterisation of the item as a complete finished product: *a chisel*.

3.3.38. Multi-edge flake tool M0021ЖI/459, blank of type B, incomplete, with current form proportions corresponding to type F, with one used edge and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with a single linear element.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 21 Ж. Database number: 459. Raw material: flint, variety Ia1. Dimensions L × W × T: 9 × 27 × 9 mm.

Stages of the tool's proposed individual history:

0 — Initial blank — blade or bladey flake;

1 — Breakage or intentional fragmentation of distal and proximal parts, producing a secondary blank (medial fragment of the original tool);

2 — Use of the transverse edge — utilisation without further secondary modification;

ΣΣ — Typological characterisation of the item as a complete finished product: *a blade fragment with use-wear retouch*.

3.3.39. *Multi-edge flake tool* M0025ГI/360 (Степанчук 2013, fig. 40: 7), blank of type B, incomplete, with current form proportions corresponding to type F comprising two secondarily modified edges and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry, with two linear elements.

Site: Mira, excavations 2000. Layer: I. Horizon: main level. Feature: n/d. Unit: 21 Г. Database number: 360. Raw material: flint, variety Ia1. Dimensions L × W × T: 35 × 22 × 8 mm.

Stages of the tool's proposed individual history:

0 — Initial blank — blade (or bladey flake);

1/2 — Retouching of the longitudinal edge, forming a retouched blade;

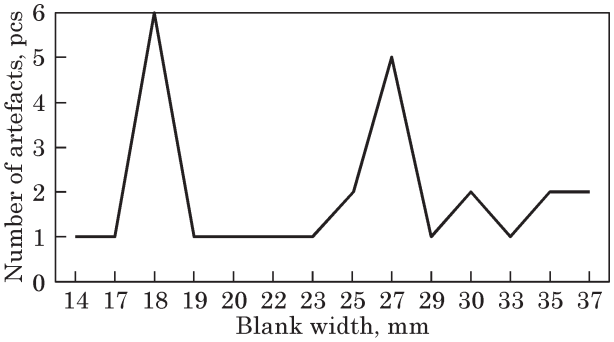

Fig. 8. Mira, Layer I. Width of blades and blade-like flakes used as blanks for the manufacture of repeatedly modified artefacts (N = 27)

Рис. 8. Міра, шар I. Ширина пластин і пластинчастих сколів, використаних як заготовки для виготовлення багаторазово модифікованих виробів (N = 27)

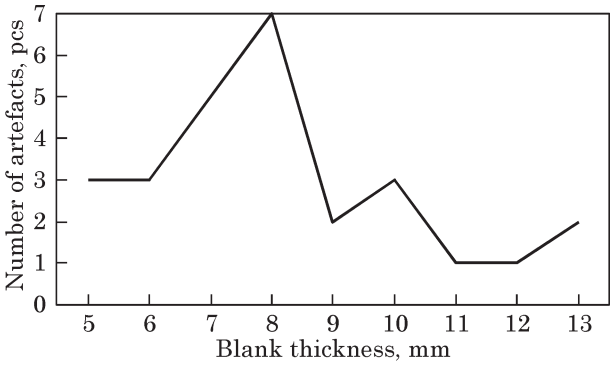

Fig. 9. Mira, Layer I. Thickness of blades and blade-like flakes used as blanks for the manufacture of repeatedly modified artefacts (N = 27)

Рис. 9. Міра, шар I. Товщина пластин і пластинчастих сколів, використаних як заготовки для виготовлення багаторазово модифікованих виробів (N = 27)

2/1 — Breakage or intentional sectioning of the basal part, producing a secondary blank (proximal fragment of the original tool);

3 — Retouching of the transverse broken edge, forming an end-scraper, and rejuvenation of the longitudinal retouched edge;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper with one lateral edge*.

3.3.40. Multi-edge flake tool M0519BI/7 (fig. 7: B: 1; Stepanchuk 2021, fig. 13: A), blank of type B, incomplete, with current form proportions corresponding to type F, with one secondary edge and fragmentation. Simple implement; conceptually, a flake tool with linear edge geometry comprising a single linear element. Site: Mira, excavations 2005. Layer: I. Horizon: main level. Feature: n/d. Unit: 19 B. Database number: 7. Raw material: flint, variety Ia1. Dimensions L × W × T: 27 × 22 × 6 mm.

Stages of the tool's proposed individual history (fig. 7: C: 1):

0 — Initial blank — blade (or bladey flake);

1 — Intentional fragmentation into several pieces, accompanied by dorsal-surface damage, produced a secondary blank (proximal fragment of the initial blank). This phase is confirmed by refitting (Stepanchuk 2021, fig. 13: A);

2 — Retouching of the transverse broken edge, formatting an end-scraper;

ΣΣ — Typological characterisation of the item as a complete finished product: *an end-scraper*.

4. Discussion. Formal cores and unmodified raw-material fragments are absent from the layer (Степанчук 2013). Some indications of the technical characteristics of knapping can be inferred from the flake assemblage. The degree of maintenance of the striking platform edge is moderate, with IF = 31.6 and Ifs = 26.6. Taken together with the relatively low Ilam value (14.5), these indices characterise the industry as rather archaic and primarily oriented towards flake production. The metric characteristics of the tool assemblage are consistent with this assessment.

Taken together, these technical indices point to a flake-oriented industry with only moderate investment in platform-edge preparation, falling within ranges more typical of Middle Palaeolithic than Early Upper Palaeolithic assemblages (Захариков 2022). However, the comparatively high Itr (44.4), reflecting trimming of the core's working surface immediately adjacent to the striking platform, raises the overall platform-preparation index to 76, indicating the complementary use of faceting and trimming in curating the properties of removals; this points to greater investment in this process and, overall, to a knapping strategy more typical of the Upper Palaeolithic (Захариков 2022). Many flakes exhibit shortened proportions, which likely do not reflect standard core reduction of large raw material pieces but rather the exploitation of available «secondary blanks» through reshaping, retouching, thinning, and deliberate bipolar reduction.

Of the 40 studied flake tools, 31 (77.5 %) were produced on blades or bladey flake blanks. This attribution is based on the preserved scar pattern, cross-section, and proportions. The metric characteristics of these blanks can be reconstructed only partially, in terms of width and thickness. On average, the width and thickness of the blades and bladey flakes are 24.96 mm and 8.59 mm, respectively. Notably, the distribution of blades and bladey flakes by width is bimodal (fig. 8), whereas their thickness distribution is unimodal (fig. 9). The estimated length of these blanks probably fell within the range of 10—15 cm. The laminar blanks are predominantly triangular or trapezoidal in cross-section, with broad surfaces formed by earlier removals.

There are nine flakes, apparently large. One of these is most likely a waste product from biface shaping. Overall, both flakes and blades appear

to have been obtained through the targeted reduction of discrete raw-material pieces.

Eight artefacts in the analysed series of flake-based tools retain areas of cortex. It is important to note that only 2 of the 31 blades and bladey flakes (c. 6.5 % of their total), whereas 6 of the 9 flakes (c. 67 %), are cortical or semi-cortical pieces, some with only very small patches of cortex. The character of the cortical surfaces suggests a tabular morphology for at least part of the exploited flint pieces.

Following breakage or intentional fragmentation / sectioning of the original tool, a fragment was created that then served as the *secondary* blank for the manufacture of a subsequent tool. Fragmentation is documented for 36 items, that is, in the overwhelming majority of cases (90 %). Unsurprisingly, the metric characteristics of secondary blanks differ from those of the initial blanks. In 33 cases (82.5 %), the proportions of the secondary blank in its current form correspond to type F (flake proportions). Only seven specimens (17.5 %) retain blade or bladey flake proportions.

As a rule, the discarded (or lost) «final» tool was preceded by fragmentation of the «original» tool. In many cases, the diagnostic features indicate intentional breakage (Любин 1978; Матюхин 1994; Inizian et al. 1999; Tsirk 2014), which is also supported by refitting (fig. 7: A). Fragmentation thus represents a key stage in the life histories of the analysed tools. Its high frequency, together with the relatively large size of the fragments, argues against accidental breakage. The fact that virtually all fragments were subsequently modified strongly supports a humanly induced origin for this fragmentation. The implements were probably often subdivided into more than two pieces, as suggested by the presence of medial fragments and the small size of some proximal and/or distal fragments. In total, 12 proximal, 10 medial, and 12 distal fragments can be identified with confidence.

Following fragmentation, several modes of subsequent transformation were applied: retouch (25 cases), a burin blow (2 cases), and thinning (18 cases); notably, all thinned pieces also carry retouch. A distinctive feature of the assemblage is the unusually high incidence of scaled thinning, predominantly on the ventral surface. The widespread use of this procedure may reflect attempts either to form chisel-like edges or to obtain blanks in the form of small flakes. It is widely recognised that the functional interpretation of *scaled pieces* — as specialised tools, by-products, or even cores — remains debated and in many respects unresolved, despite a long history of research (e. g. Le Brun-Ricalens 2006; Horta et al. 2019). Most likely, in each case the most plausible attribution depends on the technological and cultural context. For instance, *scaled pieces* are frequent in assemblages of the Gorodtsovian tradition, which provide a close parallel to Layer I at Mira on other lines of evidence as well (Anikovich et al. 2007). In addition, there appears to be a relationship between the abundance of scaled pieces and associated bipolar reduction under conditions of intensive activity and raw-material scarcity (Hiscock 2015; Horta et al. 2019). Accordingly, some of the items in the analysed sample may plausibly represent cores. The latter interpretation appears the more plausible, even though the removals produced by thinning were typically small. The presence in the same layer of microliths of comparable size (Ryzhov, Stepanchuk 2025) lends support to this suggestion.

It may be concluded that the assemblage under consideration was produced from carefully selected blanks / raw material. On the basis of its composition, selection appears to have prioritised large, broad blades — products of core exploitation — followed, secondly, by large flakes produced during decortication, i. e. products of core preparation. This, in turn, suggests that the carried reserve of flint among the occupants of the upper layer at Mira included pieces of unworked raw material, probably in the form of roughly shaped core preforms (or bifaces) (Stepanchuk 2013). Such forms are readily explained within S. Kuhn's framework: large blanks carried as a mobile reserve were not primarily intended to maximise edge-to-weight ratios, but to accommodate later reworking, including the conversion of implements into cores or other artefact classes (Kuhn 2020, p. 195). This interpretation fits well with the conclusions concerning the composition and progressive reconfiguration of the Mira toolkit. Debitage from the manufacture of bifacial tools was also utilised.

Overall, preference was given to large, robust implements with long working edges, i. e. comparatively raw-material-intensive forms. Following intensive modification, the artefacts in the analysed sample acquired a predominantly flake-like appearance, thereby obscuring the original blade character of the blanks. Whereas at the initial stage of transformation the proportion of blade blanks reached 77.5 %, by the stage of discard (or loss) only 17.5 % retained laminar (blade-like) proportions.

Systematic changes in complexity, morphology, typology, and tool-manufacture concept from the initial forms to the discarded (or lost) specimens are likewise substantial. A conventional indicator of increasing tool complexity is a rise in the number of working edges or edge segments modified by retouch, shaping, thinning, or burin blows. For the studied sample, the most informative figures concern retouched edges and thinned margins. On this basis, at the «original tool» stage the 40 artefacts collectively comprise 73 linear edges and a single instance of thinning, whereas at the discard / loss stage they display 98 linear edges and 35 instances of thinning (table).

The sharp increase in artefacts exhibiting thinning provides strong evidence for a marked conceptual elaboration in tool shaping. A similar tendency is reflected in the growing proportion of pieces with angular or mixed (linear—angular) edge geometry, rising from five to twelve artefacts between the initial and discard phases (table). A further indicator of increasing tool complexity is the increased frequency of combined tools, rising from three to fourteen instances between the initial and discard phases. These are single lithic pieces incorporating morphologically distinct, secondarily modified parts that are, in formal typological terms, sufficient for separate attribution (e. g. end-scraper-point, side-scraper-chisel) (table).

It should be noted that the typological identification of the reconstructed «preceding» reworked artefact can be offered only tentatively, and not for all items considered here. In this study, the «preceding» artefact represents an analytical reconstruction rather than a directly observable stage. Earlier diagnostic attributes are frequently overprinted by later retouch, thinning, and breakage, limiting the security of typological attribution. Unfortunately, it is impossible to determine when and where the modification of the original flake blank — resulting in the artefact here termed the «preceding» one — was carried out. What can be established with greater confidence is that this modification predates the interventions that produced the «final» configuration recorded at the moment of loss or discard, i. e. the configuration of the artefact recovered during excavation.

The overwhelming majority of flake blanks had already undergone intensive secondary modification by the stage recognised here as the shaping of the original tool. Only 5 of the 40 items (12.5 %) show no evidence of such modification at this point; in these cases, secondary working and/or use-wear represents the earliest recognisable stage of transformation. This provides indirect evidence for intensive tool reworking within Layer I at Mira. In the remaining artefacts, subsequent interventions were so extensive that earlier, discrete stages of transformation cannot be reliably traced back to the initial phase of shaping, leaving only a limited basis for recognising distinct stages within the overall sequence.

The identification of the original tool type is not equally secure across the assemblage. In some cases, only the number of working edges can be established, and the tool type itself cannot be reconstructed (table). Of the 40 artefacts, correspondence between the «original» and «discarded» tool types can be documented in 38 cases: it is full in 5, almost full in 2, partial in 18, and minimal in 6. In a further 3 cases no correspondence is present, while in 4 cases it cannot be assessed. Thus, even under intensive transformation — most commonly partial (18/40, i. e. 45 %) — a link to the initial form is retained far more often than it is lost overall (38 cases versus 3). This pattern points not to a wholesale «change of appearance», but rather to the predominant inheritance of the original configuration through successive episodes of reworking. Typological attribution may also be retained under minimal secondary modification (cf. the end-scraper in fig. 7: 5). In such cases, the tool becomes smaller, yielding changes reminiscent of the reduction sequences outlined by Dibble (1995).

Correspondence between blank type and discarded tool form (table) is confirmed in only 15 of 40 cases (with 25 showing no correspondence), indicating that intensive reworking under raw-material scarcity frequently «re-casts» initially laminar blanks into flake-like end-products and thus contributes directly to the assemblage's seemingly flake-oriented appearance.

5. Conclusion. This pilot study focuses on Layer I of the Mira site (Dnieper Valley; c. 33—31 cal. ka BP) and assesses the extent to which severe constraints in flint availability shaped the assemblage's techno-morphological character. Drawing on a random sample of 40 flake tools, it employs diacritical, artefact-by-artefact reconstruction of individual transformation histories, distinguishing the stage of the initial blank, successive episodes of reworking (including the reconstructed «preceding» tool), and the final configuration at the moment of loss or discard.

The results indicate that the apparently flake-oriented appearance of the Layer I toolkit is, to a considerable degree, secondary. Although the discarded implements are predominantly flake-like, a substantial proportion of the initial blanks exhibit laminar (blade or blade-like) proportions, implying a meaningful laminar component in the underlying production. Under conditions of limited access to knappable stone, the occupants appear to have relied on a mobile carried reserve of flint that included both unworked pieces — probably in the form of rough core preforms and/or bifacial preforms — and finished tools. A key mechanism of raw-material economy was widespread, often intentional fragmentation, producing «secondary blanks» that were subsequently transformed through retouch, burin blows, thinning, and other modes of secondary modification.

Across the reconstructed sequences, changes from initial to discard configurations are evident in both complexity and morphological expression. Tool histories tend to move from large, robust forms with relatively few modified working edges towards smaller pieces with a higher density of functional edge segments. This trend is reflected in increasing numbers of linear and angular edges, a marked rise in combined tools, and a sharp increase in thinning. The latter is interpreted not only as a shaping procedure but also as a potential means of generating small removals that could serve as blanks, an inference consistent

Mira, main parameters of the series of repeatedly modified flake artefacts

Міра, основні параметри неодноразово модифікованих виробів на сколах

Catalogue number	I. Type of blank	II. Tool form	III. «Original» tool type	Fragmentation	Further transformed by		Core-like knapping	IV. «Discarded» tool type	Correspondence between I and II	Correspondence between III and IV
					retouching	thinning				
3.3.1	F	~F	ES/P	yes	yes	no	no	ES/A	yes	near-full
3.3.2	B	~F	SS:s	yes	yes	yes	yes	SS/ES/Scp	yes	partial
3.3.3	F (BF)	~F	T:me	yes	yes	yes	no	ES/P	yes	n/d
3.3.4	BF	~F	P:th	yes	yes	no	?	ES:lr	no	partial
3.3.5	B	~F	T:te	yes	yes	no	no	ES:d	no	partial
3.3.6	B	~F	T:lr	?	yes	yes	?	ES:lr	no	partial
3.3.7	BF	~F	T:thlr	yes	yes	no	no	ES:lr	no	partial
3.3.8	B	~BF	ES:lr	no	yes	no	no	ES:lr	yes	full
3.3.9	F	~F	ES:lr	no	yes	yes	no	ES/P	yes	near-full
3.3.10	B	B	n/tr	yes	yes	no	no	B:r, tr	yes	—
3.3.11	B	~F	SS:s	yes	yes	yes	?	SS/P:th	no	partial
3.3.12	BF	~F	SS:d	yes	yes	no	no	ES:lr	no	partial
3.3.13	B	~F	B:r	yes	bb	no	no	Brn/ES	no	minimal
3.3.14	BF	~F	ES:lr	yes	no	yes	yes	ScP (core)	no	none
3.3.15	B	~BF	n/d	yes	yes	no	no	Lmc	no	n/d
3.3.16	B	~F	B:r	yes	no	yes	?	B:r	yes	full
3.3.17	BfcF	~F	SS:cn	yes	no	yes	yes	SS/ScP	yes	partial
3.3.18	BF	~F	T:thlr	yes	no	yes	yes	SS/ScP (core)	no	partial
3.3.19	B?	~F	T:te	yes	yes	no	no	ES/P	no	partial
3.3.20	B	~BF	ES:lr	yes	no	yes	yes	ES/ScP (core)	no	partial
3.3.21	B	~F	B:r	yes	no	yes	yes	ScP (core)	no	partial
3.3.22	B	~F	ES or ES/P	yes	no	yes	yes	ScP (core)	no	minimal
3.3.23	B	~F	T:se	yes	yes	no	no	SS:c	no	partial

ISSN 2227-4952 (Print), ISSN 2708-6143 (Online). Археологія і давня історія України, 2026, 1 (58)

3.3.24	B	~F	B:r	yes	yes	yes	yes	Scp (core)	no	minimal
3.3.25	F	~F	ES:lr	yes	no	yes	yes	ES/Scp (core)	yes	partial
3.3.26	B	~F	T:se	yes	yes	yes	yes	P:th	no	minimal
3.3.27	B	~BF	B:r or ES:lr	yes	yes	yes	yes	ESp/ (core)	no	partial
3.3.28	B	~F	B:r or SS;c	yes	yes	no	no	F:r	no	minimal
3.3.29	B	~BF	P	yes	yes	yes	yes	P/ScP (core)	no	partial
3.3.30	B	~F	ES/P	no	yes	no	no	ES/P	no	full
3.3.31	B	~BF	n/tr	yes	yes	no	no	B:r	yes	—
3.3.32	B	~F	SS:d	yes	yes+bb	no	no	SS:c/Brn (?)	no	partial
3.3.33	F	~F	P	yes	yes	no	no	F:r	yes	minimal
3.3.34	F	~F	ES/P	no	yes	no	no	ES/P	yes	full
3.3.35	F	~F	T:te	yes	no	yes	no	ScP	yes	none
3.3.36	F	~F	?	yes	yes	no	no	ES	no	n/d
3.3.37	B	~F	ScP	yes	no	yes	no	ScP	yes	full
3.3.38	B	~F	n/tr	yes	no	no	no	F:ur	yes	n/d
3.3.39	B	~F	B:r	yes	yes	no	no	ES:lr	no	partial
3.3.40	B	~F	n/tr	yes	yes	no	no	ES	no	—

Key. a) Blank type: B — blade; BF — bladey flake; F — flake; BfcF — biface shaping flake. b) Current tool form: ~B — blade-like; ~F — flake-like; ~BF — bladey flake-like. c) Typological definitions (simple forms): ES — end-scraper; ESp — pointed end-scraper; ES:lr — laterally retouched end-scraper; ES:d — double end-scraper; P — point; P:th — thinned point; Lmc — limace; SS — side-scraper; SS:s — simple sidescraper; SS:d — double sidescraper; SS:c — convergent side-scraper; SS:cn — canted side-scraper; ScP — scaled piece; Brn — burin; F:r — retouched flake; F:ur — use retouched flake; B:r — retouched blade; B:r, tr — retouched and truncated blade. d) Typological definitions (combined forms): ES/P — end-scraper / point; ES/A — end-scraper / awl; SS/ES/Scp — side-scraper / end-scraper / scaled piece; SS/P:th — side-scraper / thinned point. e) Typologically undefined forms: T:se — single-edged tool; T:te — two-edged tool; T:ce — convergent tool; T:me — multi-edged tool; T:lr — laterally retouched tool; T:thlr — thinned laterally retouched tool. f) Technical features: r — retouch; ur — use retouche; th — thinning; bb — burin blow; n/d — no data; n/tr — no treatment.

Ключ. a) Тип заготовки: B — пластина; BF — пластинчастий скол; F — відщеп; BfcF — відщеп формування біфаса. b) Поточна форма виробу**:** ~B — пластиноподібний; ~F — відщеподібний; ~BF — подібний до пластинчастого сколу. c) Типологічні визначення (прості форми): ES — скребок; ESp — загострений скребок; ES:lr — скребок із латеральною ретушшю; ES:d — подвійний скребок; P — гостроконечник; P:th — потоншений гостроконечник; Lmc — лімас; SS — скребло; SS:s — просте скребло; SS:d — подвійне скребло; SS:c — конвергентне скребло; SS:cn — кутасте скребло; ScP — лускатий виріб; Brn — різець; F:r — ретушований відщеп; F:ur — відщеп із слідами ужиткової ретуші; B:r — ретушована пластина; B:r, tr — ретушована й тронкована пластина. d) Типологічні визначення (комбіновані форми): ES/P — скребок / гостроконечник; ES/A — скребок / проколка; SS/ES/ScP — скребло / скребок / лускатий виріб; SS/P:th — скребло / потоншений гостроконечник. e) Типологічно невизначені форми: T:se — однолезове знаряддя; T:te — дволезове знаряддя; T:ce — конвергентне знаряддя; T:me — багатолезове знаряддя; T:lr — знаряддя із латеральною ретушшю; T:thlr — потоншене знаряддя із латеральною ретушшю. f) Технічні ознаки: — ретуш; ur — ужиткова ретуш; th — потоншення; bb — різцевий скол; n/d — дані відсутні; n/tr — без обробки.

with the presence in the same layer of small non-geometric microliths of comparable size.

The principal conclusion is that, under severe raw-material constraint and high-intensity modification, the techno-morphological appearance of an industry may shift substantially. In this sense, an assemblage dominated by heavily modified and repeatedly reworked pieces can be read as a behavioural signal consistent with raw-material stress (and / or restricted access to suitable knappable stone), although alternative drivers such as occupation intensity and mobility must also be considered. Consequently, assessments of such assemblages and their placement within contemporaneous Palaeolithic variability should explicitly take into account the degree of reworking. Future work should expand the analysed sample and apply the same diacritical principles to the Layer I debitage, as well as test the resulting interpretations against assemblages formed under comparable occupation intensity and raw-material constraints.

Acknowledgment. The 2000 excavations at the Mira site were funded by an L. S. B. Leakey Foundation General Grant (2000; V. S.). The analysis of the Layer I sample of flake tools was supported in part by the NAS of Ukraine research project *«Traditions and Innovations in Ukraine's Stone Age»* (No. 0124U00314).

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LAYER I OF THE MIRA SITE: FLAKE TOOL TRANSFORMATION AS A KEY TO UNDERSTANDING KNAPPING STRATEGIES

This pilot contribution examines Layer I of the Mira site in the Dnieper basin (c. 33—31 ka cal BP) with the aim of assessing how far severe constraints on flint availability shaped the assemblage's present techno-morphological profile. On the basis of a random sample of 40 flake tools, we undertake an artefact-by-artefact diacritical reconstruction of individual transformation histories, separating (i) the initial blank, (ii) successive episodes of reworking, (iii) the reconstructed «preceding» tool, and (iv) the final configuration at the point of loss or discard.

The analysis suggests that the seemingly flake-oriented appearance of the Layer I toolkit is, to a significant extent, a secondary effect of intensive curation. Although the discarded artefacts are largely flake-like, a substantial share of the initial blanks exhibits laminar (blade or blade-like) proportions, indicating a meaningful laminar component in the underlying production. Given restricted access to knappable stone, the Mira occupants appear to have depended on a mobile carried reserve of flint that included both unworked pieces — most plausibly rough core and/or bifacial preforms — and finished implements. Raw-material economy was further promoted by widespread, often intentional fragmentation, which created «secondary blanks» subsequently converted into new tools through retouch, burin removals, thinning, and related modes of secondary modification.

Across the reconstructed sequences, the trajectories point to a consistent trend towards greater functional subdivision and typological elaboration. Tool histories typically move from large, robust forms with relatively few modified working edges to smaller artefacts bearing a higher density of functional edge segments. This pattern is expressed in rising counts of linear and angular edges, an increase in combined tools, and a marked escalation in thinning. Thinning is interpreted not merely as a shaping procedure but also as a potential means of producing small removals suitable for use as blanks — an inference supported by the occurrence, within the same layer, of small non-geometric microliths of comparable size.

Overall, the study underscores that, under acute raw-material constraint and high modification intensity, an industry's techno-morphological appearance can be substantially reconfigured over the life histories of its tools. Heavy reworking may therefore serve as a proxy indicator of raw-material stress. Comparative assessments and the placement of such assemblages within contemporaneous Palaeolithic variability should therefore take explicit account of reworking intensity. Further work should enlarge the analysed sample, extend the same diacritical principles to the Layer I debitage, and evaluate the resulting interpretation against assemblages formed under comparable conditions of intensive activity and raw-material limitation.

Keywords: Upper Palaeolithic, diacritical analysis, stages of flake-tool modification.

В. Степанчук

ШАР І СТОЯНКИ МІРА: ТРАНСФОРМАЦІЯ ЗНАРЯДЬ НА СКОЛАХ ЯК КЛЮЧ ДО РОЗУМІННЯ ПРОЦЕСІВ КАМЕНЕОБРОБКИ

Це пілотне дослідження зосереджене на шарі І стоянки Міра, розташованої на р. Дніпр та датованої приблизно 33—31 тис. каліброваних років тому, і оцінює, до якої міри суворі обмеження щодо доступності кременю визначили техноморфологічний характер комплексу. На основі випадкової вибірки із 40 знарядь на сколах застосовано діакритичну, артефакт-за-артефактом реконструкцію індивідуальних історій трансформації з розрізненням стадії первинної заготовки, послідовних переоформлень, реконструйованого «попереднього» знаряддя та фінальної конфігурації на момент втрати або відкидання виробу.

Результати дослідження свідчать, що на перший погляд «відщепно-орієнтований» вигляд інвентарю шару І значною мірою є вторинним. Хоча відкинуті знаряддя переважно мають відщепний вигляд, значна частка первинних заготовок демонструє пластинчасті пропорції, що вказує на вагомий ламінарний компонент у вихідному виробництві. За обмеженого доступу до придатного для обробки каменю мешканці, ймовірно, спиралися на мобільний запас кременю, який вони носили, що містив як незавершені заготовки (імовірно, у формі грубих преформ нуклеусів та / або біфасів), так і готові знаряддя. Ключовим механізмом економії сировини була масова, часто навмисна фрагментація, що утворювала «вторинні заготовки», які надалі трансформували за допомогою ретушування, різцевих сколів і потоншення та в інші способи.

У межах реконструйованих послідовностей простежено спрямовану зміну як складності, так і типологічної виразності. Історії знарядь зазвичай ведуть від великих, масивних форм із відносно невеликою кількістю модифікованих робочих кромок до менших виробів із більшою щільністю функціональних крайових ділянок. Ця тенденція відображається у збільшенні кількості лінійних і кутастих кромок, помітному збільшенні числа комбінованих знарядь і різкому — кількості потоншень. Останнє можна інтерпретувати не лише як прийом формоутворення, а й як потенційний спосіб отримання невеличких сколів, що своєю чергою могли бути заготовками, що узгоджується із наявністю в тому самому шарі дрібних негеометричних мікролітів співставних розмірів.

Головний висновок дослідження полягає в тому, що в умовах жорсткого дефіциту сировини та високої інтенсивності модифікацій техноморфологічний вигляд індустрії може істотно змінюватись. Інтенсивне переопрацювання, таким чином, може слугувати опосередкованим індикатором дефіциту сировини. З огляду на це, оцінюючи комплекси і визначаючи їхнє місце в межах синхронної палеолітичної варіабельності, потрібно враховувати ступінь переоформлення. Подальші дослідження мають розширити проаналізовану вибірку, застосувати ті самі діакритичні принципи до дебітажу шару І, а також перевірити інтерпретації на комплексах, сформованих за подібних умов активної діяльності та сировинних обмежень.

Ключові слова: верхній палеоліт, діакритичний аналіз, етапи модифікації знарядь на сколах.

Отримано / Received: 28.01.2026
Прийнято після рецензування / Accepted after review: 24.02.2026
Опубліковано / Published: 31.03.2026

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