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Cultural Transmission and Convergence Process in Paleolithic Northeastern Asia and Beringia: On the basis of microblade industries.

北東アジアとベーリンジアの旧石器じだいの文化伝播と文化収斂過程：細石刃石器群に基づいて

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Introduction

Microblade technology refers to a specialized lithic production method employed by prehistoric hunter-gatherers to manufacture small, parallel-sided blades—typically less than 50 mm in length and 5–10 mm in width—from specifically prepared cores. These microblades were commonly used as insets in composite tools, such as bone or antler points and knives.

The Upper Paleolithic microblade industries are widespread from the circumpolar Arctic to the Tibetan Plateau and Kyushu Island south of the Japanese archipelago, from Eastern Siberia to British Columbia in North America (fig. 1). Research on microblade technology and associated artifacts—including microblade cores, slotted spear points, and daggers—has constituted a major focus of archaeological inquiry since the late 19th century. Over the past hundred years, scholars from Russia, Japan, China, the United States, Canada, the Republic of Korea, the Democratic People's Republic of Korea, France, Mongolia, and other nations have conducted extensive investigations into these distinctive lithic artifacts. This international effort has yielded diverse theoretical frameworks addressing the emergence, diffusion, functional applications, and raw material selection of microblade technology, published in multiple languages across global academic platforms.

These circumstances underscore three key points. First, the investigation of microblade industries has high viability for archaeological and prehistoric studies and offers considerable potential for the developments of these fields in the Asian region and beyond. Second, microblade technology held substantial social significance for prehistoric populations in Northeastern Asia and Beringia. This significance, in turn, means that studies of microblade industries reflecting variable aspects of prehistoric studies. Third, advancing scholarly

discourse on microblade industries necessitates a well-defined conceptual framework and the rigorous selection of research methods.

The study of microblade industries is significant for understanding human adaptation during the Pleistocene, particularly regarding the emergence and rapid spread of microblade technology in relation to climatic changes that occurred in the Late Pleistocene. The disappearance of microblade technology at the Pleistocene–Holocene boundary in certain regions is also believed to be linked to environmental shifts. Furthermore, research on microblade industries is closely connected to broader issues such as the migration of anatomically modern humans across Asia, the initial peopling of North America, the social and technological development of prehistoric populations, and the economic behavior of hunter-gatherer societies. In sum, the study of microblade technology encompasses a wide range of interconnected research questions and reflects the socio-cultural processes that took place in Northeastern Asia and Beringia during the Late Pleistocene and Early Holocene.

There is substantial evidence indicating the high social significance of microblade technology for prehistoric populations in Northeastern Asia and Beringia. First, this significance is reflected in the rapid and widespread dissemination of microblade technology across the Northeastern Asia and Beringia macro-region. Second, its persistence from the Last Glacial Maximum through the Early Holocene further underscores its importance. Finally, although other hunting technologies such as tanged bifacial points and osseous points were present in some areas, microblade technology was the only tool production method consistently found across all regions of Northeastern Asia and Beringia to a comparable extent.

The central hypothesis of this study is that the spread of microblade technology was linked to various social processes occurring simultaneously in Paleolithic

Northeastern Asia and Beringia. The dissemination of cultural phenomena such as microblade technology may have been influenced by several mechanisms, including cultural transmission, cultural diffusion, and cultural convergence. *Cultural transmission* refers to the process by which technological knowledge, behavioral practices, and cultural information were communicated and sustained among individuals and groups within prehistoric societies. *Cultural diffusion*, while similar, specifically concerns the spatial spread of cultural traits or technologies between groups through contact or exchange, emphasizing the "where" and "between whom" of cultural distribution. In contrast, *cultural convergence* describes the independent development of similar cultural traits, technologies, or practices among distinct human groups without direct interaction or shared ancestry. This process typically results from parallel adaptations to comparable environmental conditions, cognitive constraints, or functional requirements.

The Yubetsu and Tougeshita methods were selected as the focus of this study for several reasons. First, these are the only microblade core reduction methods found across all regions of Northeastern Asia and Beringia, including Siberia, the Korean Peninsula, the Paleo-Sakhalin–Hokkaido–Kuril Peninsula region, Northeastern China, and Alaska. Second, both the Yubetsu and Tougeshita methods appear in these regions during approximately the same time period. Third, the two methods share notable similarities in their reduction sequences, including the horizontal orientation of the preform and the preparation of the striking platform through the detachment of a longitudinal spall from the front of the core. Therefore, the investigation and comparison of the Tougeshita and Yubetsu reduction methods can yield representative data on the cultural and social processes of Paleolithic Northeastern Asia and Beringia—particularly those related to cultural transmission, cultural diffusion, and cultural convergence of microblade technology.

The tracing of processes of cultural transmission, diffusion and convergence requires a set of research methods applied to investigations of lithic artefacts. For the investigations of cultural transmission and cultural convergence processes used methods that characterize technological sequence of microblade core reduction, technique of microblade production and functions of microblades. Technological sequence of microblade core reduction investigated in the framework of refitting block analysis and scar pattern analysis. The technique of microblade making could be studied by fracture wing analysis or by technological analysis. Both methods involve experimental replication of the microblade production process. Investigations of microblade tool`s functions conducted in the framework of use-wear analysis.

Selected analytical methods are related to each other. Methods of refitting block analysis and the scar pattern analysis related because results of refitting block analysis provides data of the objective control for the scar pattern analysis data. Technological analysis and fracture wing analysis provide data of knapping methods for different raw materials. This complex of methods contributes to the objectives of studies because it characterizes features of microblade core reduction and functions of microblade essential for the characteristic of cultural transmission due to significance of knapping technique, microblade core reduction sequence, and microblade functions for the understanding of this process.

Also, all methods serve for the creation of the morphospace models of microblade and microblade cores of Tougeshita and Yubetsu reduction methods. Morphospace model concept used for the studies of parallel cultural evolution or cultural convergence. Selected methods contribute to the morphospace model. Refitting Block analysis and Scar Pattern Analysis identifies main stages of microblade core reduction and morphological/technological features necessary for the creation of techno-morphospace. As far as knapping technique

is a significant feature in techno-morphospace models, Fracture Wing analysis and Technological analysis serve the same purpose. The function is a definitive part of the morphospace as the concept. Thus, use-wear analysis is highly significant for the morphospace model. The method of use-wear analysis defines functional artifacts that make it possible to identify dimensional limits of functional microblades.

Data on the cultural processes underlying the emergence and spread of microblade technology can be compared with findings from paleoclimatic and genetic studies to trace population dynamics in Northeastern Asia (Sikora et al, 2019). Emerging evidence suggests a connection between microblade technology and Ancient Paleosiberian genetic groups, including their migration toward North America during the Last Glacial Maximum (LGM). In this context, data from genetic research, paleoclimatic reconstructions, and studies of microblade industries are closely interconnected and mutually complementary.

Although microblade industries are primarily associated with the Upper Paleolithic period, the prehistoric populations that employed this technology contributed to the cultural development of various Indigenous groups in both Northern America and Northeastern Asia.

Stone tool manufacturing technology alone is insufficient to explain the cultural development of any human group. Nevertheless, it contributes significantly to archaeological interpretation because it reflects adaptive processes, including the tasks required in daily activities, the range of available raw materials and other resources, and subsistence strategies. In addition, the evolution of stone tool production technology can provide insight into the diffusion and transmission of cultural knowledge both within and between groups.

The cultural information transmitted alongside technological knowledge includes cultural stereotypes and aesthetic preferences, which are important components of group identity. Such features may be conceptualized as *habitus* (Bruijn, 2006), reflecting the implicit and largely unconscious dimensions of cultural identity. This perspective helps explain why many contemporary Indigenous communities show greater concern for access to ritual objects and human remains, while displaying comparatively limited interest in stone tools and other everyday utilitarian items.

Cultural sequences in regions such as Alaska and Hokkaido provide evidence for continuity between Late Upper Paleolithic traditions and the cultures of Indigenous peoples. Specifically, scholars have proposed hypothetical technological continuity between prehistoric populations and the ancestors of Athabaskan–Dene groups (Ives, 2024), as well as with Inuit/Thule adaptations (McGhee, 1996).

In light of the widespread distribution and socio-technological significance of microblade industries in Northeastern Asia and Beringia, this study aims to elucidate the mechanisms behind the spread and persistence of microblade technology, particularly the Yubetsu and Tougeshita methods, through a multidisciplinary analytical framework. The primary goal of this research is to determine whether the spread of microblade technology resulted from cultural transmission, diffusion, or convergence, thereby contributing to broader discussions on human adaptation, migration, and technological evolution during the Late Pleistocene and Early Holocene.

Chapter 1. Research History of microblade industries in Northeastern Asia and Beringia.

1.1. Initial research on microblade industries

The first recorded mention of implements with inserted microblades in Northern Asia was made by N. I. Vitkovsky in 1881. He described the artifact as a “flat bone inserted with stone blades on both sides, a kind of dagger,” discovered during excavations of a Neolithic necropolis near Irkutsk in Eastern Siberia (Витковский, 1881).

Around the same period, Ivan Poliakov — a zoologist and ethnographer — conducted early explorations in Siberia and the Russian Far East. During his expeditions of 1880s he collected stone tools from Paleolithic sites (Поляков, 1881); however, his primary focus was on faunal remains and general tool typology rather than specialized lithic analysis. While he did observe the presence of small, finely made blades, he did not differentiate them from other flake-based tools (Okladnikov, 1965).

Another early mention of microblades appears in the work of D. N. Anuchin, a pioneer of Russian anthropology and archaeology, who conducted broad studies on the prehistory of Siberia. Unlike I. Poliakov, Anuchin undertook more systematic classifications of stone tools, including small blades. He observed that certain Siberian assemblages contained miniaturized tools, although he did not yet define them as part of a distinct "microblade" industry. His publication *On some peculiar stone artifacts from Eastern Siberia* (Анучин, 1886) laid important groundwork for later Soviet archaeologists, such as A. P. Okladnikov, to formalize the study of microblade technologies (Derevianko, 1998).

As noted by Okladnikov and Vasilevsky, the publication of this collection attracted the attention of Aleš Hrdlička—who was already engaged with the Beringian hypothesis of the peopling of the Americas—to visit Irkutsk in 1912

(Hrdlička, 1913). Thus, from its earliest documentation, the phenomenon of microblade technology has been closely associated with the broader question of human dispersal and the initial peopling of the Americas.

In 1923, N. K. Auerbach and G. P. Sosnovsky reported a slotted point discovered at the Afontova Gora site, which they described as a “wide osseous plate with a slot on the narrow edge, which was used for inserting stone knife-like bladelets” (Ауэрбах & Сосновский, 1923). However, microblade cores—now recognized as a key category of microblade technology—were first described by B. E. Petry.

B.E. Petry began his study of Siberian materials in 1912 and intensified his work in 1918 upon his appointment as a private-docent at Irkutsk State University (Савельев, 1991). In a 1920 letter to G. Merhart, Petry referenced the discovery of "Magdalenian epoch artifacts," including what he described as a "microlithic culture" characterized by artifacts made of "remarkable fine quality flint" (Детлова & Макаров, 2009). Later evidence confirming the advance and spread of anatomically modern humans in Siberia was introduced to European academia through French archaeologist Joseph de Baye (1853–1931) and Austrian archaeologist Gero von Merhart (1886–1959). The findings were introduced to European academic circles, establishing a distinct Siberian Paleolithic culture separate from Europe (Kato, 2022).

Comprehensive descriptions of microblade industry products appeared in Petry’s 1923 publications *Siberian Paleolithic* and *Siberian Neolithic*. For wedge-shaped microblade cores, he used the term *scraper-core* (*скребок-ядрище*), writing: “one side has facets like any core, the other is carefully retouched and turned into a kind of chisel or scraper.” Petry also described “small knives 2 cm long” and slotted daggers with “inserted bladelets, a kind of small *lames*,” although he did not associate these categories with

scraper-cores. He interpreted the function of scraper-cores as the production of small awls—likely identifying the distal parts of microblades as awls. In Petry's classification, the categories of "awls" and "scraper-cores" served as linking types between the Paleolithic and Neolithic in the Yenisei and Angara River regions (Петри, 1926).

Thus, in these early stages of microblade industry research, individual tool types were not yet conceptually linked to one another or to osseous technologies. Moreover, some microblade products were misattributed to other typological categories. For instance, a ridge spall used in platform preparation (fig. 2), illustrated in Figure XVII of *Siberian Paleolithic Atlas*, was identified as a burin (Петри, 1927).

During the 1920s and 1930s, a diffusionist framework emerged in American studies of microblade technology. This discourse emphasized the investigation of interregional connections through the analysis of microblade industries, highlighting the significance of cultural exchange. As noted earlier, the idea of connections between the cultures of East and West Beringia was initially proposed by Aleš Hrdlička, although his arguments did not rely on microblade data (Окладников & Василевский, 1976).

More substantial evidence for cultural connections during the Stone Age emerged following the discoveries of the Central Asian Expedition (1925–1928). In particular, N. E. Nelson compared lithic materials collected from Mongolia during this expedition with artifacts from the Campus Site near Fairbanks, Alaska, excavated in 1934. He concluded that "there is some close connection between the Mongolian and Alaskan core makers, only additional fieldwork can demonstrate, but the detailed similarities here pointed out look remarkably promising" (Nelson, 1937). In his analysis, Nelson employed the

term *semi-polyhedral core* to refer to microblade cores and described the microblades themselves as *prismatic flakes* (Nelson, 1937).

The next significant stage in the study of microblade industries in Siberia began in the late 1930s and was closely associated with A. P. Okladnikov's formulation of the Cis-Baikal Neolithic cultural sequence. In 1938, Okladnikov proposed a chronological sequence of funerary traditions in the Angara region, which included: (a) Khin'skaia, (b) Isakovskaia, (c) Serovskaia, (d) Kitolskaia, and (e) Glazkovskaia. Microblades and slotted tools incorporating microblades were characteristic features of the Khin'skaia and Isakovskaia traditions (Базалийский, 2012). The concept of the Cis-Baikal Neolithic gained international recognition and contributed to renewed scholarly exchanges between the USSR and the United States. Notably, it led Aleš Hrdlička to revisit Irkutsk in 1938, marking his second visit to the region (Окладников & Василевский, 1976). This visit helped foster a convergence between Soviet and American archaeological discourses.

Okladnikov's publications on Siberian microblade industries provided foundational support for theorizing cultural connections between the Siberian Neolithic and the ancestral populations of the Eskimo. For instance, Henry B. Collins (1943) highlighted similarities between Siberian slotted knives fitted with microblades and the Crooked knives of Eskimo traditions. Although active excavations in the Soviet Union largely ceased during the 1940s due to wartime disruptions, intellectual exchange persisted. Facilitated by the Society for the Promotion of Cultural Relations with Foreign Countries (VOKS), and with the support of its president, V. S. Kemenov, American archaeologists received Soviet books, journals, and manuscripts in February 1942 (Field & Prostov, 1942). However, in his own research, Collins (1943) primarily referenced pre-revolutionary works by B. E. Petry, V. Tolmachev, and N. I. Vitkovsky.

In addition to Siberia, North America, and Mongolia, Manchuria emerged as another significant area in early microblade research. Archaeological investigations in this region were primarily conducted by the "Manchuria Research Society," composed largely of Russian emigrants alongside several Japanese scholars. In Manchuria, studies of microblade industries were closely linked to broader research on the Neolithic period. In 1928, excavations near the town of Hailar were led by E. I. Titov and V. Y. Tolmachev on behalf of the Manchuria Research Society. Artifacts were recovered from the area between the Argun and Imingol Rivers, with microblade cores—referred to as *core-scrapers*—identified as the dominant tool type. Titov and Tolmachev noted that these cores closely resembled those previously described by B. E. Petry (Титов & Толмачев, 1928).

Although Titov was a student of Petry (Алкин, 2009), his methodological approach diverged significantly. In his paper "Remains of Neolithic Age in the Vicinity of Hailar as Discovered by the Explorations of 1928," Titov proposed that Asia was the origin of the European Neolithic and attempted to support this hypothesis using Manchurian archaeological data. His argument was bolstered by extensive references to archaeological sites in Manchuria and other regions of China that he believed supported this diffusionist model.

Additionally, Titov and Tolmachev engaged critically with the work of Japanese scholars. They strongly rejected Ryuzo Torii's theory (Torii, 1915), which posited the migration of Tungusic peoples from Altai and Turkestan into Eastern Mongolia and Southern Manchuria during the Neolithic, and identified these groups as part of the northern branch of the Japanese ethnogenetic tree. However, they were more receptive to Sozaburo Yagi's hypothesis (Yagi, 1924) linking the Manchurian Neolithic to the ancient Sushen and Yilou tribes (Титов & Толмачев, 1928).

Thus, several key features characterize the study of microblade technology during the late 19th and first half of the 20th century. One notable issue was the absence of standardized terminology. Researchers used a range of terms to describe microblades—such as *knife-like bladelets*, *small lames*, *awls*, and *prismatic flakes*. Similarly, microblade cores were variously referred to as *scraper-cores* or *semi-polyhedral cores*. Nonetheless, some consistency in terminology emerged within specific academic lineages, reflecting relationships between mentors and students in different archaeological schools.

Another significant characteristic of early microblade research was the tendency to treat microblade-related artifacts as isolated typological categories. This analytical separation often led to a lack of recognition of the technological and functional interconnections between different elements of microblade industries. In many cases, researchers failed to associate microblade artifacts with osseous (bone) tool industries, and some microblade products were even misclassified as belonging to unrelated technological traditions. In other words, there was no unified conceptual framework for understanding microblade technology or industry during this period.

The holistic interpretation of microblade technology as a coherent and integrated phenomenon did not begin to emerge until the second half of the 20th century. This stage in the history of research can be characterized as a period of primary data accumulation. However, even from the earliest phases of microblade studies, these artifacts were associated with investigations into intercontinental migrations and other large-scale socio-cultural processes in Asia.

1.2. Establishment of microblade studies in second half of XX century

During the 1960s and 1970s, one of the main trends in microblade studies was the unification of collected data and the development of standardized

terminology for artifacts and their components. Another significant trend was the emergence of new methods and approaches for analyzing microblade industries.

In cultural-historical studies of Northern Asian Stone Age sequence by A.P. Okladnikov wedge-shaped microblade cores had an important role (Vasil`ev, 1993). From his perspective, the "Gobi type" of microblade core represented a transitional or end-to-end form that indicated a technological and cultural link between the prehistoric cultures of Siberia and Alaska (Окладников, Василевский, 1976).

Noteworthy milestones from this period include the North American Seminar held in Ottawa from November 25–27, 1969, and a series of influential publications by scholars such as G. I. Medvedev, Z. A. Panichkina, Z. A. Abramova, I. P. Laricheva, K. Hayashi, D. Sanger, and J. S. Aigner. In 1959, Z. A. Panichkina (Паничкина, 1959) introduced the term "wedge-shaped core" (клиновидный нуклеус), which was later fully defined by G. I. Medvedev as: “a wedge-shaped core has a clear convergence of lateral edges forming a keel, or a ridge and a keel in combination” (Медведев и др., 1974). The creation of a unified definition was critical during the 1970s due to the absence of a standardized typology across Northern Asia (Медведев и др., 1974). Concurrently, the term “boat-shaped core” was also in use (Hayashi, 1968; Morlan, 1966), known in Soviet and Russian archaeology as *ladievidnyi*. Terminology for individual structural elements was also being developed: for example, "front" (Sanger, 1970), "platform contour", and the "longitudinal" and "transversal axes" of the platform (Hayashi, 1968). In addition, a terminological framework for microblade morphology was introduced. Based on materials from the Anangula site (Aleutian Islands), Aigner proposed terms for various blade elements, including the *margin* (¼ of the width from the edge), and the *proximal*, *medial*, and *dorsal* parts of the blade (Aigner, 1970).

Numerous significant methodological contributions from this period were conducted by Japanese scholars. T. Yamahara and Y. Terasaki divide the research history of the Paleolithic in Hokkaido into four distinct periods. The first, centered in the 1950s, was marked by the initial accumulation of archaeological data and the extensive application of Quaternary geological methods. The second period, spanning the 1960s to 1970s, was characterized by efforts to systematize the growing body of evidence. However, it was also marked by methodological contradictions, particularly in distinguishing between microblade cores and burins. A concurrent development was the use of microblade core types as potential chronological markers. The third period, extending from the 1980s to the mid-1990s, saw the refinement of a techno-typological approach, which ultimately helped resolve the "microblade core vs. burin" debate. The fourth period, beginning in the late 1990s, is characterized by a multidisciplinary framework, incorporating studies of raw materials, production technology, and the functional analysis of microblade industries (Terasaki, Yamahara, 1999).

The first period of Paleolithic research in Hokkaido is associated with the emergence of the “Sen-Doki” (pre-pottery) concept. This term refers to the archaeological stage preceding the Jomon period. The discovery and excavation of the Iwajuku site in 1949 in Gunma Prefecture marked a turning point, establishing the presence of a pre-ceramic phase in Japanese prehistory. In Hokkaido, pre-ceramic sites began to be excavated and published in the late 1950s by researchers such as S. Chosuke, Y. Masakazu, O.Toshio, and K. Sakuzaemon. According to the prevailing framework of this period, the cultural succession of pre-ceramic assemblages in Hokkaido was understood as follows: (1) Shirataki locations 27, 4, 13, 33, and 30; (2) Sakkotsu; (3) Tachikawa; and (4) Yubetsu. Within this framework, microblade technology was considered to have first appeared in association with the Sakkotsu complexes. More broadly,

the Paleolithic assemblages of Hokkaido were attributed to the Araya cultural tradition, which is distributed across northeastern Japan (Sugihara & Tozawa, 1961).

The most prominent feature of the second period was the debate over the identification of microblade cores and burins. This controversy highlighted fundamental methodological contradictions between morphological typology and technological typology (Takakura 2020). A notable example is H. Ohi interpretation of materials associated with the Tougeshita method from the Taisho site, which he classified as burins and burin spalls (Ohi, 1963). These divergent interpretations underscored the limitations of morphology-based classification when applied to complex lithic technologies. The debate was eventually resolved through the adoption of the technique-typological approach, which emphasized the reconstruction of reduction sequences and technological intention (Takakura, 2020).

One of the key breakthroughs of the second period was implementation of refitting block analysis in the study of microblade industries. This methodological advancement enabled Yoshizaki Masakazu to reconstruct and describe the Yubetsu method of microblade core reduction. By refitting ski spalls and bifacial blanks recovered from the Shirataki 33 site, he successfully demonstrated the sequential stages of the Yubetsu reduction process (Yoshizaki, 1961).

Another methodological breakthrough of the methodology of microblade studies in Japan was K. Hayashi's 1968 work, *The Fukui Microblade Technology and Its Relationship in Northeast Asia and North America*. In this study, Hayashi developed and applied a technical-typological method of analysis. He defined technology as the sum of processes involved in both the production and use of microblades, though his focus lay primarily on

production, viewing it as a reflection of methodical traditions passed through generations. According to K. Hayashi, functional analysis was not suitable for correlating archaeological complexes; thus, his typological framework relied solely on morphological characteristics—such as orientation, preform types, and blank forms—without incorporating experimental research into lithic tool use (Hayashi, 1968).

Another issue extensively discussed during the 1960s and 1970s was the relationship between microblade industries and migration processes across Northern Asia. K. Hayashi argued that the emergence of microblade industries in the Japanese Archipelago was the result of migratory movements originating from the Lake Baikal region, which dispersed and branched out across Northern Asia. In his view, core reduction techniques such as the Yubetsu and Towarubetsu methods represent distinct branches of this broader technological impulse. K. Hayashi noted significant technological correlations between the Fukui and Towarubetsu methods, as well as with continental materials (Hayashi, 1968). However, some scholars expressed skepticism regarding such interregional comparisons due to the absence of a unified classification system and standardized terminology for microblade industries at the time (Медведев и др., 1974).

During the third period, most of the known methods of microblade core reduction were described (Nakazawa, Yamada, 2015). An important tendency of this period was the partial rethinking of previously defined technological types within the framework of the technique-typological methodology. It was during this time that the concept of techno-complexes was formulated. For instance, H. Kimura grouped the Yubetsu, Horoka, and Pirika methods into a single Yubetsu-Horokazawa technological complex (Kimura, 1992). Additionally, the multidisciplinary tendencies that define the modern stage of microblade industry research began to emerge in the 1980s–1990s. For example, investigations into

raw materials and striking techniques used in the microblade industries of Hokkaido commenced in the 1980s (Orikasa, 1992).

The modern period of microblade studies is characterized by the unification of microblade core typology (Nakazawa et al., 2005), the adoption of multidisciplinary approaches, and the emergence of processual tendencies. Multidisciplinary approaches include investigations into both the function and production technology of microblades. Functional analyses of microblade complexes were conducted at sites associated with the Pirika and Oshorokko methods, specifically at the Kashiwadai 1 and Yoshiizawa sites, respectively. These studies employed both high- and low-magnification microscopy. In both cases, the geography, flora, and fauna of the Paleo-Sakhalin–Hokkaido–Kuril Peninsula (Paleo-SHK) were analyzed to draw conclusions about adaptive strategies and settlement patterns. The sample selections were non-random and focused primarily on formal tools (Iwase, 2016; Iwase et al., 2016).

At the Kashiwadai 1 site, 120 microblades were analyzed. The results suggest that microblades functioned primarily as hunting-related implements. According to Akira Iwase, projectile points inset with microblades represent an adaptation to the mammoth steppe environment in the southern Paleo-SHK peninsula. He also raises the issue of the relationship between microblade technologies and osseous tools (i.e., those made from antler, bone, and ivory) in the context of microblade dispersal (Iwase, 2016).

At the Yoshiizawa site, 454 artifacts were sampled and analyzed, including 18 microblades and one platform spall. Microscopic use-wear analysis revealed no clear evidence of use on the microblades. Nonetheless, the authors suggest a correlation between artifact morphology and function, concluding that microblades were associated with a limited range of specific tasks. From their

perspective, this pattern implies that microblade complexes were linked to systems of low residential and logistical mobility (Iwase et al., 2016).

According to T. Yamada, the standardization of stone tools serves as an indicator of task-specific activities and increased logistical mobility (Yamada, 2006). A milestone in adaptation studies was the publication *"Toward an Understanding of Technological Variability in Microblade Assemblages in Hokkaido, Japan"* (Nakazawa et al., 2005). The authors highlighted the lack of persuasive hypotheses regarding the formation processes underlying technological variability. The central argument of the article is a geoarchaeological explanation for such variability during OIS-2. From this perspective, the observed differences in microblade assemblages were shaped by unique regional environmental conditions, which the authors reconstructed through extensive geological surveys and paleolandscape analysis.

As a result, the study introduced key questions concerning behavioral variability, including group mobility strategies, the risks and costs associated with microblade production, and the transportability of lithic materials. Additionally, the authors emphasized the need to reexamine existing classifications of microblade core types (Nakazawa et al., 2005).

These research goals were partly addressed in subsequent studies. One such effort involved the reexamination of microblade core typologies through the mathematical evaluation of technocomplex richness. By comparing the richness index across different chronological phases, the authors aimed to assess diachronic changes in the composition of technocomplexes (Nakazawa, Yamada, 2015). Further investigations into mobility, risk, and cost were carried out through analyses of the Sakkotsu and Oshorokko core reduction methods. In these studies, the authors applied mathematical formulas to estimate risk management strategies associated with each method. They also explored the

relationship between risk management and the transportability of microblade cores, linking these variables to mobility patterns among Upper Paleolithic populations in Hokkaido (Nakazawa, Akai, 2016).

The research history of microblade technologies in Northeast Asia and Alaska in the second half of XX century has been significantly shaped by studies of the Dyuktai Paleolithic Culture in Siberia, as well as Denali Complex and Norton Tradition of Alaska. The Dyuktai Culture, first defined by Yuri Mochanov (1977), established Siberia as a key source of microblade technology transmission to the New World, with wedge-shaped cores and pressure-flaking techniques linked to Beringian migrations (Goebel, 2002).

In Alaska, the Denali Complex (c. 12,000–6,000 BP), identified by F. West (1967), shared technological similarities with Dyuktai, supporting theories of a Pleistocene microblade dispersal into the Americas (Potter, 2011). By contrast, the Norton Tradition (c. 3,000–1,000 BP) exhibited sporadic microblade use, suggesting either cultural continuity or reinvention/cultural convergence (Dumond, 1982; Anderson, 1988). These complexes remain central to debates on human adaptation, migration, and technological innovation in circumpolar regions.

One of the most significant contributions to microblade research at the beginning of the twenty-first century was the publication of the volume *Thinking Small: Global Perspectives on Microlithization*. In this work, the emergence and development of microblade technology were examined within the broader global phenomenon of microlithization, observed in regions such as Australia, Western Europe, and Africa. The volume includes four chapters specifically devoted to microblade technology in Japan (Bleed, 2002), Siberia (Goebel, 2002), North America (Yesner & Pearson, 2002), and Northern Asia more broadly (Elston & Brantingham, 2002).

The major outcomes of this period include, first and foremost, the recognition of microblade technology as a distinct and coherent phenomenon. Secondly, this era marked the initial development of a terminological register aimed at standardizing the description of microblade industry products. Thirdly, it saw the emergence of the techno-typological method of analysis, which provided a systematic framework for investigating lithic assemblages. Lastly, studies of problematic microblade industries and interregional connections gained momentum within the framework of the cultural-historical approach, emphasizing the role of cultural diffusion and migration in shaping technological traditions.

1.3. Technological and Functional Studies of microblades (1980s–2000s)

The 1980s–1990s marked a significant shift toward the development of technological and functional approaches in microblade studies. A particularly notable advancement during this period was the emergence of experimental research focused on core preparation and microblade production by pressure flaking. Early experiments with wedge-shaped microblade cores were carried out by R. Bonniksen and R. Morlan, who used indirect percussion for production of microblades from Horoka and Yubetsu-type cores fixed in a vice made of two wooden boards. In 1983, a further important experiment was conducted by Sollberger and Patterson, who applied pressure using a lever press on conical microblade cores also secured in a wooden vice. E. Callahan later contributed a key innovation with the design of a handheld vice suitable for manual pressure flaking, a concept further developed by A.V. Tabarev, who proposed the use of portable vices in the prehistoric stone industries of Northeastern Asia (Табарев, 2008). J.J. Flenniken's experimental work, based on materials from the Dyuktai culture in Siberia, not only replicated microblade production by pressure but also explored raw material selection and the use of heat treatment in core preparation (Flenniken, 1987).

One of the most significant contributions to the technological study of microblade industries was made by the editors and contributors of the volume *The Emergence of Pressure Blade Making*. Within this work, microblade technology is situated within the broader context of pressure blade production—a field of study with deep roots in ethnographic observations. The concept for this collective monograph was initially discussed in 2006 by N. Rahmani and P.M. Desrosiers (Desrosiers, 2012). The volume includes notable chapters by scholars such as J. Pelegrin and J. Takakura. In his contribution, J. Pelegrin introduced a theoretical framework outlining five distinct modes of pressure blade production, differentiated by the position of the flintknapper, the types of implements employed, and the dimensional characteristics of the resulting blades. Additionally, Pelegrin addressed the influence of raw material properties on technological choices (Pelegrin, 2012). His model has since become a foundational reference for understanding the variability of pressure knapping and for highlighting the methodological potential of experimental archaeology in reconstructing prehistoric lithic technologies.

The chapter by J. Takakura represents another significant contribution to the technological discourse on microblade studies. He introduced the method of *fracture wing analysis* as a means to objectively determine the knapping technique employed in obsidian tool production (Takakura, 2012). This analytical method has proven particularly valuable in addressing questions surrounding the emergence of pressure blade technology in Hokkaido and, by extension, throughout Northern Asia. In parallel, an innovative theoretical model for understanding microblade core reduction was developed by P. Bleed using *Event Tree Analysis* (Bleed, 2002). This model incorporated the assessment of both failed and pending outcomes within the technological sequence, providing a structured framework for evaluating decision-making processes in lithic production. Bleed's approach laid the groundwork for

subsequent studies addressing the risk and cost of microblade core reduction—an important shift toward processual archaeology and the analysis of technological efficiency and adaptive strategies.

The functions of microblades have been investigated by numerous scholars across different countries. A comprehensive overview of the application of use-wear analysis to microblade industries is provided in Chapter 2.

In recent decades materials of microblade sites provided foundation to speculations about patterns of adaptation of Upper Paleolithic Hunter-Gatherers. T. Goebel examined microblade technology within the framework of Siberia's recolonization following a hiatus during the Upper Paleolithic. Through analysis of the spatial organization of archaeological sites, the quantity of curated tools, and the size of prey species, he argued that Paleolithic hunter-gatherers in Siberia exhibited high mobility. In this context, microblade cores are interpreted as multifunctional core-tool-weapon complexes, conceptually analogous to the bifaces used by Paleoindian groups. Consequently, microblade technology is viewed as a technological adaptation reflecting the high mobility of Siberian hunter-gatherers (Goebel, 2002).

A notable example of adaptive strategy research is the study by Y. Nakazawa and F. Akai, who applied mathematical-statistical methods and derived formulas based on the number of microblades produced by the Oshorokka and Sakkotsu methods. Using these data, the authors assessed the relative risk and efficiency associated with each production strategy. Their analysis concluded that the Sakkotsu method is better suited to high-mobility foraging strategies in varied landscapes, which may explain its broader distribution. Although this diffusion could be partially attributed to migration, the authors emphasize cultural transmission as the primary mechanism driving the spread of the Sakkotsu method (Nakazawa & Akai, 2017).

Conclusion

The research history of microblade industries spans more than a century and remains a dynamically evolving field within modern archaeology.

Period of late 19th – Early 20th Century could be characterized as a period of descriptive archaeology and Imperial Science. Communication of findings of microblades in this period occurred mainly through descriptive publications and personal correspondence. Knowledge transfer was uneven: Siberian materials entered European discourse slowly and were often interpreted through European Paleolithic frameworks (e.g., "Magdalenian" analogies), reflecting asymmetrical intellectual exchange. Japanese archaeologists of this period were primarily concerned with ethnogenesis, not lithic technology. Fieldwork were mostly conducted in colonial territories (Manchuria, Korea, Sakhalin) and Microblades were often classified as burins, scrapers, or knife-like flakes, mirroring early Siberian misclassifications. Lithic evidence was subordinated to racial-historical narratives, especially attempts to link Northeast Asian populations to the origins of the Japanese people.

The interwar Period`s key features are Diffusionism and Transcontinental Comparisons. Between the 1920s and 1930s, microblade research became embedded in diffusionist models explaining cultural similarities across Eurasia and North America. Expeditions to Mongolia, Alaska, and Manchuria created comparative datasets that encouraged cross-regional synthesis. Scholars of this period actively compared assemblages across political and cultural boundaries, while debates over origins (Asia → Europe, Siberia → Americas) shaped interpretation. Knowledge circulated through international journals, expeditions, and scholarly travel, despite growing geopolitical tensions. The following period of 1940s characterized as a period of active Soviet-American exchange. Although World War II curtailed fieldwork, intellectual exchange persisted

through translations, book exchanges, and organizations such as VOKS. American researchers relied heavily on pre-revolutionary Russian literature, illustrating how earlier publications continued to mediate cross-regional knowledge flow. The postwar period is characterized by methodological convergence and standardization. From the 1960s–1970s, microblade studies entered a phase of international methodological convergence. Conferences (e.g., Ottawa 1969), collaborative publications, and parallel research traditions in the USSR, North America, and Japan fostered shared terminology and analytical frameworks. Japanese archaeology played a particularly important mediating role, synthesizing continental and insular data while advancing refitting and techno-typological methods. The period of late 20th – early 21st centuries is a period of global integration and multidisciplinarity. By the 1980s–2000s, microblade research operated within a global scientific context shaped by experimental archaeology, processual theory, and advanced analytical techniques. Ideas circulated rapidly through international volumes, collaborative projects, and shared methodological standards. Microblade technology became a comparative platform for studying mobility, risk, and adaptation, transcending earlier diffusionist narratives and emphasizing cultural transmission and behavioral variability.

Despite significant advancements, several core research problems identified as early as the 1970s–1980s remain relevant today. These include the lack of a unified and widely accepted terminology—particularly across different languages such as Russian—the analysis of interregional connections between Asian and American microblade assemblages, the investigation of associated migration processes, and continued studies on the technology and function of microblades.

Contemporary research trends increasingly emphasize international collaboration and interdisciplinary integration. Notably, regional archaeological

research is becoming more interconnected, and studies of microblade industries are beginning to incorporate broader frameworks, such as genetic research on population dynamics during the Paleolithic. These developments promise to shed new light on long-standing questions and open new avenues for understanding the cultural and technological complexities of prehistoric societies.

Chapter 2. Materials and Methods

2.1. Theoretical background

2.1.1. Conceptions of microblade technology emergence

The definitions of "microblade" and "microblade technology" vary depending on the theoretical approach adopted. These approaches can be broadly categorized into three branches: functional, morphological, and techno-metric.

The functional approach is exemplified in the works of H. Ohi, who defines microblades based on their use. Ohi states, "...if the blades were used inserted without modifications, the author [Ohi] prefers to call them microblades" (Ойи, 1980). While conceptually comprehensive, this definition is challenging to apply to specific archaeological materials due to its reliance on inferred use rather than observable physical attributes.

The morphological approach focuses on the physical characteristics of microblades, distinguishing them from other lithic artifacts through metric parameters. According to this framework, microblades are characterized by their small size (bladelets), parallel margins, dorsal facets, and the alignment of the knapping axis with the dorsal ridges (Бердникова, 2003). This approach emphasizes the formal attributes of microblades, making it more applicable to archaeological analysis.

The techno-metric approach defines microblades as products of specific technological operations with precise dimensional criteria. Y.A. Gómez Coutouly (2018) synthesized various definitions and proposed terminal limits for microblade dimensions: 50 mm in length, 7 mm in width, and approximately 2 mm in thickness. Additionally, this approach highlights the systematic production of microblades from wedge-shaped or conical cores, often through pressure knapping techniques (Graf, 2010; Terry et al., 2016).

From these definitions, several key features of microblades can be identified:

1. Linear dimensions: Microblades are typically small, with specific size thresholds.

2. Production from prepared cores: They are systematically detached from specially prepared conical or wedge-shaped microblade cores.

3. Standardization and regularity: Microblades exhibit consistent morphological and technological traits, reflecting controlled production processes.

In this study, the author adopts the techno-metric approach to define the term “microblade,” as it provides a clear, measurable framework for identifying and analyzing these artifacts within archaeological contexts.

The emergence of microblade technology is a subject of significant scholarly debate, with six primary hypotheses proposing distinct geographic and temporal origins: (1) in Siberia before the Last Glacial Maximum (LGM) (Kuzmin et al., 2007); (2) in Siberia immediately after the LGM (Goebel, 2002); (3) in Northeastern China, based on a long tradition of prismatic flake production (Chen, 1984); (4) on the Korean Peninsula (Seong, 2011); (5) in the Paleo-Sakhalin-Hokkaido-Kuril Peninsula region (Takakura, 2012); and (6) as a result of multi-regional convergence (Barton et al., 2007).

The hypothesis of microblade technology originating in Siberia, particularly around Lake Baikal, was widely accepted during the latter half of the 20th century (Chun and Xiang-Qian, 1989). Evidence from the Altai region, including wedge-shaped microblade cores dated to approximately 35,000 B.P., supports this hypothesis (Derevianko et al., 1998). The Ust'-Karakol variant of the Altai Upper Paleolithic, dated to around 40,000 B.P., is often cited as the earliest manifestation of microblade technology, evolving from local Middle Paleolithic traditions. Artifacts from sites such as Ust'-Karakol 1, Denisova Cave, Anui 3, Tumenchina 4, and Strashnaya Cave include prismatic, conical, and wedge-shaped "tortsovyi" cores, backed bladelets, and geometric microliths (Деревянко et al., 2003).

The Kara-Bom variant further supports this hypothesis, with technological analyses suggesting early microblade production. However, these studies focus on pressure retouching rather than pressure flaking, complicating claims about the origins of pressure knapping in the Middle Paleolithic. Small bladelets in Kara-Bom industries are produced using sub-prismatic and "narrow edge" (tortsovyi) techniques (Славинский et al., 2017). A key critique of this hypothesis is its broad definition of "microblade," which does not consistently align with pressure knapping techniques.

Y.A. Mochanov proposed another pre-LGM hypothesis, suggesting that microblade technology emerged in eastern Yakutia based on materials from sites such as Ikhine 2, Ezhantsy, and Ust'-Mil' (Fig. 3: 1–4). This "Proto-Duktai" model (Мочанов, 1977) has been extensively criticized for its lack of robust evidence (Абрамова, 1979; Yi et al., 1985).

The hypothesis of microblade technology emerging in Siberia after the LGM is supported by several scholars. T. Goebel (2002) argues that microblade technology developed as an adaptive response to the post-hiatus recolonization

of Siberia, evolving from Middle-Upper Paleolithic industries. Evidence from sites such as Mal'ta, Igeteiskii Log, Ui-1, and Kashtanka, dated to approximately 25,000–20,000 B.P., supports this view. Goebel posits that microblade technology appeared around 18,000 B.P., following the LGM.

V.V. Pitul'ko (2010) links the emergence of microblade technology to the decline of the mammoth population in Siberia. The reduction in mammoth numbers created "raw material stress," leading to the innovation of slotted points with microblades. Radiocarbon dating of sites with abundant mammoth remains supports this hypothesis, aligning the emergence of microblade technology with the extinction of woolly mammoths in the region.

Despite these hypotheses, archaeological sites predating 18,000 B.P. in Eastern Siberia, such as Verhnetroitskaya Cave and Kurla I (Fig. 4: 5–8), suffer from poor geological contexts or unreliable radiocarbon dates (Goebel, 2002; Молчанов et al., 2019). The Krasnyi Yar site, with wedge-shaped microblade cores dated to 25,000–22,000 B.P. (Бердникова et al., 2021), is often cited as evidence for early microblade technology. However, the loss of the Krasnyi Yar collection undermines its reliability as a foundation for this hypothesis.

The hypothesis of microblade technology emerging in Northeastern China is based on a long tradition of prismatic flake production (Chen, 1984). This model, popular among Chinese scholars from the 1970s to the 2000s, proposes that microblade industries originated in the middle Yellow River region and spread eastward to the Korean Peninsula and the East China coast (Fig. 5). However, this hypothesis lacks robust testing on specific archaeological materials (Shen, 2007). Current discoveries of microblade assemblages in Xishantou, Xishahe, Shizitan and other sites indicated emergence of microblade technology in Northeastern China around 28-30 cal ka. However, earliest microblade assemblages represent not wedge-shaped microblade cores but

variable boat-shaped, narrow-faced, cylinder and pyramidal morphologies (Takakura, 2024).

At least 17 archaeological sites on the Korean Peninsula contain microblade assemblages. The oldest sites, such as Sokchangni, Shinbuk, Hopyeong-dong, Daejeong-dong, Jangheangni, and Suyanggae, have yielded microblade components. However, the dating of Sokchangni and Shinbuk varies by approximately 10,000 years, making their chronologies unreliable. The Jangheangni site has two proposed dates for its microblade complex: 30,500–28,000 cal B.P. and 22,500–18,000 B.P. Currently, the most reliable dates are 28,200–24,550 cal B.P. for Hopyeong-dong (fig. 6: 3–7) and 18,900–18,200 cal B.P. for Suyanggae (Gomez Coutouly, 2018). C. Seong (2011) argues that the dates from Jangheung-ri (29,550±800 cal B.P. and 29,200±1,250 cal B.P.) and Sinbuk (30,150±600 cal B.P. and 28,750±600 cal B.P.) support the independent emergence of microblade technology on the Korean Peninsula around 30,000 years ago.

Hokkaido is another proposed region for the emergence of microblade technology. The Kashiwadai 1 site, dated to around 20,000 B.P., is the earliest microblade site on the island (Takakura, 2012). The discovery of the Kashiwadai 1 microblade complex (fig. 7) supports M.L. Inizan's hypothesis that microblade technology emerged in Northern Asia around 20,000 B.P., with pressure debitage as a key component (Inizan et al., 1992).

Recent studies suggests that microblade technology *sensu lato* emerged in Northeastern China and the Korean Peninsula around 28,000–30,000 cal BP, but initially, it was characterized by diverse core morphologies such as boat-shaped, narrow-faced, cylindrical, and pyramidal forms (Takakura, 2024). The origins and spread of wedge-shaped microblade cores and particular methods of reduction, such as Yubetsu, a hallmark of later microblade industries, remain the

subject of debates. The principal contradiction between pre-LGM and post-LGM hypotheses lies in the definition of microblade technology. Pre-LGM conceptions focus on core morphology and bladelet size, while post-LGM hypotheses emphasize pressure debitage as a defining feature (Gomez Coutouly, 2018). Post-LGM hypotheses often frame microblade technology as an adaptive response to climatic and environmental changes (Goebel, 2002; Питулько, 2010), whereas pre-LGM hypotheses view it as an evolutionary development of local Middle-Upper Paleolithic traditions (Chen, 1984; Мочанов, 1977; Деревянко et al., 2003).

The majority of hypotheses regarding the emergence of microblade technology are not mutually exclusive. The independent emergence of microblade industries in Siberia after the LGM (Goebel, 2002) and on the Korean Peninsula before the LGM (Seong, 2011) suggests the possibility of convergent evolution. Based on current evidence, three primary regions—the Korean Peninsula, Hokkaido, and Northeastern China—are likely centers of convergent microblade technology emergence. Applying theories of cultural transmission and cultural convergence may further clarify the origins, spread, and nature of microblade technology in Northeastern Asia.

2.1.2. Theory of cultural transmission

The concept of cultural transmission, initially formulated by F. Ratzel within the framework of migrationism, is rooted in the idea of *Kulturkreis* (cultural circles) (Клейн, 2011, p. 354). Ratzel defined cultural transmission as the mechanism of influence, reciprocity, and transfer of cultural information across space and time. In contrast, cultural convergence refers to the independent emergence of similar phenomena in different social groups. Ratzel hypothesized that convergence in material culture could occur only for utilitarian artifacts, not for artistic or symbolic elements (Клейн, 2011).

Cultural transmission and cultural diffusion are closely related concepts in archaeology. Cultural diffusion is defined as “transmission by contact, and thus the spread of norms from one person to another and more broadly from people of one local tradition to another” and “the process in which an innovation is communicated through certain channels over time among members of a social system” (Storey and Jones, 2011). Both concepts deal with cultural interaction between social groups, but they differ methodologically.

While different models of cultural diffusion are useful, they are more applicable to agricultural societies and cases involving linguistic data (Storey and Jones, 2011). The most applicable for Paleolithic studies model of cultural diffusion is Stimulus Diffusion. According to this model, cultural information might spreads through low-intimacy social contacts.

The systematic theory of cultural transmission was developed by L.L. Cavalli-Sforza and M.W. Feldman, who applied an evolutionary framework to cultural processes. They compared cultural information transmission to genetic transmission, treating cultural innovations as analogous to biological mutations. Their quantitative approach, based on epidemiology and genetics, focused on population-level analysis (Cavalli-Sforza et al., 1982).

Cavalli-Sforza and Feldman defined cultural transmission as the acquisition of behaviors, attitudes, or technologies through imprinting, conditioning, imitation, teaching, and learning. They classified cultural transmission into three modes (Cavalli-Sforza et al., 1982):

1. Horizontal Transmission: Transfer of cultural information between individuals of the same generation.

2. Vertical Transmission: Transfer between generations (e.g., from parents to children).

3. Oblique Transmission: A combination of horizontal and vertical transmission, often associated with migration.

They also identified three modes of transmission (Cavalli-Sforza et al., 1982).:

1. Many-to-One: Associated with conservative social structures, characterized by slow cultural change.
2. One-to-Many: Involves rapid cultural change with low variability (e.g., teacher-student relationships).
3. One-to-One/One-to-Few: Involves moderate rates of cultural change and promotes heterogeneity within and between generations.

R. Boyd and P.J. Richerson further developed cultural transmission theory by emphasizing social learning as the primary mechanism of cultural inheritance. They introduced the concepts of biased and unbiased transmission. Biased transmission includes:

1. Direct Bias: Preference for certain cultural traits.
2. Indirect Bias: Includes prestige-based and conformist transmission, where individuals adopt traits based on their perceived social value or frequency (Boyd and Richerson, 1985; 2005).

In their book *The Origin and Evolution of Cultures*, Boyd and Richerson explored the role of adaptation in cultural evolution and the reconstruction of cultural phylogenies. They argued that social learning is a form of adaptation, enabling the transmission of cultural traits across generations (Boyd and Richerson, 2005).

J.W. Eerkins and C.P. Lipo introduced the concepts of content and context in cultural transmission. Content refers to the cultural information being transmitted, while context refers to the cultural environment in which transmission occurs. They emphasized the complexity of information, its presentation, and the cognitive and social filters that influence transmission (Eerkins and Lipo, 2005; 2007).

P. Jordan's *Technology as Human Social Tradition* (2014) synthesizes the ideas of Cavalli-Sforza, Feldman, Boyd, Richerson, Eerkins, and Lipo. Jordan defines tradition as the material manifestation of a transmission system in which cultural information is inherited, reproduced, and transformed. His framework examines the role of technology in human societies, focusing on:

1. Congruence: Mutual influence between cultural traditions.
2. Propagation: Reproduction of traditions through social learning.
3. Coherence: The content and genealogy of cultural traits (Jordan, 2014).

Jordan's concept of cultural traits—defined as the sum of operational sequences, including choices in raw material selection, processing methods, and design—aligns closely with the archaeological concept of *habitus* (Bourdieu, 1977). However, while habitus is limited to vertical transmission, cultural traits can propagate through horizontal and oblique transmission, making Jordan's framework more versatile for studying cultural change and innovation.

Another theoretically developed model of cultural information spread is Stimulus diffusion. Stimulus diffusion refers to the spread of ideas about an object rather than the specific technology of its manufacture. This process often occurs over long distances or between culturally distant groups. In contrast, technology diffusion requires close social intimacy, as it involves complex,

embodied practices that are taught and learned through extended interaction (Tostevin, 2007).

The distinction between stimulus diffusion and cultural convergence lies in the evidence of social contact. Stimulus diffusion results in artifacts with similar morphologies but different production technologies, while cultural convergence involves independent innovation. Differentiating these processes requires analyzing the geographical spread, chronology, and technological details of artifacts (Tostevin, 2019).

Cultural transmission theory provides a robust framework for studying the spread and evolution of microblade technology in Northeastern Asia and Beringia. By examining the lineage of material culture, deviations, and cultural exchange, researchers can reconstruct the social processes underlying technological change. This approach requires detailed analysis of *chaîne opératoire*, chronology, and geographical distribution, enabling the identification of social contacts and the directions of cultural influence.

The value of this theoretical approach lies in its role as a middle-range explanatory model for describing the spread of broadly similar artifact types that nevertheless differ in technological reduction sequences, morphology, and other attributes. In other words, the model can account for distributions of lithic technologies that cannot be adequately explained by direct cultural transmission. Another important contribution of stimulus diffusion as a concept is that it addresses a different form of human interaction—social contacts of relatively low intensity—distinguishing it from models based on close social learning or direct transmission.

2.1.3. Cultural transmission theory and concept of cultural convergence in microblade technology studies

Cultural transmission theory has been applied to the study of microblade industries in various contexts. Initially, it was used as a framework to explain the interregional spread of microblade technology (Takakura, 2019). However, in these studies, cultural transmission was often invoked as a general concept without supporting quantitative or qualitative investigations.

Intra-regional studies of microblade industries within the framework of cultural transmission theory have primarily relied on qualitative research. For example, investigations into the late Pleistocene–early Holocene period in the Lower Vitim region focused on the semiotic characteristics of artifacts and the role of social learning. Artifacts from this period were interpreted as "indicators of the emergence of new types" (Тетенькин, 2015). The coexistence of three synchronous assemblage types—Bol'shoy Yakor' (Yubetsu microblade cores), Avdeiha (vertically oriented wedge-shaped microblade cores), and Bol'shaya Severnaya (conical microblade cores)—was interpreted as evidence of durable and stable vertical cultural transmission (Тетенькин, 2015).

Another example is the study of microblade assemblages in Northeastern China by L. Barton and colleagues. They concluded that the spread of microblade technology in this region resulted from prestige-biased cultural transmission, a mode that facilitates the rapid dissemination of cultural behaviors within and between spatially structured populations. Barton et al. (2007) argue that the broad and rapid spread of microblade technology across northeastern Asia was driven by social transmission rather than migration or colonization. This process was enabled by the emergence of coordinated, group-functional institutions during the environmental deterioration of the Last Glacial Maximum (LGM).

Unlike cultural transmission, cultural convergence is not tied to a specific theoretical framework. However, it is deeply relevant to Paleolithic archaeology, particularly the study of microblade industries. Cultural convergence, like cultural transmission, draws on concepts from evolutionary biology. For instance, M.J. O'Brien defines cultural convergence as "the phenomenon by which evolutionary processes result in the same, or similar, forms in independent lineages due to functional or developmental constraints." In the context of stone tools, identifying convergence is crucial because similarities in form and function are often mistakenly attributed to historical connections between prehistoric groups (O'Brien et al., 2018).

Another biological concept applied to cultural convergence is morphospace, which refers to the spectrum of possible variations in the development and material manifestation of a phenomenon. The boundaries of morphospace are defined by variations that are functionally or developmentally impossible (McGhee, 2018). Understanding an artifact's function is essential for identifying these limits, as cultural development can only occur within them. Thus, similarities in artifact morphology resulting from convergent evolution can be explained by the constraints imposed by morphospace.

The microlithization of stone tools during the late Pleistocene is often cited as a global example of cultural convergence. C. Clarkson and colleagues deconstructed the so-called "microlithic package" into three elements: backing, miniaturization (systematic production of small flakes from fine-grained stone), and microblade production from prismatic cores. They argue that these elements often occur independently and should not be uncritically treated as a unified package. Clarkson et al. (2018) reject the idea that the global spread of microliths resulted from diffusion or migration, instead attributing it to independent local developments driven by dramatic climate change and associated economic risks.

Evidence for the convergent evolution of microlithic technology includes (Clarkson et al., 2018):

- Indian and Southwest Asian backed-microlithic technologies, which are associated with microblade production;
- Howiesons Poort microliths in South Africa, made from small flakes produced using Levallois cores;
- The Robberg industry in South Africa, characterized by abundant microblades but few backed artifacts;
- The Holocene Wilton industry, which features numerous backed pieces but few microblades;
- Uluzzian, Sri Lankan, and Australian microliths, typically made on small flakes or bipolar flakes, with no evidence of microblade production.

Clarkson et al. (2018) conclude that the independent emergence of microlithic technology in different regions was a response to significant climatic and landscape changes, which necessitated small, standardized, transportable, and multifunctional tools. They argue that cultural convergence is the only viable explanation for the widespread but temporally disparate appearance of microlithic technology in regions with no recent common ancestry or direct contact.

In Beringia, cultural convergence has been studied through the Arctic Small Tool tradition and the Plateau tradition of North America, particularly the Denbigh and Lehman core types. These traditions share similarities with Asian microblade industries, such as the use of cobbles and chunks as raw materials and the use of weathered or natural surfaces as striking platforms. Given the

chronological gap between Asian microblade assemblages and the Arctic Small Tool tradition (3,000–1,000 B.C.) and the Plateau tradition (5,000–4,500 B.C. to 500 A.D.), these similarities are best explained as the result of cultural convergence rather than direct cultural transmission (Chun and Xiang-Qian, 1989).

The multiregional hypothesis, proposed by L. Barton and colleagues, suggests that archaeologists should examine each case of pre-LGM microblade industries independently rather than searching for a single origin. They argue that microblade technology likely emerged convergently and independently in multiple regions as an adaptive response to local conditions (Barton et al., 2007).

2.1.4. Application of lithic analysis protocol for the estimation of cultural transmission and cultural convergence

2.1.4.a. Lithic technology in the context of cultural transmission and cultural convergence

For a long time, studies of cultural transmission and the diffusion of lithic artifacts relied primarily on morphological analysis. However, the implementation of technological analysis and detailed descriptions of operational sequences have significantly enhanced our understanding of social and cultural connections in prehistoric societies.

The reconstruction of operational sequences has proven essential for tracing cultural transmission. For example, studies of Paleolithic bifacial industries in North America have demonstrated this approach. By examining the entire sequence of operations—from raw material selection to biface production and core reduction—researchers concluded that there was no cultural transmission between Paleoarchaic and Paleoindian technological traditions. Instead, these traditions emerged independently. These findings provided insights into

migration dynamics during the final Pleistocene in North America (Davis et al., 2012).

Current studies of microblade industries in Northeastern Asia and North America are primarily based on techno-typological analysis, which focuses on partial characteristics of the operational sequence of microblade core reduction. Early conceptions of microblade industry dispersal, such as J.W. Smith and N.C. Nelson's idea of the Northeastern Asian–Northwest American Microblade Tradition (Inizan et al., 1992), were initially rooted in morphological analysis. However, significant advancements in the 1960s and 1970s shifted the focus toward technological approaches.

Key Contributions to techno-typological analysis of microblade industries were made in the 1960s by Japanese scholars. Yoshizaki Masakazu (1961): Published the results of refitting block analysis, leading to the discovery of the Yubetsu microblade core reduction method. Later, Kensaku Hayashi (1968) In his seminal work, *The Fukui Microblade Technology and its Relationship in Northeast Asia and North America*, Hayashi developed a techno-typological method of analysis. He defined technology as the sum of processes involved in the production and use of microblades, emphasizing production techniques as reflections of cultural tradition. Hayashi's typology was based on morphological characteristics such as orientation, type of preforms, and blanks, though it lacked experimental research on lithic tool use.

The "Burin-Microblade Core Debate" also took place in Japanese archaeology in the 1960s. This discussion highlighted methodological contradictions between morphological and technological typologies. For instance, Haruo Ohi initially identified materials from the Taisho site, produced using the Tougeshita method, as burins and burin spalls (Ohi, 1963). These contradictions were later

resolved through the adoption of a techno-typological approach (Takakura, 2020).

The work of Japanese archaeologists established a framework for understanding microblade industries through dynamical models. Rather than focusing solely on the final forms of microblade cores, these studies emphasized the operational sequences of core reduction. This approach allowed for a more nuanced understanding of the emergence and spread of microblade industries.

Additionally, many studies consider only the general sequence of microblade core reduction, occasionally incorporating additional characteristics such as pressure techniques (Inizan et al., 1992) or heat treatment (Flenniken, 1987).

The shift from morphological to technological analysis has significantly advanced our understanding of microblade industries. By reconstructing operational sequences and employing techno-typological methods, researchers can trace cultural transmission and distinguish it from independent cultural convergence. However, future studies must address the current limitations of techno-typological analysis by incorporating scar pattern analysis and examining a broader range of reduction methods and technological operations. This will provide a more complete picture of the variability and transmission of microblade technology across regions.

2.1.4.b. The technique of microblade production and cultural transmission process

The question of microblade production techniques is central to understanding the emergence and spread of microblade technology in Northeastern Asia and Beringia. The use of pressure flaking as a method for microblade detachment is a defining feature in some interpretations of microblade technology. According to Y.A. Gómez Coutouly, the pressure technique is crucial for defining the nature of microblade technology's emergence and dispersal. Gómez Coutouly

(2018) argues that the Far East, particularly regions with abundant obsidian, may have been the birthplace of microblade technology. However, this claim is contested, as the earliest microblade sites in Hokkaido (Kashiwadai 1) and Northeastern China (Xishantou) utilized raw materials other than obsidian (Iwase, 2016).

Microblade industries in Hokkaido exhibit significant variability in knapping techniques. For example, the Yubetsu method has been identified as employing pressure flaking, a conclusion supported by experimental studies (Inizan et al., 1992; Pelegrin, 2012). In contrast, the Tougeshita method demonstrates a combination of techniques. Tougeshita Mode 2 involved primarily pressure flaking. In turn, Tougeshita Mode 1 and Mode 3 has a combination of percussion and pressure flaking (Takakura, 2020).

This variability highlights the complexity of microblade production and underscores the need for detailed technological analysis to understand regional differences and transmission patterns.

In 1992, M.L. Inizan, M. Lechevallier, and P. Plumet emphasized the role of pressure flaking in tracing Pleistocene population migrations into North America. They proposed that Northeastern Asia, including Northeastern China and the Paleo-Sakhalin-Hokkaido-Kuril Peninsula, served as the nuclear area for the emergence of microblade technology. The diffusion of pressure flaking techniques from this region to Eastern Siberia and North America was posited to have occurred between 20,000 and 12,000/9,000 B.P. (Inizan et al., 1992).

The identification of pressure flaking in microblade production is a critical aspect of studying the emergence and spread of microblade technology. The choice between pressure and percussion techniques represents a key characteristic of the zone of latent solutions, a concept that describes the range of possible technological choices within a cultural context. Accurately

identifying the techniques used in microblade production enables researchers to trace cultural transmission pathways and distinguish between independent innovations and shared technological traditions.

The question of microblade production techniques—particularly the use of pressure flaking—is fundamental to understanding the emergence and spread of microblade technology in Northeastern Asia and Beringia. While pressure flaking is often highlighted as a defining feature of microblade technology, regional variability in knapping techniques complicates this narrative. Detailed technological analyses, including the identification of pressure and percussion techniques, are essential for reconstructing cultural transmission pathways and addressing broader questions about the adaptive and migratory dynamics of Pleistocene populations.

2.1.4.c. Functions of microblades in the context of cultural transmission and cultural convergence

To understand the processes of cultural transmission and cultural convergence, it is essential to classify implements with inserted microblades. These implements can be broadly divided into two groups: weapons and tools.

The group of weapons includes: 1. Projectiles (e.g., arrows, darts); 2. Polearms (e.g., spears) and; 3. Short-edged weapons (e.g., daggers).

Paleolithic daggers are rare in Northeastern Asia. A notable example is the slotted dagger from the Chernoozerie II site in Siberia. This dagger features a triangular convergent osseous blade, a hole at its base, and two grooved slots for microblades. It is decorated with V-shaped, rhomboid, cross, and pit patterns (Шмидт, 2021, 2022). Early Holocene examples from Eastern Siberia show evidence of cutting and stabbing use-wear on the inserted microblades, as revealed by functional analyses (Volkov and Zhambaltarova, 2011; Жилин, 2019).

Late Pleistocene osseous points in Northeastern Asia are classified into eight classes and 14 variations. Slotted points are represented in Classes III, IV, V, and VI (Kato, 1993):

- Class III: Double-edged points less than 20 cm long, with flat or lanceolate bases.
- Class V: Single-edged points less than 20 cm long, with flat or lanceolate bases.
- Class IV: Double-edged points 20 cm or longer, with flat bases.
- Class VI: Single-edged points 20 cm or longer, with flat bases

Points with flat bases are hypothesized to be polearm tips, as longer points (≥20 cm) typically have flat bases, aligning with ethnographic descriptions of hunter-gatherer polearms.

Projectile delivery systems in Northeastern Asia and Beringia likely included spear throwers (atlatls) and bows and arrows. Evidence for atlatls includes an ivory artifact from the Broken Mammoth site in Alaska, interpreted as a possible atlatl handle (Yesner, 1994; 2001). While direct evidence of bows and arrows is absent, hypotheses suggest an association between small slotted points, microblade technology, and early bow use (Dixon, 2011; Сериков, 2012). Solid evidence of arrows with inserted microblades appears in the Early Holocene of the Northern Angara region (Кузнецов et al., 2017). Alternatively, darts may have been thrown by hand, a method supported by Pleistocene evidence (Milks et al., 2019; Schmitt et al., 2003).

The group of slotted tools can be divided into three classes:

1. Slotted tools with parallel multiple inserted microblades (e.g., osseous single-edged knives);
2. Slotted tools with a single parallel microblade (e.g., wooden-handled knives);
3. Tools with a longitudinally attached single microblade (hypothetical reconstruction).

Slotted Tools with Parallel Multiple Microblades, such as osseous single-edged knives, are widely represented in Early Holocene sites like Zhokhova in the circumpolar Arctic (Giria and Pitul'ko, 1994) and Ust'-Khaita in Eastern Siberia (Ulanov et al., 2024). They often feature a sub-oval hole in the distal part of the osseous artifact, similar to slotted daggers.

Slotted Tools with a Single Parallel Microblade typically have wooden handles, as seen in artifacts from the Zhokhov Island site. A cylindrical wooden handle with a split proximal end holds a single microblade, and use-wear analysis indicates hide-cutting activities (Гиря and Питулько, 2003). Similar handles are found in Paleoeskimo culture artifacts from Avayalik Island (Jordan, 1980; Rast, 2010).

Tools with Longitudinally Attached Single Microblades lack direct archaeological evidence and are reconstructed based on use-wear patterns. Hypothetically, these tools consist of a long stick with a microblade attached to a split end (Уланов et al., 2020).

Despite the variability in handle types, there is no clear correlation between handle class and tool function (except for tools with longitudinally attached microblades). Microblades exhibit a wide range of functions (Tab. 1), and even weapons like daggers and spearpoints show evidence of secondary use for butchery and meat cutting (Volkov and Zhambaltarova, 2011; Жилин, 2019).

Ethnographic observations support this functional flexibility, as arrowheads and spearpoints are often used for primary corpse processing, and spears can be repurposed as knifes (Семенов, 1957).

Use-wear analysis, while valuable for defining the general functional range of microblades, has limitations. For example, similar impact use-wear can result from different projectile delivery systems. Nevertheless, it remains a critical tool for understanding the broad functional spectrum of microblade implements.

The functional range of microblades provides insights into cultural transmission and convergence. A similar functional range across regions may indicate either transmission or convergence, depending on the operational sequences and knapping techniques used. Deviations in functional range, such as the expanded uses of microblades in Early Holocene sites (Tab. 1), suggest transmission with innovations.

2.2. Methods

2.2.1. Morphological description

Before describing the methods of microblade industry analysis, it is first necessary to define the terms *"microblade," "microblade core,"* and *"wedge-shaped microblade core,"* as well as key terminology related to the morphological description of cores.

Multiple definitions of the term *"microblade"* have been proposed, but the most precise has been synthesized by Y.A. Gomez Coutouly (2018). In this framework, a *microblade* is defined as a small, narrow, standardized, parallel-sided stone blade, typically measuring between 10–50 mm in length and less than 6 mm in width, intentionally detached from a specially prepared core.

A *microblade core* refers to a lithic nucleus that has been specifically prepared for the systematic detachment of microblades. These cores exhibit deliberate

platform preparation and recurrent flaking designed to maximize blade production (Gómez Coutouly, 2018). Microblade cores are classified according to both their morphology and reduction strategies, with common types including wedge-shaped, conical, and cylindrical variants (Seong, 2008).

A *wedge-shaped microblade core* can be defined as a specialized lithic core characterized by a triangular or trapezoidal cross-section, systematically reduced to produce parallel-sided microblades. This category of microblade cores may utilize bifacial or unifacial blades or flakes as preforms.

The morphological model of a wedge-shaped microblade core includes several distinct elements: the *front*, *platform*, *contre-front*, *keel*, and *faces* (fig. 8).

The *front* is the defining feature of a microblade core, distinguishing it from other types of lithic artifacts (Медведев et al., 1974; Sanger, 1970). It is shaped by the negative scars of detached microblades and is typically located at the narrow end of the core. In the case of bifrontal cores, fronts are present at both narrow ends. The typical shape of the front is sub-triangular, tapering to a narrow distal point. In Tougeshita-type microblade cores, however, the front tends to be characteristically asymmetrical (Nakazaw a et al., 2005).

The *platform* is a morphological element located at the proximal end of the microblade core. In Tougeshita microblade cores, the platform is typically shaped by the removal of a negative ridge spall. The platforms of Yubetsu microblade cores, in contrast, are formed by the detachment of a ridge spall in combination with one or more ski spalls (Nakazawa et al., 2005).

The *contre-front* is a morphological element located on the side of the core opposite the front. It is usually shaped by the convergence of the retouched edge of the preform and the striking platform. In wedge-shaped microblade cores, the contre-front is generally connected to the keel (Медведев et al., 1974). This feature is absent in bifrontal microblade cores.

The *keel* is formed by the convergence of the core's faces along the edge. Specifically, it is produced by unifacial or bifacial retouch during preform preparation (Медведев et al., 1974). The keel is located opposite the platform.

The *faces* or *laterals* of the core are shaped during the preform preparation stage. Yubetsu microblade cores typically utilize bifacial preforms with symmetrically processed faces. In contrast, Tougeshita microblade cores may exhibit one unprocessed face (Nakazawa et al., 2005).

Despite some similarities, Yubetsu and Tougeshita microblade cores could be distinguished one from another. On the morphological level the most vivid difference is cross-section of the blanks (bifaces for Yubetsu and unifaces for Tougeshita). In terms of technological reduction sequence the main difference is detachment of single or multiple ski-spalls from the platform of Yubetsu microblade core which is absent in Tougeshita core reduction sequence. Both technologies were recognised in Upper Paleolithic materials in China, Siberia and Alaska (Chen, 2007; Gómez Coutouly, 2011; Золотарев, Бердникова, 2022).

2.2.2. Analysis of the technological sequence of microblade production

2.2.2.a. Refitting block analysis

Refitting block analysis, also known as the application analysis method, is one of the most objective approaches to studying lithic industries. This method involves the retrospective reconstruction of the stages of flake detachment from a core or tool by physically refitting the flakes back to their original positions (Fig. 9).

In Paleolithic studies, refitting block analysis is closely tied to the concept of *chaîne opératoire*, introduced by A. Leroi-Gourhan. He defined technique as "both motion and tool, which are organized to form a chain by a true syntax that

gives to the operating series their rigidity and their adaptability" (Leroi-Gourhan, 1964). Later, R. Cresswell provided a functional definition of *chaîne opératoire* as "a series of operations that transform a raw material into a product, whether it is a consumer object or a complete tool" (FP 01. Chaîne opératoire..., 2019). The *chaîne opératoire* begins with raw material acquisition and ends with the discarding of the artifact (Sellet, 1993). In other words, this method was designed for understanding the society, behavior, and cognition of a time by analyzing the processes from material selection to tool production, use, and disposal.

While the concept of *chaîne opératoire* was developed independently, refitting block analysis became a key methodological tool for its application. Although Leroi-Gourhan's laboratory in the 1960s had only one researcher specializing in lithic refitting, significant results from refitting studies of Magdalenian open-air sites were published in the 1980s (Audouze et al., 2018). Thus, refitting block analysis is not directly tied to the invention of the *chaîne opératoire* concept but has been instrumental in its development.

Refitting block analysis has played a pivotal role in the study of Japan's Paleolithic lithic industries. Yoshizaki Masakazu used this method to reconstruct the Yubetsu method of microblade core reduction by refitting ski spalls and bifacial blanks from the Shirataki 33 site (Yoshizaki, 1961) (Fig. 9: 1). This breakthrough influenced subsequent studies of microblade industries in Japan, including Kobayashi Tatsuo's conception of two technological systems of microblade production, which was partly based on refitting block analysis (Kobayashi, 1970).

In the Soviet Union, refitting block analysis was first applied by M.P. Aksenov in 1981. Drawing on local Siberian materials and results published abroad (primarily in Japan), Aksenov defined the goal of refitting block analysis as the

study of lithic production techniques and the reconstruction of related labor processes (Аксенов, 1981). He emphasized that this method not only reconstructs technological sequences but also clarifies and validates data obtained through other methods, such as experimental replication and graphic reconstruction.

Refitting block analysis has yielded significant insights into Paleolithic microblade industries in Siberia and Hokkaido. In Eastern Siberia, refitting studies have reconstructed the bifacial technological strategy at the Bol'shoi Yakor' I site, based on the Yubetsu method (Fig. 9: 2). This strategy was interpreted as an adaptive response to limited raw material availability and specific mobility patterns (Ineshin and Teten'kin, 2017). Another notable result is the description of the "kovrizhka technique" of microblade core reduction (Fig. 9: 3). Refitting blocks provided the primary evidence for A. Tetenkin's description of this technique, which combines reduction, rejuvenation, and microblade detachment operations (Тетенькин, 2017).

Refitting block analysis is extensively used in Hokkaido to study Paleolithic microblade industries (Kimura, 1997: 326–354; Naoe, Suzuki, Sakamoto, 2016). Representative refitting blocks illustrate the reduction sequences of the Yubetsu, Tougeshita, and Momijiyama microblade core methods (Yamada, 2006: 54; 67–85; 114). The scarcity of refitting blocks for other methods, such as the Oshorokko method, may reflect both preservation conditions and differences in mobility patterns associated with specific reduction techniques.

Refitting block analysis is a powerful tool for reconstructing the technological sequences of lithic production and validating data from other analytical methods. Its application in Siberia and Hokkaido has provided critical insights into microblade industries, revealing adaptive strategies and technological variability. Despite its limitations, refitting block analysis remains indispensable

for understanding the *chaîne opératoire* and the cultural dynamics of Paleolithic societies. Thus, refitting block analysis serves two primary goals:

1. Objective Reconstruction of Technological Sequences: This method allows for the detailed reconstruction of lithic production processes. However, due to preservation challenges, complete or partial reconstruction of the *chaîne opératoire* is only possible in a limited number of cases.

2. Correction and Clarification of Data: Refitting block analysis validates and refines data obtained through other methods, such as experimental replication and use-wear analysis (Аксенов, 1981; Sellet, 1993).

2.2.2.b. Scar pattern analysis

Scar pattern analysis, also known as working stage/step analysis, is a method used to study the *chaîne opératoire* of lithic production. This approach aims to reconstruct the tool manufacturing process by determining the chronological sequence of scars visible on artifact surfaces (Kot, 2017). The analysis procedure consists of four stages: (1) identification of scar fracture direction; (2) determination of the mutual sequence of neighboring scars; (3) grouping of scars into flaking sequence units based on shared characteristics (e.g., position, angle, size, direction); and (4) creation of a graphic representation of sequence units (Шалагина et al., 2019). The graphic scheme generated through scar pattern analysis illustrates the objectives of each technological operation.

The first application of scar pattern analysis to Middle Paleolithic bifacial tools was published by J. Richter and A. Pastoor (Pastoors, 2000; Richter, 2001). This method is typically applied to the study of bifacial tools, large lithic tools such as scrapers on spalls, and geometric microliths. However, scar pattern analysis is not limited by artifact size or the intensity of modification. Notably, this method has also been applied to the study of carinated cores from the

Kulbulakian Upper Paleolithic complexes of Central Asia (Kharevich et al., 2021).

Currently, published results of scar pattern analysis for wedge-shaped microblade cores are limited. One notable example is the analysis of a microblade core from the Kuyacha site in the Altai region. This study meticulously described the technological stages involved in the production of the microblade core, including: 1. Flake-preform making; 2. Formation of laterals and keel; 3. Microblade production; 4. Platform formation; 5. Rejuvenation of the platform and keel; 6. Fragmentation.

This precise description enabled the authors to compare the microblade core with bifacial Upper Paleolithic industries in the region, providing valuable insights into the technological continuity and variability of lithic production strategies (Федорченко, 2024).

The application of scar pattern analysis to microblade industries, however, necessitates modifications to conventional graphic schemes of technological unit sequences (Fig. 10). Due to the distinct characteristics of microblade cores, graphic representations should be divided into three columns: the first for the left face of the microblade core, the second for the platform and front, and the third for the right face. Technological units are arranged in chronological order, with the earliest scars positioned at the top and the latest scars at the bottom. Each unit is marked with a specific color and letter, while squares in the central column may be labeled with an index such as SS1 (Ski Spall 1st) or Mb1 (Microblade Detachment 1st). The leftmost section of the graphic scheme should indicate the technological stages of microblade core reduction, including the primary processing of the blank, blank face formation, margin retouching, platform formation, microblade detachment, secondary processing of microblade core faces, and platform rejuvenation.

Scar pattern analysis, therefore, enables the reconstruction of the *chaîne opératoire* of microblade core reduction, tracing the process from raw material selection and blank preparation to the final production of microblades, which represents the primary objective of microblade core reduction. However, a more comprehensive understanding of the *chaîne opératoire* can only be achieved by integrating scar pattern analysis with knapping technique studies and lithic function analysis.

2.2.3. Analysis of knapping methods of microblade production

2.2.3.a. Fracture wing analysis method

The fracture wing analysis method is based on the observation and measurement of velocity-dependent microscopic fracture markings known as "fracture wings." These markings form as a result of longitudinal stress in knapped raw materials, with the sharpness of the fracture angle depending on the speed of crack formation (Takakura, 2012). Fracture wing analysis of microblade production techniques is particularly applicable when obsidian is used as a raw material. Given the widespread use of obsidian for microblade production in Northeastern Asia and Beringia, this method is highly significant for understanding microblade manufacturing techniques.

The development of fracture wing analysis, also referred to as gull-wing analysis (Faulkner, 1972; Tsirk, 2014), began in the 1970s as an attempt to interpret microscopic fractures on obsidian artifacts (Takakura, 2021). This method has been applied to various archaeological contexts, including studies of Clovis biface production technology. In these studies, channel-flake facets of bifaces were microscopically examined, leading to the conclusion that pressure flaking with a chest crutch was the primary technique for channel-flake production (Hutchings, 1999). Additionally, fracture wing analysis has been employed in the study of obsidian blade knapping techniques in the Neolithic

period of the Southern Caucasus, revealing the presence of pressure blade knapping methods (Takakura & Nishiaki, 2020). Furthermore, this method has been widely used to investigate microblade-like debitage and microblade industries in the Japanese archipelago (Takakura, 2012; 2021).

The mechanical process of fracture wing formation is triggered by the passage of a fracture wave and is largely determined by crack velocity and material properties. Crack velocity (C) is calculated using the formula:

$C/C2=\cos(\Psi/2)$

where Ψ represents the angle of divergence of the fracture wing on the plane of the primary crack front, and C2 is the elastic wave velocity. The elastic wave velocity of obsidian has been measured at approximately 3507 m/s, based on an average of C2 values from multiple obsidian specimens (Tomenchuk, 1988).

The velocity of fracture formation varies depending on the knapping technique, categorized into three groups (Takakura, 2021):

- **Group I:** Pressure flaking, with velocities ranging from 178 to 620 m/s (average values for different pressure tools are approximately 385–415 m/s).
- **Group II:** Indirect percussion or direct percussion using soft hammers (e.g., wood, bone, or antler), with velocities between 460 and 1055 m/s (average values from different techniques and punches range from approximately 640 to 700 m/s).
- **Group III:** Direct percussion using hard hammers, with fracture velocities ranging from 764 to 1353 m/s (average values from different hammers are approximately 1000–1040 m/s).

2.2.3.b. Technological analysis method

The study of knapping techniques within technological analysis originated in ethnographic research. One of the earliest accurate descriptions of the flintknapping process was based on observations of Ishi, a Native American worker from the Yahi people, at the University of California Museum. N.C. Nelson meticulously documented Ishi's toolkit, the sequential stages of stone tool production, and various techniques, including direct percussion and pressure flaking (Nelson, 1916). The identification of diverse flaking techniques significantly influenced the broader understanding of prehistoric archaeology. For instance, P.I. Boriskovsky hypothesized the use of pressure flaking for blade production at the Pushkari I site (Гиря, 1997). However, further advancements in technological analysis were contingent on the integration of experimental archaeology.

One of the earliest experimental studies of knapping techniques was conducted by S.A. Semenov in the late 1950s. His analysis of micro-traces and conical fractures on blade platforms provided new insights into lithic production methods (Гиря, 1997). Since the 1970s, technological approaches to lithic studies have been extensively developed within French archaeology, particularly through the work of A. Leroi-Gourhan, F. Bordes, J. Taxier, and J. Pelegrin. The methodological advancements in technological analysis profoundly altered the epistemology of prehistoric archaeology. Rather than being merely classified and described, lithic artifacts are now interpreted as material evidence of human behavior within economic, technological, and social dimensions (Pelegrin, 1990).

The study of blade industries has emerged as a major subfield within technological analysis. For an extended period, experimental replications of pressure-made blades were largely unsuccessful, as demonstrated in Semenov's

early experiments. The first successful replication of obsidian blades was reported by D. Crabtree on the Mesoamerican materials, who demonstrated that blades could be produced through direct percussion, indirect percussion, and pressure techniques (Crabtree, 1968). A significant contribution to the study of blade production techniques, particularly pressure blade knapping, was made by J. Pelegrin. Beginning in 1981, Pelegrin conducted extensive experimental investigations into pressure techniques, with a key focus on describing knapping tools, holding devices, and the variations in body position and tool use during blade pressure knapping (Pelegrin, 2012).

Several studies have specifically focused on microblade production techniques. During the 1980s, results of experimental microblade replication were published by R. Bonniksen, D. Sollberger, L. Patterson, E. Callahan, and K. Onuma (Табарев, 2008). In 1987, J.J. Flenniken conducted a replicative study on the Dyuktai pressure blade technique. His experiments included raw material selection (flint, jasper, chalcedony, and other siliceous rocks), bifacial blank production, heat treatment, ski spall removal, and pressure blade production (Flenniken, 1987).

J. Pelegrin also investigated microblade production between 1984 and 1987. His findings indicated that the Yubetsu and Horoka microblade core reduction methods correspond to Pressure Mode 1, in which microblades are produced using a hand-held pressure tool or an antler tine (fig. 11: 1). In this technique, the core is held directly in the left hand, with a leather pad used to protect the palm and fingers (Pelegrin, 2012).

Alternative hypotheses regarding microblade production techniques have also been proposed (fig. 11: 2-3). A. Tabarev suggested that compact wooden vises may have been used to enhance the regularity of microblade production (Табарев, 2008). Another experimental approach, tested by D. Sollberger and L.

Patterson, involved a combination of a wooden vise and a lever mechanism for microblade detachment (Sollberger & Patterson, 1983).

The identification of blade production techniques is based on both qualitative and quantitative criteria. Qualitative criteria for pressure blade production include the following characteristics (Inizan et al., 1992; Allard et al., 2017):

1. The platform of pressure-made blades is always narrower than the maximum blade width;

2. The blade reaches its maximum width near the platform;

3. The platform is very small, sometimes punctiform;

4. There are no obvious ripple marks on the ventral surface.

Quantitative criteria of the knapping technique definition are estimated statistically. According to the general results of experimental technological analysis of blade production, there are seven main criteria for blade production technique identification:

1. Bulb morphology;

2. Lip formation;

3. Presence or absence of bulbar scar;

4. Conus formation;

5. Butt morphology;

6. Regularity;

7. Interior platform angle (fig. 12).

The first four criteria could be investigated of the proximal part of the blade on the ventral surface. Bulb morphology and lip formation could be diffuse,

pronounced, or characterized by the absence of a bulb/lip. Differences in bulb morphology and lip formation are seen visually with the naked eye. Bulbar scars correspond to a parasitical flake removed at the very moment the blade breaks off. Whereas bulbar scar was identified as present or absent. Conus formation was categorized into four categories: none, ring crack on the butt, ventral fissures, and detached bulb. The interior platform angle corresponds to the angle formed between the platform surface and the ventral blade face. The interior platform angle was measured in degrees where the platform remnant and ventral blade face intersected and then collapsed into a new variable with five categories to better correspond with the scale of the other attributes. (Damniel, 2015).

Butt morphology could be investigated on the distal part of the blade. Butt morphology was defined by measuring the platform remnant width/thickness in relation to the blade width/thickness. Punctiform butts measure less than 1 mm, small butts are <50% of blade width and thickness, and small, thick butts are <50% of blade width and >50% of blade thickness. Thin oval butts are >50% of blade width and <50% of blade thickness, large and oval butts are >50% of blade width and thickness, whereas large and thick butts measure >75% of blade width and thickness (Damniel, 2015).

2.2.3.c. Experimental results of fracture wing analysis and technological analysis methods

Experiments with pressure and percussion production of microblades were carried out by author. Experimental results did not highlighted significant differences from the previously published data. A total of 211 microblades were produced from 19 microblade cores to investigate the striking techniques used in microblade production. The raw materials utilized included Shirataki

obsidian, fine-grained shale collected from the northern part of Rebun Island, rhyolite from Heilongjiang Province, China, effusive rock from the Vitim River Valley, and flint from the Belaya River Valley in Eastern Siberia.

Primary flakes for microblade core blanks were detached using a hard hammer, specifically a basalt pebble measuring 149.6 × 76.2 × 53.8 mm and weighing 949 g. Face formation was conducted using a soft hammer, a roe deer antler measuring 235 × 36.4 mm and weighing 112 g. Marginal retouching was performed using pressure flaking with an antler pressure tool (fig. 13).

Microblade production by pressure was carried out following Mode 1, as described by J. Pelegrin (2012). The microblade core was held in the left hand, protected by a piece of leather, while microblade detachment was performed in a seated position. Pressure was applied by transmitting a force impulse directly to the edge of the striking platform using a hand-held pressure tool. Percussion-based microblade production was conducted through indirect percussion, utilizing an antler point in combination with a wooden hammer (130 g). In both cases, microblade detachment was followed by abrasive reduction of the overhang on the core's front (fig. 13:5).

The results of fracture wing analysis provide qualitative data relevant to microblade production technology. Fracture wings are observable on the surfaces of both microblades and microblade cores under magnification of approximately ×200. The angle of fracture wings on microblades produced by pressure ranges between 160° and 170°. In contrast, microblades produced by percussion exhibit fracture wing angles ranging from 130° to 160°. More specifically, angles within the 130°–140° range are associated with hard hammer percussion, while indirect percussion with an antler point typically results in fracture wing angles of approximately 150° (fig. 14).

Morphological characteristics of microblades do not vary significantly across different raw materials, including obsidian, siliceous rock, effusive rock, and shale. The defining features of pressure-produced microblades include a small punctiform platform, maximum width near the proximal end, and a significant difference between platform width and maximum microblade width (figs. 15, 16). However, microblades produced from effusive rock tend to develop punctiform platforms less frequently (fig. 17).

2.2.4. Use-wear analysis

2.2.4.a. Use-wear analysis of microblade industries

Prior the experiments previously published data of functional analysis of microblades were analysed. The functions of Late Pleistocene–Early Holocene microblades have traditionally been considered as components of hunting equipment, including their use as inserts in projectile points and knives for hunting, butchering, and processing animal products (Seong, 2008). However, functional analyses conducted over the past decades have demonstrated a broader functional flexibility of microblades beyond hunting-related activities.

Use-wear analysis of microblade assemblages from Alaska has revealed diverse functional patterns in both the Alaskan Paleolithic and the Arctic Small Tool Tradition. At Swan Point Cultural Zone 4B, microblades exhibited multifunctionality, including use in butchering and scraping soft, abrasive-worked materials (Gauvrit Roux et al., 2022). Analysis of microblades from the Arctic Small Tool Tradition site at Matcharak Lake indicated that obsidian microblades were employed as expedient cutting tools, possibly for tailoring, while chert microblades were likely produced to replace slotted antler point insets or knives (Tremayne, 2015).

Functional studies of Late Pleistocene–Early Holocene microblades in Siberia have also yielded significant insights. Use-wear analysis of cultural component

6 at the Kovrizhka IV site identified two primary functions: cutting soft, non-abrasive materials (as knives) and serving as projectile points (Gauvrit Roux et al., 2021). In the Russian Far East, use-wear analysis was conducted at the Ushki I and Srednee Ozero V sites (Диков, Кононенко, 1990; Федорченко, 2019). Additionally, microblade assemblages from Gorbatka 3 and Ilistaya 1 were examined, although no wear traces were identified on the microblades from these sites (Kuznetsov et al., 2020).

At the Srednee Ozero V site in Western Chukotka, N.N. Kononenko identified multiple tool types made from microblades and ridge spalls, including four gravers, two micro-end scrapers, three borers, two knives, a micro-chisel, and a saw. Microblades from the Zhokhov Island site were found to have been used for processing meat, hide, wood, antler, bone, and ivory, as well as for hunting equipment (Giria & Pitul'ko, 1994; 2003).

A use-wear study of the Early Holocene Pavlova I site conducted with the participation of the author of this dissertation revealed traces of use on ridge spalls, frontal spalls, and microblades, indicating their function as knives for wood shaving and meat cutting, micro-scrapers for bone and antler, gravers for soft mineral and antler materials, borers for skin, and saws for soft mineral sawing. Notably, a distinct "knife-carver" category was identified, characterized by the use of the narrow microblade edge for grooving antler and bone (Уланов, et al., 2020).

Use-wear analysis of microblade industries in Japan often indicated variable use-wears related to processing soft organic material and bone/antler working (Iwase, 2015). A significant contribution to the use-wear analysis of microblade industries has been made by Y. Kanomata. This scholar has developed a typology of micropolish based on experimental studies and systematic observations of use-wear patterns on lithic tools. The classification of

micropolish types draws on the foundational work of the Tohoku University Use-Wear Research Team (Akoshiima, 1981; Kajiwara, Akoshima, 1981) and incorporates the author's own experimental results. This typology enables the identification of materials processed by the tools—such as hide, bone, and meat—based on the distinctive characteristics of the polish observed under microscopic analysis.

Microblades from several sites, including Tachikarushunai No. 5, Araya, Sasayamahara No. 27, Akatsuki Loc. I, Oruika 2, and others, have been subjected to use-wear analysis. The results have revealed a range of functional uses, including woodworking, hide and bone/antler processing, and meat cutting. Additionally, wear patterns associated with the hafting of microblades into slotted points have been repeatedly documented, highlighting the versatility and multifunctionality of microblade technology in prehistoric toolkits. These findings underscore the importance of use-wear analysis in reconstructing the technological and subsistence practices of past societies.

Functional traces on microblades have been extensively documented at multiple archaeological sites across Hokkaido and Honshu, including Kashiwadai I, Toyooka 7, Obarubetsu 2, Pirika 1, and Yoshiizawa. At Kashiwadai I, microblades were identified as projectile inserts based on the presence of impact damage (Iwase, 2014, 2016). In contrast, at Yoshiizawa, no impact damage was observed; however, one microblade exhibited use-wear consistent with scraping, whittling, or planing along a lateral edge (Iwase et al., 2016).

At the Ogachi-Kato 2 site, microblades displayed use-wear patterns indicative of soft material processing (Iwase, 2012). Similarly, use-wear analyses conducted at several sites on Honshu, including Orose I & II, Nakatsuchi, Tsukioka, and Hakoda Isekigun Uehara, revealed a diverse functional range. These microblades were employed in cutting soft organic materials, bone and

antler working, and hide processing (Iwase, 2021) —functions comparable to those identified at Paleolithic sites in Hokkaido.

In China, use-wear analysis has seen significant development in recent decades. Analysis of microblades from the Shizitan 29 site in Shanxi Province indicated their function as knives for various worked materials (Song et al., 2019). Similar results were obtained from use-wear studies at Xiachuan and Chaisi in the same province, where microblades were identified as knives and scrapers for a variety of materials (Chen et al., 2016). At the Helong-Dadong site, microblades exhibited traces of scraping, planing, and cutting, suggesting their use on soft and hard animal materials as well as herbaceous materials (Ting et al., 2024).

Use-wear analysis of microblades in Korean archaeology remains underdeveloped. However, a functional study of materials from the Hopyeong-dong site identified microblades used as knives, scrapers, and saws for processing meat, hide, and plant materials (Hong, Kononenko, 2008).

In summary, the functions of microblades in Northeastern Asia and Beringia included use as projectiles, knives, scrapers, gravers, shaving tools, borers, saws, chisels, and knife-carvers (Tab. 1). Worked materials varied widely and included wood, bone, antler, ivory, hide, meat, and soft mineral substances. Notably, functional diversity appears to be greater in Early Holocene contexts compared to Paleolithic sites, suggesting an expansion in the range of microblade applications over time.

2.2.4.b. Use-wear analysis protocol for microblade industries studies

Due to the specific characteristics of microblade industries, a specialized protocol for experimental functional analysis is required. This protocol must consider the variability of raw materials and incorporate findings from previous studies on microblade functions. The main method of identification of lithic functions is use-wear analysis. The use-wear analysis method aims to define the

function of the lithic implement by the characteristic of microscopic and macroscopic traces of work, traces of manufacturing, and general nonutilitarian wear (Semenov, 1973). The use-wear analysis is an empirical interpretive method with the specific sampling of artifacts, visualization, and interpretation of research results (Van Gijn, 2014). In this work, use-wear analysis was conducted according to all general statements of the use-wear analysis method (Keeley, 1980, Semenov, 1973).

Experimental studies on the functions of microblade tools were conducted as part of this research by the author. Experiments with all mentioned functions of microblades (except for projectiles, where we used published data of previous research) were conducted according to variability of raw material. The experiments employed microblades manufactured from a range of raw materials, including Shirataki obsidian, black fine-grained shale collected on Rebun Island, effusive rocks from Siberia, and siliceous rocks obtained from Siberia and northeastern China.

The functional variability of microblades and the diverse kinematics of working operations necessitate different hafting designs for microblade-inserted tools. For functions such as shaving, hide cutting, graving, and scraping, we employed reconstructions of Paleo-Eskimo wooden handles from the Avayalik Island site (Jordan, 1980; Rast, 2010), which have analogs in materials from the Zhokhov Island site (Giria & Pitul'ko, 2003). Functions such as drilling, boring, micro-end scraping, and knife-carving required microblades to be fastened to long stick handles. For butchery knives, microblades were inserted into slotted bone knives and secured with pine tree resin.

A total of 108 microblades were used in the experiments (36 obsidian, 36 shale, 36 effusive, and 36 siliceous). Each tool was tested in working sessions of 5, 15, and 30 minutes. Before analysis, artifacts were cleaned with water and

high-concentration alcohol or, in cases involving meat and raw bones, with hydrogen peroxide (H_2O_2, 5%). For the cleaning of archaeological artifacts alcohol and acetone for the label removal were used.

For use-wear analysis, the following equipment was employed: Binocular optical microscope: Meiji Techno EMZ-TR (magnification 5.6×–36×); Lomo MBS 10 (x8,4 – x98 magnification range); Metallographic microscope: Olympus BXFM-S (magnification range 50×–1000×) with a Meiji Techno HD1500M camera; Digital microscope: Dino-Lite Edge (magnification 20×–220×) for low-magnification photography; Software: Capture V2.2 for microscopic images, DinoCapture 2.0 for digital microscope operation and low-magnification photography, and Helicon Focus 7 for stacking microscopic images at various magnifications.

Knife

Working motion: Longitudinal back-and-forth movements, with perpendicular and diagonal pressure applied to the edge. Both faces of the microblade are in equal contact with the worked material (Fig. 18).

Worked material: A combination of materials with varying abrasiveness, including flesh, adipose tissue, blood vessels, tendons, and cartilage. Microblades were inserted into slotted flat bone or wooden handles and secured with melted pine tree resin.

Use-wear: Meat-cutting use-wear is characterized by bifacial, aligned, or isolated scars, typically half-moon, semi-circular, or, rarely, triangular in shape. Terminations are thin or feather-like. Contact with bone produces small groups of aligned or overlapping scars with irregular, semi-circular, or trapezoidal shapes and feather-like or step-like terminations (Fig. 19).

Scraper

Working motion: Unidirectional scratching of the worked material's surface with a 90° working angle. Only the lower face of the microblade contacts the worked material and chips, while the upper face remains untouched, except for macroscopic scars that may emerge along the working edge (Fig.20).

Use-wear: Scraping scars are aligned, triangular, semi-circular, or trapezoidal with scalar and feather terminations. Overlapping scars form rows of small scars combined with singular or two-three larger scars, particularly pronounced on obsidian microblades. Micropolish appears on effusive and siliceous microblades as mildly developed flat shiny spots, localized along one face of the microblade's edge (Fig. 21).

Micro-Endscraper

Working motion: Similar to scraping, but with the working edge located on a breakage perpendicular to the microblade's long edge. Microblades were fastened to split wooden handles without glue (Fig. 22).

Use-wear: Similar to scraping but with better-pronounced edge rounding and no visible micropolish. Scars are aligned and overlapping, semi-circular, and have thin or feather terminations. Use-wear is concentrated on the breakage surface and is almost absent from the dorsal and ventral surfaces (Fig. 23).

Graver

Working motion: Longitudinal cutting into worked material using only the narrow edge of the microblade. Both faces make contact (Fig. 24).

Use-wear: Bifacial, aligned triangular, semi-circular, and trapezoidal scars. Additional striations parallel to the working edge indicate abrasive contact. Wear is narrowly distributed along the edge (Fig. 25).

Planning Tool

Working motion: Unidirectional shaving with a sharp working angle (~15°–20°). The lower face contacts the worked material extensively, while the upper face only contacts the removed chips (Fig. 26).
Use-wear: Upper-face wear includes overlapping, denticulated scars with scalar terminations. Lower-face wear consists of isolated scars, linear striations, and micropolish, which appears as bright, high-contrast, flat spots localized along the edge (Fig. 27). Micropolish is particularly pronounced on shale and siliceous microblades.

Borer

Working motion: Reciprocating transversal spinning through 4–5 mm thick leather, using the distal margins of the microblade (Fig. 28).
Use-wear: Isolated or aligned semi-circular scars with thin terminations, often accompanied by visible tip breakage (Fig. 29).

Saw

Working motion: Longitudinal reciprocating motions with perpendicular pressure. Contact occurs on both faces of the microblade (Fig. 30).
Use-wear: Large half-moon scars with bending initiation. Overlapping semi-circular, trapezoidal, and irregular scars with step-like or feather-like terminations. The working edge becomes denticulated, with abrasion retouch visible at the macro level (Fig. 31).

Drill

Working motion: Reciprocating transversal spinning, performed by rotating a split-ended wooden handle between the palms (Fig. 32).
Use-wear: Bifacial irregular, semi-circular, and trapezoidal scars with feather-like and step-like terminations. Use-wear deforms the microblade's distal edges, and macro-level abrasions form a U-like tip (Fig. 33).

Knife-Carver

Working motion: Unidirectional longitudinal cutting, with the breakage end or 36striking platform as the contact surface (Fig. 34).

Use-wear: Complex micropolish, scars, and striations located at the edge between the breakage surface and the ventral surface. Scars are aligned, amorphous, and have scalar terminations. Micropolish is highly reflective, with a domed and smooth microstructure. Striations are sub-parallel, oriented along the microblade's long axis (Fig. 35).

Projectile

Experiments with projectiles were not conducted by author of this research. Data of previously published researches were used for examination of use-wear of usage of microblade-based weapons. Identification of projectile use-wears is based on standard descriptions of impact fractures on lithic projectiles (Fisher et al., 1984). Impact fractures such as spin-off fractures have been widely documented on microliths and backed bladelets (Gauvrit Roux et al., 2020; Нужний, 2007). Experimental studies of spears and arrows with microblade inserts (Lynch, 2023) confirm that impact use-wear includes bending, burin-like, and spin-off fractures with lengths ≥2 mm, low-angle impact scars with bending initiation ≥1 mm, and linear impact traces associated with these fractures (Fig. 36).

2. 3. Archaeological context

The study area encompasses Eastern Siberia, Northeastern China, and the Korean Peninsula (fig. 37), a region situated at the convergence of the Eurasian and North American tectonic plates. This geographic location is characterized by significant seismic activity due to its proximity to the boundaries of the Eurasian, Pacific, and North American plates (Chapman & Solomon, 1976).

The relief of Eastern Siberia is predominantly characterized by lowlands and midlands, with notable geographic features distributed across the region. To the west, the Middle Siberian Plateau, the largest plateau in Russia, dominates the landscape. In the east, the terrain becomes more complex, featuring mountain systems such as the Verkhoyanskiy and Cherskiy ridges, interspersed with plateaus (e.g., Yanskoye, Elginskoye, Alazeyskoye, Yukagirskoye) and highlands (e.g., Oymyakonskoye, Kolymskoye). The southern part of Eastern Siberia is marked by extensive highlands, including the Stanovoi, Aldan, and Patom highlands. Alpine relief with modern glaciation is present in certain mountain ranges, such as the Orulgan, Moma, and Sunta-Khayata ranges. In contrast, the northern region is dominated by vast lowlands, including the North Siberian, Yano-Indigir, and Kolyma lowlands (Антипова, 1975).

Eastern Siberia is bordered to the north by the Kara, Laptev, and East Siberian Seas. The inland area is home to five major lakes: Lake Baikal, Lake Taymyr, Lake Khantayskoye, Lake Lama, and Lake Pyasino. Additionally, the region is traversed by 13 large rivers, with a combined total length of approximately 700,000 kilometers. These include the Lena, Yenisey, Angara, Aldan, Vitim, Vilyuy, Selenga, Olyokma, Kolyma, Indigirka, Yana, Nizhnyaya Tunguska, and Khatanga rivers. These extensive river systems and diverse topographic features have likely played a significant role in shaping the ecological and cultural dynamics of the region throughout history.

Northeastern China consists of the North China Plain and the Mongolian Plateau. The western part of the North China Plain has an altitude of approximately 100 m and is characterized by an ancient, expansive, and gently sloping landscape formed by merged alluvial ridges. This region contains a thick layer of alluvial deposits, primarily composed of redeposited loess transported from the Loess Plateau. The eastern part of the plain, with an altitude of around 50 m, is a flat alluvial-marine plain with minimal slopes and

numerous shallow depressions filled with floodwaters. Many of these depressions form swamps or small lakes. The Shandong Peninsula extends into the Yellow Sea, while the Yellow River advances into the sea by nearly 50 m per year.

In the central part of the North China Plain, the Shandong Mountains rise, with Mount Yuhuanding reaching a peak altitude of 1,524 m. To the south, remnant hilly erosional-alluvial plains extend across the landscape (Zhu, 1989). The region encompasses several geological formations, including the Khingan Mountains, the Changbaishan Mountains, the Song-Nen Plain, the Sanjiang Plain, and the Liaohe Plain (Yue et al., 2019). The major rivers of Northeastern China include the Amur, Songhua, Ussuri, and Argun.

Approximately four-fifths of the Korean Peninsula is characterized by mountainous terrain. The North Korean mountain ranges extend predominantly northward, featuring a series of arched-block ridges, such as the Hamgyong, Pujollyon, Gangnam, and Chogyuryon ranges, which alternate with expansive plateaus, including the Kema Plateau. These ridges are typically mid-mountain in elevation, with steep slopes and deep gorges. The high plateaus, reaching elevations of up to 1,000 meters, represent ancient leveling surfaces and are relatively less fragmented. In the northeastern region, near the border with China, lies the Changbaishan basaltic plateau, which includes the highest point in the Democratic People's Republic of Korea (DPRK): the Pektusan volcano, standing at 2,750 meters above sea level. From west to southeast, the terrain is marked by ridges such as Puktebon and Masinnyon. The East Korean Mountains extend westward through spurs, including the Myorak Range, which divides the western part of the peninsula into distinct flat and mountainous regions. In some areas, low-altitude hills and ridges, such as Mount Kuvolsan, which reaches 954 meters, extend close to the Yellow Sea coast. The most extensive plains of the peninsula are located along the coastal regions, including

the Pyongyang Plain on the western coast and the Khamkhyn Plain near the East Korean Gulf (Алексеева, 2000). The major river systems of the Korean Peninsula include the Amnok, Tuman, Taedong, Imjin, Han, Bukhan, Namhan, Geum, and Nakdong rivers.

To characterize the emergence of microblade technology and to explore the socio-cultural processes underlying cultural transmission and/or cultural convergence, it is essential to examine the material culture conditions that preceded the advent of microblade industries. In this section, the case of North America will be discussed, focusing on the non-microblade complexes of the Paleolithic period in Alaska.

The Northern Asian Paleolithic is associated with a trans-Eurasian phenomenon characterized by Early Upper Paleolithic artifacts. The lithic technology of this period is distinguished by the production of large blades from sub-prismatic cores. The framework of the trans-Eurasian Early Upper Paleolithic phenomenon identifies seven key marker artifacts: (1) points with thinned transversal edges made on blades; (2) beveled points; (3) points or blades with a blunted edge; (4) knives on blades; (5) leaf- or oval-shaped bifaces; (6) tanged blades; and (7) burin-cores (see fig. 38). Additionally, the Early Upper Paleolithic period in Northeastern Asia is notable for the presence of pendants crafted from tubular bone with furrowed edges and beads made from ostrich eggshells (Рыбин, 2014).

The reference sites for the Central Siberian region include the Maltat II sites, dated to approximately 43,000–33,000 years B.P., and the Derbina V and IV sites, dated to 33,000–30,000 years B.P. The lithic technology at these sites is characterized by the production of blades using Makarovo-type parallel blade detachment techniques. Diagnostic artifacts of Central Siberia include leaf- or oval-shaped bifaces and points with truncated bases (Рыбин, 2014).

The reference sites for the Early Upper Paleolithic of the Cis-Baikal region include Makarovo IV, Gerasimova I, Mamony II, Schapova, Bol'shoy Naryn, and the Igetey site (Рыбин, 2014; Медведев, Новосельцева, 2011). Marker artifacts associated with this region consist of points with truncated bases and leaf-shaped tanged artifacts (Когай, 2018; Рыбин, 2014).

The lithic technology of southwestern Trans-Baikalia is characterized by flake production industries and Karabom-type blade production techniques. This region contains all marker artifacts except for bifaces. The primary reference site for this region is the Hotyk site, specifically cultural components 4/2–6, which are dated to earlier than 38,000–35,000 years B.P. (Рыбин, 2014).

The Early Upper Paleolithic assemblages of Northeastern China exhibit significant variability and encompass seven distinct industries. During the initial stage of the Early Upper Paleolithic (41.5–40 cal ka), a large blade industry was prominent in the western part of the region. This industry is characterized by recurrent laminar bifacial hierarchical core reduction or the production of blades from unifacial hierarchical cores (Kato, 2021).

The period from approximately 40 to 28 calibrated thousands years ago (cal ka) corresponds to a phase of lithic industry diversification in Northeastern China. According to S. Kato (2021), during this interval, five distinct lithic technological traditions are evident. The first, the *denticulate tool industry*, is defined by the production of triangular, trapezoidal, and rectangular thick flakes from polyhedral pebble cores and simple single-platform cores. Tools were predominantly manufactured on flakes, frequently modified through denticulate retouching. Primary tool types include notches, becks, thick scrapers, and points such as Tayac and Quinson variants, alongside spheroids. Assemblages associated with this industry have been identified at sites including Xibaimaying, Banjingzi, Sjara-osso-gol (Salawusu), Liujiacha, Wulanmulun,

Gezidong, Xinmiaozhuang, and Shiyu. The *second industry* is distinguished by its predominant use of quartz as a raw material, bipolar core reduction techniques, and a focus on denticulated tools. Representative assemblages derive from Layer 10 and 11 of Lingjing, Xujiacheng, the upper section of Layer 2 and Layer 3 of Xiaogushan, Xianrendong, Longquandong, Shuiliandong, and Zhoukoudian Upper Cave. The *third industry* comprises a pebble-tool complex characterized by choppers, chopping tools, discoidal cores, and denticulated implements. The *fourth industry* is typified by backed tools, including knives, truncated pieces, and trapezes, while the *fifth industry* features side scrapers, end scrapers, and lithics with lateral burin retouch. By approximately 28,000–27,000 calibrated years before present (cal BP), lithic production shifted toward a standardized Upper Paleolithic toolkit, marked by the systematic manufacture of small prismatic blades (~3 cm) from conical cores (Kato, 2021).

In the Korean Peninsula, the Early Upper Paleolithic (40,000–30,000 cal BP) is represented by sites such as Suyanggae, Chongok, Galsanri, Songamri, Hopyeong-dong, and Hwadaeri. This phase is primarily characterized by pebble-tool industries, with a limited presence of blade cores and tools lacking a systematic technological framework. Around 30,000 cal BP, a significant technological transition occurred, marked by the emergence of prismatic blade industries, signaling a shift toward more controlled lithic production systems (Heonjong and Sangseok, 2019).

The Hopyeong-dong site assemblage comprises cores, flakes, blades, tanged points, and scrapers. The majority of artifacts were manufactured from quartz, though blades were exclusively produced using tuff and rhyolite. Notably, two blade cores crafted from tuff were identified. Similarly, the Hwadaeri site artifact collection includes cores, blades, flakes, choppers, points, tanged points,

awls, denticulates, and notches (fig. 39). While quartz predominates, porphyry and quartzite were also utilized (Heonjong and Sangseok, 2019).

In Hokkaido, Paleolithic assemblages predating the Last Glacial Maximum (LGM) are represented by sites such as Wakaba no Mori and Kyoei 3. These sites are attributed to the initial stage of Hokkaido's Upper Paleolithic, dated to approximately 27,000–25,000 cal BP (Naoe, 2014). The lithic industry at Wakaba no Mori includes end scrapers and flakes exhibiting shell-, fan-, trapezoid-, and triangular-shaped morphologies, with a length-to-width ratio near 1.0 (fig. 40). Flake blanks are characterized by considerable thickness, large percussion platforms, and pronounced bulbs of percussion. Margins and overall flake morphology display irregularity. The pre-LGM lithic production technology in Hokkaido is defined by a unifacial reduction strategy, wherein flakes were sequentially detached using the dorsal surface of a preceding flake as the striking platform and the ventral surface as the working face (Terasaki, 2006).

In summary, the Early Upper Paleolithic of Northeastern Asia exhibits pronounced technological diversity, encompassing industries such as bifacial tools, large blade production, pebble tool complexes, small bladelets, and flake-based technologies. This technological variability stands in marked contrast to the relative ecological homogeneity observed in the region's landscapes, climatic regimes, and faunal assemblages. Such incongruity may plausibly reflect prolonged adaptive processes during the early Marine Isotope Stage 2 (MIS-2), as human populations negotiated dynamic environmental pressures. Following the climatic upheavals of the Last Glacial Maximum (LGM), however, microblade technology emerged as a dominant, unifying technocomplex, rapidly superseding prior technological diversity across Northern Asia.

Taking the archaeological context into account, the study of cultural transmission and convergence requires the selection of representative archaeological sites across all key regions. The criteria for site selection were as follows:

1. The site is located within one of the principal regions of the microblade technology distribution zone, specifically Northeastern China, the Korean Peninsula, Hokkaido, or Eastern Siberia.
2. The archaeological assemblage includes microblade cores associated with the Tougeshita and/or Yubetsu reduction methods.
3. Data from the selected sites have been previously published in sufficient detail.
4. The stratigraphy and chronology of the layers containing microblade assemblages are well documented and supported by reliable dating evidence.

Based on these criteria, the following sites were selected for analysis.

2.3.1. Hopyeong- dong

The archaeological site is situated in Namyangju City, Gyeonggi Province, South Korea, within the southeastern foothills of Baekbong Mountain (fig. 41). This location, approximately 149 meters above sea level, lies near the Gu-ryong Stream valley, an area characterized by gently sloping terrain and a rich natural environment. Geographically, Namyangju City itself lies northeast of the Seoul metropolitan area, placing the site within a transitional zone between the mountainous interior and the broader lowlands to the west. This location would have been advantageous for prehistoric hunter-gatherers, offering access to both upland resources, such as stone materials for tool production, and lowland ecosystems abundant with game and plant resources (Hong, Kononenko, 2008). The site’s position in the valley suggests that prehistoric communities

strategically selected this location to access both water resources and the diverse flora and fauna supported by the surrounding semi-forested landscape. The proximity to the stream not only provided water for daily activities but may have also served as a natural transportation and resource corridor. The site is located approximately 350 meters southeast of a modern urban development area, where construction activity first exposed the stratified archaeological deposits.

The stratigraphic sequence (fig. 41) at the site is composed of four main layers, each reflecting distinct depositional and environmental conditions. The uppermost layer, Layer 1, consists of topsoil and disturbed deposits, indicative of recent activity and construction-related disturbances. Below this, Layer 2 comprises a dark yellowish-brown colluvial deposit, characterized by mixed rock fragments and sands, likely deposited by water flow and slope processes. Layer 3 is a yellowish-brown sand layer, composed of interbedded sands and silts. This layer includes localized organic materials, reflecting intermittent depositional stability. Layer 3 is further divided into layers 3a and 3b, the former corresponding to the 2nd cultural layer and the latter to the 1st cultural layer.

Dating of the site was conducted using radiocarbon analysis (Accelerator Mass Spectrometry or AMS) on charred organic materials, including wood fragments and charcoal recovered from Layers 3 A. AMS 14C dates of 22,200±600 B.P., 16,600±720 B.P. and 21,100±200 B.P. were obtained from the obsidian artifact rich Section A (Seong, 2011).

The lithic assemblage is dominated by flaked stone tools crafted from quartz and obsidian. Quartz artifacts include cores, flakes, scrapers, etc. The obsidian assemblage comprises microblade cores, microblades, and retouched flakes, bladelets, scrapers, burins, and awls.

The recovery of refitted lithic fragments highlights deliberate recycling practices, further emphasizing resourcefulness and strategic planning. The discovery of hammerstones and anvils points to in situ tool production, suggesting that parts of the site functioned as workshops. The spatial distribution of these tools, alongside production debris, indicates a degree of spatial organization, with distinct activity zones likely dedicated to specific functions such as tool manufacture, food preparation, and habitation. Organic materials found in association with the lithic artifacts further contextualize human activity at the site. Charcoal fragments, wood, and other plant remains suggest the utilization of fire for purposes such as cooking, heating, etc.

The variety and complexity of the artifact (fig. 42) assemblage underscore the technological proficiency and adaptability of the site's inhabitants. The combination of locally sourced quartz and imported obsidian suggests a dynamic socio-economic system that incorporated both local and external resources.

The Hopyeong-dong Paleolithic assemblage provides evidence of operational sequences associated with both the Yubetsu and Tougeshita methods of microblade core reduction. This dual presence highlights the technological diversity and adaptability of microblade production strategies at the site.

2.3.2. Wolpyeong

The Wolpyeong site, discovered in 1998 by researchers from the Chosun University Museum, encompasses an area of approximately 70,000 m². Located in the southern part of the Korean Peninsula (fig. 41), the site lies within the Boseong River basin, surrounded by mountains reaching elevations of ~600 m and bordered by the meandering Songgwang stream (Lee, 2015).

The stratigraphy of the Wolpyeong site comprises eight lithological layers (fig. 41). The lower portion of the 2 m-thick stratigraphic profile consists of gravel,

sand, and silt, indicative of fluvial deposition. In contrast, the upper section includes five layers of clayey sand or sandy clay, which have yielded Paleolithic artifacts and are interpreted as slope deposits (Tab. 2).

Radiocarbon dating of soil samples from Upper Paleolithic layers 4 and 3 has provided dates of 10,840 ± 350 B.P. and 18,200 ± 100 B.P., respectively (Lee, 2015).

A total of 9,570 artifacts were recovered from cultural layer 4, while 1,399 artifacts were excavated from cultural layer 3. Formal tools constitute 3.3% of the assemblage in layer 4 and 2.6% in layer 3. These tools include scrapers, burins, becs, awls, tanged points, leaf-shaped points, notches, and microblade cores. The average ratio of retouched formal tools to cores in layers 4 and 3 is 79.8% and 8.0%, respectively. Among the retouched tools (fig. 43), end-scrapers, side-scrapers, and notches are predominant (31.0%, 23.6%, and 26.2%), while denticulates, awls, and burins are less common (6.0%, 3.5%, 2.0%). Hunting-related implements, such as tanged points, points, and leaf-shaped points, are rare, constituting only 1–4%, 2.3%, and 0.3% of the assemblage, respectively (Lee, 2015).

The lithic raw materials include vein quartz, rhyolite, hyaline quartz, obsidian, and tuff. Vein quartz artifacts dominate the assemblages across all layers. However, microblades, blades, burins, and tanged points were exclusively manufactured from rhyolite (Lee, 2015).

Artifacts associated with microblade production include microblade cores, microblades, and striking platform tablets used for core rejuvenation. The microblade cores are classified as Type IC, characterized by unifacial preparation of core blanks and the initiation of microblade detachment from a transverse orientation (Lee, 2006; Otani and Lee, 2017). Thus, microblade

assemblage could be estimated as belonging to Tougeshita method of microblade core reduction.

2.3.3. Helong Dadong

The Helong Dadong archaeological site is situated in the Changbaishan region of Jilin Province, People's Republic of China (fig. 44). Located in the southern part of the Changbaishan Mountains, the site was discovered in 2007, with subsequent excavations conducted in 2007 and 2010. The initial excavation in 2007 uncovered an area of 49 m² (Yue et al., 2021), while recent investigations indicate that the site spans approximately four square kilometers (Lian et al., 2023).

The Helong Dadong site lies approximately 75 km west of the Changbaishan volcanoes, whose volcanic activity has significantly influenced the geological features of the region. The stratigraphy of the site comprises seven geological layers (Tab. 3), with Layers 3, 4, and 5 exhibiting evidence of ice wedge formation. Ice wedges originated in Layer 3 and extended downward into the underlying clay layers (fig. 44). Stone artifacts are predominantly concentrated in Layers 1, 3, 4, and 5, with a limited number of smaller artifacts recovered from Layer 6. Radiocarbon dating from the 2010 excavation places Layer 4 within the range of 25,900–25,340 calibrated years before present (cal kyr B.P.). More recent optically stimulated luminescence (OSL) and radiocarbon dating of the 2021 profile suggest that Layer 3 dates to approximately 15,000 B.P., Layer 4 to around 25,000 B.P., and Layer 5 to around 27,000 B.P. Layers 6 and 7 were deposited between 60,000 B.P. and 40,000 B.P. (Lian et al., 2023).

The artifact assemblage from Helong Dadong (fig. 45) includes side scrapers, end scrapers, burins, notches, points, microblades, microblade cores, and associated debitage (Yue et al., 2021). Obsidian constitutes the primary raw material for lithic production at the site. Microblade technology is characterized by a diverse range of core reduction methods, utilizing both bifacial and unifacial blanks (Lian et al., 2023). One prominent method of microblade core

preparation at Helong Dadong is the Yanguan type, which is synonymous with the Tougeshita method (Chun and Xiang-Qian, 1989). However, other microblade core reduction method, in particular Yubetsu, are also represented.

2.3.4. Huayang site

The Huayang site is located on the second terrace of the Tangwanghe River, at an elevation of 180 meters above sea level (m asl), approximately 20 meters above the river level (fig. 44). Discovered in 2011, the site was excavated as part of a rescue archaeological project directed by Li Y.Q. of the Heilongjiang Provincial Institute of Cultural Relics and Archaeology. These excavations were conducted in conjunction with archaeological surveys linked to the reconstruction of the Tieli-Jinshantun and Haonanhe-Nancha highways. The total excavated area of the Huayang site includes three primary excavation zones and numerous test pits, covering approximately 1,000 m². The site is estimated to span a total area of 70,000 m², with the main excavation zone encompassing around 560 m² (Yue et al., 2019).

The stratigraphic profile of the Huayang site consists of six lithological layers, with cultural layers associated with all but the modern topsoil (fig. 44). Three distinct cultural layers (CL 1, CL 2, and CL 3) were identified based on sedimentary facies and artifact concentrations. Radiocarbon dating of charcoal samples from these layers has provided the following calibrated dates: 5,992–5,916 cal. B.P. for CL 1, 14,355–14,025 cal. B.P. for CL 2, and 18,614–17,885 cal. B.P. for CL 3 (Yue et al., 2020). CL 2 is interpreted as representing the Palaeolithic-to-Neolithic transition period, evidenced by the discovery of several pottery fragments. In contrast, CL 3 is attributed to the Paleolithic period (Yue et al., 2019).

The lithic assemblage of Cultural Layer 3 comprises 40 artifacts, including wedge-shaped microblade cores, blades, scrapers, burins, end-scrapers, and

borers. The stone tool technology of CL 3 is characterized by curated production, reflected in the elaborate retouching of tools. In contrast, the CL 2 assemblage includes over 25,000 lithic artifacts alongside a small number of potsherds (Yue et al., 2021). The CL 2 collection (fig. 46) exhibits significant morphological variability, with scrapers represented by 44 artifacts and arrowheads by five bifacially retouched points of small size (~25 mm). Other formal tools from the site include axes, adzes, chisels, and similar implements (Yue et al., 2019). The raw materials used for artifact production at Huayang are highly diverse, including shale, tuff, felsite, tuffaceous sandstone, felsophyre, and banded rhyolite (Yue et al., 2020, b).

Microblade cores Cultural Layer 2 at the Huayang site are characterized by bifacial processing of wedge-shaped blanks. However, only two microblade cores were identified in Cultural Layer 2, indicating a marked decline in microblade production during the Palaeolithic-to-Neolithic transition period compared to the Paleolithic (Yue et al., 2019). The primary method of microblade production at the Cultural Layer 3 of Huayang site is identified as the Tougeshita method of microblade core reduction.

2.3.5. Bol`shoy Yakor` I site

The Bol'shoy Yakor' I site was discovered by E.M. Ineshin in 1985 and subsequently excavated during multiple field seasons (1985–1992, 1995, and 1998). These excavations revealed the site to be a highly representative archaeological context, offering extensive paleoecological, paleontological, and geological data alongside its archaeological significance for understanding the Baikal-Patom highland of Eastern Siberia (Ineshin and Tetenkin, 2017).

The site is situated on a fragment of a 13–14-meter-high terrace that has been significantly eroded by lateral fluvial processes. According to Ineshin and Tetenkin, this terrace was originally deposited as a result of tectonic activity and

is estimated to have been positioned 17–19 meters above the Vitim River level (fig. 47). The stratigraphy of the Bol'shoy Yakor' I site comprises 16 levels (Tab. 4). Taphonomic processes at the site, in addition to tectonic alterations, include the impact of frost wedges, which have been identified between cultural levels 7 and 8, as well as between levels 4B and 4V (Ineshin and Tetenkin, 2017, p. 93).

The site contains 17 cultural levels, with the Upper Paleolithic period represented by 13 levels (3A to 12), dated to approximately 11,750–12,700 B.P. Microblade cores were recovered from cultural levels 3V, 4, 4B, 6, 7, 8, and 9. The lithic industries of the Paleolithic component at Bol'shoy Yakor' I are attributed to the Duktay culture (Ineshin and Tetenkin, 2017). The lithic assemblage (fig. 48) includes wedge-shaped microblade cores, scrapers, bifaces, and burins. Additionally, several cultural layers yielded osseous artifacts, such as points, slotted points for microblades, harpoons, needles, and antler soft hammers. Cultural layer 6 is the most representative, containing 10 wedge-shaped microblade cores, 2 radial reduction cores, 8 complete (refitted) bifaces and 2 fragments, 3 pebble unifacial tools, 1 scraper made from a large spall, 27 transversal burins, 8 scrapers, 1 complete slotted point, 1 fragment of a slotted point, 2 blunt-edged bone points, 1 bone awl fragment, 1 harpoon, 2 needles, and 1 antler soft hammer (Инешин and Тетенькин, 2006).

The bifaces at Bol'shoy Yakor' I are predominantly oval-shaped and asymmetric, with one sub-triangular biface made of crystal quartz and two half-moon-shaped bifaces. Endscrapers and sidescrapers are primarily made from flakes, with hyperbolic, parabolic, and elliptical blade shapes. Transversal burins are also fashioned from retouched flakes, with burin spalls detached from the proximal end. A distinctive feature of these burins is the retouching of a concave edge near the working edge. The sharpening angle of the working edge

exceeds 90° in several cases, suggesting unintentional retouching due to use-wear (Инешин and Тетенькин, 2006).

The raw materials used at Bol'shoy Yakor' I are predominantly local, accounting for 95% of the assemblage. The most intensively exploited materials include acid-effusive rocks (e.g., trachydacites), intermediate effusive rocks (e.g., porphyries in light-green, gray-green, and brown hues), and basic effusive rocks (e.g., diabase and basalt in dark-gray or black) (Ineshin and Tetenkin, 2017).

Osseous artifacts (fig. 48) are primarily hunting-related implements. Bone points are extensively polished, with grooved bases likely used for hafting to shafts. A harpoon fragment, carved from the tubular bone of a large mammal, features 11 downward-oriented teeth along one edge. The harpoon's base has a protrusion with two notches, and its surface is highly polished. The artifact measures 95 mm in length and 4 mm in width. A slotted bone point, made from a massive straight bone, was found broken into four pieces. The point has an elliptical cross-section, with a groove for microblades along one edge. The groove, which does not reach the tip, is 3 mm deep and less than 1.7 mm wide, with a U-shaped cross-section. Five microblades, each no more than 12 mm long and 3–4 mm wide, were preserved within the groove. The base of the point is flattened, with transverse and longitudinal notches for hafting. The point measures 273 mm in length, 17 mm in width, and 7 mm in thickness (Ineshin and Tetenkin, 2017).

The microblade industry at Bol'shoy Yakor' I is based on the Yubetsu method of bifacial reduction. The site's materials demonstrate a durable tradition of microblade production within a single technological framework (Тетенькин, 2015). Bifacial blanks are typically asymmetrical, with a convex lateral cutting edge and a straight-backed opposite edge. Bifacial processing is sometimes

partial, and the reduction process involves detaching longitudinal ridge spalls and ski-spalls. Variability within this technology includes trimming lateral core faces, creating a second front on the microblade core, removing ski-spalls and edge-flakes from opposite ends, using ski-spalls as microblade core blanks or transversal burin blanks, and rejuvenating striking platforms with short frontal spalls (Ineshin and Tetenkin, 2017). A notable feature of the Bol'shoy Yakor' I collection is the significant number of refitting blocks among microblade production products, making it highly valuable for technological studies.

2.3.6. Mamakan VI site

Archaeological investigations at the Mamakan VI site, located near Mamakan village, were initiated in 1986 by E.M. Ineshin. The site was formally recognized as a distinct archaeological entity in 2002. However, these investigations revealed that the site had been significantly damaged by a quarry operating in the area since the 1950s. Full-scale excavations were conducted between 2010 and 2011 under the direction of E.M. Ineshin and A.V. Tetenkin (Тетенькин, 2014).

The Mamakan VI site is situated on the remnants of a 32-meter-high paleo-delta of the Mamakan River, approximately 300 meters from the Mamakan River and 570 meters from the Vitim River. The stratigraphy of the site (fig. 47) comprises 14 layers (Tab. 5). The deltaic sediments are facially divided into two macro-layers: a lower pebble layer with sand interlayers (up to 11 meters thick) and an upper layer of polymictic, horizontally stratified, gray, fine-grained, carbonated sands (8.5–10 meters thick). The orientation of the boulder and pebble deposits, sub-perpendicular to the flow of the Vitim River, indicates the direction of sediment transport from the Mamakan River to the Vitim River. The boulder and pebble layer has been dated to approximately 48,000 B.P. based on remains of Woolly Mammoth and Steppe Mammoth (Тетенькин, 2014).

The upper sand macro-layer corresponds to the middle Sartan glaciation through the Early Holocene, as indicated by radiocarbon dates from charcoal interlayers. These dates include 20,900 ± 300 B.P. (COAH-8263), 6,670 ± 600 B.P. (COAH-4546), 1,770 ± 110 B.P. (ГИН-14596), and 7,300 ± 400 B.P. (ГИН-14595) (Тетенькин, 2014).

The Mamakan VI site has been significantly affected by destructive processes, complicating taphonomic and chronological evaluations. Cultural remains were largely destroyed by quarrying activities, and the stratigraphy was further disrupted by solifluction processes (Тетенькин, 2014). Despite these challenges, the age of Cultural Layer 1 has been estimated to range between 21,000 and 18,000 B.P. (Тетенькин, 2018).

Raw Materials of lithic assemblage is predominantly composed of porphyry (95%), with minor contributions from hornfels (0.3%), crystal quartz (4%), and smoky quartz (0.7%). All wedge-shaped microblade cores are made of porphyry (Тетенькин, 2014).

The artifact assemblage from the Mamakan VI site consists of 229 items (fig. 49), including four scrapers, one retouched flake, one amorphous core, and four microblade cores. The first scraper is round, with a diameter of 14 mm, and made of black hornfels. A transversal burin spall was detached from its base. The second scraper is an endscraper fashioned from a large blade with a triangular cross-section, measuring 3.6 cm in length, 2.2 cm in width, and 0.9 cm in thickness. The striking platform retains cortical remnants. The third scraper is an asymmetric double-edge side-scraper with a drop-like shape, crafted from crystal quartz. The fourth scraper is a sidescraper made from a smoky quartz flake. The amorphous core is a quartz crystal with unsystematic flake detachment scars.

The first microblade core was fashioned from a horizontally oriented uniface. One lateral surface is the ventral side of the flake blank with minimal flake scars on the keel, while the other lateral exhibits unifacial retouching directed toward the central axis. The striking platform was prepared by a longitudinal spall and rejuvenated by a lateral spall. Dimensions: length – 21 mm, platform width – 14 mm, front height – 15 mm. The second microblade core, also made from a horizontally oriented uniface, features a bifacially retouched keel. The striking platform was prepared using a combination of lateral and longitudinal spalls. Dimensions: length – 33 mm, width – 11 mm, height – 18 mm. The third microblade core, similarly unifacial, has a bifacially retouched front and a platform rejuvenated by multiple lateral spalls. Dimensions: length – 32 mm, width – 18 mm, height – 14 mm.

2.3.7. Oruika 2

The Oruika 2 site, located in Chitose City, Hokkaido, investigated during the construction of National Route 337 near New Chitose Airport with a total excavation area of 828,000 m² (fig. 50). Investigations of the "Central Regional Highway 337" project were conducted between 1991 and 2005. The Oruika 2 site was discovered in 1991. Systematic excavations started in 2001. In 2002 the total excavated area was 3,230 m². In 2004 excavated 5,500 m². Final report was prepared by M. Miura, A. Abe, and Y. Hirota. For the investigation of Paleolithic artifacts, advice and cooperation were provided by H. Suzuki and Y. Naoe (Hokkaidō Maizō Bunkazai Center, 2005).

The site is situated on a gentle slope at an elevation of 12–15 meters, characterized by thick deposits of volcanic ash from Mt. Tarumae and Mt. Eniwa, which have preserved the stratigraphic layers exceptionally well. The research history of Oruika 2 is part of a broader regional survey initiated in the 1990s, focusing on the impact of infrastructure development on buried cultural

properties. Previous investigations in the area, such as those at the nearby Oruika 1 and Chipni sites, provided contextual insights into the settlement patterns and material culture of the region. The site's localization near the Oruika River and its proximity to other key archaeological sites, such as the Keyaki and Maruyama sites, highlight its importance in understanding the prehistoric and historic occupation of the Ishikari Lowlands. The excavation uncovered features like Ainu-period dwellings, Jomon pit houses, and Paleolithic stone tool concentrations, offering valuable data on subsistence strategies and cultural transitions (Hokkaidō Maizō Bunkazai Center, 2005).

The stratigraphic sequence is occasionally disturbed by root action and bioturbation, but the volcanic layers remain intact, allowing for precise dating and correlation with regional chronologies. The stratigraphy of the Oruika 2 site is characterized by well-defined volcanic ash layers and soil horizons that provide a clear chronological framework for its archaeological deposits. The uppermost layer (Layer I) consists of modern topsoil and road fill, underlain by the Ta-a (Tarumae-a) tephra from the 1739 eruption of Mt. Tarumae, which serves as a key stratigraphic marker. Below this, Layer III represents a black soil horizon (LB layer) containing Ainu-period features such as postholes and hearths. The Ta-c (Tarumae-c) tephra, deposited around 2,300–2,500 years ago, separates Layer III from the underlying Layer V, a black soil horizon associated with Jomon-period artifacts and features. Layer VI, a brown soil, lies above the En-a (Eniwa-a) tephra (21,000-19,000 cal yr BP), which caps the VII layer—a dense, yellowish-brown loam containing Paleolithic cultural remains. In addition to tephra-chronological data there are three radiocarbon dates obtained from charcoal. These dates ranging between 14,9 – 18 Kcal yr BP (Hokkaidō Maizō Bunkazai Center 2003, 2005).

The Paleolithic assemblage of the Oruika 2 site is characterized by a concentration of lithic artifacts predominantly composed of obsidian. XRF

analysis of the obsidian sources (Hokkaidō Maizō Bunkazai Center, 2003, 2005) reveals that obsidian from Shirataki was used for the Sakkotsu-type microblade core, and obsidian from Shirataki, Oketo, and Tokachi-Mitsumata was used for the microblades.

The lithic assemblage of layer VII of Oruika 2 site is typical Sakkotsu type lithic assemblage (Akai, 2017). It consists of end scrapers, burins, side scrapers, drills made on flakes and Sakkotsu type microblade cores and microblades.

Oruika 2 paleolithic cultural component's collection (fig. 51) consists of 76 scrapers, five bifaces, 18 burins, 10 burin spalls, 11 microblade cores, 14 pieces of by-products of microblade production, and 460 microblades (Hokkaidō Maizō Bunkazai Center, 2005). Burins were manufactured on blanks derived from bifacially processed flakes. Burin spalls were detached diagonally relative to the long axis of the burin, resulting in asymmetrical cross-sections. The bifaces from the Paleolithic cultural layer at the Oruika 2 site exhibit an oval shape with a broad base. Their cross-sections are lens-shaped, with bifacial surfaces formed through center-directed flake removals.

All microblade cores were produced using the Yubetsu method. A key by-product of microblade core reduction is the presence of tablets—ski spalls detached longitudinally from the bifacial preforms. These tablets are diagnostic of the Yubetsu method of microblade core preparation. Several microblade cores exhibit refitting relationships with both tablets and biface-thinning flakes. The raw material for all microblades, microblade cores, and associated by-products is obsidian (Hokkaidō Maizō Bunkazai Center, 2005).

All of the microblade cores were recovered from the northern part of the site. One flake that refits with a microblade core was found approximately to the southwest of the core itself. Many of the microblades found in the vicinity of the core appear to originate from different parent materials, suggesting they are not

products of that specific core. Furthermore, microblades were rarely found in the eastern part of the site, with a tendency for higher concentrations from the central to the western areas. No associated evidence such as platform preparation spalls or platform rejuvenation flakes that refit with the recovered cores, nor lateral retouch flakes, were identified. This absence suggests that the production of microblade cores and the detachment of microblades likely did not take place directly at the site (Hokkaidō Maizō Bunkazai Center, 2003).

2.3.8. Osatsu 2

The Osatsu 2 site is located in the northeastern part of Chitose City, approximately 250 meters southeast of the right bank of the Osatsu River and about 0.9 kilometers upstream from the river's confluence with the Chitose River. As part of a river drainage project, the middle and lower reaches of the Osatsu River were straightened over a length of 2.5 kilometers. Prior to this modification, the river followed a course approximately 250 meters southeast of the present channel, near the East 7th Line road (Hokkaidō Maizō Bunkazai Center, 1996). Investigations at the Osatsu 2 site began in 1986, with the site boundaries identified in 1987. Full-scale excavations were carried out between 1991 and 1994, covering an area of 2,330 square meters (Hokkaidō Maizō Bunkazai Center, 1996).

The stratigraphy of the Osatsu 2 site comprises nine lithological layers (Tab. 6), including two tephra layers of volcanic origin. Layer II contains Ta-a pumice, which dates to 1739 CE, while Layer IX corresponds to the En-a descending pumice formation (Fig. 50). Despite the fact that reliable dates for En-a are not known, based on tephrochronological data and typology of artefacts, the Upper Paleolithic Layer III is estimated to date between 16,000 and 14,000 B.P. (Machida, 1992).

A total of 121 lithic artifacts were recovered from the site, including: one microblade core, 23 microblades, five flakes, two blades, one scraper, one burin, six spalls, 71 chips, and 10 broken pebbles (Fig. 52). The microblade production assemblage comprises a microblade core, microblades, a ridge spall used for platform preparation, and frontal spalls. The microblade core is attributed to the Tougeshita method and was produced from a unifacial blank. The striking platform was created on a cortical surface, prepared through the removal of short spalls. The dorsal face is also partially covered with cortex.

Of particular note is a ridge spall used in platform preparation, which exhibits bifacial processing. One face of the ridge spall retains a portion of the cortex. The frontal spalls are ventrally curved and display asymmetrical frontal projections. In one instance, the left face of a spall preserves traces of retouch related to frontal ridge preparation (Ulanov, 2023).

Chapter 3. Results

3.1. Operational sequence of microblade cores reduction

Tougeshita

Korea

Raw-material of Tougeshita method microblade cores includes chert, obsidian, shale and rhyolite. The preforms used in the Tougeshita method are represented by retouched spalls (including those with cortex) and flakes. The sizes of the preforms vary significantly, ranging from 55 × 40 mm to 16 × 10 mm.

The operational sequence of Tougeshita method microblade cores from the Hopyeong-Dong and Suncheon Wolpyeong sites includes the following stages: primary flaking, face formation, marginal retouching, platform preparation, microblade production, and platform rejuvenation. Evidence of primary flaking is observed in surfaces with cortex and talons (striking platforms) on the spall that served as the preform for the microblade core. Face formation involves the detachment of spalls oriented toward the long central axis, either vertically or sub-diagonally. The scars of marginal retouch are relatively large, and the retouch is primarily concentrated in the keel area of the cores. Microscopic scars on the platform and in the proximal part of the front indicate abrasive overhang reduction (fig. 53). Platform rejuvenation was carried out using spalls directed along the long axis of the striking platform. These spalls could be removed either from the front or the counter-front of the microblade core. The resulting scars from the rejuvenation spalls are typically multiple, short in length, and often exhibit a scalar cross-section.

The number of technological units involved in the production sequence varies between 7 and 15, with an average of 11. In most cases, face formation involves five or fewer technological units; however, in two instances, 9 and 10 units were

identified. The shaping of faces is asymmetrical, with two cores exhibiting ventral faces consisting of a single scar surface. Marginal retouching is generally minimal; two microblade cores show marginal retouch only on one face, while six cores lack marginal retouch altogether.

Rejuvenation of striking platforms is widely observed in Tougeshita microblade cores, involving one to three technological units. Notably, two artifacts are bifrontal microblade cores, indicating that microblade production in these cases required at least two technological units.

These observations could be supplemented with data of previous publications. Thus, production wear was identified on two microblade cores from the Helong-Dadong site crafted from chert and rhyolite. Both cores exhibit bright, smoothed polish spots on their lateral faces, particularly along the ridges and intersections of scars. These polished areas are accompanied by a few randomly oriented sleek striations. The distribution and texture of the polished spots and associated striations indicate that the microblade cores were likely held and secured in wooden devices during use (Hong, Kononenko, 2008).

Northeastern China

Raw-materials of Tougeshita microblade cores of Helong-Dadong and Huayang sites are rhyolith and obsidian. Preforms are oval or sub-rectangular retouched flakes. Size of microblade core`s blanks vary between 20x41 and 98x37.

The analysis of the operational sequence reveals an asymmetrical processing pattern in the preparation of core blanks. The lithic assemblages from both sites include microblade cores characterized by the absence of retouch on one face. Furthermore, the Helong-Dadong site exhibits microblade core with dorsal face that have been processed exclusively through marginal retouch. The platforms of these cores are formed by a longitudinal spall, consistent with the Tougeshita

method. Notably, several rhyolite microblade cores from the Huayang site display spirally twisted fronts (see fig. 54).

The technological patterns of platform rejuvenation exhibit significant diversity. These patterns include: (1) the removal of short spalls directed from the front to the counter-front, from the counter-front to the front, and from lateral edges either perpendicular or diagonal to the long axis of the striking platform, often occurring in variable combinations; (2) secondary modification of lateral edges through the removal of short spalls originating from the platform; and (3) rejuvenation of the platform through the removal of multiple standard short spalls from the lateral edge, with spalls oriented perpendicular to the long axis of the striking platform.

The technological units of Tougeshita method microblade cores from the Helong-Dadong and Huayang sites average 11, with a minimum of 9 and a maximum of 18 units. Face formation was achieved using between 1 and 12 technological units, with an average of 5 units. Marginal retouch is absent in some instances and does not exceed 3 technological units when present. Platform rejuvenation, as a distinct stage in microblade core reduction, involves up to 4 technological units (fig. 55).

Siberia

The raw materials used for the microblade cores at the Mamakan VI site consist of igneous rock (porphyry) and crystal quartz. The preforms of these microblade cores are thick, retouched flakes with wide proportions. Sizes of microblade cores are 21x15 – 33x18 mm.

The operational sequence includes primary flaking, face formation, marginal retouching, platform preparation, microblade production, and platform rejuvenation. Face formation is asymmetrical and achieved through the detachment of spalls directed toward the center of the core. Marginal retouching

is also asymmetrical; in two cases, it is present on only one face of the microblade core. Platform rejuvenation is represented by single or multiple spalls detached from the front, oriented along the long axis of the microblade core, or multiple short spalls from the lateral sides, oriented perpendicular to the long axis. In one instance, the reduction of the platform's overhang was documented.

The microblade cores from the Mamakan VI site exhibit 10 to 13 technological units involved in microblade core reduction. The face formation stage includes 2 to 6 technological units, while the marginal retouching stage involves 1 to 4 units. Platform rejuvenation typically consists of a single technological unit, with only one case requiring two units for this stage (Fig. 56).

Japan

The raw material of the Tougeshita microblade core from the Osatsu 2 site is obsidian. The assemblage from Osatsu 2 exhibits two distinct methods of striking platform preparation. In the first case, scars on the surface of a ridge spall indicate the stages of face formation and marginal retouching. The number of technological units is unequal between the left face (5 units) and the right face (2 units), a pattern typical of the Tougeshita method of microblade core reduction (fig. 57).

The second method of platform preparation involved the use of the natural cortex surface of the raw material nodule. This is demonstrated by the Tougeshita microblade core in the Osatsu 2 collection. The blank is a unifacially retouched split pebble. The face formation stage is represented by only three technological units, while the platform was shaped from the laterals and the contre-front. However, the angle between the front and the platform preserved part of the original cortex surface. The platform preparation stage consists of

four technological units, with rejuvenation of the striking platform achieved by short spalls detached along the long axis of the core (fig. 58).

General results

Yubetsu microblade cores from archaeological sites across continental Northeastern Asia exhibit a broadly consistent technological reduction sequence, underscoring a shared technological tradition. However, regional variations are evident. In Korea, for example, the sizes of microblade cores tend to be smaller compared to those from other regions. At the Bol'shoy Yakor' 1 site, deviations in the reduction sequence include the conversion of ski spalls into microblade cores. Despite these regional differences, the core reduction strategies of the Yubetsu method remain fundamentally similar across the study regions, indicating a sustained technological coherence in the reduction of microblade cores. In particular, similarities between Yubetsu microblade cores of two distant regions, Eastern Siberia and Hokkaido Island, are remarkable.

Yubetsu

Korea

Raw-material of microblade cores of Helong-Dadong site includes obsidian, chert, shale and rhyolite. The preforms of Yubetsu microblade cores are relatively compact, measuring approximately 55 × 25 mm, and exhibit a symmetrical, leaf-shaped bifacial design. The faces are shaped by amorphous scars oriented perpendicular or sub-diagonally to the central long axis of the biface. Marginal retouch is predominantly concentrated in the keel area, suggesting that keel formation was the primary objective of this process.

The operational sequence for Yubetsu microblade cores includes the formation of the bifacial preform (involving face shaping and marginal retouch) and subsequent utilization of the artifact as a microblade core. This sequence

comprises the creation of a striking platform, microblade production, and platform rejuvenation. In one instance, fragmentation of a microblade core was documented. Platform rejuvenation was achieved by chipping away portions of the platform toward the faces of the microblade core.

The authors results are in line with previously published results. In particular, use-wear analysis conducted by N. Kononenko on obsidian microblade cores and technical spalls revealed evidence of production-related wear. Spall rejuvenation on the front of the microblade cores preserved deep, sleek striations that run perpendicular to the edge of the striking platform. Similar abraded surface patches were also identified along the ridge of crested spalls (Hong, Kononenko, 2008).

The number of technological units observed in the analyzed Yubetsu microblade cores from the Hopyeong-Dong site ranges from 11 to 20. The distribution of technological units between the left and right faces is nearly equal. Approximately half of these units are associated with face formation, while two to six units are linked to marginal retouch, primarily for keel formation.

Northeastern China

The raw material used for the Yubetsu microblade cores at the Helong-Dadong site consists exclusively of obsidian. The blanks are characterized as oval bifaces, with dimensions ranging from 70 × 55 mm to 25 × 26 mm. The faces of these bifaces are shaped through the removal of wide, long spalls, which are consistently oriented toward the horizontal axis of the biface.

The operational sequence characteristic of the Yubetsu method involves the systematic shaping of bifaces, which includes two primary stages: (1) the general formation of faces and (2) marginal retouching. The placement of the marginal retouch suggests that its primary objective was to shape key structural features, such as the keel, frontal ridge, and counter-front. Platform preparation

is achieved through the detachment of a ridge spall followed by a ski spall. Beyond ski spall detachment, platform rejuvenation is carried out through the removal of short spalls originating from the front. This sequence reflects a highly structured and intentional approach to core reduction, emphasizing the creation of functional platforms and the maintenance of core morphology for efficient microblade production.

The technological units of the Yubetsu microblade cores from the Helong-Dadong site range from 12 to 23, with an average of 17 units. The majority of these units (6–18) are associated with the face formation process. Marginal retouching, though comparatively extensive, accounts for 2–4 units. Platform rejuvenation, apart from the detachment of ski spalls, is minimally represented, with only 1 unit observed when present.

Siberia

The raw material used for the assemblages at the Bol'shoy Yakor' I site is dominated by locally available lithic resources, accounting for 95% of all cases. The most intensively exploited raw materials include a variety of acid-effusive rocks, intermediate effusive rocks, and various porphyries in light-green, gray-green, and brown colors, as well as basic effusive rocks such as diabase and basalt, typically dark-gray or black in color (Ineshin & Tetenkin, 2017).

The preforms of the microblade cores at the Bol'shoy Yakor' I site are wide, leaf-shaped, or oval bifaces. The dimensions of the microblade cores range from 85 × 55 mm to 35 × 20 mm.

The operational sequence for microblade core reduction at this site is notably complex. The formation of the core faces was achieved by detaching wide spalls directed toward the center of the biface. Marginal retouch is concentrated along

the keel and ridge areas. Platforms were prepared using a combination of ridge spall and ski spall detachment. In one instance, a microblade core exhibited two fronts. Platform rejuvenation operations are primarily represented by ski spall detachments, which could occur multiple times, with a maximum of five ski spalls observed. Another platform rejuvenation pattern involves the detachment of short spalls from the front.

In cultural component 7, ski spalls detached from microblade cores were further modified and converted into additional microblade cores. These newly formed cores underwent secondary face modification, with the scar surface of the ridge or ski spalls used as the platform.

The microblade cores from the Bol'shoy Yakor' I site (Fig. 59) exhibit a range of 12 to 29 technological units, with an average of 21.6 units. The face formation stage involves 8 to 17 technological units, averaging 11.8 units. Marginal retouch ranges from 1 to 7 units, with an average of 3.8 units. The Bol'shoy Yakor' I site exhibits a significant number of front and platform reduction units, varying between 3 and 10, with an average of 6.3 units.

Japan

The operational sequence of microblade cores discovered at the Oruika 2 site can be reconstructed through Scar Pattern Analysis and Refitting Block Analysis. Numerous refitting blocks in the Oruika 2 assemblage provide detailed evidence for the production and reduction processes of bifaces and microblade cores.

Based on these refitting blocks, the technological sequence of Yubetsu biface/microblade core reduction can be reconstructed as follows: 1. Selection of raw material piece; 2. Bilateral shaping of faces; 3. Marginal retouching aimed at forming the frontal ridge, counter-front, and keel.

At this point, the biface might have been used as a tool (see section 3.2, *Use-wear analysis*). The refitting blocks from Oruika 2 demonstrate that reshaping and retouching of the faces could be conducted repeatedly on a single artifact.

Following face shaping and marginal retouching—or after several cycles of these operations—Stage 4 involves the detachment of a longitudinal ridge spall. The negative surface of this detached ridge spall might have been used as the working edge of a planning or scraping tool (see section 3.2, *Use-wear analysis*). This is followed by Stage 5, the detachment of one or multiple ski-spalls. During this stage, both the core with the negatives of ski-spall detachments and the ski-spalls themselves could have been used as tools. The use of ski-spall negatives as scraping or planning edges corresponds to Stage 6, which involves resharpening the working edge by detaching flakes from the lateral part of the Yubetsu core. The scars from these flakes typically extend from the striking platform down to the keel.

Finally, Stage 7 represents microblade production initiated from the narrow end of the microblade core preform. Once the frontal surface was exhausted, microblade production could continue by removing blades from the opposite narrow end or by detaching a frontal spall and reshaping the frontal ridge.

Yubetsu microblade cores from the Oruika 2 site demonstrate variable degrees of biface and core reduction. Cores exhibiting not extensive face processing—characterized by three to six technological units on a single face—were typically produced from comparatively large chunks of raw material (fig. 60). However, despite differences in the number of technological units, the overall reduction sequence remains consistent. This pattern reflects internal variability within a single technological complex. The Yubetsu technology thus maintained a stable and standardized operational sequence while allowing

flexibility in the number of technological units and detached ski-spalls. The occurrence of both single-front and double-front microblade cores further represents variation within this unified technological tradition.

General results

The Tougeshita microblade cores from Northeastern Asian Paleolithic sites exhibit considerable diversity in the specifics of microblade core reduction. While certain overarching features, such as the general operational sequence, the asymmetry of face formation, and the average number of technological units, demonstrate consistent similarities across materials sampled from Korea, Northeastern China, Hokkaido, and Siberia, other aspects show significant variability. For instance, raw material selection, the sizes of microblade cores, the patterns of face shaping, and the methods of striking platform rejuvenation lack sustainable correlations across these regions. This variability suggests that while the broader technological framework of the Tougeshita method was widely shared, some reasons like local adaptations and resource availability likely influenced specific reduction strategies and core morphologies.

3.2. Use-wear analysis

Korea

According to previous use-wear analysis, microblades from Hopyeong-dong (22 artifacts) were primarily used for processing soft, elastic materials such as hide, skin, and meat, as well as soft wood, including fresh stems and fronds. These investigations were conducted by N. Kononenko in 2008 (Hong, Kononenko, 2008). Same investigations indicated usage of wooden vice for microblade core processing. Simillar results were obtained in analyses conducted by the author of this dissertation.

On the lateral of two microblade cores from Wolpyeong site were indicated use-wears of not-utilitarian abrasion. On the edges between scars indicated spots of edge rounding combined with shining and perpendicular striations (fig. 61). This abrasion could indicate transportation or wooden vise clamping. Another group of use-wears identified on microblade cores from Wolpyeong site is semi-circular and trapezoidal scars with scalar termination located at the edge of striking platform (fig 61). Presence of these scars interpreted as result of abrasive reduction of the overhang of microblade cores platform.

Siberia

Materials of Bolshoy Yakor` I were previously observed by use-wear analysis specialists N. Kononenko (Ineshin, Tetenkin, 2017) and P. Moroz. However, the results were not widely published. Published data presenting use-wears of cutting and scraping on the edges of bifacial preforms of microblade cores and on platforms of microblade cores (Ineshin, Tetenkin, 2017).

A significant amount of microblades in materials of Bolshoy Yakor` 1 site requires sampling of artifacts before observations. For the investigations 253 microblades (including inserted in projectile point) were selected from highly representative cultural components 6 and 7. Additionally, ridge spalls of platform making and ski spalls of cultural components 6,7 and 3B were observed.

Use-wears were identified on 18 microblades. The following functions were identified (fig. 62): butchery knife (n 9); burin (n 2); scraping (n 2); planning (n 1); borer (n 2); projectile (n 4).

Butchering use-wears are presented as aligned semi-circular and triangular scars with denticulated edge and feather-like termination. Interestingly, butchering use-wears were identified on two microblades inserted into single-edged projectile point (cultural component 6). This situation is unlikely to indicate the

function of this osseous tool as a butchery knife. Rather this means accidentally using spearpoint for carcass cutting. Semenov S.A. mentioned a similar case in his book “Prehistoric Technology” (1973). There are wide ethnographic and archaeological analogues of this situation.

For instance vivid example is San (Bushmen) of Southern Africa use points with inserted microliths for skinning and defleshing hunting preys (Deacon, Deacon, 1999). Multifunctional use of hunting arrows was studied for Pume hunters of Venezuela (Greaves, 1997). Another ethnographic example of secondary functions of hunting points is Kimberley points (pressure-flaked stone tools typically made of glass) that were used for hunting, butchering kangaroos, and fine cutting tasks by indigenous people of Australia (Akerman & Bindon, 1995).

Use-wear analysis of Folsom fluted points (Ahler, Geib, 2000) and Clovis points (Frison, 2004) also indicate some range of functions of points other than high velocity contact with the target. In particular, use-wears of cutting and scraping are represented in both cases.

In addition to use-wear analysis of microblades ski-spalls were observed too. Use-wears on ski-spalls were identified as the result of both previous (by N. Kononenko and P. Moroz (personal communication - P. Moroz; E.M. Ineshin) and current examinations. By the location of the use-wears ski-spalls could be divided into two groups: 1. with wears of usage before detaching, 2. ski-spall used after detaching from the microblade core.

Ski-spalls with wears of usage before detaching indicating usage not of ski-spall itself but bifacial preform or microblade core as a tool. Examples are refitted blocks from cultural components 3V and 4B with use-wear of scraping on ski-spalls (Ineshin, Tetenkin, 2017: p.222; p. 204).

Ski-spalls used after detachment from microblade core has wears on the ventral surface. Example is given on (fig. 62) presenting ski-spall used as borer. Wears of usage located on the ventral surface in the distal part of ski-spall. Abrasion represented by poorly developed rounding and semi-circular scars with thin cross-section. Additionally, there are examples of ski-spalls with detached burin spall.

This situation indicates the specific role of ski-spall in the Yubetsu method of microblade core reduction. Traditionally, ski-spall is considered as a technological element detached for the preparation or rejuvenation of striking platforms in Yubetsu microblade core technological sequence (Hirasawa, Holmes, 2017). Morphological characteristics of ski-spalls with a relatively thin and an even longitudinal profile could be considered as indicators of Yubetsu technology (Gryba, 2020). However, wears of usage on ski-spalls forces us to rethink the role of ski-spall in the overall Yubetsu reduction process. Functional usage of ski-spalls could mean that these artifacts were not by-products of Yubetsu technological sequence but intentionally produced artifacts. From the morphological functional point of view ski-spall could be considered as a blade or bladelet. In this case we can consider Yubetsu cores as designed for production of both microblades and bladelets. Also, the platform of Yubetsu core in fact is a front for bladelets detaching. At the same time the microblade core front is turned to be a bladelet platform. This situation demonstrates the relativity of pure morphological approach to microblade industry analysis.

Japan

Materials of the Oruika 2 site were previously observed and analysed by Yoshitaka Kanomata. Results of use-wear analysis was published in 2013. A small number of microblades exhibit parallel striations, sometimes C-shaped, located along dorsal ridges and ventral bulbs, in addition to secondary retouch

and impact-related scars. Microscopic observation confirmed that these traces are consistent with wear produced during hafting and use as inserts rather than through direct cutting of organic materials. The recurrent presence of impact fractures suggests that microblades were primarily employed as components of composite hunting weapons, likely hafted into bone or antler shafts. Totally six microblades exhibited use-wears (3 pieces from Block 1; one piece from Blocks 2 and 4; one outside the blocks) (Kanomata, 2013).

The spatial distribution of these artifacts, together with evidence of repair and replacement activities, indicates that Oruika 2 functioned as a short-term camp where hunting gear was maintained and refurbished rather than as a production locus for new tools. These results demonstrate that microblade technology at Oruika 2 was closely tied to hunting strategies in the wetland environment adjacent to the site, underscoring their role as consumable elements within composite projectile systems (Kanomata, 2013).

However, within the framework of this research, the sample for use-wear analysis was expanded to include the edges of a biface/microblade core refitting block, microblade cores, ski-spalls, and one ridge spall associated with platform preparation. Use-wear traces on Yubetsu microblade cores from the Oruika 2 site were identified on the bifacial edges of cores and on fragments detached from bifaces prior to their reshaping into microblade cores, as well as on the laterals and striking platforms.

Use-wear traces located on the platforms of microblade cores were in some cases visible to the naked eye as aligned or isolated semicircular scars distributed along the edge of the platform surface parallel to the long axis. Under microscopic examination, these wear traces appeared as pronounced striations oriented subparallel to the long axis of the platform, accompanied by a characteristic surface polish and overlapping trapezoidal, semicircular, or

amorphous scars. In one instance, however, the striations were oriented subperpendicularly to the long axis, suggesting an alternative kinematic motion during use (fig. 63).

Overall, the use-wear patterns identified on the striking platforms of three microblade cores suggest that these artifacts functioned as implements for scraping or planing, utilizing the negatives of ridge or ski spall detachment as active working surfaces. Comparable results have been reported from the Bolshoy Yakor' I site (Ineshin & Tetenkin, 2017).

Use-wear traces on the laterals of microblade cores are located at the points of contact between the negatives of face-formation scars—that is, along the highest ridges of the microrelief. These use-wears are expressed as dull surface polish accompanied by intersecting fine scratches and striations (fig. 63).

Use-wear traces on the bifacial edges were identified on a refitting block that combines debitage from different stages of biface/microblade core reduction. The use-wear is expressed as a combination of edge rounding and intersecting sub-parallel striations oriented along the bifacial edge (fig. 63). This pattern indicates back-and-forth working motions. Notably, the use-wear observed on fragments from both before and after the reshaping of the biface into a microblade core shows analogous characteristics, suggesting continuity in tool use throughout the reduction sequence.

At the Osatsu 2 site, a range of functional traces was identified on microblades, reflecting diverse patterns of use. Evidence of butchery is represented by bifacial groups of aligned semi-circular and half-moon scars with conical initiation and feather-like cross-sections. Such wear patterns were observed on four microblades, including one relatively thick specimen detached by percussion (Fig. 64:1). Scraping use-wear is characterized by unifacial abrasion composed of overlapping semi-circular, triangular, and trapezoidal deep scars.

These exhibit step-like and feather-like cross-sections with conical or bending initiation. In one case, a poorly developed edge micropolish was also identified (Fig. 64:2). Shaving-related use-wear is visible on both macro and micro levels: macroscopically as general edge damage, and microscopically as overlapping semi-circular, triangular, and trapezoidal deep scars with step-like and feather-like cross-sections and conical initiation on the dorsal face. The ventral face displays faint striations (Fig. 64:3–4). Finally, graving use-wear was documented on two microblades, appearing as aligned and overlapping trapezoidal, semi-circular, and triangular scars with feather-like cross-sections and conical or bending initiation (Fig. 64:5).

General results

Use-wear analyses from Korea, Northeastern China, Siberia, and Japan in sum demonstrate that microblade technologies in Northeastern Asia were employed in a broad range of functional contexts, including hunting, butchering, hide and wood processing, and tool maintenance. Despite regional variability in raw materials, site function, and assemblage composition, common technological and behavioral patterns emerge. These patterns indicate that microblade technology across the region was not limited to projectile function but encompassed a wider toolkit for subsistence and craft activities of prehistoric hunter-gatherers.

In Korea, functional analyses reveal that microblades were primarily used for working soft, elastic materials—such as hide, meat, and soft wood—and occasionally for harder vegetal or animal substances. The presence of awls, cutting tools, and woodworking implements suggests a versatile toolkit integrated into multiple stages of subsistence activity. Hafting traces on some microblades indicate their inclusion in compound tools, confirming the presence

of standardized composite implements. Additionally, the discovery of non-utilitarian abrasion and clamping wear on microblade cores, likely resulting from fixation in wooden vises, reflects an advanced operational system and careful technological preparation.

At Helong Dadong in Northeastern China, use-wear studies (Ting et al., 2024) similarly identified microblade utilization for cutting and sawing soft to medium materials, including both animal tissues and herbaceous plants. However, the overall degree of use-wear is comparatively low, and hafting traces were not observed. This may reflect variable reasons, including differences in site function, tool discard behavior, or the availability of high-quality raw materials such as obsidian, which preserve microwear less distinctly.

In Siberia, particularly at the Bolshoy Yakor' I site, microblade and core use-wear analysis provides a more complex picture consistent with the Yubetsu technological system. Identified functions include butchering, scraping, planing, boring, and use as projectile inserts. Of particular interest is the dual role of ski-spalls—spalls typically detached during the preparation of Yubetsu microblade cores—which exhibit use-wear both before and after detachment. Some ski-spalls bear traces of scraping and boring, indicating that they served as active tools rather than mere by-products of core rejuvenation. This finding challenges the conventional view of ski-spalls as purely technical waste and instead positions them as intentional components within a curated technological sequence. The multifunctionality of microblades and ski-spalls in Siberian Yubetsu assemblages thus reflects an integrated approach to raw material economy, where each stage of reduction potentially produced usable implements. The presence of impact and cutting wear on projectile points further supports the interpretation of microblades as both hunting and processing tools, closely tied to the adaptive strategies of highly mobile Paleolithic groups.

In Japan, at Oruika 2, use-wear on microblades and microblade cores demonstrates a close association with hunting activities. Impact fractures, hafting polish, and edge striations indicate their use as inserts in composite projectiles, while additional traces of scraping and planing on core platforms suggest that exhausted or reshaped cores were reused as functional implements. The identification of similar wear on bifacial fragments both before and after transformation into microblade cores underscores the continuity of tool use across reduction stages—a hallmark of curated technological systems. At Osatsu 2, a wider functional spectrum is documented, including butchery, scraping, shaving, and graving. The presence of multiple working motions and variable edge wear indicates that microblades were used for both subsistence and craft-related tasks, further confirming the versatility of microblade technology in Late Pleistocene Japan.

When viewed comparatively, several regional commonalities emerge. Across all studied regions, microblades were used for processing organic materials, primarily animal tissue, hide, and wood. Cutting and scraping motions dominate, with occasional evidence of piercing, boring, or shaving. Hafting traces—when present—suggest the widespread use of compound tools incorporating microblade inserts. The general patterns of use-wears is consistent across sites, implying shared kinematic and functional principles in tool use. This uniformity supports the notion of a broadly connected technological tradition in Northeastern Asia, maintained through cultural transmission of stimulus diffusion.

In conclusion, the use-wear evidence from sites across Northeastern Asia demonstrates that microblade technology represented a flexible and multifunctional system, integrated within diverse subsistence and technological strategies. The coexistence of the Yubetsu and Tougeshita methods of microblade core reduction is not strongly reflected in the functional variability

of microblades themselves. Instead, the primary distinction between these two methods lies in the broader technological role of the Yubetsu system. The Yubetsu method functioned as a comprehensive and sustainable technological chain that extended beyond microblade production, encompassing the manufacture and use of bifacial tools, scraping implements, blades, and microblades derived from a single preform.

Because it is difficult to identify a single functional explanation for the coexistence of two or more microblade core reduction techniques, this variability is likely influenced by additional factors beyond tool function. The selection of a particular core reduction method may depend on variables such as access to raw materials. For example, the more curated and multifunctional Yubetsu cores are comparatively efficient in terms of raw material conservation. The Yubetsu method produces not only microblades but also bladelets and cores that can be used as tools, while maintaining economical raw material consumption; these characteristics may have favored its selection under conditions of raw material scarcity. Conversely, the more expedient Tougeshita method may have been preferable in contexts where raw material availability was less constrained. Nevertheless, the coexistence of multiple reduction methods within a single archaeological complex is more likely to reflect the superposition of different activity contexts or occupational episodes.

3.3. Knapping technique of microblade production

The techniques of microblade knapping were examined through a combination of experimental technological analysis and fracture wing analysis, with attention to the specific properties of raw materials as well as the techno-morphological characteristics of microblades and microblade cores (Inizan, 2012; Inizan et al., 1992; Gómez Coutouly, 2018; Takakura, 2012). The aim of this integrated

approach is to determine the knapping method or methods employed within the context of each particular Paleolithic microblade assemblage.

Korea

There is limited published data on studies of knapping techniques in Korean microblade industries. Y.A. Gómez Coutouly (2018) proposed that pressure flaking was employed at several sites, including Sokchangri, Sinbuk, Hopyeong-dong, and Daejeong-dong, although this technique was not confirmed for the Jangheungni site. It should be emphasized that Gómez Coutouly's assessments were largely based on published drawings and photographs of microblade cores, rather than direct technological analysis. The author inferred the probable use of pressure flaking by applying a set of diagnostic criteria, including: (1) regularity and parallelism of edges and arrises; (2) very thin profile; (3) straightness of profile; (4) butt narrower than the maximum width of the microblade, with maximum width reached immediately below the bulb; (5) absence of marked ripples on the ventral surface; (6) punctiform pressure butt; (7a) short, pronounced bulb, and (7b) discreet lip beneath the butt; (8) distal section curved and ending in feathering; (9) well-pronounced hackles; (10) overhang abrasion extending onto the debitage surface; and (11) scratched pressure platforms (visible only on cores).

Thus, further conclusions require more precise analysis of archaeological materials. One of the more reliable methods for identifying knapping techniques is the estimation of the exterior platform angle (EPA) of a microblade or microblade core. An angle of 90° has traditionally been considered the maximum threshold for detaching a flake by percussion (Speth, 1981). However, experimental studies have demonstrated that flakes can also be detached by percussion at angles up to 95°. In one such experiment, percussion

was applied to a glass core with a platform prepared using a diamond saw, using a steel hammer mounted in a knapping apparatus operated by a pneumatic cylinder. The authors emphasized the extreme level of accuracy required to detach such flakes, which raises important questions regarding the proficiency of prehistoric knappers. This may, for example, explain the use of indirect percussion on cores with high EPAs: by placing an intermediary punch precisely at the intended point, knappers could compensate for inaccuracies inherent in direct hammer use (Dibble & Rezek, 2009).

However, in my view, the production of debitage by percussion from cores with an exterior platform angle greater than 90° does not seem realistic outside the highly controlled conditions of model experiments using glass cores and pneumatic steel hammers. Dibble and Rezek (2009) also noted that the presence of flakes with EPAs exceeding 90° in archaeological assemblages may often be the result of measurement error. It is also important to note that in a replication of the earlier experiment conducted a decade later, the detached flakes consistently displayed exterior platform angles not exceeding 90° (Dogandžić et al., 2020).

Thus, it can be stated that microblade cores with exterior platform angles greater than 90° are most likely associated with pressure knapping techniques. Accordingly, data on microblade knapping methods can be refined through systematic measurement of platform angles on microblade cores.

Among the sampled materials from the Wolpyeong site, two microblade cores exhibit exterior platform angles greater than 90°. At the Hopyeong-dong site, three such cases were identified. It is notable that only one Yubetsu-type microblade core displayed an angle exceeding 90°. Based on this evidence, it can be concluded that both Tougeshita and Yubetsu assemblages employed pressure knapping techniques to some extent. However, the precise proportion

of pressure versus percussion knapping in Korean microblade assemblages remains unclear. Nevertheless, the current data suggest that both techniques were utilized in the production of microblades at the Wolpyeong and Hopyeong-dong sites.

Northeastern China

Knapping techniques in Northeastern Chinese microblade assemblages have been studied using material from the Helong Dadong site. According to the results of fracture wing analysis published by X. Ting and colleagues, only a few microblades from the Paleolithic layers at Helong Dadong were identified as products of pressure knapping (Ting et al., 2024). For the majority of microblades, the knapping technique could not be determined. However, the presence of specimens with thick striking platforms and pronounced bulbs of percussion suggests that at least a portion of the assemblage was produced using percussion knapping. These findings indicate that in the mixed Tougeshita–Yubetsu assemblage context of Northeastern China, pressure knapping was the predominant technique, while percussion was employed as a secondary method for microblade production.

Japan

Layer III of the Osatsu 2 site belongs to the Tougeshita Mode 1 microblade complex according to morphological criteria. The fracture wing angles of microblades from the Osatsu 2 collection vary between 160.64° and 167°, indicating pressure flaking as the most probable technique of detachment (fig. 65: 1, 4). However, another group of microblades characterized by less regular margins, curved profiles, and comparatively thicker cross-sections displays fracture wing angles ranging between 146.47° and 151° (fig. 65: 1, 3), suggesting percussion flaking as the employed technique.

Microblades from the Oruika 2 assemblage exhibit fracture wing angles varying between 163.32° and 176°, which likewise indicates pressure flaking as the principal method of microblade production (fig. 66). The negative of ski-spall detachment on one of the microblade cores demonstrates a fracture wing angle of 149.57°, corresponding to percussion flaking during the removal of ridge or ski spalls (fig. 66). Furthermore, the general morphology of ski and ridge spalls—combined with the wave-like cross-sections of microblade cores bearing detached ski spalls—strongly supports the interpretation that these blanks were produced exclusively by percussion.

Siberia

At the Mamakan VI site, the exterior platform angles of all sampled microblade cores do not exceed 81°. Other characteristics of these cores include both parallel and regular margins of microblade negatives, as well as negatives with irregular margins. The technique of microblade flaking on Mamakan VI site could not be estimated precisely on the current level of studies. However, overall characteristics of microblade cores allows assumption of mixed percussion and pressure flaking techniques.

By contrast, at the Bolshoy Yakor' I site, six microblade cores exhibit exterior platform angles ranging from 91° to 97°. The fronts of Yubetsu-type microblade cores from this site display highly regular and parallel microblade negatives—features typically associated with pressure knapping.

Microblades from the Bolshoy Yakor' I site exhibit a high degree of regularity, with well-parallel edges and arrises. The profile of the vast majority is thin and straight or shows only slight curvature. The butts are narrower than the proximal part near the bulb, which represents the maximum width of the artifact. Butt shapes are typically punctiform or small and narrow, and they do not display marked ripples on the ventral surface. Instead, the ventral surface commonly

shows a short, pronounced bulb accompanied by a discreet lip beneath the butt. The distal sections of the microblades are slightly curved and terminate in feathering. Taken together, these technological and morphological features indicate that pressure flaking was the dominant knapping technique employed in the Bolshoy Yakor' I microblade industry.

In addition to the analysis of microblades, four ridge spalls and thirty-five ski-spalls were examined. A subgroup of six ski-spalls excavated from Layer 6 exhibits technological attributes characteristic of pressure knapping. The butts of these specimens are small and thick, and the margins are regular and parallel. Ring cracks on the butts, bulbar scars, and ventral fissures are absent. The exterior platform angles of the six ski-spalls exceed 90°. An atypical feature is the presence of flat proximal ventral areas without pronounced bulbs. Nevertheless, the overall technological and morphological characteristics of this group strongly indicate production by pressure flaking.

However, the majority of ski-spalls and ridge spalls from the Bolshoy Yakor' I site exhibit attributes consistent with percussion flaking. First, the size and curvature of their profiles make production by pressure difficult to assume. Second, in all cases the exterior platform angle is less than 90°. The butts are thick and large in form. In nine cases, ring cracks were observed on the butts, and in two cases bulbar scars were visible on the ventral surfaces. These characteristics indicate that percussion was the predominant technique for detaching ridge spalls and ski-spalls. Nevertheless, isolated evidence suggests that pressure flaking was also occasionally employed in the production of ski-spalls.

3.4. Morphospace model

The concept of *morphospace* is used to define the limitations of morphological dimensions within material phenomena. A morphospace model is constructed

by accounting for a set of possible dimensions. This concept is fundamental to convergence studies, where different forms originally occupying distinct regions of the morphospace evolve toward similar morphologies (McGhee, 2018). In other words, morphospace provides a framework within which material culture can independently develop and be reinvented. It represents the theoretical boundary of evolutionary development.

However, given the complexity of microblade industries as a cultural phenomenon, a comprehensive morphospace model must encompass not only the dimensional variability of microblade cores and microblades but also technological variabilities (including knapping techniques, blank types, and platform rejuvenation methods) and raw material variability.

The concept of *techno-morphospace* (or *technospace*) has been specifically developed for lithic artifact studies. In contrast to conventional tool morphospace models that define spatial dimensions based on quantitative morphological attributes, technospace is structured around different states of manufacturing techniques and technologies (Charbonneau, 2018). This approach requires a precise definition of techniques and their possible variations. In the case of microblade industries, the highest hierarchical level of the technological morphospace model corresponds to the blank type used for microblade cores, while lower levels represent platform-making and rejuvenation methods (Fig. 67).

Beyond illustrating cultural convergence, a morphospace model can also help identify *stimulus diffusion*. The technological morphospace framework can reveal instances of copying errors, which act as variation-generating mechanisms within pre-existing technological systems (Charbonneau, 2018). Such copying errors may result from low-intensity social interactions. In this

context, technological exchange occurring under conditions of minimal direct contact can indicate a process of stimulus diffusion (Storey & Jones, 2011).

Thus, constructing a morphospace model for microblade industries requires defining the dimensional range of microblade cores and microblades, raw material variability, and technological and methodological variability in microblade core reduction.

3.4.a. Variability of Raw Materials in Microblade Industries

The range of raw materials used by hunter-gatherers in the Late Pleistocene–Early Holocene of Northeastern Asia and Beringia is notably diverse. Archaeological sites selected for this study contain microblade artifacts made from obsidian, shale, effusive rocks, and siliceous rocks (Tab. 7).

Obsidian is an extrusive igneous rock, typically formed by the rapid cooling of felsic lava. Due to the high viscosity of silica-rich lavas, nucleation of crystals is inhibited, resulting in a glassy texture. Obsidian is generally black and has a shiny or glassy luster, with a highly reflective surface when polished. It is relatively hard, measuring 5–6 on the Mohs scale, making it ideal for tool production. One of obsidian's most distinctive properties is its conchoidal fracture pattern, which produces sharp, curved edges optimal for cutting tools and weapons (Atlas of Magmatic Rocks, 2019).

Shale is a laminated sedimentary rock composed predominantly of silt, clay, and mineral components such as quartz and plagioclase. It is characterized by its ability to break along thin laminae, a property known as fissility (Okeke & Okogbue, 2011). Archaeological materials primarily include siliceous shale, a dense, fine-grained rock composed of 67.5–97% SiO_2, with impurities such as iron and manganese oxides, chlorite, organic matter, and microfossils. Shale is typically black or gray with a matte fracture surface and exhibits a conchoidal fracture pattern (Козловский, 1987).

Effusive rocks, also known as volcanic rocks, form when lava solidifies on the Earth's surface (Atlas of magmatic Rocks, 1995). Archaeological examples include rhyolite and various porphyritic rocks with fine-grained textures. *Rhyolite*, a common material for microblade production, is a felsic extrusive rock rich in quartz (>20%) and alkali feldspar (>35%). Due to its high silica content, rhyolite lava is highly viscous. It exhibits variable coloration and a glassy, aphanitic, or porphyritic texture (Bonewitz, 2012).

Siliceous rock, commonly referred to as chert, is a fine-grained sedimentary rock composed of microcrystalline or cryptocrystalline quartz (SiO_2). It forms organically through biogenic sedimentation or inorganically via chemical precipitation. Chert occurs as nodules, concretionary masses, and layered deposits, displaying a wide range of colors. It has a cryptocrystalline texture and a hardness of 6.5–7 on the Mohs scale (Bonewitz, 2012).

Apart from listed raw materials in rare cases in Siberia and Korean peninsula microblade cores could be made of framework silicate minerals such as cristall quartz, chalcedony and rauchtopas. This kind of raw material is characterized as isotropic high quality raw material for lithic production.

Despite variations in geological classification and formation processes, the raw materials used for microblade production share common properties: fine-grained or cryptocrystalline structure, conchoidal fracture patterns, and similar hardness levels.

3.4.b. Morphospace Model of Wedge-Shaped Microblade Cores

The morphological and technological variability of wedge-shaped microblade cores is extensive. In the classification of Hokkaido Paleolithic microblade cores, seven major reduction methods are recognized, further subdivided into 14 subtypes (Yamada, 2006). Other regions also exhibit distinctive core reduction strategies, such as the Kovrizhka method (Тетенькин, 2017).

Key variables within the morphospace model include: 1. Blank type (e.g., flake, blade, retouched blade, biface, broken tool, or ski spall); 2. Core orientation (vertical or horizontal); 3. Striking platform formation (e.g., ridge spall detachment from front, lateral detachment, partial/complete ridge removal); 4. Number of striking platforms (single or polar); 5. Number of working fronts (one or two); 6. Platform rejuvenation methods (detachment from the front, lateral, counter-front, or combinations thereof).

The sum of these variables defines a highly complex morphospace model of microblade core reduction strategies.

Comparing the sizes of microblade cores is often uninformative due to the detachment of flakes and tablets during the reduction process. More reliable data on the maximum dimensions of microblade cores can be obtained from measurements of bifacial blanks, which typically range from 102–75 mm in width, 70–52 mm in height, and 15–18 mm in thickness. The minimum dimensions of Yubetsu method microblade cores are approximately 30 mm in width, 40 mm in height, and 10 mm in front thickness.

The Yubetsu method primarily uses bifacial blanks for microblade core production. In rare cases, ski spalls are converted into microblade cores, but the reduction of a biface is always a prerequisite for microblade core production. Based on techno-typological analysis, the Yubetsu method exhibits three sub-types: Pirika, Sakkotsu, and Shirataki (Yamada, 2006).

The rejuvenation of striking platforms in Yubetsu method microblade cores is limited to two variations: 1. Additional ski spall detachment; and 2. Short scars from the front, aligned with the long axis of the microblade core's platform.

Notably, rejuvenation techniques involving lateral spalls (directed perpendicularly to the long axis) or longitudinal spalls from the counter-front

are absent. Bifrontal cores, though rare, are also documented within the Yubetsu method.

The Yubetsu method's morphospace model includes 6 technological variations, which combine to form 15 possible reduction sequences for microblade core production. This variability reflects the adaptability and flexibility of the Yubetsu method in response to raw material constraints and functional requirements.

Tougeshita microblade cores exhibit maximum dimensions of approximately 70 mm in width, 45 mm in height, and 25 mm in front thickness. The minimum dimensions are around 20 mm in width, 14 mm in height, and 10 mm in front thickness.

Tougeshita microblade cores can be produced from a variety of blanks, including retouched blades, flakes, retouched flakes, or bifaces. All Tougeshita cores feature a single striking platform, although rare examples with two fronts have been documented (Yamada, 2006).

Techno-typological analysis identifies three modes of the Tougeshita method in the Paleolithic of Hokkaido Island:

1. Mode 1: Characterized by a long base and a thick, elongated shape. The average height-to-width ratio is approximately 2.0.
2. Mode 2: Features a short base relative to the core's height and is generally thinner than Mode 1.
3. Mode 3: Similar in length to Mode 2 but with a greater height (Yamada, 2006).

Fracture wing analysis of Hokkaido Paleolithic materials indicates that Mode 2 primarily used the pressure technique for microblade production, while Modes 1

and 3 employed a combination of pressure and percussion techniques (Takakura, 2020).

The striking platform design in Tougeshita microblade cores is highly variable, encompassing eight distinct variations:

1. Natural cortex surface.
2. Surface of the scar from ridge spall detachment.
3. Rejuvenation by a long spall from the counter-front.
4. Rejuvenation by short spalls from the front.
5. Single long spall from the front.
6. Rejuvenation by multiple long spalls from the front.
7. Multiple short spalls from the lateral.
8. Combination of the above operations (Fig. 68).

The Tougeshita method's morphospace model includes 17 technological variations, which combine to form 66 possible reduction sequences for microblade core production. This extensive variability reflects the adaptability and flexibility of the Tougeshita method in response to raw material constraints and functional requirements.

3.4.c. Morphospace Model of Microblades

As the intended final product of microblade core reduction, microblades require a dedicated morphospace model that accounts for both dimensional and morpho-technological variability. According to the definition of *microblade*,

these lithic artifacts typically measure approximately 50 mm in length, 12 mm in width, and 3 mm in thickness (Gomez Coutouly, 2018).

Functional microblades may be either complete or fragmented, with functional use observed in proximal, medial, and distal fragments. The variability in microblade cross-sections includes triangular, trapezoidal, and polyhedral forms. Technomorphological variability among microblades is closely linked to the stage of core reduction. Microblades exhibiting cortical remnants or residual ridges are typically associated with the early stages of core reduction. Similarly, microblades with triangular cross-sections are often indicative of early-stage reduction.

However, to construct a meaningful morphospace model, the focus must be on *functional* microblades rather than all produced specimens. The proportion of microblades exhibiting use-wear is generally low (Gauvrit Roux et al., 2021). Therefore, dimensional measurements for the morphospace model are based on microblades with confirmed use-wear traces. The observed dimensions of functional microblades are as follows:

- Maximum dimensions: 62 mm in length, 12 mm in width.
- Minimum dimensions: 3 mm in length, 1.5 mm in width.
- Thickness range: 0.5–3 mm (Gauvrit Roux et al., 2021; Hong, Kononenko, 2008; Gauvrit Roux et al., 2022).

Additionally, microblades inserted into projectile points tend to be smaller. The maximum recorded length for microblades used in hunting equipment is approximately 9 mm (Fig. 69). However, these measurements are only approximate due to the fragility of microblades and the potential for breakage resulting from use, post-depositional processes, or excavation-related alterations.

Chapter 4. Application of Cultural Transmission and Convergence conceptions to the Notheastern Asian Upper Paleolithic studies

4.1. Reconstruction of Microblade Technology Operational Sequence

A complex approach to studying microblade technology has enabled a more precise and comprehensive reconstruction of the operational sequence and related behaviors. This reconstruction is applicable to both the Yubetsu and Tougeshita methods of microblade core reduction, and likely to other wedge-shaped microblade core reduction methods as well.

The raw materials used for microblade cores are highly diverse, encompassing various rock types of different geological origins, which may be either locally sourced or imported. The key common feature of these materials is their isotropic, homogeneous structure, which ensures a smooth surface on the detachment scars. These characteristics might be considered as a key raw material limitation of microblade technology. However, no particular correlation between microblade technology or any particular method of microblade core reduction (Yubetsu or Tougeshita) and any particular raw material (obsidian, flint, etc.) was not identified.

The formation of core faces involves the detachment of spalls directed either toward the long axis of the core preform or toward the central point of the blank. The shape and size of these scars suggest that this stage of core reduction was accomplished using percussion techniques.

When present, marginal retouch is concentrated along the keel and ridges. The size and shape of the retouch scars indicate the use of both percussion and pressure retouching.

The thorough retouching of ridges is likely related to the preparation for subsequent spall detachment during platform and front formation. Retouching

of the keel may be associated with the use of a wooden vise, a hypothesis supported by several scholars (Табарев, 2008; Sollberger & Patterson, 1983). Use-wear evidence from microblade cores at the Hopyeong-dong (Hong, Kononenko, 2008) and Wolpyeong sites further supports this interpretation. Thus, the use of a wooden vise can be included in the general reconstruction of the microblade core reduction sequence.

Microblade production, whether conducted by pressure or percussion, is followed by abrasive processing of the platform and the proximal part of the front. Platform rejuvenation involves the detachment of tablets or a series of small spalls. Notably, different rejuvenation techniques may be applied within a single reduction cycle.

Microblades produced from the wedge-shaped cores were used with variable handles that evidenced by discoveries of handles, knives (Giria, Pitul'ko, 1994) and by use-wears of fastening on the surfaces of microblades (Kanomata, 2013). Slotted tools can be divided into three classes: 1. Slotted tools with parallel multiple inserted microblades (e.g., osseous single-edged knives); 2. Slotted tools with a single parallel microblade (e.g., wooden-handled knives); 3.Tools with a longitudinally attached single microblade (hypothetical reconstruction).

Tougeshita microblade core production begins with the preparation of a blank, which may be an unretouched flake, a retouched flake, or a retouched blade. In the case of retouched blanks, the frontal ridge, platform preparation ridge, and keel are shaped by retouch. However, even in microblade cores with retouched preforms, the striking platform may consist of an unmodified natural surface of the raw material piece. The formation of faces was carried out by percussion retouch combined with marginal pressure retouch. Platform preparation spalls were detached using percussion, while the ridge spall used for front formation could be removed either by pressure or percussion.

After the preparation of the faces, platform, and front, the production of microblades began. Experimental studies have demonstrated that microblades could be detached while the core was held in the hand or between legs. However, some results of use-wear analysis suggest that wooden vices may also have been employed to fasten the cores during knapping. The carefully shaped keels observed on many Tougeshita microblade cores might support this interpretation. Given the wide chronological and geographical distribution of Tougeshita-type cores, it is likely that various methods of fastening were used.

Microblade detachment from Tougeshita cores involved pressure flaking, percussion flaking, or a combination of both, followed by abrasive reduction of the overhang in the contact zone between the front and the striking platform.

A key element of the Tougeshita microblade core reduction sequence was the rejuvenation of the striking platform. The observed variability in platform modification among Tougeshita cores includes the following types: Natural cortex surface; Surface of the scar from ridge spall detachment; Rejuvenation by a long spall from the counter-front; Rejuvenation by short spalls from the front; Single long spall from the front; Rejuvenation by multiple long spalls from the front; Rejuvenation by multiple short spalls from the lateral. Some cores exhibit platforms rejuvenated through a combination of the operations listed above. After the rejuvenation of the platform production of microblades started again. The process repeated until deposition of the microblade core.

Reconstruction of the Yubetsu microblade core reduction sequence demonstrates a complex technological system consisting of several interconnected stages, including the production and use of bifaces, the use of microblade core preforms as tools, and the manufacture and use of blades (ski-spalls) and microblades. As in the Tougeshita method, no stable correlation between the Yubetsu reduction sequence and any specific type of raw material

has been identified. A variety of isotropic rocks were employed, depending on the geographical location of the archaeological sites.

Oval bifaces were used as blanks for microblade core production. As a result of face formation, these bifaces acquired symmetrical shapes and cross-sections, and their edges were modified by marginal retouching. Use-wear analysis revealed traces of use along the edges of bifaces, indicating their functional application prior to core transformation. In particular, wear traces were identified on bifacial fragments from a refitted block discovered at the Oruika 2 site, suggesting that the biface had been used as a tool before being reshaped into a microblade core. However, in most cases, it remains difficult to determine whether artifacts were used before or after the biface-to-core transformation.

The next stage of the Yubetsu technological sequence involves the detachment of a longitudinal ridge spall, which was conducted by percussion. Both the ridge spall and the resulting core blank could be utilized as tools after this operation. The surface of the platform formed during ridge spall detachment could serve as a working edge. Use-wear analysis identified traces of scraping and planning on the Yubetsu core platforms and on the dorsal faces of ski-spalls. The reshaping of faces from the platform, identified through scar pattern analysis and observed on refitted blocks, is most likely related to shaping and re-sharpening of the working edges.

The subsequent stage is the detachment of ski-spalls. In the majority of cases, ski-spalls were detached by percussion; however, several ski-spalls discovered in cultural layer 6 could be attributed to pressure production. Morphologically, ski-spalls can be described as blades with trapezoidal cross-sections. Use-wear analysis indicates variable functional usage of ski-spalls, including cutting, scraping, and planning. Furthermore, the collection from the Bolshoy Yakor' I

site includes microblade cores and transverse burins made from ski-spalls, indicating the reuse of these products in tool production.

The following stage is the production of microblades by pressure knapping from the narrow end of the core, or from both ends in the case of bifrontal cores. Apart from the absence of percussion microblade production, the general process of microblade manufacture in the Yubetsu method is largely similar to that of the Tougeshita microblade core reduction sequence. Microblade detachment was preceded by careful preparation of the platform and frontal ridges, followed by sequential pressure removal of microblades.

Rejuvenation of Yubetsu core platforms shows limited variability and is represented primarily by retouching of the platform with short spalls or by detachment of additional ski-spalls. Assemblages from Oruika 2 and Bolshoy Yakor' I demonstrate cases of front rejuvenation by percussive removal of the entire front surface. The refitted block from Oruika 2 includes a detached frontal spall and a re-formed frontal ridge, illustrating the process of frontal rejuvenation and ridge restoration.

Considering the use of ski-spalls both as tools and as blanks for microblade cores, it can be concluded that the Yubetsu technology is sustainable and integrated technological complex encompassing the production of blades, microblades, scraping tools from a single bifacial blank. The expedient reuse of by-products, such as ridge spalls, further supports the interpretation of the Yubetsu method as a highly adaptive, multipurpose technological strategy aimed at maximizing raw material use through a continuous sequence of transformation and reconfiguration of lithic blanks.

4.2. Expedient and curated microblade technologies

The differences in the technological operational sequences of Yubetsu and Tougeshita microblade core reduction suggest that these methods can be

distinguished as curated and expedient. The Yubetsu method, with its standardized and structured reduction process, reflects a curated approach, likely associated with planned tool production and long-term technological maintenance. In contrast, the Tougeshita method, characterized by high variability in knapping operations and platform rejuvenation techniques, represents a rather less curated, suggesting more flexible and situational tool-making strategies.

The concept of curation in prehistoric archaeology was first introduced by Lewis Binford (1973, 1979) and has since been extensively developed and refined by various scholars, including Odell (1996) and Bleed (1986). The notion of "curated tools" refers to stone implements that were deliberately designed for long-term use, maintenance, and transport by prehistoric populations. These tools are characterized by evidence of careful production, systematic maintenance, and, in some cases, reshaping or repurposing over their use-life. This behavior reflects a strategic approach to tool production and use, indicative of foresight and planning in response to specific environmental and subsistence challenges (Andrefsky, 2008).

In contrast, "expedient tools" are typically produced quickly for immediate, short-term tasks and are often discarded after use. These tools lack the systematic maintenance and long-term planning associated with curated tools. The distinction between curated and expedient tools provides valuable insights into the technological organization and adaptive strategies of prehistoric societies. Curated tools, with their emphasis on durability and reusability, suggest a mobility strategy and resource management system that prioritizes efficiency and reliability, particularly in environments where raw materials were scarce or where groups were highly mobile.

The degree of curation in a lithic assemblage serves as a valuable indicator of the mobility patterns, resource availability, and technological organization of ancient societies (Odell, 1996). High levels of tool curation often imply that a group anticipated limited access to suitable raw materials, leading them to invest time and effort in producing, maintaining, and transporting versatile tools over long distances.

This behavior reflects a strategic adaptation to environments where raw materials were scarce or where groups were highly mobile, necessitating tools that could be reused, resharpened, or repurposed over extended periods. Conversely, in regions where raw materials were abundant and easily accessible, expedient tool use might have been more prevalent. In such contexts, tools were often produced quickly for immediate tasks and discarded after use, as the need for long-term maintenance and transport was less critical. This pattern suggests a more opportunistic approach to tool production and use, tailored to environments where resource procurement was not a limiting factor. By examining the degree of curation in lithic assemblages, archaeologists can infer how prehistoric groups organized their technological systems in response to environmental constraints and subsistence needs. For example, highly curated toolkits might indicate long-distance mobility, seasonal movements, or adaptations to resource-poor environments, while expedient tool use might suggest more sedentary lifestyles or resource-rich settings. This analytical framework not only enhances our understanding of prehistoric technological strategies but also provides insights into the broader socio-economic and ecological dynamics of ancient societies.

Conceptions of curated and expedient tools in context of cultural transmission raise the questions of how different degrees of curation of variable microblade core reduction methods (for instance, Tougeshita and Yubetsu) and what kind of technological knowledge was transmitted and to what extent? Yubetsu method

could be estimated as highly curated lithic technology because of usage of bifacial preforms and highly complex technological operational sequence. Tougeshita method demonstrating lower level of curation because of unifacial preforms, specialization on production of microblades (but not ski-spall bladelets), lower number of technological units. However, the Tougeshita method can not be characterized as an expedient technology of lithic production due to frequent evidence of secondary modifications, such as variable modifications of striking platforms. Thus, the Tougeshita method is considered to be less curated than the Yubetsu method of microblade core reduction.

In this case it is important to answer the question: how curated tools are related to the transmission of cultural information? It is logical to hypothesize that tools with a higher level of curation are more likely to be objects of cultural transmission than those with lower curation, while expedient technologies may be less likely to be transmitted due to their simplicity and short-term use. This assumption is grounded in the fact that the production of curated tools in volves complex technological operational sequences, which require detailed knowledge, skill, and planning. The reproduction of such complex technologies necessitates social learning — a primary mechanism of cultural transmission—where knowledge is passed down through teaching, imitation, and practice within a community.

This argument suggests that curated tools are more likely to be transmitted culturally because their complex production sequences require social learning. The structured and consistent nature of curated technologies implies intentional teaching, apprenticeship, or other forms of knowledge transfer within groups. Since curated tools are often maintained, transported, and reused, they hold greater social and economic value, reinforcing their role in cultural continuity.

In contrast, expedient tools—produced quickly for immediate use—do not require extensive learning or specialized skills, making them less likely to be objects of cultural transmission. Their production is more intuitive and situational, reducing the need for structured knowledge transfer.

Applying this to the Yubetsu and Tougeshita methods, the Yubetsu system, with its standardized operational sequence, curated nature, and strategic planning, is more likely to be culturally transmitted. In contrast, the high variability and flexible production of the Tougeshita method suggest a more situational, possibly independently reinvented approach, aligning with the concept of cultural convergence in some contexts (e.g. Mamakan VI in Siberia) and stimulus diffusion in other contexts.

4.3. Transmission and convergence

Based on the data presented, the spread of the Yubetsu and Tougeshita methods of microblade core reduction appears to be linked to distinct socio-cultural processes that shaped the Upper Paleolithic of Asia. These technological traditions likely reflect variations in adaptive strategies, mobility patterns, and intergroup interactions within prehistoric hunter-gatherer societies.

However, before making conclusions about transmission or convergence of microblade industries it is necessary to compare full lithic assemblades containing Yubetsu and Tougeshita microblade cores. Lithic assemblages containing Tougeshita microblade cores in Northeastern Asia presented both flake and blade industries. The complex of lithic tools usually includes scrapers and burins as key components. In some cases tanged point, awls, and notches are presented. Upper Paleolithic assemblages with Yubetsu microblade cores in general have the same stone tool complex composition. The main difference is the presence of the bifacial industry. Bifaces are presented as a separate group of artifacts as well as bifacial preforms of microblade cores. Low presence of

bifaces in lithic assemblages containing Tougeshita microblade cores is interesting because Tougeshita microblade core preforms are often processed bifacially on ridges. In sum, overall characteristics of Northeastern Asian Upper Paleolithic industries are similar despite regional variabilities. The main difference between Yubetsu and Tougeshita assemblages is the presence of bifacial tools.

The Yubetsu method represents a highly efficient technological system adapted for foraging landscapes by highly mobile hunter-gatherers. Investigations indicate that Yubetsu core reduction involved a complex yet sustainable set of technological operations. This method is characterized by a consistent number of technological units, the use of pressure technique for microblade production, low regional variation in technological sequences, and a highly curated character of cores. Thus, the spread of Yubetsu method in Northeastern Asia should be estimated as the result of cultural transmission.

The most compelling evidence for the cultural transmission of the Yubetsu technology lies in its consistent occurrence across two geographically distant regions of Northeastern Asia—Hokkaido and Eastern Siberia. In both areas, the Yubetsu complex is represented not only by the characteristic morphology of microblade cores or by the general technological sequence but also by the entire operational system of production. This includes the manufacture of bifaces, scraping tools, blades (ski-spalls), and microblades, all reproduced with remarkable technological uniformity. Such consistency indicates that the Yubetsu technological tradition was transmitted across the broader macro-region of Northeastern Asia with minimal modification, reflecting a stable and well-preserved system of knowledge transfer.

In Eastern Siberian Upper Paleolithic, the Westmost area of this research work, assemblages the Yubetsu industry of Bolshoy Yakor I site likely presents the

result of cultural transmission due to the significant number of analogies in all territories of Northeastern Asia and Beringia and lower technological variability of microblade core reduction. Investigations indicate that Yubetsu core reduction involved a complex yet sustainable set of technological operations. In every region of study Yubetsu microblade industries share common features of function, operational sequence, and technique of microblade production.

However, regional variations present specific and unique features of Yubetsu microblade cores in every region. The main two differences of Yubetsu microblade core reduction sequence in the region of Eastern Siberia are in some cases ski-spall detachment by pressure and reshaping of ski-spalls into microblade cores.

The dispersal of Tougeshita method microblade cores is likely the result of distinct socio-cultural processes. The morphospace model of Tougeshita exhibits significantly wider boundaries compared to Yubetsu, reflecting greater technological variability. The types of technological operations—particularly platform rejuvenation—are highly diverse, encompassing nearly all possible knapping combinations without strong correlations. Additionally, microblade production techniques range from percussion to pressure flaking. This variability suggests that the spread of Tougeshita microblade cores may be best explained through cultural convergence or stimulus diffusion rather than a single, standardized technological tradition.

Arguments can be made for both stimulus diffusion and cultural convergence in explaining the presence of Tougeshita microblade cores across different regions of Asia. In the case of the Mamakan VI site in Eastern Siberia, the evidence suggests cultural convergence. All other microblade complexes of comparable age in Eastern Siberia, such as Krasnyi Yar I and Tuyana, contain microblade cores with bifacial preforms (Kozyrev et al., 2014; Shchetnikov, et al., 2019),

making Mamakan VI the only known manifestation of the Tougeshita method in the region dated to 21,000–18,000 B.P. The closest analogy of Togeshita microblade complexes could be found in Northeastern China (Feng, 2020). Later Eastern Siberian microblade assemblages that include Tougeshita cores—such as those from Cheremushnik I, Cheremushnik II (cultural component I), Ust'-Belaya (cultural components 14–16), and Malta-Most 3 (cultural components 1–2)—are dated to a much later period, between 14,700 and 11,700 B.P. (Золотарев, Бердникова, 2022). Long hiatus between manifestations of Tougeshita method of microblade core reduction can be interpreted as the evidence of re-invention of the same technology independently.

The morphological and technological variability observed in Tougeshita-like industries or sub-type 1 wedge-shaped cores of Northeastern China (Feng, 2020) makes *stimulus diffusion* the more plausible explanation for their spread. The presence of analogous industries in Transbaikalia, Mongolia, and Northeastern China suggests the possibility of long-range diffusion of cultural information between these regions, rather than direct technological transmission. However, re-invention of Tougeshita microblade core reduction sequence after the long hiatus could be considered as the result of cultural convergence.

The situation in the Korean Peninsula and Northeastern China is best interpreted as a result of stimulus diffusion, given the geographical and chronological proximity of archaeological assemblages. The diffusion of technology likely occurred through social interactions. However, the high variability in operational sequences suggests that the spread of the Tougeshita method in these regions was not the result of direct cultural transmission.

Instances of technological convergence in microblade production are observable across various regions of Eurasia and in different archaeological periods. These cases correspond to key factors of cultural convergence of lithic industries: function, raw material factor, reduction sequence and basic technology/fracture mechanic (Abdolahzadeh et al., 2025). One notable example is provided by the Neolithic assemblage of Kaletepe, which contains unidirectional cores (Fig. 70). These cores are characterized by carefully prepared posterior crests with alternating bifacial treatment. Their platforms are flat, slanting toward the crest, and show no traces of re-preparation. This feature distinguishes them from bidirectional cores, which usually exhibit evidence of platform rejuvenation. In the Kaletepe specimens, the platform also plays a role in shaping the lateral surfaces, while the convexity of the posterior crest permits minor distal adjustments of the debitage surface. Cores were generally discarded once the length of extracted bladelets fell below 75 mm (Binder & Balkan-Atli, 2001).

The associated prismatic bladelets typically bear two or three parallel ridges. Similar to bidirectional reduction, their detachment follows intensive overhang abrasion, often carried out with a rhyolite abrader. This abrasion occurs after the removal of microbladelets, giving the proximal end a rib-like morphology. The lateral bladelets are moderately arched in accordance with the convexity of the core margins, which allows them to be distinguished from bidirectional products. They are also recognisable by their thin cross-sections. Central bladelets usually display a proximal inflection, a straight midsection, and a distal inflection, with plunging accidents occurring rarely (only one specimen from Layer 3), and with no examples of hinge fractures. Distal ends are most often pointed.

Several traits indicate the probable use of pressure flaking, such as the consistent profile of the bladelets, the detachments that systematically reach the distal end, the high degree of ridge parallelism, the small and pronounced bulbs

of percussion, the occasional presence of a small lip, and the absence of identifiable impact points. Exhausted cores generally exhibit five negatives converging toward the centre, and each reduction series seems to yield no more than three central bladelets. Although the total output per core remains uncertain, it is likely that a substantial number of central bladelets were produced.

Although this technique is technically less complex than the naviform method, its execution nonetheless required considerable expertise. Much of the difficulty lies in shaping the core and maintaining a controlled rhythm of blade extraction. Particularly well-suited for obsidian, pressure flaking—though not absolutely confirmed in this context—would have facilitated both detachment and rhythm maintenance.

This distinctive debitage style is currently unknown in Central Anatolia. The prismatic pressure-flaked bladelets identified at Çatalhöyük differ significantly in form and size and, to current knowledge, are not associated with bipolar production. In contrast, the obsidian bladelets that circulated widely in Levantine Pre-Pottery Neolithic B (PPNB) contexts retain strong technological ties to the Kaletepe tradition, despite being integrated into local bidirectional flint and chert industries. At Dja‘dé (transition from Early to Middle PPNB, ca. 9200 BP), obsidian bladelets closely resembling Kaletepe products have been documented, and pressure technique has been suggested as the method of production (Pernicka, Keller, & Cauvin, 1997). Geochemical analyses identified part of this obsidian as deriving from Kömürcü, and the assemblage was associated with some of the most elaborate examples of flint naviform cores.

At Mureybet, obsidian from Kömürcü was present from the Mureybetian phase into the Middle PPNB. However, prismatic obsidian bladelets do not appear in

the Mureybetian (Level III) or Early PPNB (Level IVa) levels, but emerge in the Middle PPNB (Level IVb).

At Shillourokambos (Levels 1 and 1–2), a technological study by F. Briois clearly identified features of the Kaletepe P-C4 prismatic tradition, again with pressure flaking suggested. Provenance studies by B. Gratuze confirmed that the obsidian originated from Kömürcü and was dated to the Middle PPNB (8800–8600 BP). Earlier Cappadocian obsidian from Level 2 (Early PPNB, 9310 ± 80 BP) has yet to be characterised in technological terms.

Similarly, at Tell Halula, prismatic obsidian bladelets—some sourced from Kömürcü—were identified from Middle PPNB contexts dated to ca. 8700–8600 BP (Levels IV-B-C1f; I-A-B2). To date, no prismatic flint industries comparable to these imported obsidian products have been documented in the Levantine PPN. The technological style thus appears to have been introduced into the Levant exclusively as Anatolian imports. Prismatic blade industries from Cappadocian workshops can be compared with Early PPNB unidirectional flint and obsidian reduction systems from Eastern Anatolia and the Taurus, where pressure flaking is well established for bullet cores and suspected for prismatic debitage with posterior crests (Binder, 2007).

Description of morphology and technological operational sequence (Binder, Balkan-Atli, 2001) indicates that similarities in morphology between unidirectional cores and Yubetsu cores derives from the similarities in Chaîne Opératoire. These similarities was previously pointed out in a doctoral dissertation of Y.A. Gomez Coutouly (2011).

Another example of cultural convergence of microblade technology is presented in Northern Europe (Söderlind, 2018). Handle cores are single-fronted, elongated blade cores with the production front set at one narrow end; in southern Scandinavia and northern Germany they typically show a single,

faceted platform, limited lateral preparation, and characteristic frontal trimming just “on top of the platform,” while morphologically similar but technologically distinct single-fronted variants occur east of the Baltic (Upper Volga/Southern Lithuania), indicating parallel but separate traditions rather than a single uniform concept (Söderlind, 2024).

Their chaîne opératoire begins with selection of a nodule (most commonly) or large flake, creation of a single striking platform, shaping of the back and sides, and placement/cresting of the production front; blade removal proceeds predominantly by pressure, yielding long, narrow, regular blanks with weak or absent bulbs and complete platforms (Söderlind, 2024).

Functionally, the elongated form facilitated clamping or otherwise immobilized knapping, enabling stable pressure debitage; associated debitage includes platform-preparation and frontal-rejuvenation flakes, crested blades, abundant narrow blades, retouch micro-debitage, micro-burins/burin flakes from secondary transformation, and ultimately exhausted cores—an assemblage consistent with the production of microlithic inserts for slotted bone/antler points and small cutting/scraping tools, as corroborated by use-wear and residue observations (Söderlind, 2024). Radiocarbon modelling places the earliest single-fronted cores in western Russia at ca. 10,500–9300 cal BCE, followed by major concentrations in southern Scandinavia (ca. 6400–5200 cal BCE) and southeastern Norway (ca. 5600–4900 cal BCE), with activity declining after ca. 3800 cal BCE; spatially, secure distributions cluster across southern Scandinavia and northern Germany (Maglemose–Kongemose–Ertebølle), with additional occurrences in northern Europe and overlap with the southern extent of high-quality Scandinavian flint (Söderlind, 2024). In broader comparative perspective, handle cores belong to a family of single-fronted pressure-blade technologies that arose across northern Eurasia in the Late Pleistocene/Early Holocene: they are explicitly juxtaposed with the Japanese Yubetsu

(wedge-shaped) and Horoka methods, illustrating that pressure technique diffused with multiple core morphologies (wedge-shaped, conical, flake-based) rather than a single template (Inizan, 2012; Söderlind, 2024). Likewise, the unidirectional/naviform pressure-blade systems of the Near Eastern and Anatolian Pre-Pottery Neolithic (often called “unidirectional cores” in Turkish contexts) are technologically convergent with handle-core production in their reliance on pressure debitage and regular blade blanks, but they differ in core morphology and details of preparation and rejuvenation (Altınbilek-Algül et al, 2012). Taken together, the evidence situates handle cores as a distinct Scandinavian/N. German single-fronted pressure-blade tradition—recognizable by its core preparation (including frontal trimming), regular pressure debitage, and characteristic by-product signature—embedded within a wider Eurasian sphere of pressure-blade know-how that includes the Yubetsu/Horoka lineage in Japan and naviform/unidirectional systems in Anatolia (Inizan, 2012; Altınbilek-Algül et al., 2012; Söderlind, 2024).

Wedge-shaped microblade cores from Upper Paleolithic assemblages of the Altai, Western Siberia, may also be interpreted as a result of cultural convergence. The geographical and temporal characteristics of the earliest Altai microblade complexes have led some researchers to suggest that Northeastern Asian microblade technology may have originated in this region (Gomez Coutouly, 2018; Song et al., 2019; Derevianko et al., 2005; Yi et al., 2016). Assemblages from sites such as Ust’-Karakol 1, Denisova Cave, Anui 2, Tumenchina 4, and Strashnaya Cave include prismatic, conical, and wedge-shaped (“tortsovyi”) cores, as well as backed bladelets and geometric microliths (Деревянко и др., 2003). However, comparison of published data from the Altai Upper Paleolithic with assemblages from Eastern Siberia, Northeastern China, Korea, and Hokkaido reveals a number of significant differences. These differences, in our view, support the interpretation of a

convergent rather than a diffusion-based emergence of the Altai microblade complexes.

First, unlike in Eastern Siberia, Northeastern China, Korea, and Hokkaido—where wedge-shaped microblade cores rarely occur in synchronous association with other microblade or bladelet core types—the Altai assemblages contain a wide variety of prismatic, sub-prismatic, and sub-conical microblade and bladelet cores (Михиенко & Козликин, 2023; Деревянко и др., 2003). Second, in this region retouched microblades, bladelets, and geometric microliths are widely represented, whereas they are typically absent from the Upper Paleolithic of Hokkaido, Eastern Siberia, Korea, and Northeastern China. Finally, technological analysis does not demonstrate clear correlations between wedge-shaped microblade cores of the Early and Middle Upper Paleolithic Altai and pressure-blade production (Михиенко, Козликин, 2023). Instead, percussion-based microblade and bladelet production is well documented at Denisova Cave (Михиенко & Козликин, 2023). Moreover, wedge-shaped cores from Ust'-Karakol 1 and Anui 2 display fronts with irregular and sub-parallel negative scars, most likely indicative of percussion bladelet production (Деревянко и др., 2003).

4.4. Population dynamic

The spread of microblade assemblages is related to population dynamics in Pleistocene Asia and associated with Ancient Paleosiberian genetic group. This group is represented by individual 9.8 kya Kolyma 1. According to Sikora et al (2019) Ancient Paleosiberian are derived from the first major genetic shift observed in the region after the Ancient North Siberian genetic group. Principal component analysis, outgroup f3-statistics and mtDNA and Y chromosome haplogroups (G1b and Q1a1a, respectively) demonstrate a close affinity between Ancient Paleosiberian and present-day Koryaks, Itelmen and Chukchis,

as well as with Native Americans. While these populations predominantly derive their ancestry from East Asia, admixture modelling shows that Kolyma1 derives from a mixture of Early East Asians and Ancient North Siberians ancestry similar to that found in Native Americans, although Kolyma1 carries a greater EEA contribution (75% versus 63%) (Sikora et al., 2019).

The spread of microblade industries, as well as the migration of the Ancient Paleosiberian group, is closely linked to the climatic conditions of the Last Glacial Maximum (LGM). Sikora et al. (2018) proposed the existence of potential refugia in southeastern Beringia, along with a possible coastal corridor along the Sea of Okhotsk and the Kamchatka Peninsula, which may have facilitated the migration of Ancient Paleosiberians toward North America during the LGM. These findings align with recent evidence suggesting that microblade industries with diverse morphological characteristics emerged between 30 and 28 cal. ka in Northeastern China and the Korean Peninsula (Takakura, 2024).

Overall, it is reasonable to infer the occurrence of northward migration processes between 24 and 18 cal. ka, accompanied by associated cultural transmission. Furthermore, recent studies indicate that microblade technology is linked to diverse genetic population groups, including the Ancient Beringian population (Potter, 2023). Thus, there is little doubt that migratory waves were directly associated with the spread of microblade industries. However, these migrations and population dynamics represent only a fraction of the complex socio-cultural transformations that took place during the Late Pleistocene–Early Holocene, which likely involved multiple migration events, cultural transmissions, and diffusion processes.

4.5. Conclusion

The comparative technological and behavioral analysis conducted in this chapter demonstrates that the Yubetsu and Tougeshita methods of microblade core reduction represent two distinct but interconnected trajectories in the technological development of the Upper Paleolithic of Northeastern Asia. Although both share the fundamental concept of wedge-shaped microblade core reduction, their operational sequences, degrees of standardization, and patterns of technological organization reveal significant differences in curation, adaptability, and mechanisms of cultural transmission. The Yubetsu method embodies a curated, stable, and transmissible technological tradition, while the Tougeshita method reflects a more flexible, locally adapted, and situationally variable technological practice, often resulting from stimulus diffusion (and possible case of convergent reinvention after hiatus) rather than direct cultural transmission.

Reconstruction of the operational sequences (chaînes opératoires) for both methods clarifies that the Yubetsu system is a highly integrated technological complex encompassing bifacial production, the use of ski-spalls, and pressure-based microblade manufacture. The interconnection of these technological stages reflects a well-structured and planned system of resource management, where each stage of reduction was embedded in a long-term strategy of raw material conservation and tool versatility. The Yubetsu system thus illustrates a holistic technological behavior, in which the life history of lithic artifacts extended from bifacial tool use to microblade core transformation and finally to microblade detachment and use. This cyclic and interrelated character implies an advanced level of technological knowledge, shared and maintained across vast regions through deliberate cultural transmission.

In contrast, the Tougeshita method demonstrates a more dynamic and variable operational framework. Its use of unifacial or bifacially retouched blanks, diverse platform rejuvenation strategies, and flexible combinations of percussion and pressure techniques indicate that this technological tradition was less standardized and more situationally responsive. The Tougeshita method was capable of adaptation to different raw materials and local conditions, emphasizing flexibility rather than stability. Such variability suggests that the Tougeshita reduction sequence was transmitted within looser cultural networks or may have been independently reinvented in multiple regions, reflecting cases of technological convergence rather than a single diffusion event.

The distinction between curated and expedient technological systems provides a conceptual bridge between technological organization and cultural behavior. The Yubetsu method's high degree of curation implies not only long-term planning but also the existence of structured mechanisms for knowledge transmission, such as apprenticeship, imitation, and formalized learning within groups. The Tougeshita method, while technologically sophisticated, reflects a lower degree of curation, corresponding to shorter-term, situational tool production strategies. By relating these observations to broader anthropological models of technological organization (Binford, 1973; Bleed, 1986; Odell, 1996; Andrefsky, 2008), the analysis supports the conclusion that curated systems, like Yubetsu, are more likely to be culturally transmitted due to their complexity and social embeddedness, whereas less curated systems, like Tougeshita, may spread through stimulus diffusion or arise independently through convergent adaptation inside one region.

Comparison of lithic assemblages containing these core types further reinforces these interpretations. Yubetsu-associated industries consistently exhibit the presence of bifacial tools and bifacial preforms, while Tougeshita-associated assemblages are characterized by a predominance of flake and blade industries

with limited bifacial elements. Despite their technological differences, both methods coexisted within the general technological landscape of Northeastern Asia, suggesting overlapping adaptive strategies among Upper Paleolithic hunter-gatherer populations. The presence of shared tool types—scrapers, burins, notches, and awls—indicates that both systems fulfilled comparable functional needs within different cultural and environmental contexts.

The geographical and chronological distribution of Yubetsu and Tougeshita microblade industries across Hokkaido, Korea, Northeastern China, and Eastern Siberia reveals distinct patterns of cultural transmission and convergence. The Yubetsu method, with its remarkable technological uniformity across thousands of kilometers, represents a clear case of cultural transmission maintained through stable social networks and shared cognitive templates. In contrast, the dispersed and variable manifestations of the Tougeshita method suggest episodes of technological convergence or independent reinvention, influenced by similar functional demands and raw material conditions. The intermittent chronological appearance of Tougeshita-like industries in Eastern Siberia, separated by long temporal gaps, further supports this conclusion.

Comparative data from other regions of Eurasia and beyond—such as the unidirectional prismatic core industries of Anatolia, the handle cores of Northern Europe, and the microblade complexes of the Altai—demonstrate that technological convergence was a widespread phenomenon in late Pleistocene lithic traditions. In these cases, similarities in reduction sequence and morphology often resulted from analogous adaptive solutions rather than direct contact or diffusion.

Finally, the integration of archaeological and genetic data suggests that the dispersal of microblade technologies was closely intertwined with the movement of the Ancient Paleosiberian populations during and after the Last

Glacial Maximum. The cultural and genetic evidence jointly support a scenario in which northward migrations, coupled with localized technological innovation, produced the mosaic of microblade traditions observed across Northeastern Asia and Beringia. The Yubetsu method, transmitted across this macro-region with remarkable consistency, represents the technological signature of one such migratory and cultural lineage. The Tougeshita method, in contrast, reflects the persistence of regional experimentation and convergence within the broader Paleosiberian techno-complex.

In sum, the analyses presented in this chapter reveal that microblade technologies of Northeastern Asia cannot be understood solely through typological or morphological frameworks. Instead, they must be interpreted as dynamic, culturally embedded systems that record patterns of knowledge transmission, innovation, and adaptation. The Yubetsu and Tougeshita methods represent two complementary modes of technological organization—curated and less curated, transmitted, diffused and convergent—that together illuminate the complex interplay between culture, cognition, and environment in the late Pleistocene. This comparative framework establishes the foundation for the final synthesis of the dissertation, which situates these findings within the broader context of human technological evolution and cultural transmission across Pleistocene Eurasia.

Conclusion

This dissertation examined the origins, development, and transmission of microblade technology across Northeastern Asia and its peripheral regions, focusing on the Yubetsu and Tougeshita microblade core reduction methods. Through an integrated analytical framework combining techno-typological reconstruction, scar pattern analysis, and use-wear studies, this research sought to clarify the technological and behavioral mechanisms underlying the

emergence and spread of wedge-shaped microblade core reduction methods. The comparative analysis of assemblages from Japan, Korea, Northeastern China, and Siberia provided new insights into the processes of cultural transmission and technological convergence during the Late Pleistocene. The results demonstrate that microblade technology functioned as a flexible and adaptive system that recorded both stable traditions of knowledge transfer and episodes of independent innovation across a vast geographic range.

The first chapter outlined the historical development of microblade research, from the initial discoveries in Siberia during the late nineteenth and early twentieth centuries to the establishment of a coherent methodological framework in the latter half of the twentieth century. This historiographical review demonstrated how the interpretation of microblade technology evolved from early typological descriptions toward integrated technological and behavioral analyses. It highlighted the crucial role of Soviet, Japanese, and North American scholars in establishing shared terminology and in defining the wedge-shaped microblade core as a key diagnostic element of Upper Paleolithic industries across Northern Eurasia. The chapter also situated the study of microblade technology within broader theoretical debates concerning interregional diffusion, cultural evolution, and the peopling of the Americas. In this context, microblade technology was identified not merely as a tool production system but as an important cultural and cognitive marker of human adaptation to high-latitude environments during the Late Pleistocene.

Chapter 2 provided the theoretical and methodological foundation for this research. It introduced a comparative framework integrating the concept of the chaîne opératoire, the distinction between curated and expedient technological systems, and the analytical principles of cultural transmission theory. These perspectives allowed for the reconstruction of technological sequences as structured expressions of social learning and adaptive behavior. By analyzing

the internal organization of reduction sequences, this study moved beyond morphological typology and addressed how technological knowledge was maintained, modified, and transmitted within and between prehistoric groups. Scar pattern analysis and refitting studies served as key methodological tools for reconstructing operational sequences, while use-wear analysis provided direct evidence of artifact function and tool use. Together, these methods established a multi-scalar approach that connects lithic technology with broader questions of behavioral ecology and social interaction.

Chapters 3 and 4 applied this framework to the comparative analysis of microblade assemblages across four major regions: Japan, Korea, Northeastern China, and Siberia. The results demonstrated that both the Yubetsu and Tougeshita methods represent distinct but related technological systems characterized by differing degrees of standardization, operational complexity, and curation. The Yubetsu method, originally defined in Hokkaido, was revealed as a highly structured and curated system that integrated bifacial production, ski-spall detachment, and pressure-based microblade manufacture into a coherent technological continuum. This sequence reflects long-term planning, raw material conservation, and a strong reliance on socially transmitted knowledge. In contrast, the Tougeshita method displayed greater technological variability, flexible use of unifacial or semi-bifacial preforms, and a combination of percussion and pressure techniques. These attributes indicate a less curated, more situational technological organization, likely influenced by localized resource conditions and independent reinvention.

The reconstruction of operational sequences confirmed that the Yubetsu system encompassed multiple interlinked stages of production and use, from bifacial tools to microblade cores and from ridge and ski-spalls to finished microblades. Use-wear evidence from the Oruika 2 and Bolshoy Yakor' I sites further demonstrated that these artifacts were functionally integrated into subsistence

systems involving both hunting and processing activities. Ski-spalls, traditionally interpreted as technological waste, were shown to have been intentionally utilized as functional blades or transformed into new microblade cores, illustrating a cyclical technological logic of reuse and transformation. These findings support the interpretation of Yubetsu as a curated technological complex optimized for high-mobility strategies in resource-limited environments.

By contrast, the Tougeshita system exhibited considerable flexibility in core preparation and rejuvenation, with multiple alternative sequences of ridge and platform modification. The technological diversity within Tougeshita assemblages across Korea, Northeastern China, and parts of Siberia indicates the coexistence of numerous operational variants rather than a single standardized reduction model. Use-wear analysis from Korean sites such as Hopyeong-dong and Wolpyeong showed that Tougeshita-type microblades served multiple functions—cutting, scraping, boring, and sawing soft organic materials—implying an expedient use of available tools. These findings align with the interpretation of the Tougeshita method as a less curated technological tradition, transmitted through weaker social mechanisms or independently reinvented through convergent adaptation.

The comparative functional analysis of regional assemblages revealed both shared behaviors and local adaptations. Across all regions, microblades were used primarily for cutting, scraping, and piercing organic materials such as meat, hide, and wood. Hafting traces identified in the Japanese and Siberian collections indicate widespread use of composite tools, particularly in hunting contexts. The consistent presence of semi-circular and trapezoidal use-wear scars, feather-like terminations, and light polish patterns demonstrates a common technological grammar of use across different cultural contexts. At the same time, regional variability in the degree of tool curation, standardization,

and hafting reflects distinct adaptive strategies shaped by raw material availability, mobility, and subsistence demands. These patterns collectively support a model in which microblade technology functioned as a shared technological substrate that was variably elaborated and transmitted among Late Pleistocene hunter-gatherer populations.

The broader implications of this research concern the mechanisms of cultural transmission and convergence in prehistoric technological systems. The Yubetsu method, characterized by high technological standardization and low regional variability, is best explained as a case of cultural transmission through stable networks of knowledge exchange. Its wide distribution from Hokkaido to Eastern Siberia reflects the spread of a coherent technological tradition maintained by structured learning and social teaching. Conversely, the Tougeshita method, with its pronounced variability and episodic reappearances across large temporal gaps, illustrates the role of technological convergence—independent innovation driven by similar functional and environmental pressures. These contrasting cases demonstrate that the diffusion of microblade technology in Northeastern Asia cannot be attributed to a single linear process but rather to the interplay of transmission, adaptation, and reinvention within interconnected human populations.

From a population-dynamic perspective, the findings of this study contribute to understanding the cultural and demographic processes that accompanied the dispersal of Ancient Paleosiberian groups during and after the Last Glacial Maximum. The spatial and technological continuity of the Yubetsu complex suggests that it may represent a material correlate of population movements linking Hokkaido, the Amur Basin, and Eastern Siberia, ultimately extending toward Beringia. The technological and functional coherence of the Yubetsu system thus provides archaeological support for the hypothesis that the northward and eastward expansions of these groups were accompanied by the

transmission of shared technological knowledge. In contrast, the localized and temporally discontinuous manifestations of Tougeshita technology reflect the persistence of regional experimentation and the capacity for independent innovation within the same broad cultural sphere.

Thus, the cultural processes underlying the distribution of microblade technologies are closely linked to population-level processes, including migrations within Northeastern Asia and movements from Northeastern Asia into the North American continent. Because cultural transmission is understood as the direct transfer of knowledge through social learning, it is strongly tied to the intergenerational dynamics of prehistoric populations.

Overall, the study of Upper Paleolithic microblade industries indicates that complex socio-cultural processes operated in Paleolithic Northeastern Asia. Three major social processes can be identified through the analysis of microblade industries.

The first is cultural transmission, most clearly associated with the Yubetsu method of microblade core reduction. The distribution of this method indicates strong and sustained direct connections across Northeastern Asia and Beringia. The transmission of this technology across broad spatial and temporal scales suggests, first, the existence of direct interaction networks linking populations of Eastern Siberia, Alaska, northeastern China, the Korean Peninsula, and Hokkaido, and second, the high social and technological significance of this method within these populations.

The second process can be described as stimulus diffusion. This process is most closely associated with the Tougeshita method of microblade core reduction. As a less curated and more expedient technological strategy, its distribution suggests dissemination through different forms of social interaction than those involved in cultural transmission. The spread of this method across Hokkaido,

Korea and northeastern China is therefore hypothesized to reflect social contacts of relatively low intimacy, in which technological ideas rather than complete technological traditions were transmitted.

The third socio-cultural process identified is cultural convergence. Independent invention of morphologically and/or technologically similar microblade core reduction methods occurred both within and beyond Northeastern Asia, reflecting comparable adaptive responses to similar environmental and economic constraints rather than direct social connections.

Methodologically, this dissertation demonstrates the value of integrating multiple analytical approaches—scar pattern analysis, refitting, and use-wear studies—within a single comparative framework. This integration allows for the reconstruction of technological behaviors in high resolution and bridges the gap between typological description and behavioral interpretation. It also shows that detailed technological analyses can yield meaningful insights into broader anthropological questions concerning learning, adaptation, and social interaction in prehistoric societies. The identification of curated and less-curated technological systems offers a productive model for linking lithic analysis to theories of cultural transmission, providing a means to distinguish between inherited and independently developed technologies.

In conclusion, this research establishes that microblade technology in Northeastern Asia was both a stable and a dynamic phenomenon. It embodied long-term traditions of knowledge transmission, exemplified by the Yubetsu method, while simultaneously allowing for local flexibility and innovation, as seen in the Tougeshita method. The coexistence of these two technological systems reflects the complex cultural mosaic of Late Pleistocene hunter-gatherer populations and their adaptive responses to diverse ecological conditions. Beyond its regional significance, the study contributes to broader discussions on

the evolution of technological systems, the mechanisms of cultural transmission, and the nature of convergence in human prehistory. Future research should aim to expand the comparative database of microblade assemblages, incorporate high-resolution chronological frameworks, and integrate archaeological evidence with genetic and paleoenvironmental data to further elucidate the relationship between technological behavior, population movement, and cultural interaction across Pleistocene Eurasia.

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Fig. 37. Map of Northeastern Asia with indicated Paleolithic sites selected for the survey.

Fig. 38. Archaeological materials of Early Upper Paleolithic sites of Siberia and Central Asia: 1-54 – lithic artifacts; 54-63 – personal ornamentation artifacts. Modified from: Рыбин, 2014; Медведев, Новосельцева, 2011).

Fig. 39. Archaeological materials of Early Upper Paleolithic sites of Korean Peninsula: 1 -11 Hopyeong-dong; 12- 25 Songarmi Waesill; 26 - 28 Hwadaeri; 29 -34 Chongok; 35 -46 Galsanri (Heonjong, Sangseok, 2019).

Fig. 40. Archaeological materials of Early Upper Paleolithic sites of Hokkaido: 1-5: Kikyo 6-12: Shukubai-kaso (Loc. Sankakuyama) 13-18: Wakabanomori; 19-25: Kyoei-3; 26-33: Okushiarataki-1, Sb1-3 36-53: Kamishirataki-8, Sb1-13.. From (Terasaki, 2006).

Fig. 41. Location of Hopyeong-dong and Wolpyeong sites. Stratigraphy modified from (Hong, Kononenko, 2008; Lee, 2006).

Fig. 42. Archaeological materials of Hopyeong-dong site, Cultural Layer 2: 1.-3. Quartz core; 4.- 7. Scrapers; 8.-10. Microblade cores; 11.-12. Blades; 13.-15. Microblades; 16.-17. Ridge Spalls; 18. Retouched bladelet. Modified from (Hong, Kononenko, 2008)

Fig. 43. Artifacts of Wolpyeong site: 1 – simple angle burin on transverse break; 2 – simple angle burin on truncation; 3-7 endscrapers; 8,9 -

roundscrapers; 10-12 tanged points; 13-19 microblade cores. Modified from (Lee, 2006).

Fig. 44. Location of Huayang and Helong Dadong sites. Stratigraphy modified from (Lian et al., 2023; Yue et al., 2020).

Fig. 45. Artifacts of Helong Dadong site: 1, 4, 7–8 Layer 3; 10 Layer 4; 2–3, 5–6, 9 surface collection. 1-6 Microblade cores; 7, 10 - scrapers; 8 - retouched blade; 9 - burin. Modified from (Yue et al., 2021).

Fig. 46. Artifacts of the Huayang site: 1-5 bladelet cores; 6,7 - microblade cores; 8-12 cores; 13,14 arrowhead; 15 point on bladelet; 17 - borer; 16,18 - convex scraper; 19 - bifacial point; 20 - backed scraper. Modified from (Yue et al., 2019).

Fig. 47. Map of location of Bol`shoy Yakor` I and Mamakan VI sites in Eastern Siberia. Stratigraphy from (Тетенькин, 2014; Инешин, Тетенькин, 2006).

Fig. 48. Archaeological materials of Bol’shoy Yakor’ site: 1-7 bifaces; 8-12 scrapers; 13-20 burins; 21-29 osseous artifacts; 30-34 wedge-shape microblade cores; 35-36 frontal spalls; 37 - ridge spall; 38-42 microblades refitting blocks. Modified from (Инешин, Тетенькин, 2006).

Fig. 49. Archaeological materials of Mamakan VI site: 1 - round scraper with transversal burin spall; 2, 4, 5 - microblade cores; 3, 6, 7 - scrapers; 8 – medial segment of retouched blade; 9 - medial segment of the blade; 10 - distal segment of the blade; 11, 12, 14, 15, 16, 20 - proximal segments of the blades; 13, 17, 18, 21 - blades; 19 – fragment of a flake with marginal retouch. Modified from (Тетенькин, 2014).

Fig. 50. Location and stratigraphic profiles of Paleolithic sites in Hokkaido Island, Japan: 1. - Osatsu 2 site; 2. - Oruika 2 site (Hokkaidō Maizō Bunkazai Center, 1996; Hokkaidō Maizō Bunkazai Center, 2005).

Fig. 51. Artifacts of microblade industries of Oruika 2 site. Modified from (Hokkaidō Maizō Bunkazai Center, 2005)

Fig. 52. Artifacts of Osatsu 2 site; 1-26 microblades; 27 ridge spall; 28 microblade core. Modified from (Hokkaidō Maizō Bunkazai Center., 1996)

Fig. 53. Korean peninsula. Results of Scar Pattern Analysis: 1.-2. Tougeshita microblade cores; 3. Bifrontal microblade core

Fig. 54. Korean peninsula. Results of Scar Pattern Analysis: 1.-2. Yubetsu method microblade cores

Fig. 55. Huayang site, Northeastern China. Microblade core with twisted front

Fig. 56. Northeastern China. Results of Scar Pattern Analysis: 1.- Yubetsu method microblade core; 2. - Tougeshita microblade core

Fig. 57. Results of Scar Pattern Analysis of Tougeshita method microblade cores from Mamakan VI site, Eastern Siberia

Fig. 58. Scar pattern analysis of Tougeshita method microblade cores from Hokkaido Island, Osatsu 2 site

Fig. 59. Scar pattern analysis of Yubetsu method microblade cores from Bol`shoy Yakor` I site, Eastern Siberia

Fig. 60. Oruika 2 site, Hokkaido. 1. - Refitting block of Yubetsu method microblade core with use-wears on bifacial edge; 2. - Scar Pattern Analysis scheme of Yubetsu microblade core

Fig. 61. Korean peninsula, Wolpyeong site. Use-wear analysis results of microblade core.

Fig. 62. Eastern Siberia, Bolshoy Yakor` 1 site. Results of Use-wear analysis: 1. Impact fracture; 2. butchery knife; 3. borer; 4. scraper

Fig. 63. Hokkaido island, Oruika 2 site. Results of Use-wear analysis: 1.-5. Use-wears located on microblade cores; 6.-7. Use-wears located on ski-spall

Fig. 64. Osatsu 2 site use-wear analysis result: 1 - butchery; 2 - scraping; 3 - shaving, dorsal face; 4 - shaving, ventral face; 5 - graving

Fig. 65. Osatsu 2 site fracture wing analysis result

Fig. 66. Oruika 2 site, Hokkaido Island. 1 - negative of ski-spall detachment; 2-4 microblades

Fig. 67. Morphospace model of wedge-shaped core: 1. - general morphospace model; 2. - variability of core blanks: a. - blade, b. - flake, c. - ski spall, d. - broken tool, e. - biface; 3-5: morphospace range of microblade cores

Fig. 68. Variability of Tougeshita microblade cores striking platforms rejuvenation; 1 - Osatsu 2 site (Hokkaidō Maizō Bunkazai Center, 1996); 2-9 - Taisho site (Ohi, 1963); 10 - Meboshigawa 2 site (Chitose-shi Kyōiku Iinkai, 1983)

Fig. 69. Morphospace model of microblade: I - Cross-sections of microblades: 1. - trapezoidal, 2. - triangular, 3. - polyhedral; II - fragmentation of microblades; III: 1. - microblade with cortex, 2. - with rudiment of ridge; IV dimensional morphospace of microblades: 1. - with general functions, 2. - inserted in projectile point; V - sizes of microblades inserted in projectile point (Bol`shoi Yakor` site)

Fig. 70. Anatolia, Turkey: a.b.-(Binder, Balkan-Atli, 2001); c. (Balkan-Atli; Bender, 2002) Neolithic unidirectional bladelet cores from Keletepe site; Northern Europe: Sværdborg I: 1. - 2. Handle core without the blade scar front; 3. Keeled core; 5.-6. Conical cores (Söderlind, 2024)

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Tables

region	Alaska		Siberia				Hokkaido		China				Korea
site	Swan Point	Matcharak Lake	Kovrizhka IV, cc 6	Pavlovo I	Zhokhov	Srednee Ozero V	Kashiwadai I	Yoshiizawa	Shizitan 29	Xiachuan	Chaisi	Helong Dadong	Hopyeong-dong
function													
projectile	X	X	X		X		X						
knife	X	X	X	X	X	X			X	X	X	X	X
scraper	X			X	X	X				X	X	X	X
graver				X	X	X							
planning				X	X			X				X	X
borer				X		X							
saw				X		X						X	X
chisel						X							
knife-carver				X									

Table. 1. Functions of microblades in Northeastern Asia and Beringia according to the results of published studies

	sediments
1	Modern soil layer
2	Brown clay - cultural layer 4
3	Yellowish brown clay - cultural layer 3
4	Dark brown clayey sand - Middle cultural layer
5	Yellowish brown sandy clay - cultural layer 2
6	Yellowish brown clayey sand - cultural layer 1
7	Yellow silt
8	Dark brown sandy gravel

Table 2. Stratigraphy of Wolpyeong site. By (Lee, 2015)

	sediments	Thickness m
1	Loose, yellowish-brown topsoil rich in humus	0.05-0.1
2	Grayish-white volcanic ash	0.02-0.05
3	Grayish-brown compact, blocky silty clay	0.2-0.3
4	Black compact, blocky silty clay	0.4
5	Yellow compact, blocky silty clay	0.3
6	Loose, yellowish-brown silt. Subdivided into 6A and 6B sub-layers based on grain size	1.2
7	Basaltic gravels mixed with coarse sands	

Table 3. Stratigraphy of Helong Dadong site. From (Lian et al., 2023).

	Sediments	Thickness m
1	modern soil	0,07-0,15
2	Disturbed layer of grey sandy loam *Cultural layer 1*	0,10-0,25
3	Light-colored heavy sandy loam	0,08-0,18
4	Buried soil; pale, reddish-brown, heavy sandy loam with tectonic origin cracks	0,04-0,08
5	Yellowith-grey sandy loam	0,03-0,08
6	Buried soil; reddish-brown sandy loam *Cultural layer 2*	0,04-0,10
7	Yellowish-green sandy loam *Cultural layer 2A*	0,02-0,15
8	Buried soil; reddish-brown sandy loam with charcoal inclusions *Cultural layer 3*	0,04-0,10
9	Laminated alluvial sediments *Cultural layer 3A and Cultural layer 3B* 11,750±190 BP (ГИН-8980); 12,000±250 BP (ГИН-6460); 12,080±220 BP(ГИН-6459)	0,35-0,45
10	A packet of rhytmically bedded strata of light and dark grey sand *Cultural layer 4* 11,740±140 BP (ГИН-6461)	0,18-0,22
11	A packet of rhythmically bedded loam soils and sands *Cultural layer 4A* 10,320±140 BP (ИМСОАН-968); 10,070±540 (ЛЕ-4173А)	0,30-0,40
12	A packet of alternating heavily-gleyed light loam and light sandy strata *Cultural layer 4B;Cultural layer 4V;Cultural layer 5* 11,970±170 BP (ГИН-6464А);12,220±80 BP (ГИН-847)	0,45-0,50
13	A packet of thinly bedded alluvial sediments *Cultural layers 6-9* 12,380±250 BP (ГИН-6425); 12,380±250 BP (ГИН-6468); 12,700±140 BP (ГИН-8470)	0,58-0,64
14	Finely laminated bluish-grey loamy sediments *Cultural layers 10-11*	0,38-0,45
15	Deposit of light and medium light brown loam *Cultural layer 12*	0,40-0,50
16	bedrock	–

Table 4. Stratigraphy of Bol'shoy Yakor' I site (Ineshin, Tetenkin, 2017)

	Sediments	Thickness m
1	Modern soil	0,04-0.08
2	Sediments of industrial genesis	0,04-0,10
3	Buried soil layer	0,04-0,08
4	Sediments of industrial genesis	0,60-0,70
5	Buried soil layer	0,02-0,05
6	Podzol layer	0,01-0,08
7	Red-orange-brown light soliflucciated loam	0,04-0,28
8	Light yellow oxidized soliflucciated sand	0,02-0,25
9	Light dark brown, cryogenically deformed loam. 7300±400 BP (ГИН-14595).	0,01-0,06
10	Light dark brown, pyrogenic impacted loam with abundant iclusions of charcoal and flaked rock fragments	0,025–0,40
11	Light, bluish, ogle, soliflucciated loam. 20900±300 BP (СОАН-8263), 18670±600 BP (СОАН-4546)	0,02–0,35
12	Heavy lumpy dark brown loam with inclusions of charcoal. 11770±110 л. н. (ГИН14596)	0,01–0,04
13	Bluish yellow sand	0,05–0,18
14	Grayish-yellow medium-grained sand with inclusions of gravel and small pebbles and bluish thin sublayers	0,25-...

Table 5. Stratigraphy of Mamakan VI site. Translated from (Тетенькин, 2014)

	Sediments
1	Modern plowed soil mixed with volcanic sediments.
2	Ta-a pumice layer dated back to 1739.
3	I a. Dark brown clayey soil. Sediment deposited in the hollows of the remains of a dugout dwelling. The layer contains artifacts from the Ainu cultural period.
4	I b. Grayish-brown Clayey soil. Sediments in the hollows, slopes, and areas of pit dwellings. The layer contains artifacts from the Ainu cultural period.
5	II a. Buried Black soil layer. It contains fallen pumice from Tarumae c volcanic ash. The layer presented artifacts of Epi-Jomon - Ainu cultural periods.
6	II b. Buried Black soil layer. The layer contains artifacts of the Jomon period.
7	III. Dark brown soil. This layer contains paleolithic artifacts including microblades and microblade cores.
8	IV a. Brown loam layer.
9	Eniwa A descending pumice formation.

Table 6. Stratigraphy of Osatsu 2 site. Translated from (Hokkaidō Maizō Bunkazai Center, 1996).

	raw material			
sites	obsidian	shale	effusive rock	siliceous rock
Osatsu 2	X			
Mikawa	X			
Oruika 2	X			
Suyanggae	X	X	X	
Wolpyeong			X	
Helong Dadong	X			
Huayang		X	X	X
Mamakan VI			X	
Bol`shoy Yakor` I			X	
Dry Creek	X		X	X
Swan Point				X

Table. 7. Raw material of microblade production from sites selected for survey

Figures

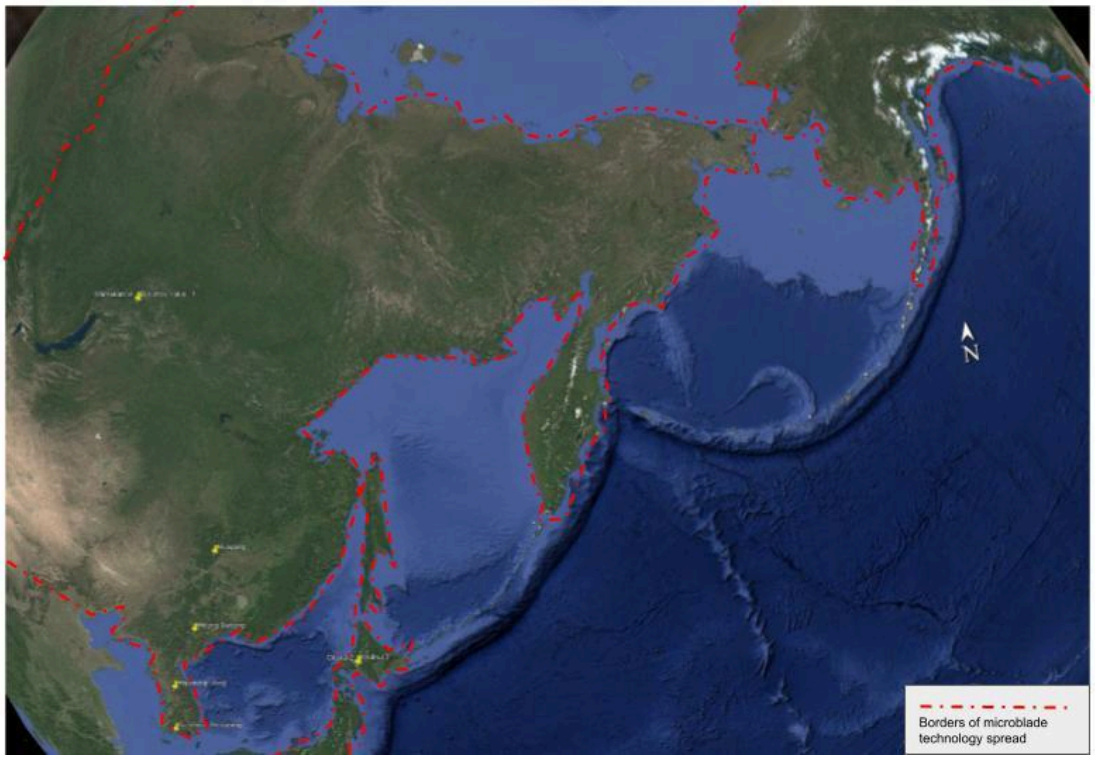


Fig. 1. Approximate area of Paleolithic microblade technology distribution in Northeastern Asia

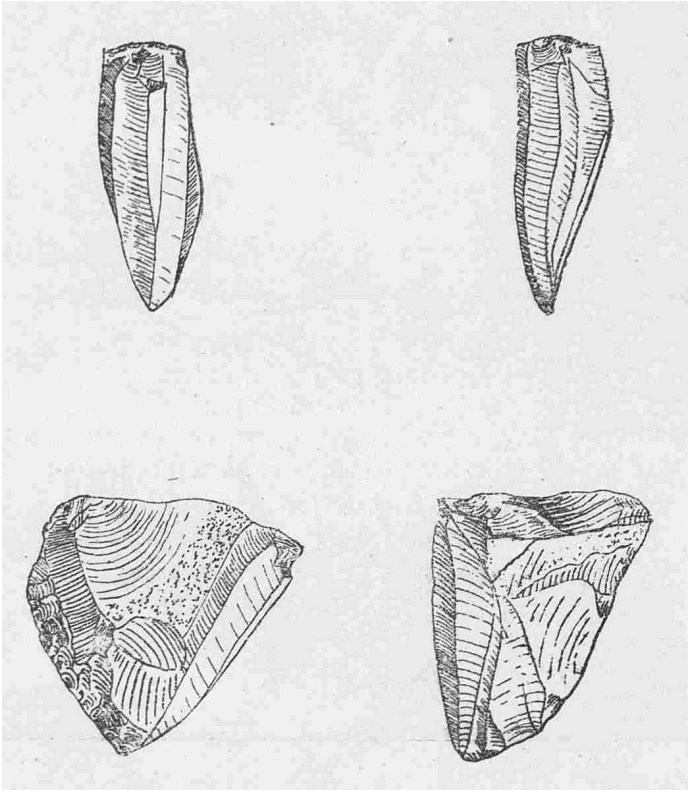


Fig. 2. Wedge-shape microblade core (scraper-core / *скребок-ядрище*) published by B.E. Petry (1927)

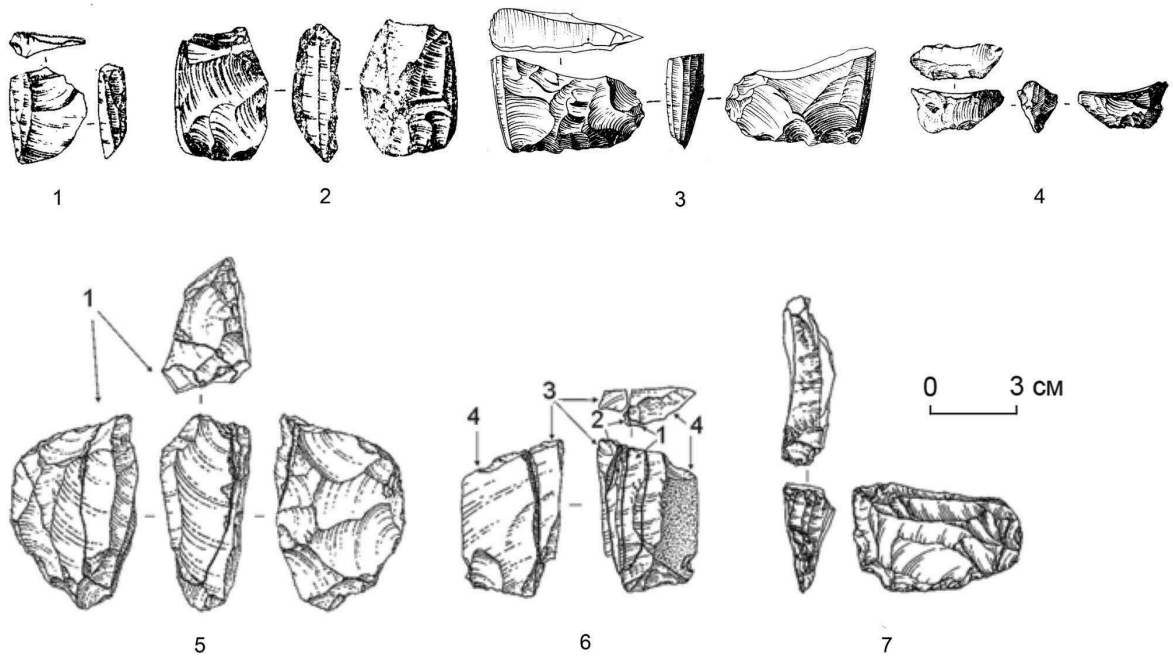


Fig. 3. Microblade industries of Eastern Siberia: 1, 2 - Ezhantsy; 3- Ikhine 2; 4- Ust`-Mil`; 5-7 Kara-Bom. Modified from (Славинский и др., 2016; Мочанов, 1977).

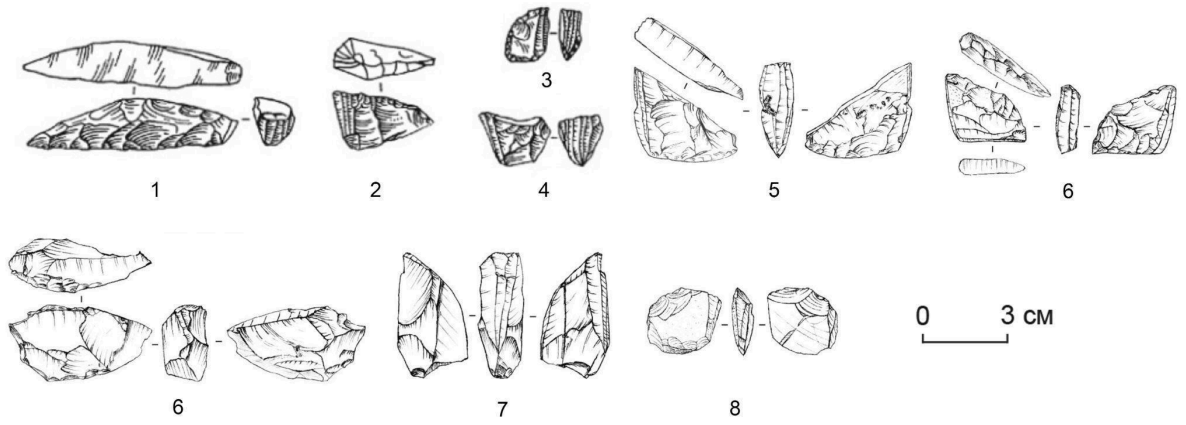


Fig. 4. Microblade industries of Eastern Siberia: 1-4 Krasnyi Yar; 5-8 Kurla I. Modified from (Бердникова и др., 2021; Молчанов и др., 2019).

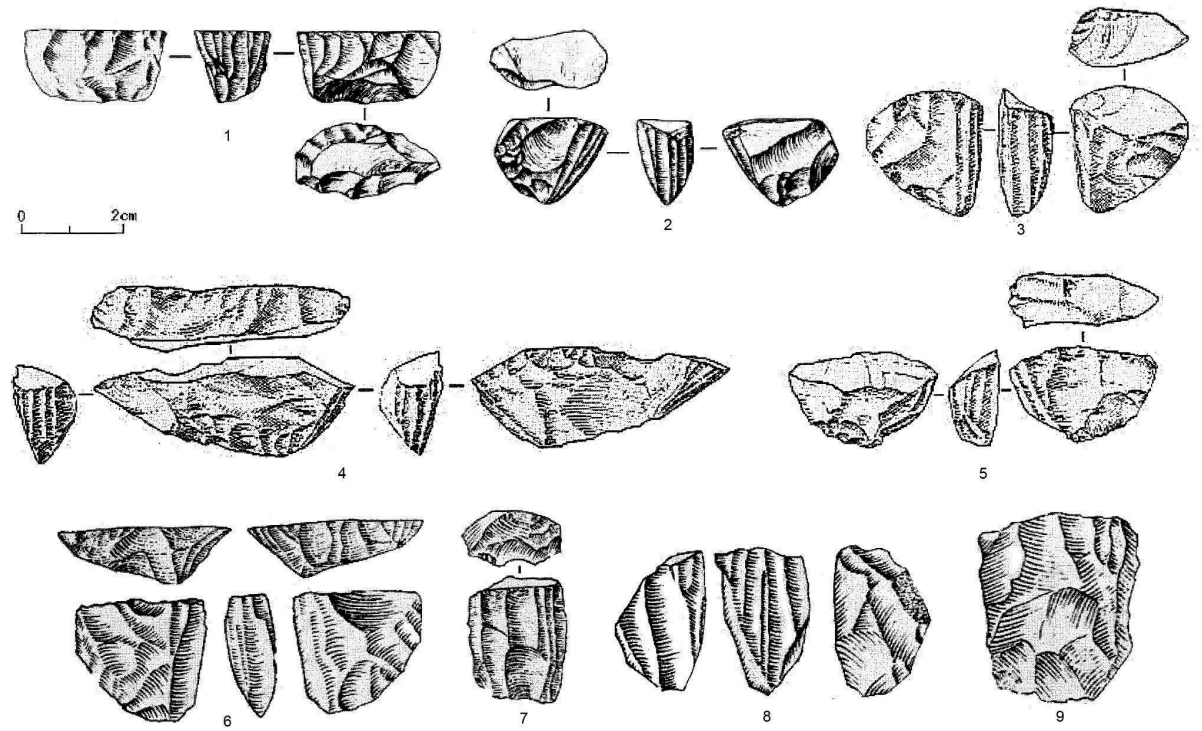


Fig. 5. Microblade industries of North China: 1,2 - Chaisi; 3-5 Xueguan; 6-9 Youfang. Modified from (Chen, 2007).

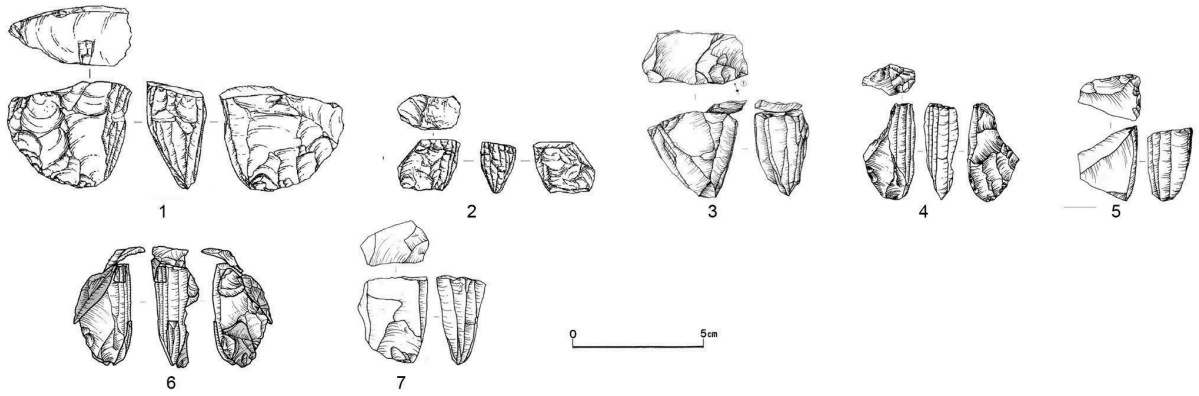


Fig. 6. Microblade industries of Korean Peninsula: 1, 2 - Sinbuk site; 3-7 Hopyeong-dong site. Modified from (Lee, 2012; Gomez Coutouly, 2018)

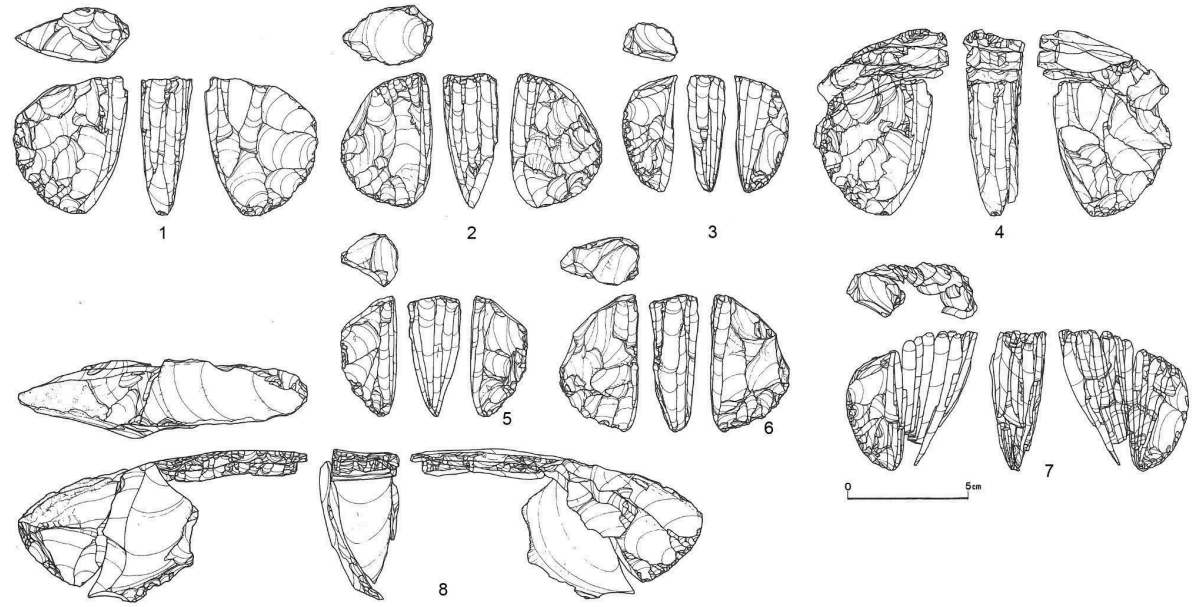


Fig. 7. Microblade industries of Hokkaido Island: Kashiwadai 1 site. Modified from (Hokkaidō Maizō Bunkazai Center, 1999).

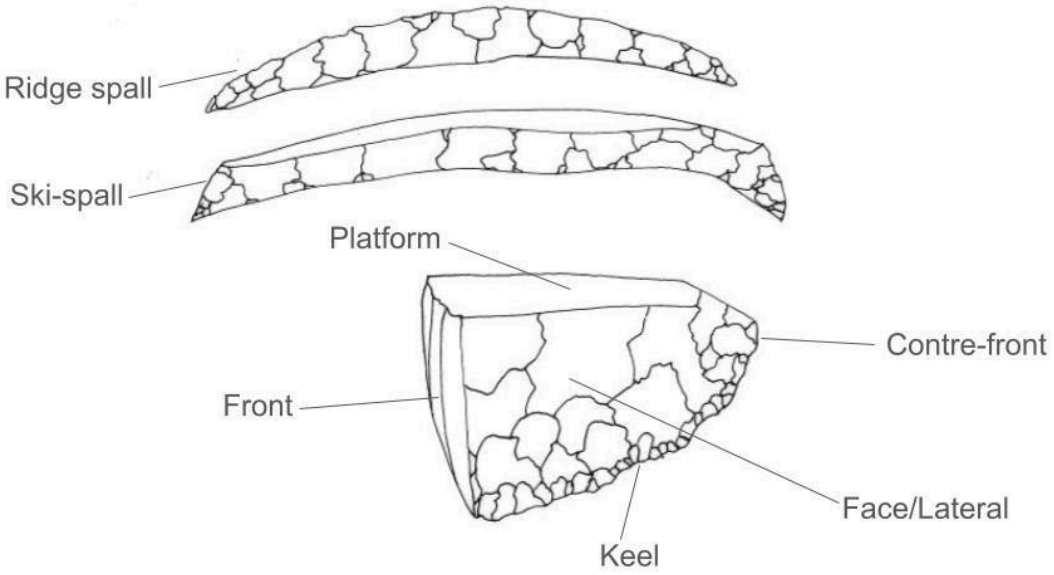


Fig. 8. Morphological elements of the microblade core and related debitage.

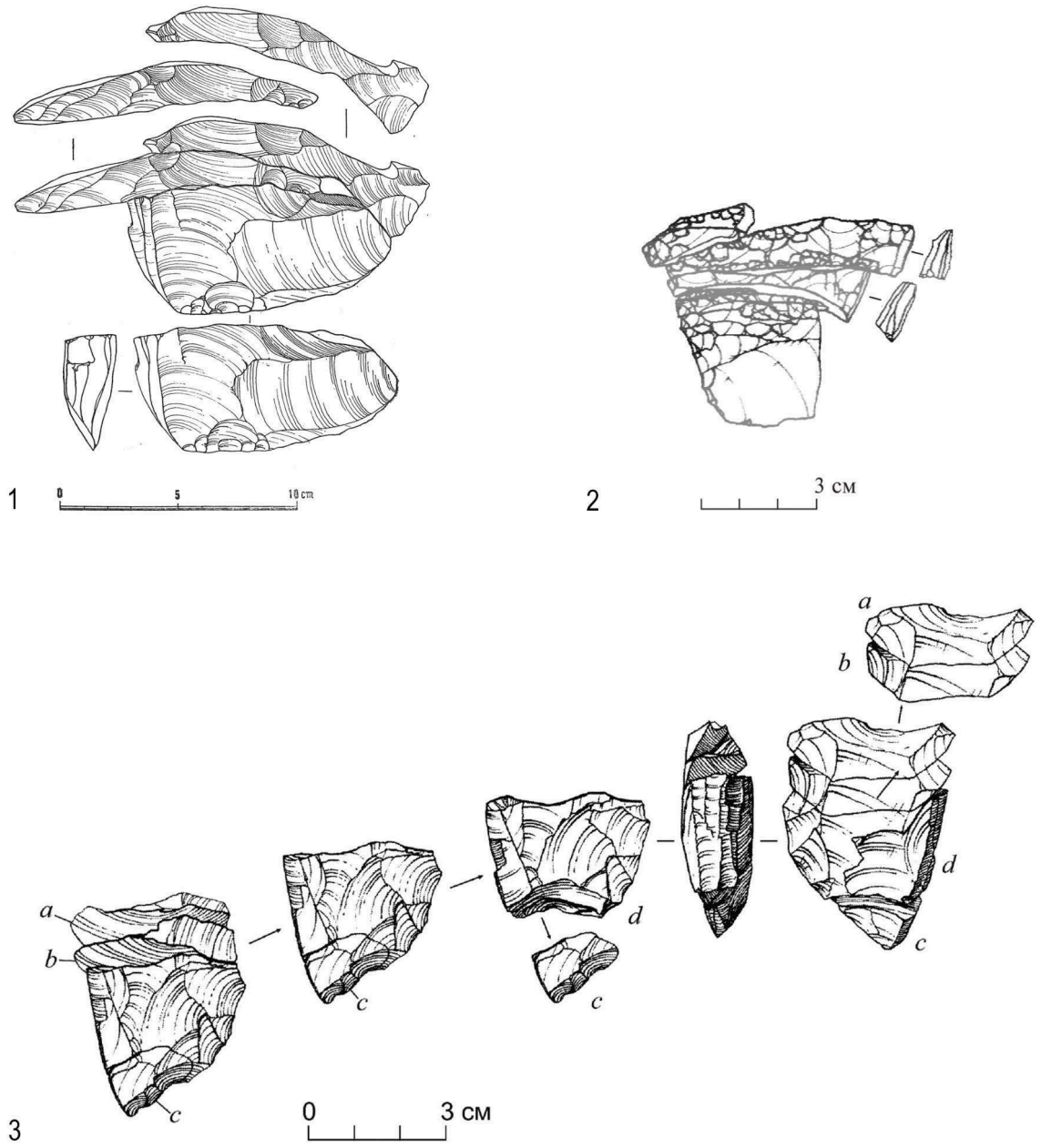


Fig. 9. Refitting blocks of microblade cores and attached debitage: 1.- Shirataki 33 site. Modified from Yoshizaki (1961); 2.- Bol`shoy Yakor` I site. Modified from Ineshin, Teten'kin, (2017); 3.- Kovrizkha IV site. Modified from Тетенькин, (2017).

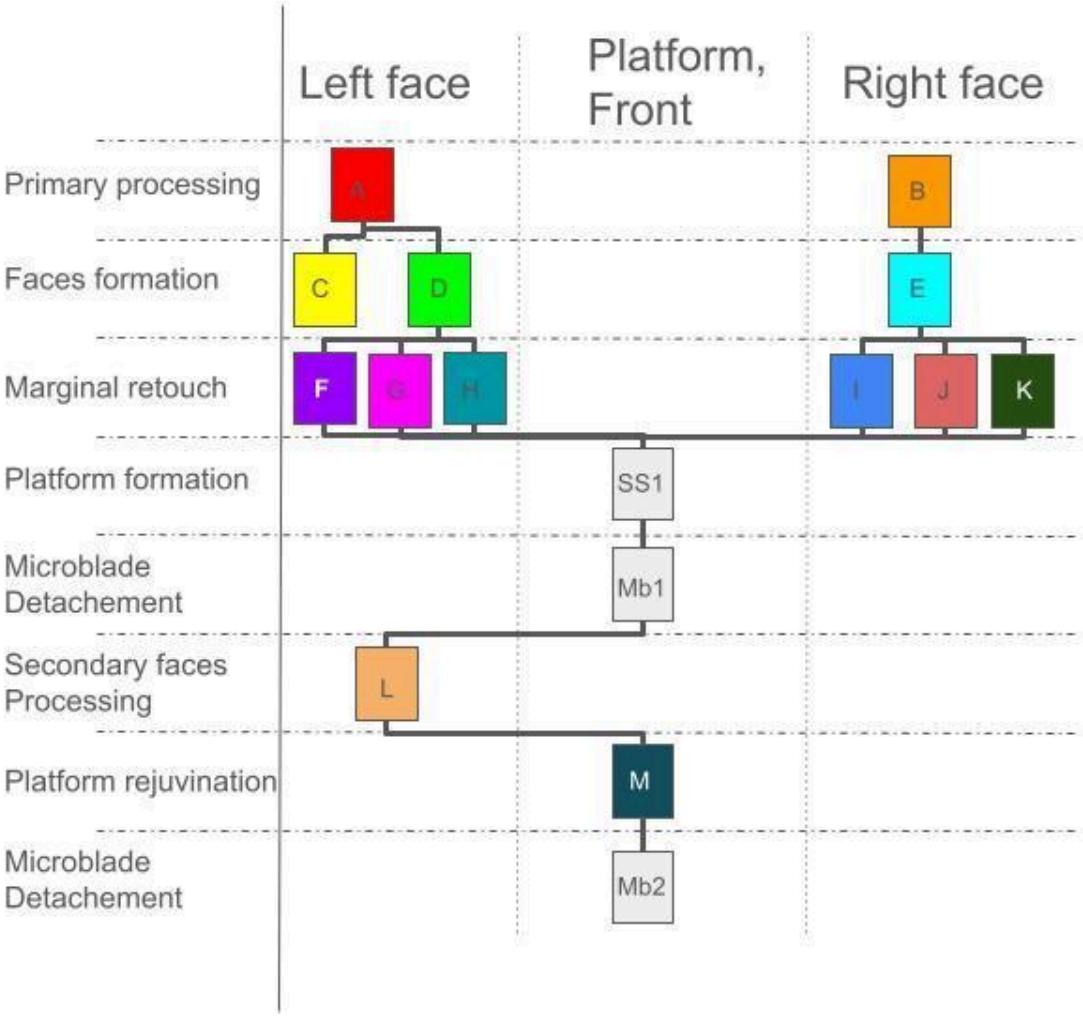


Fig. 10. Graphic scheme of scar pattern analysis for microblade cores.

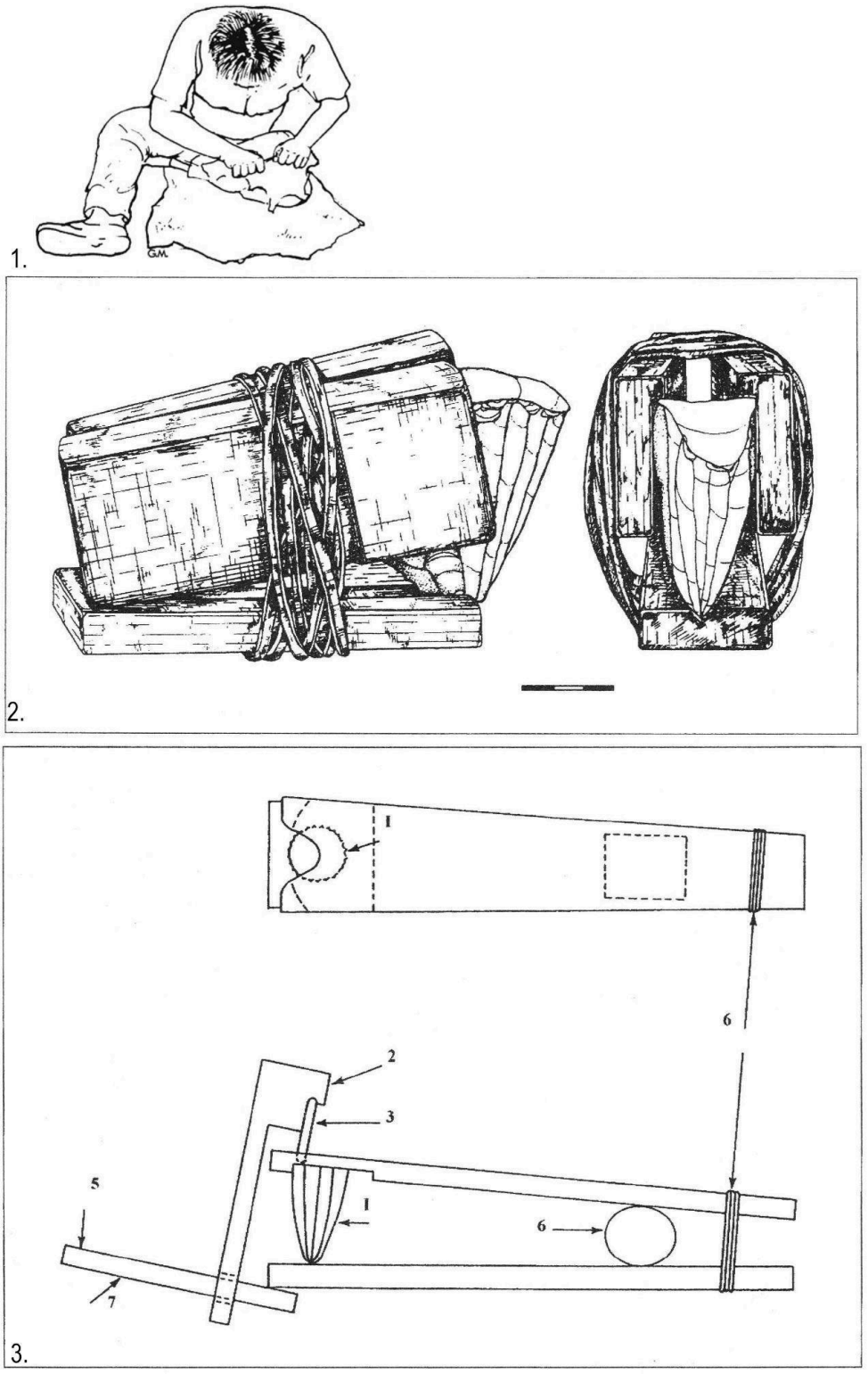


Fig. 11. Methods of pressure microblade production; 1. Mode 1 by J. Pelegrin (2012); 2. Wooden Vice by A. Tabarev (2008); 3. Vice combined with level by D. Sollberger and L. Patterson (1983).

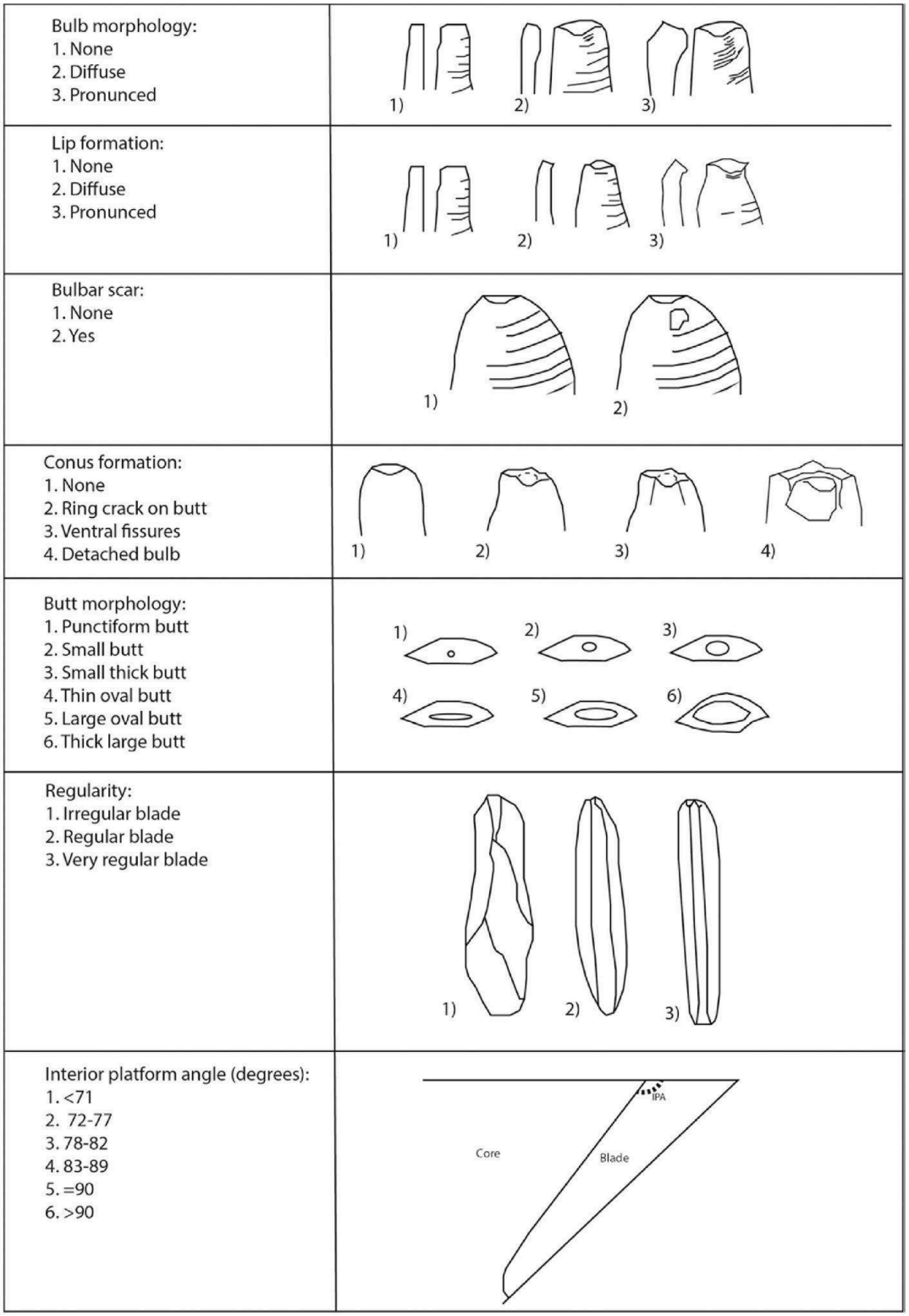


Fig. 12. Criteria of technological analysis of blade industries. By (Damniel, 2015)



Fig. 13. The process of experimental microblades production: 1.- Hard hammer knapping; 2.- Soft hammer knapping; 3.- Pressure microblade detachment; 4.- indirect strike microblade detachment; 5.- Abrasive overhang reduction; 6.- flinknapping tools used for experiments; 7-11 – Experimentally produced microblade cores

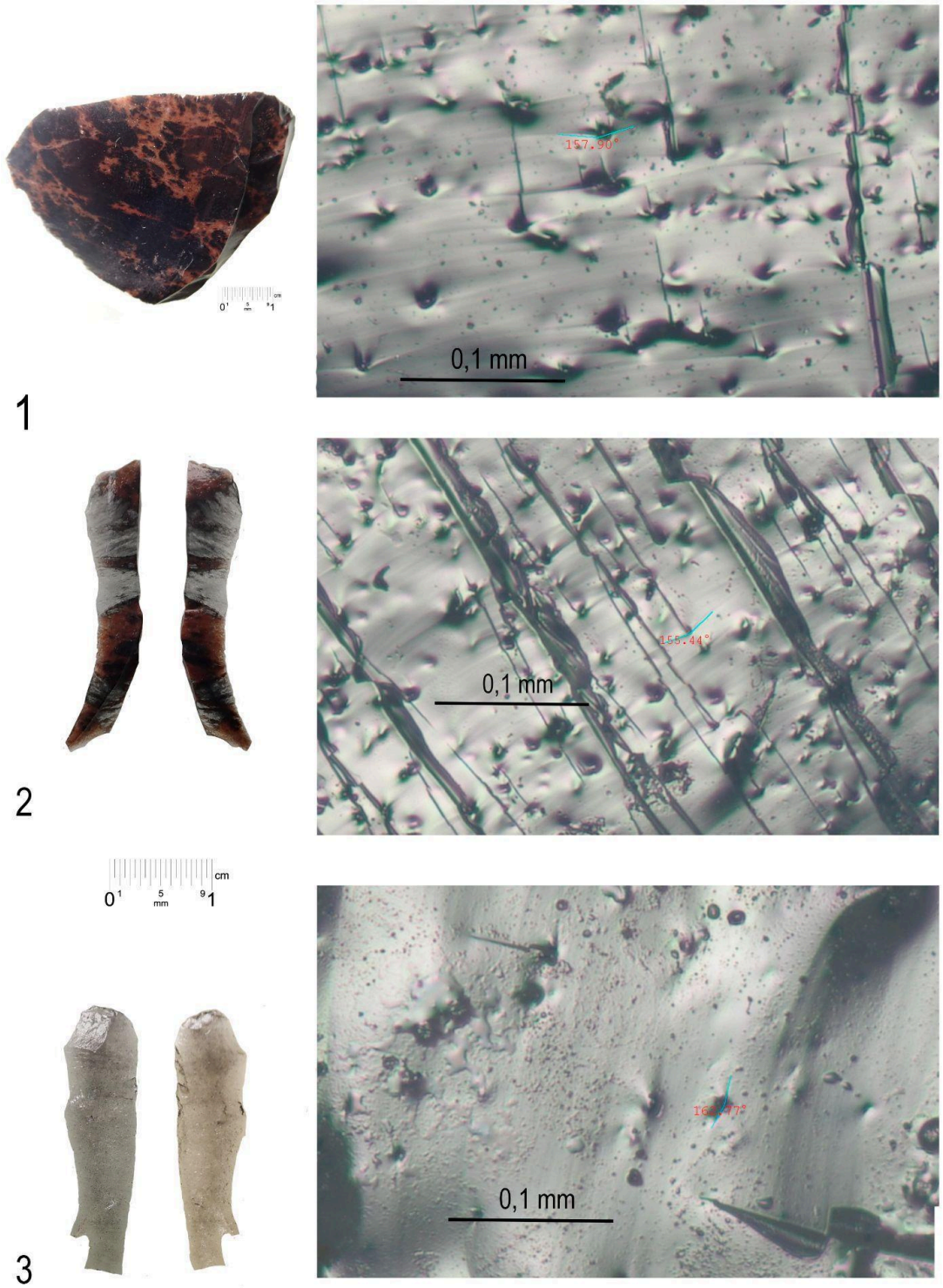


Fig. 14. Experimental obsidian artifacts with fracture wings: 1. front of microblade core processed by indirect percussion, fracture wing degree - 157,9; microblade detached by indirect percussion, fracture wings degree - 155.4; microblade detached by pressure, fracture wings degree - 162,7

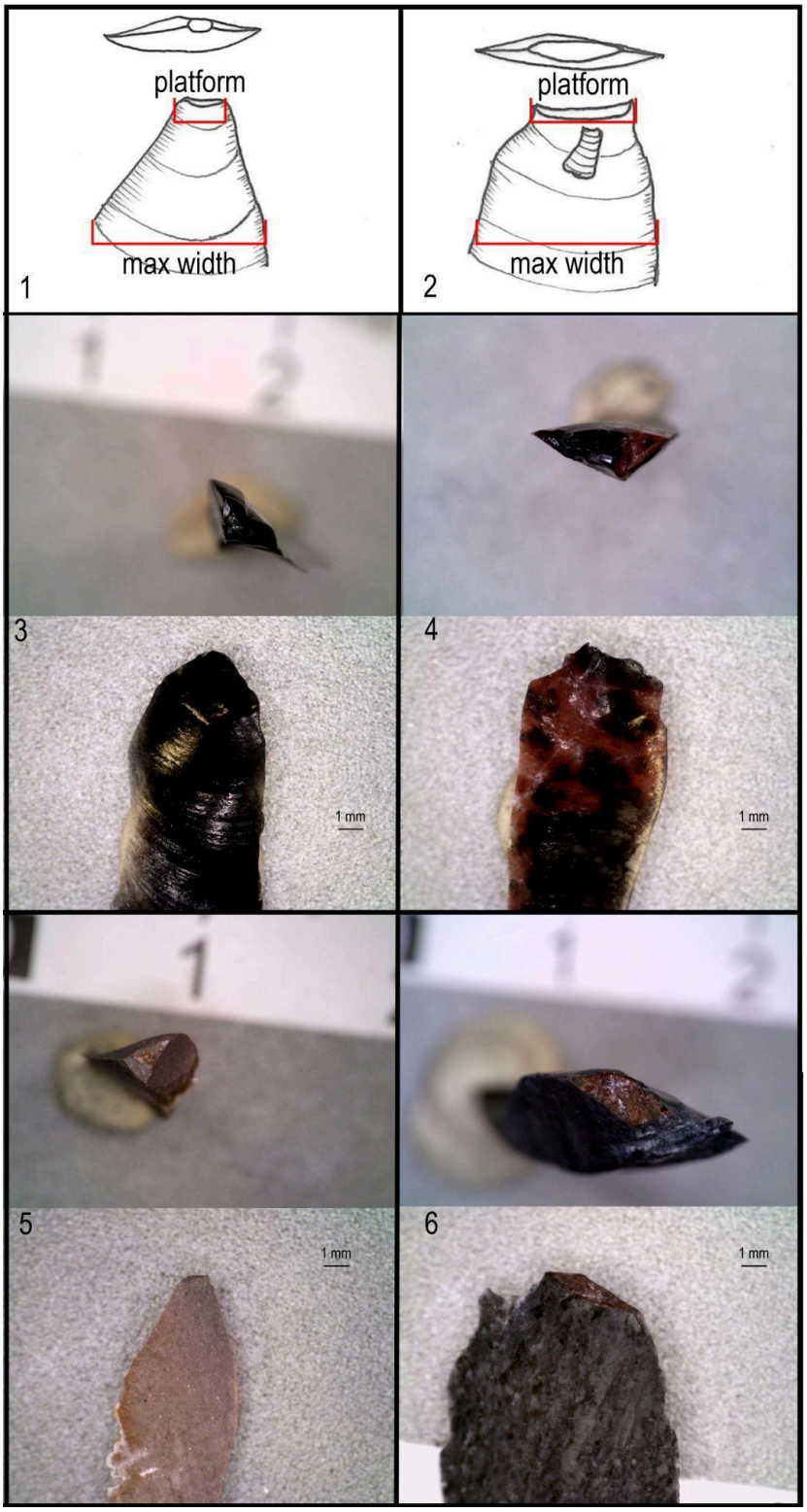


Fig. 15. Morphological features of experimentally produced microblades: 1. - graphic scheme of microblade detached by pressure; 2. - graphic scheme of microblade detached by percussion; 3. - obsidian microblade detached by pressure; 4. - obsidian microblade detached by percussion; 5. - flint microblade detached by pressure; 6. - flint microblade detached by indirect percussion

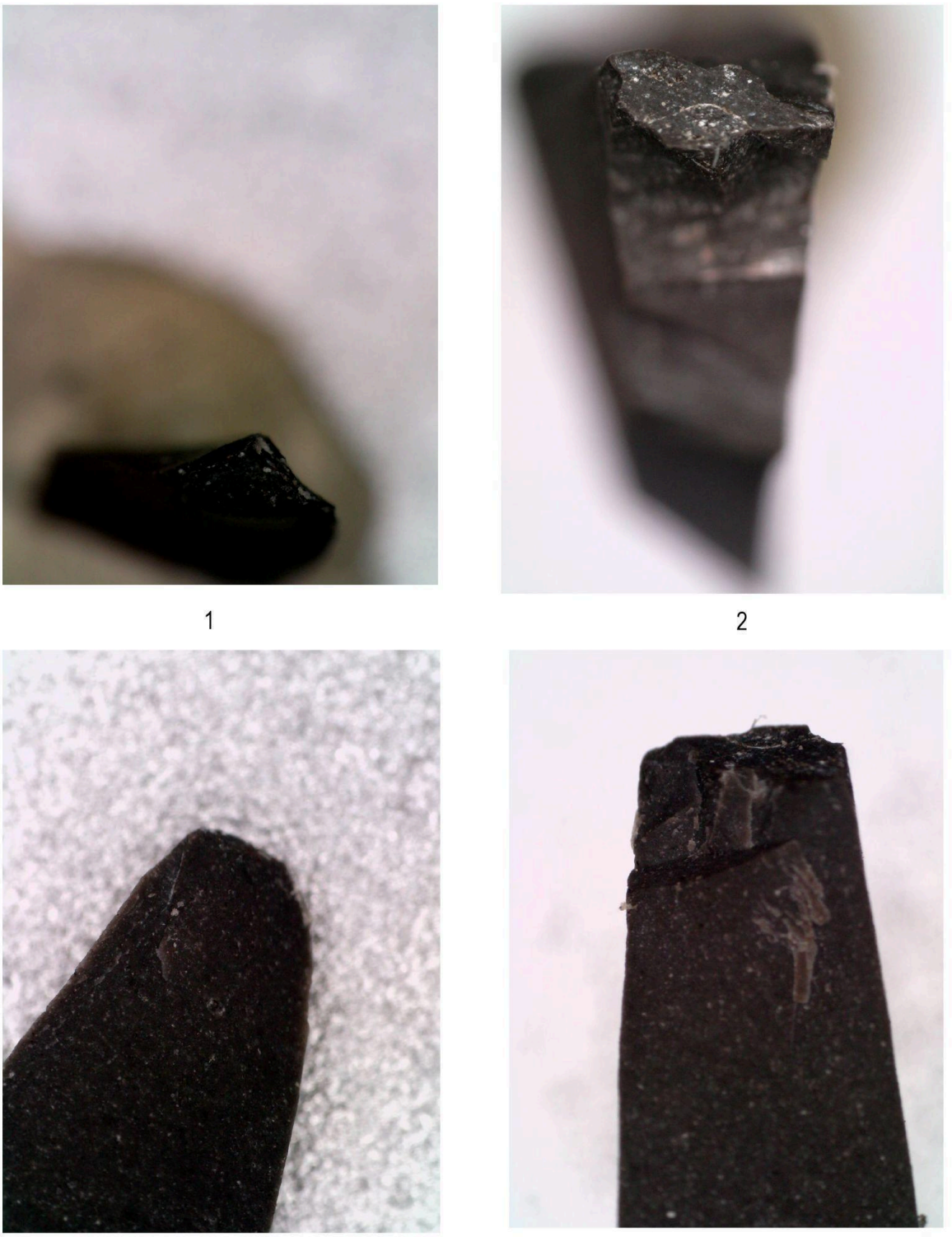


Fig. 16. Experimentally produced shale microblades: 1. - microblade detached by pressure; 2. - microblade detached by indirect percussion

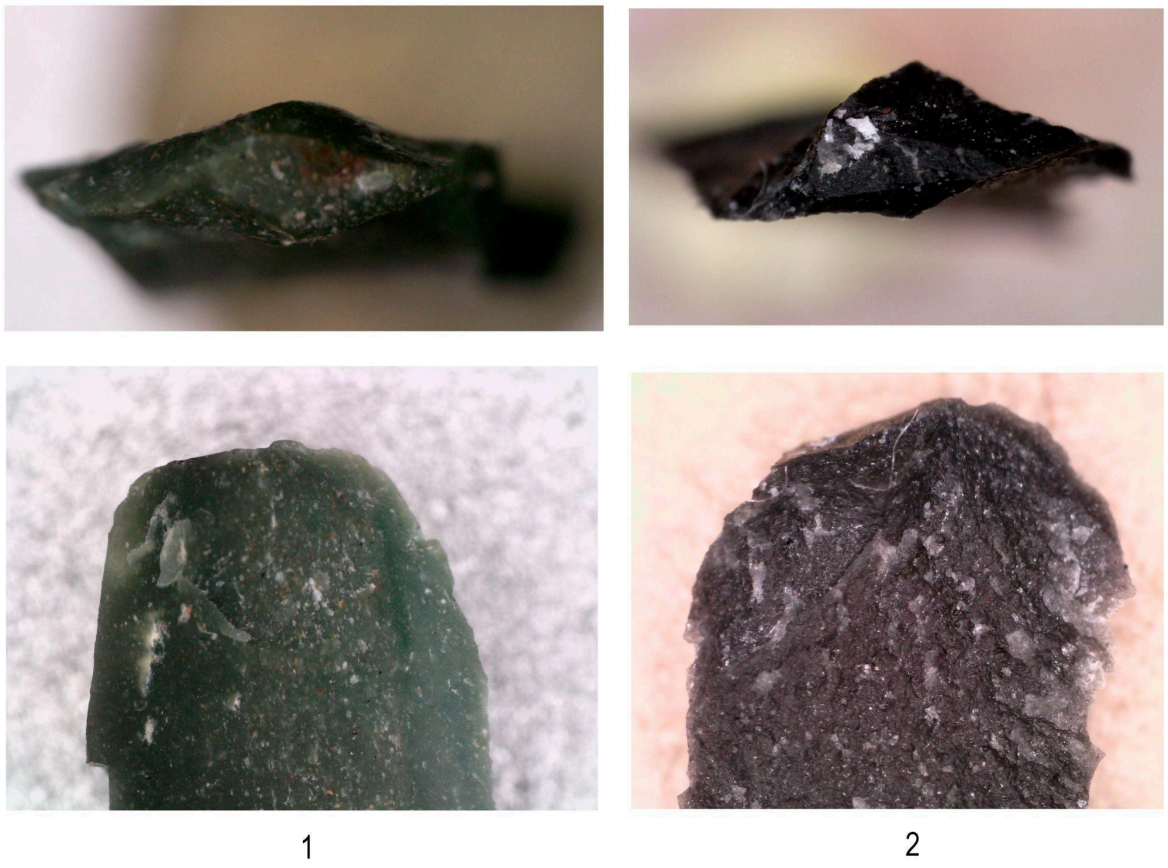


Fig. 17. Experimentally produced effusive rock microblades: 1. - microblade detached by pressure; 2. - microblade detached by indirect percussion

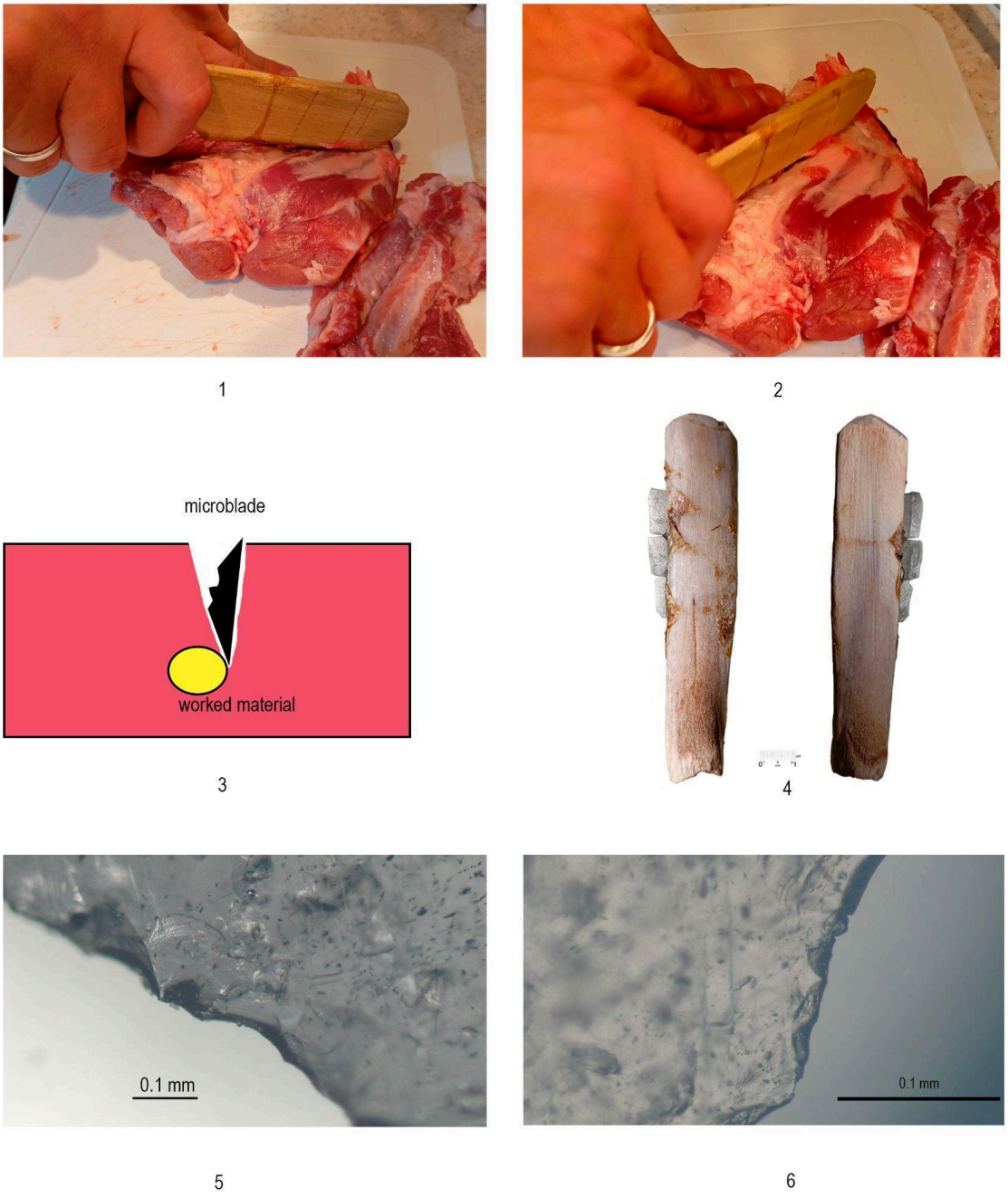
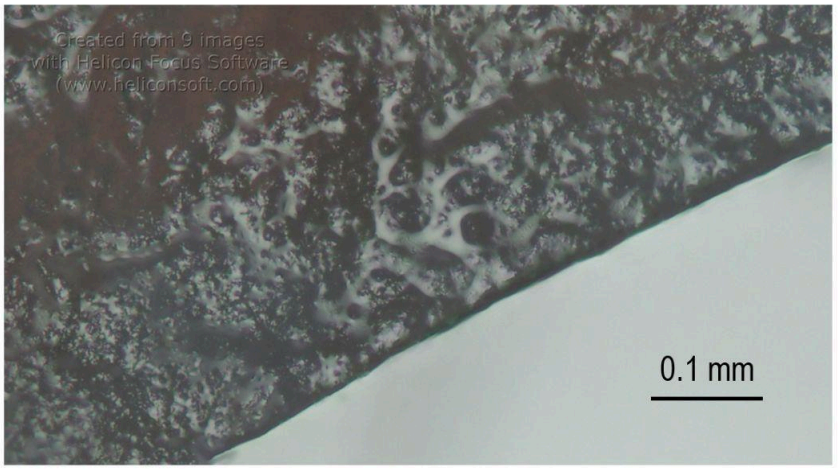
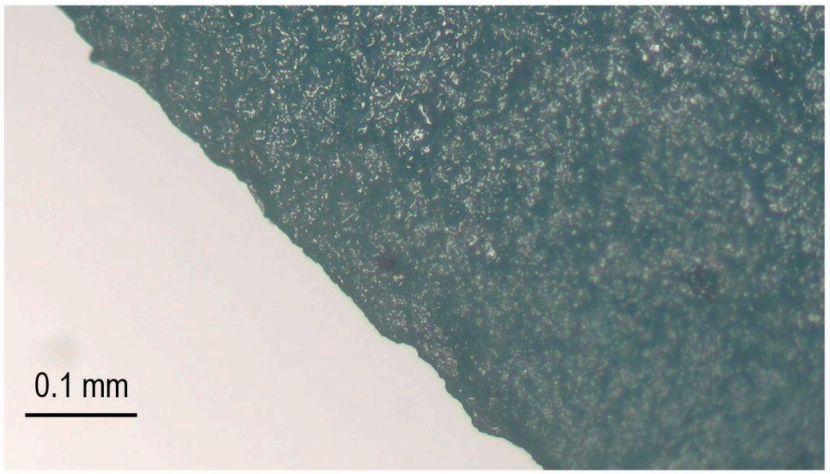


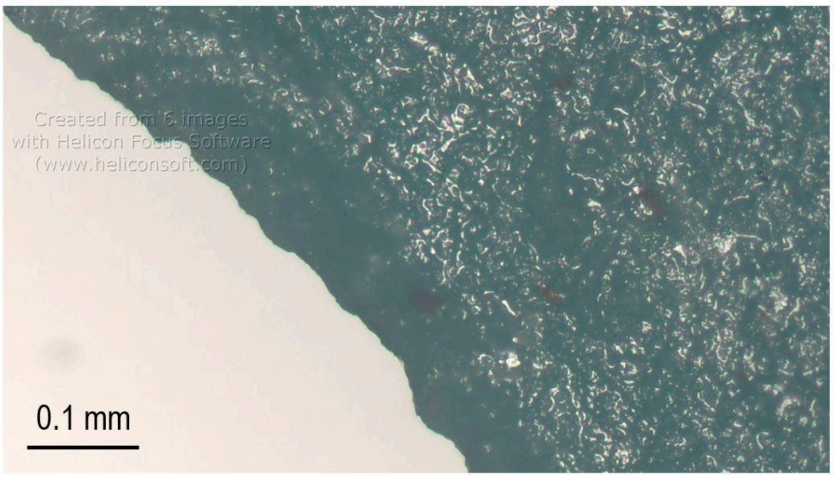
Fig. 18. Experimental process of butchery. 1-2. – process of the experiment; 3. – graphic scheme of butchering process; 4. Slotted knife used for experiments (obsidian microblades, 15 minutes of working process); 5-6. – aligned semi-circular, trapezoidal and half-moon scars with feather and scalar termination.



1



2



3

Fig. 19. Use-wears of butchery: 1. Flint, 15 minutes of working process, micropolish; 2. Shale, 5 minutes; 3. Effusive rock, 15 minutes

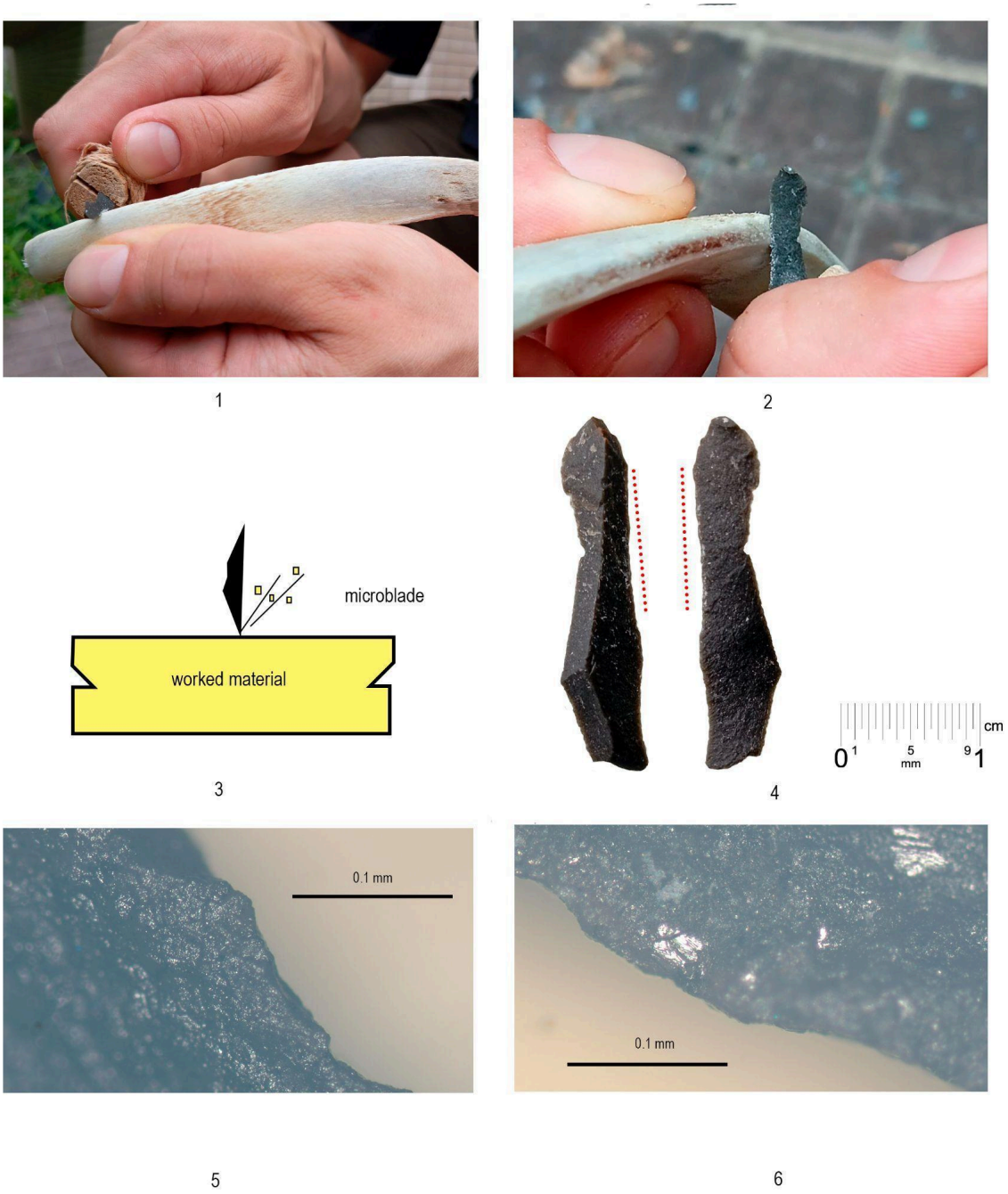


Fig. 20. Experimental scraping: 1-2. – process of experiment of bone scraping; 3. - graphic scheme of scraping process; 4. - effusive rock microblade used in experiment; 5. - aligned scars of triangular, semi-circular and trapezoidal shape with the scalar and feather ending ; 6. - mildly developed spots of flat shiny micropolish on the effusive rock experimental microblade

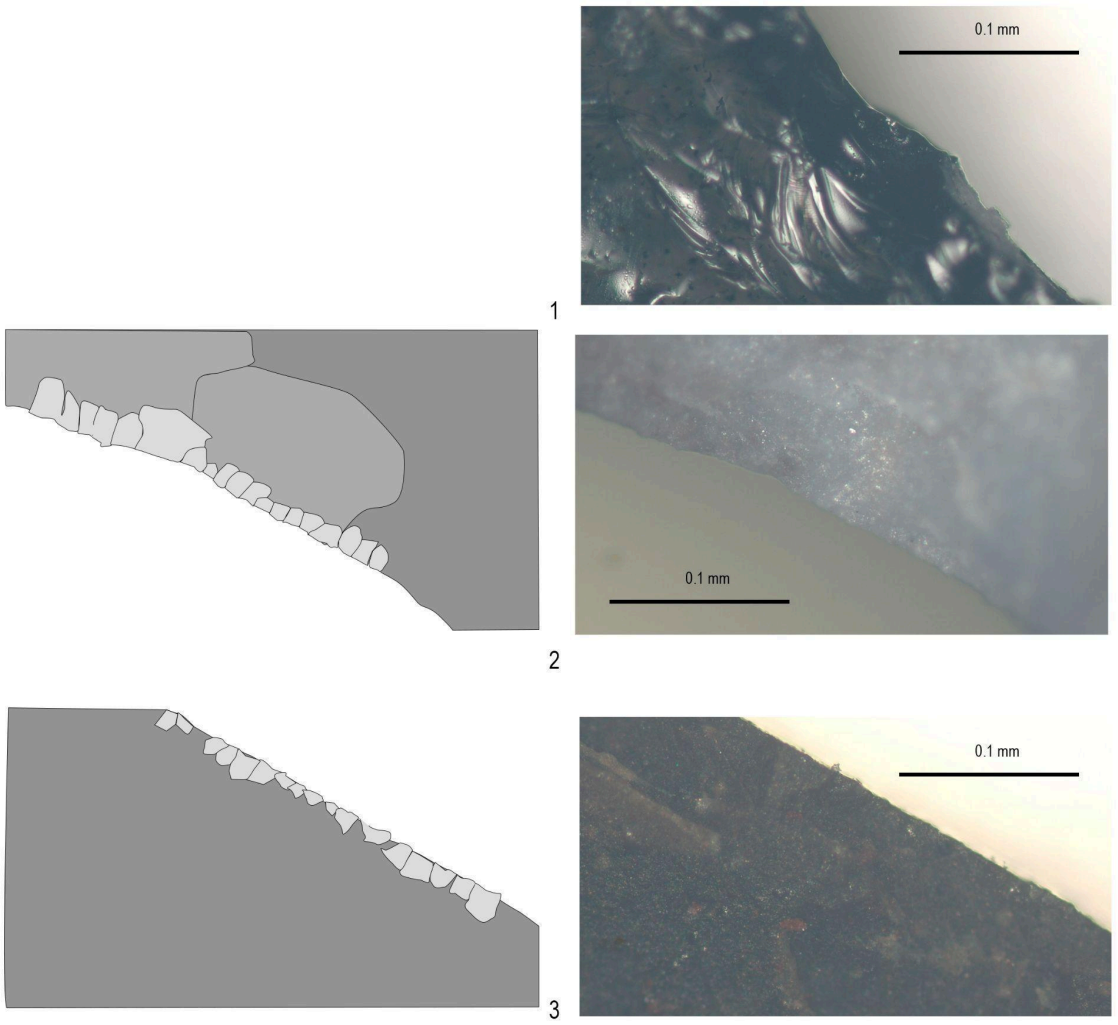


Fig. 21. Experimental scraping: 1. Obsidian microblade: overlapped scars of semi-circular and trapezoidal shape with bending termination; 2. Siliceous rock microblade; overlapped and aligned semi-circular, trapezoidal and amorphous scars with feather and scalar termination. 3. Shale microblade: aligned semi-circular, sub-square and trapezoidal scars with feather and scalar termination.

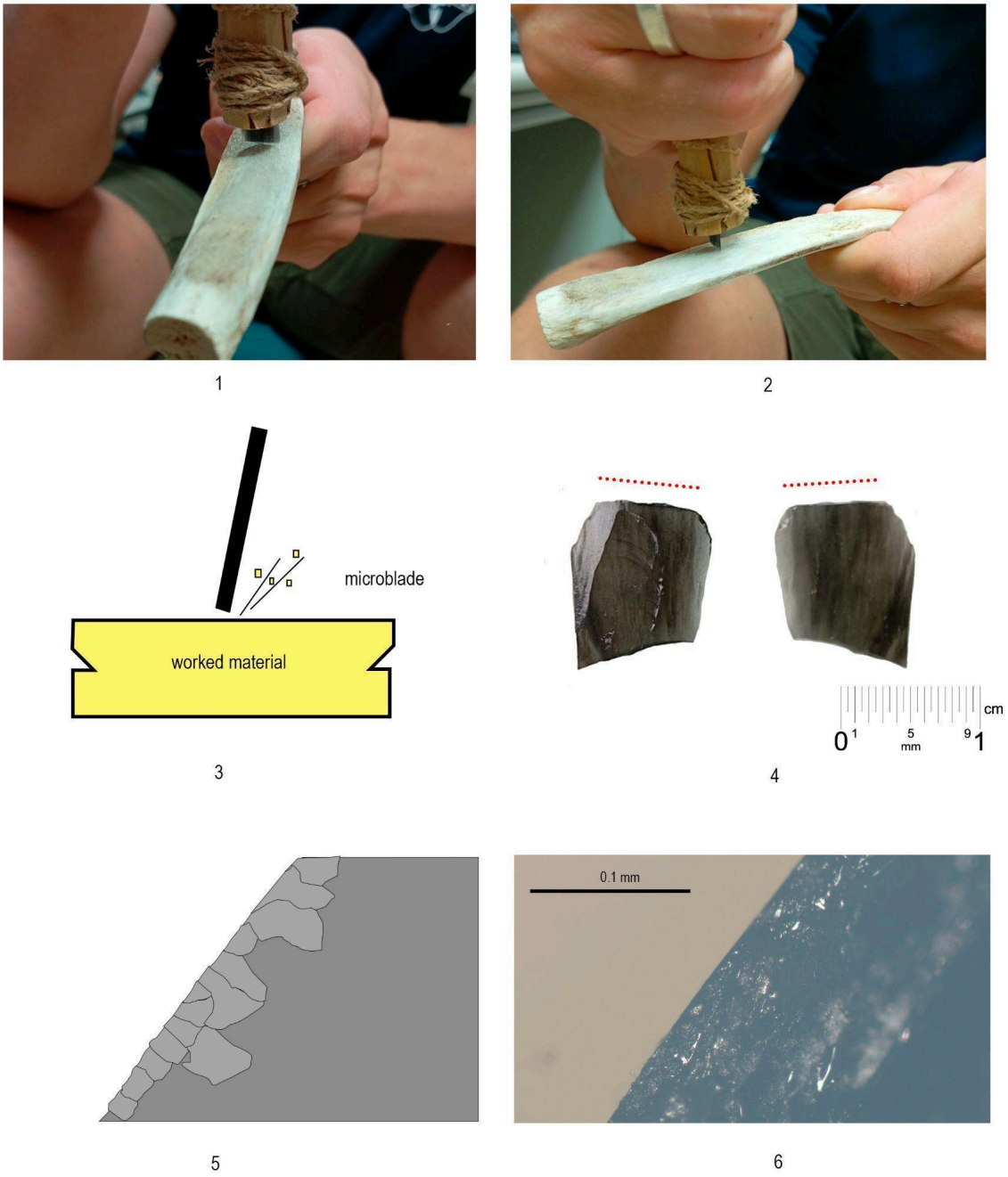


Fig. 22. Experiment with micro-endscraper: 1,2 – process of experiment; 3. - graphic scheme of micro-scraper`s working process; 4. - obsidian microblade used in experiment; 5,6 – use-wears with edge rounding, aligned and overlapped semi-circular scars with thin or feather termination

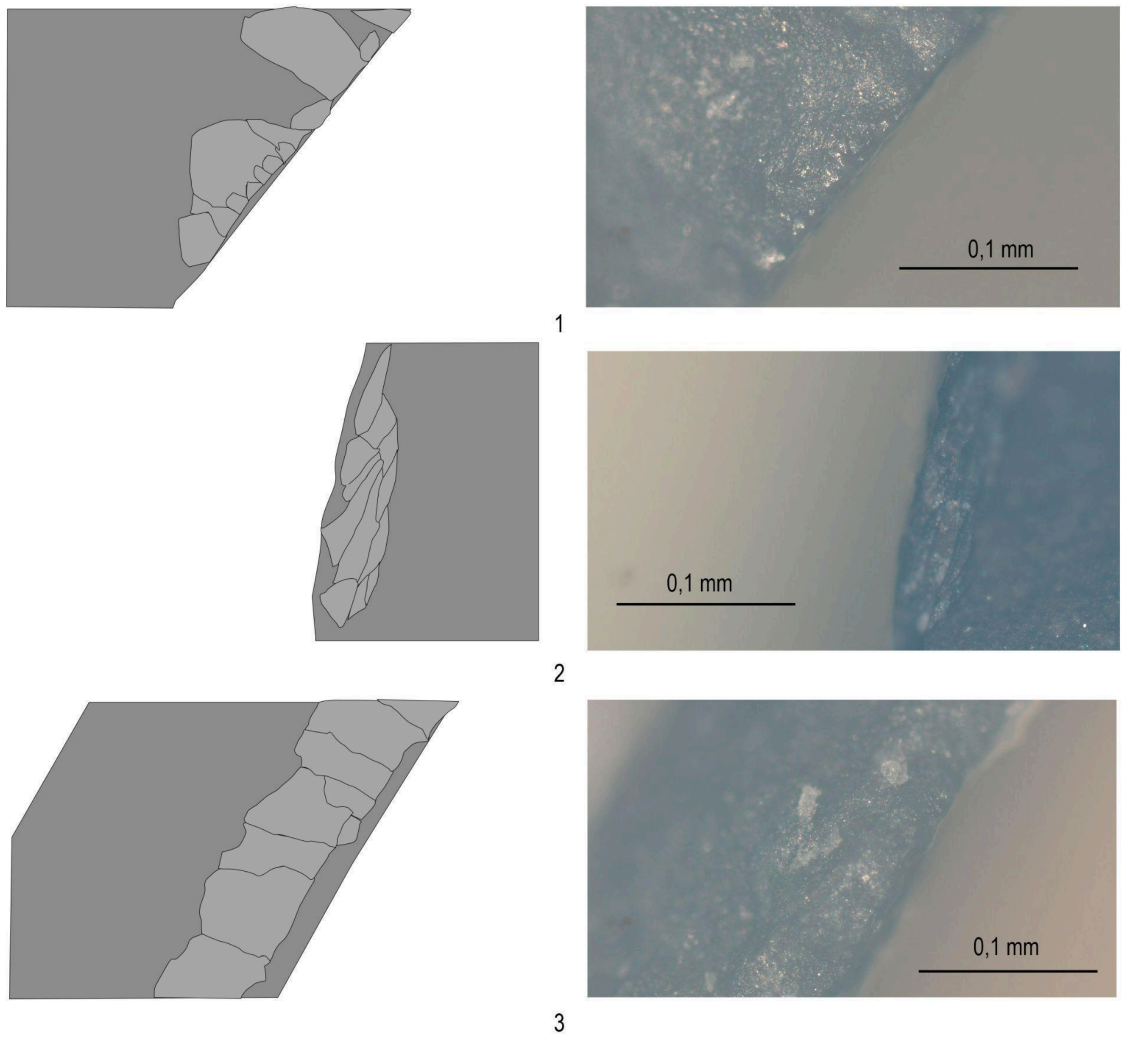


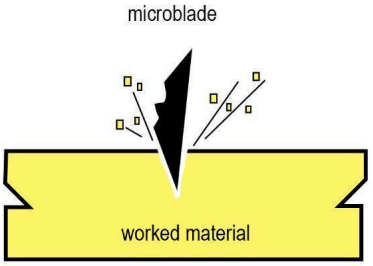
Fig. 23. Experiment with micro-endscraper: 1. - Siliceous rock microblade: use-wears with edge rounding, aligned and overlapped semi-circular scars with thin or feather termination; 2. - Shale microblade; overlapped amorphous, semi-circular and trapezoidal scars; 3. - Effusive rock; use-wears with edge rounding, aligned semi-circular scars with feather termination



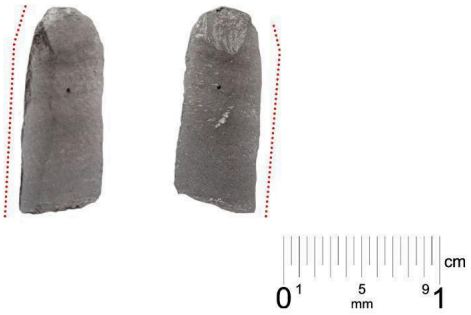
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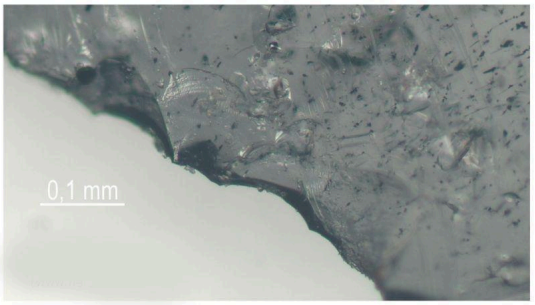
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6

Fig. 24. Experiment with graving: 1,2 – process of experiment; 3. - graphic scheme of graving working process; 4. - obsidian microblade used in experiment; 5,6 – use-wears with edge rounding, aligned and overlapped trapezoidal and semi-circular scars with feather and scalar termination

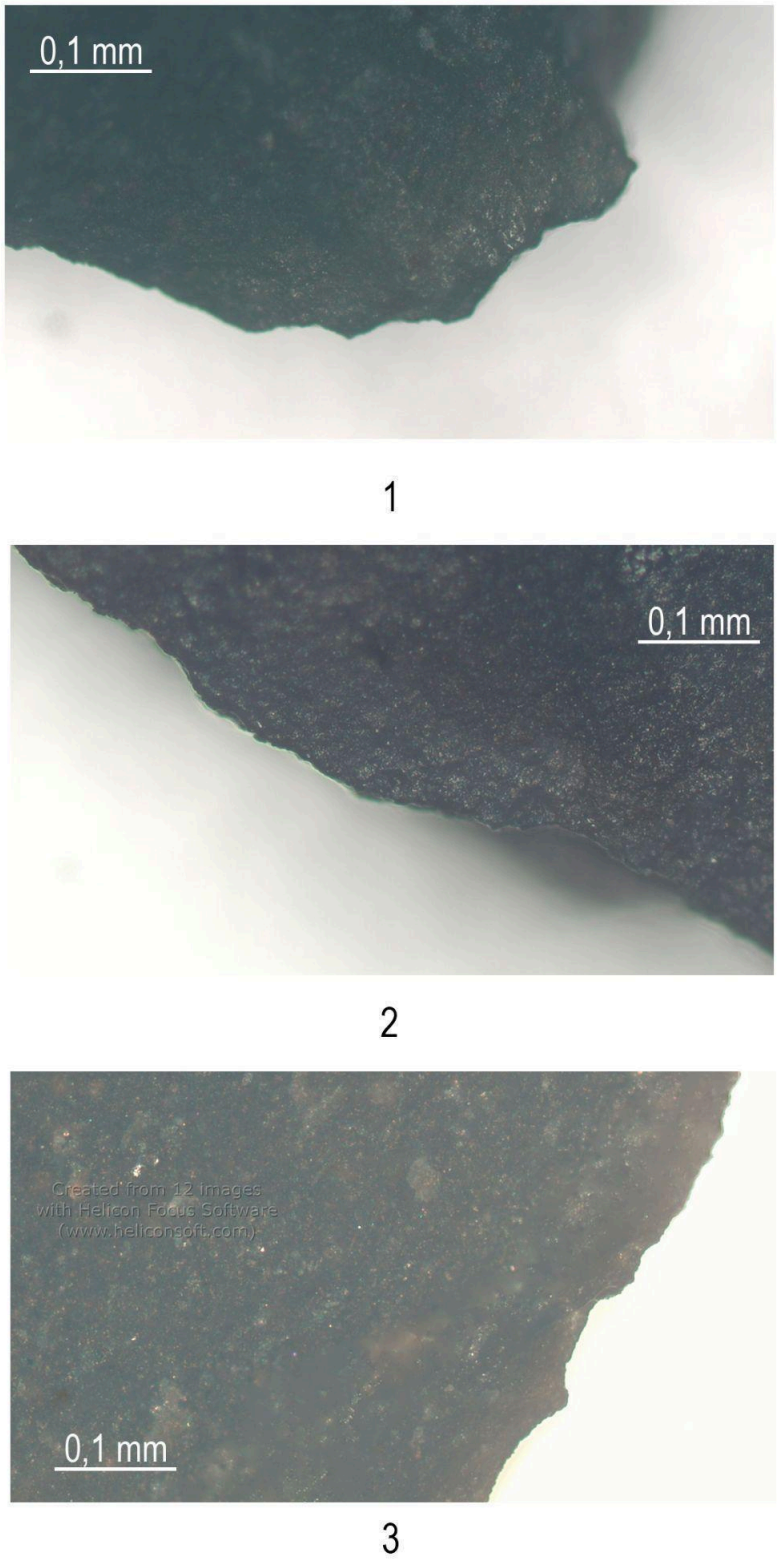


Fig. 25. Use-wears of graving: 1. - Effusive rock, 5 minutes; 2. - Shale, 15 minutes; 3. - Flint, 15 minutes

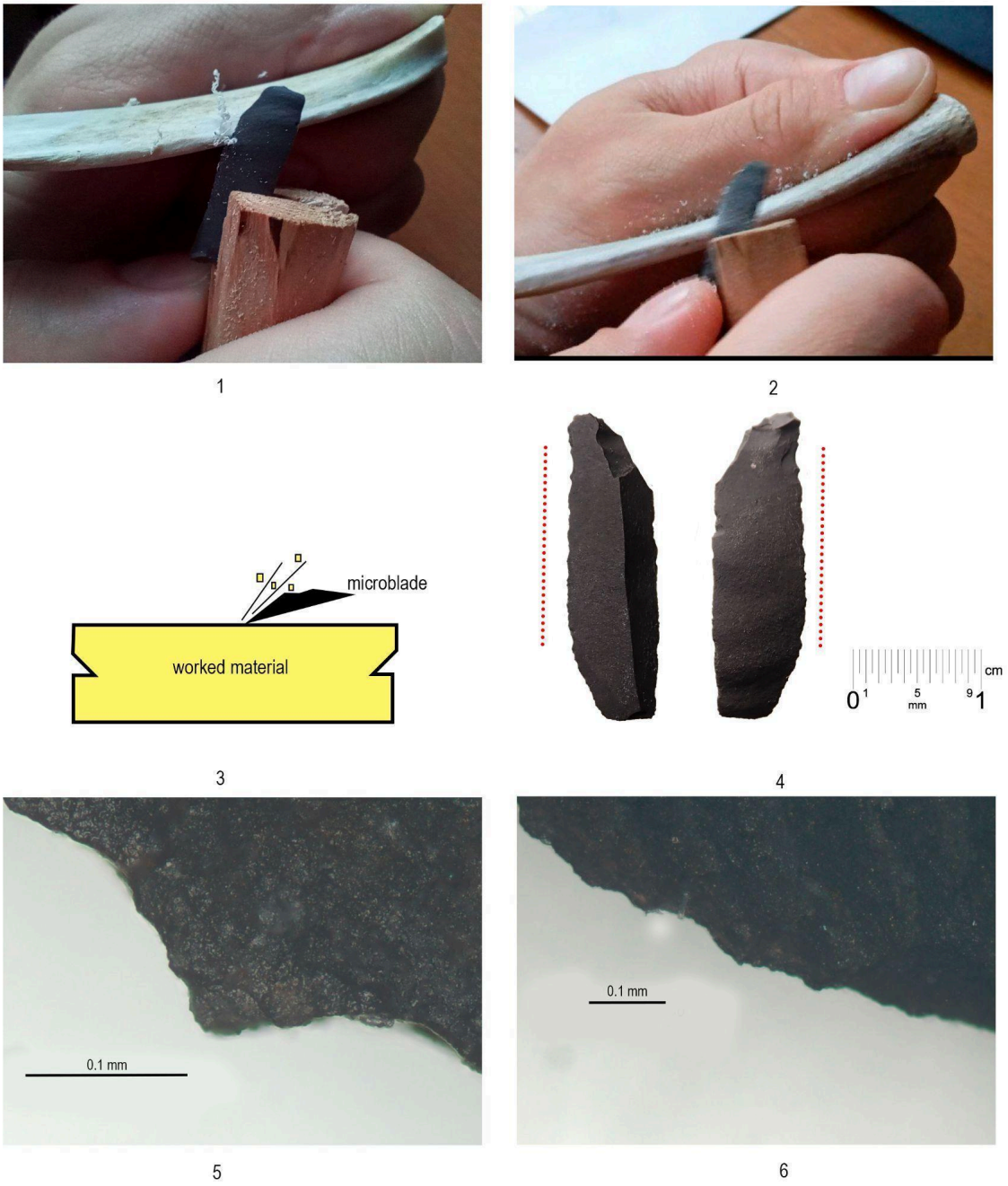


Fig. 26. Experimental planning. 1-2. – process of experiment of bone planning; 3. - graphic scheme of planning process; 4. - shale microblade used in experiment; 5. - micropolish on the shale experimental microblade; 5. - Overlapped scars with scalar ending and trapezoidal and semicircular shape on shale microblade

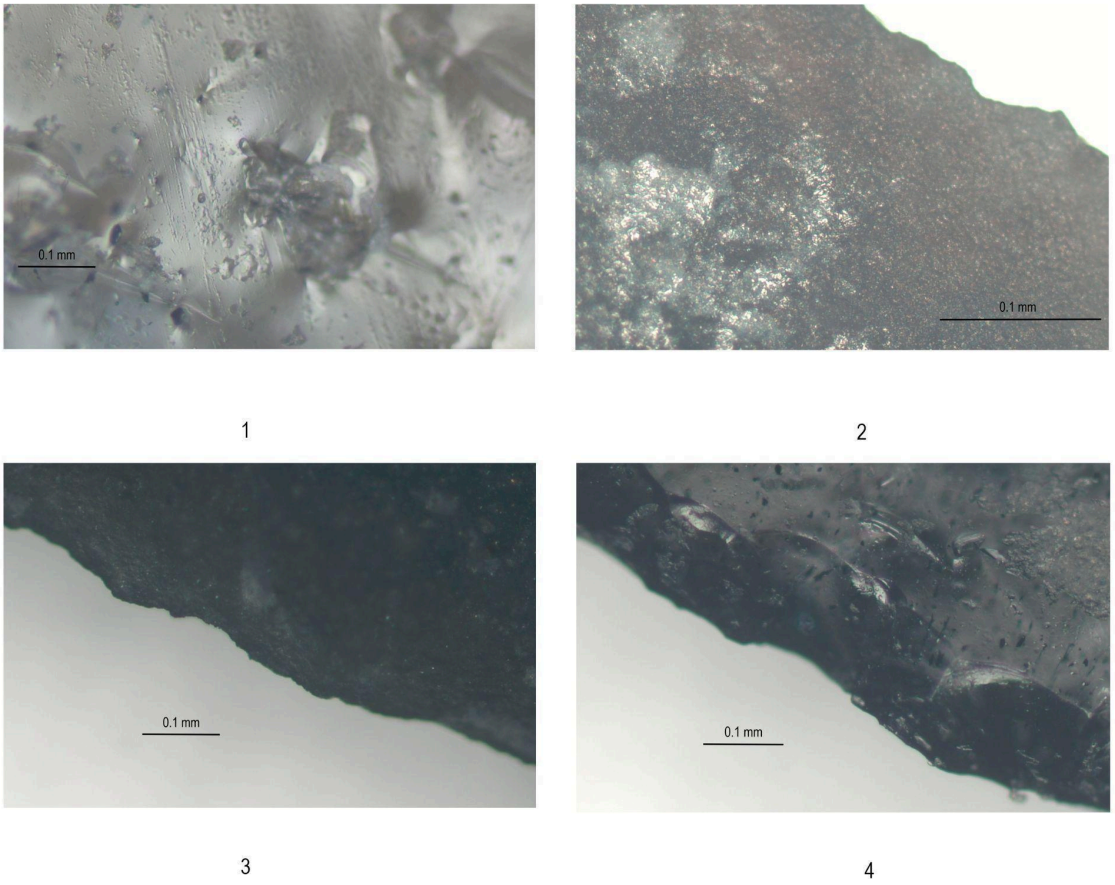


Fig. 27. Use wears of bone planning: 1. - linear striations on obsidian microblade; 2. - Spots of bright micropolish on the chert microblade; 3. - Overlapped scars with scalar ending and trapezoidal, semicircular and sub-square shape on effusive rock microblade; 4. - Overlapped scars with scalar ending and trapezoidal, semicircular and sub-square shape on obsidian microblade.

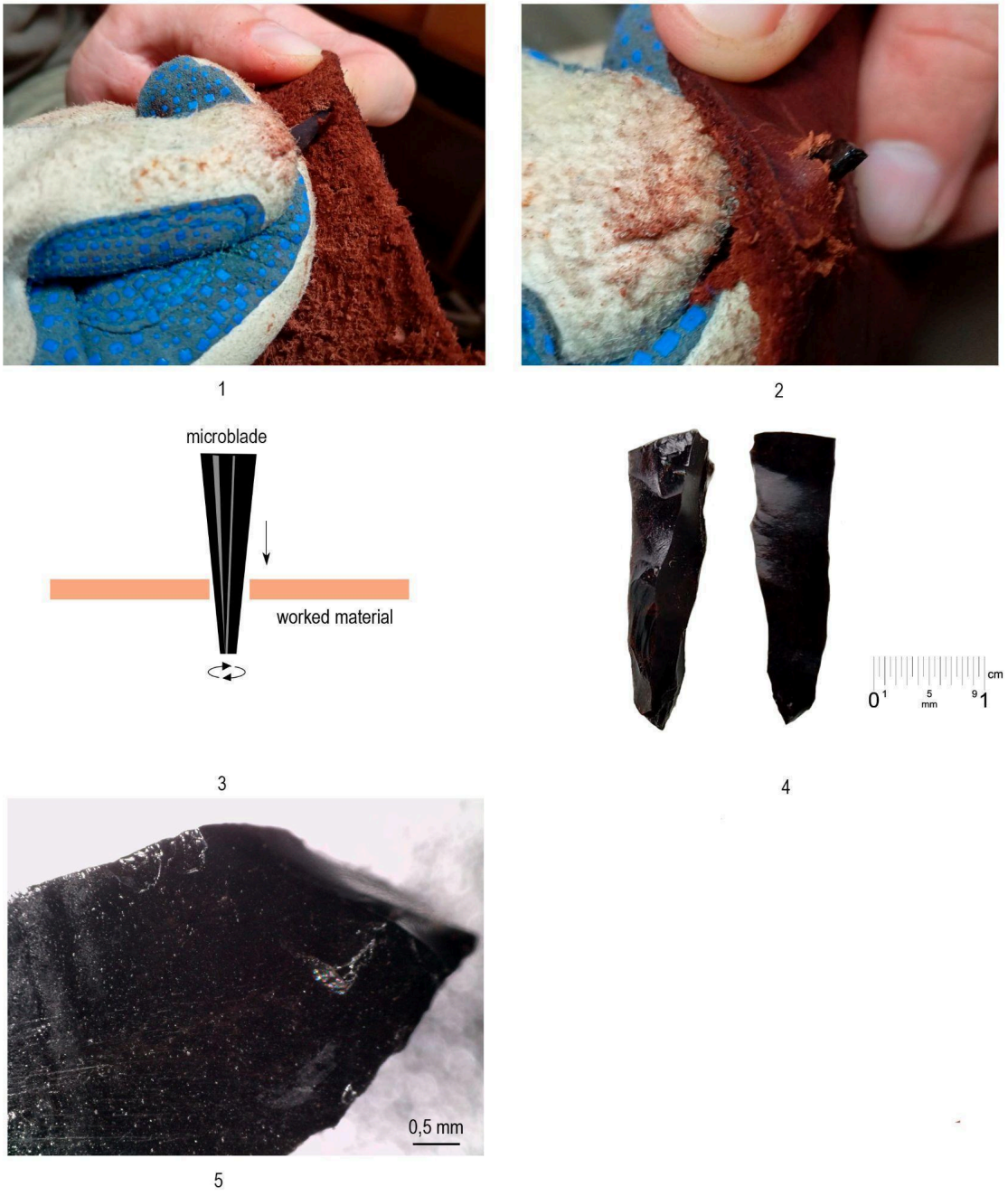
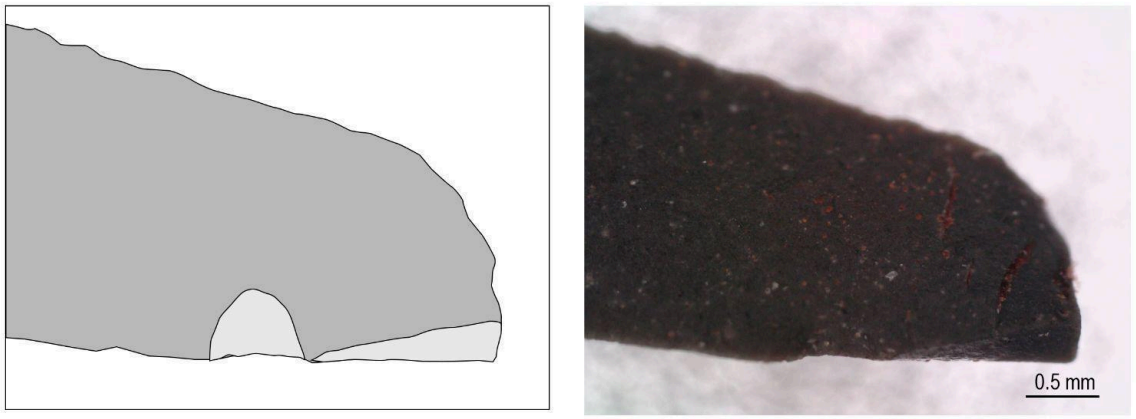
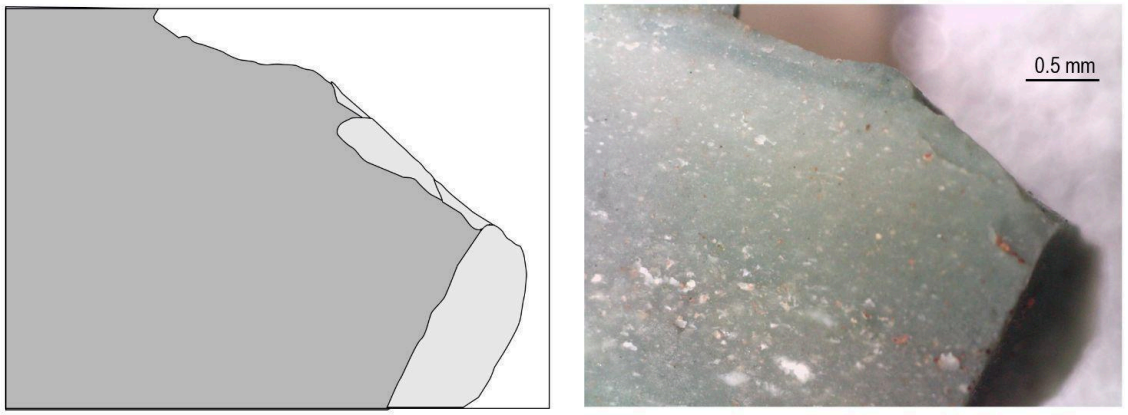


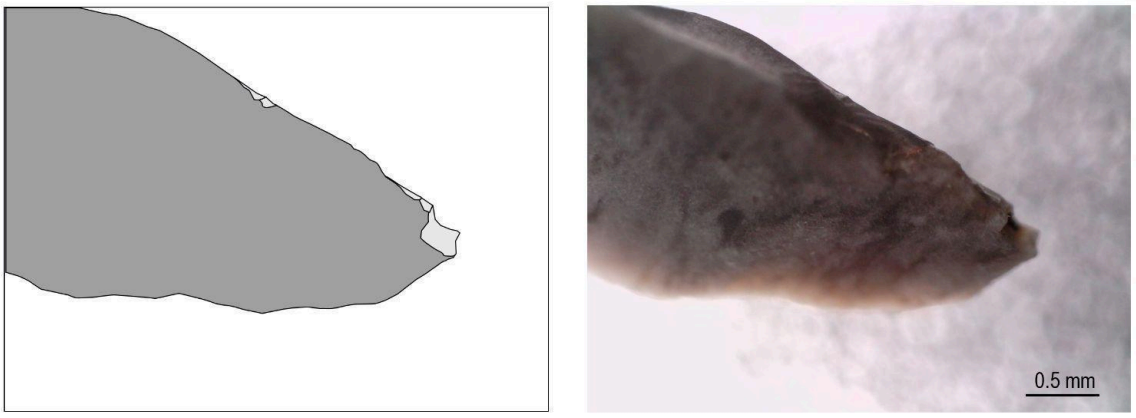
Fig. 28. Experiments with borer usage. 1-2. – experimental process of leather piercing; 3. - graphic scheme of piercing process; 4. - obsidian microblade used in experiment; 5. - thin aligned semicircular scars and broken tip of borer.



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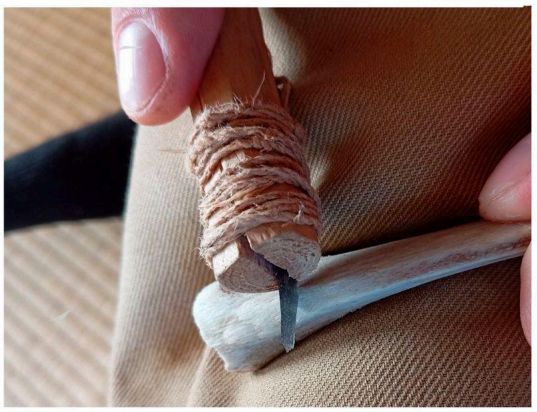


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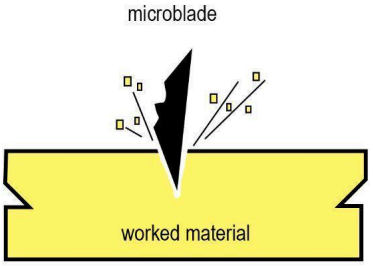
Fig. 29. Use-wears of leather piercing: isolated and aligned scars with thin or feather termination and breakage of the tip of microblade. 1. – Shale, 15 minutes; 2. – Effusive rock, 15 minutes; 3. – Flint, 15 minutes



1



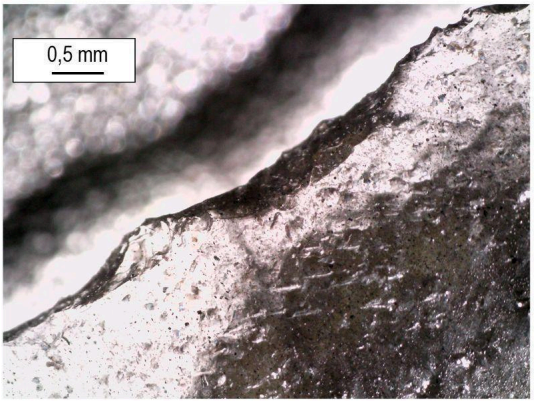
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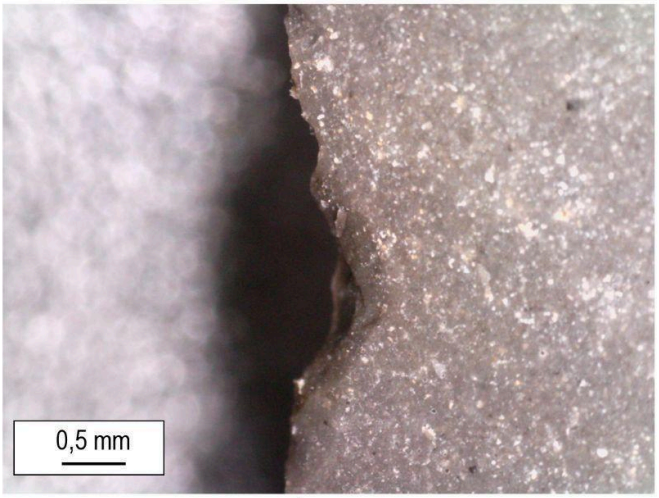


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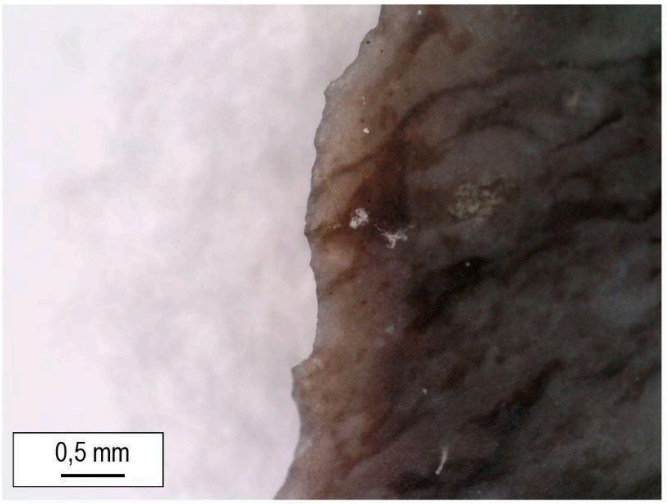


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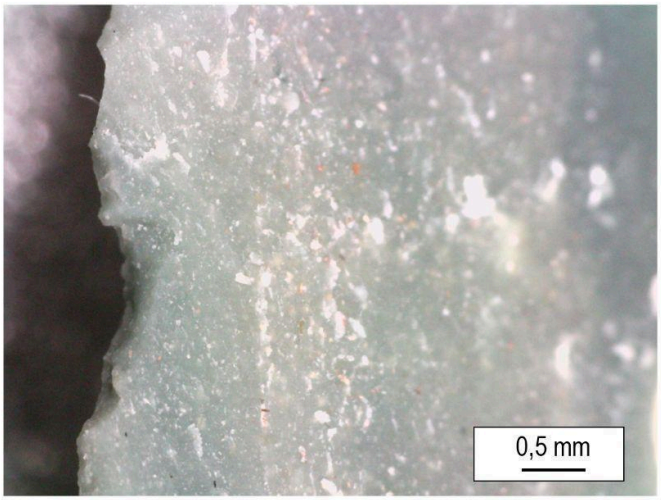
Fig. 30. Experiment with sawing: 1,2 – process of experiment; 3. - graphic scheme of micro-scraper`s working process; 4. - obsidian microblade used in experiment; 5,6 – use-wears – aligned and overlapped semi-circular scars with scalar termination combined with half-moon edge abrasion scars.



1



2



3

Fig. 31. Use-wears of sawing: 1. - Shale, 5 minutes; 2. - Flint, 5 minutes; 3. - Effusive rock, 5 minutes

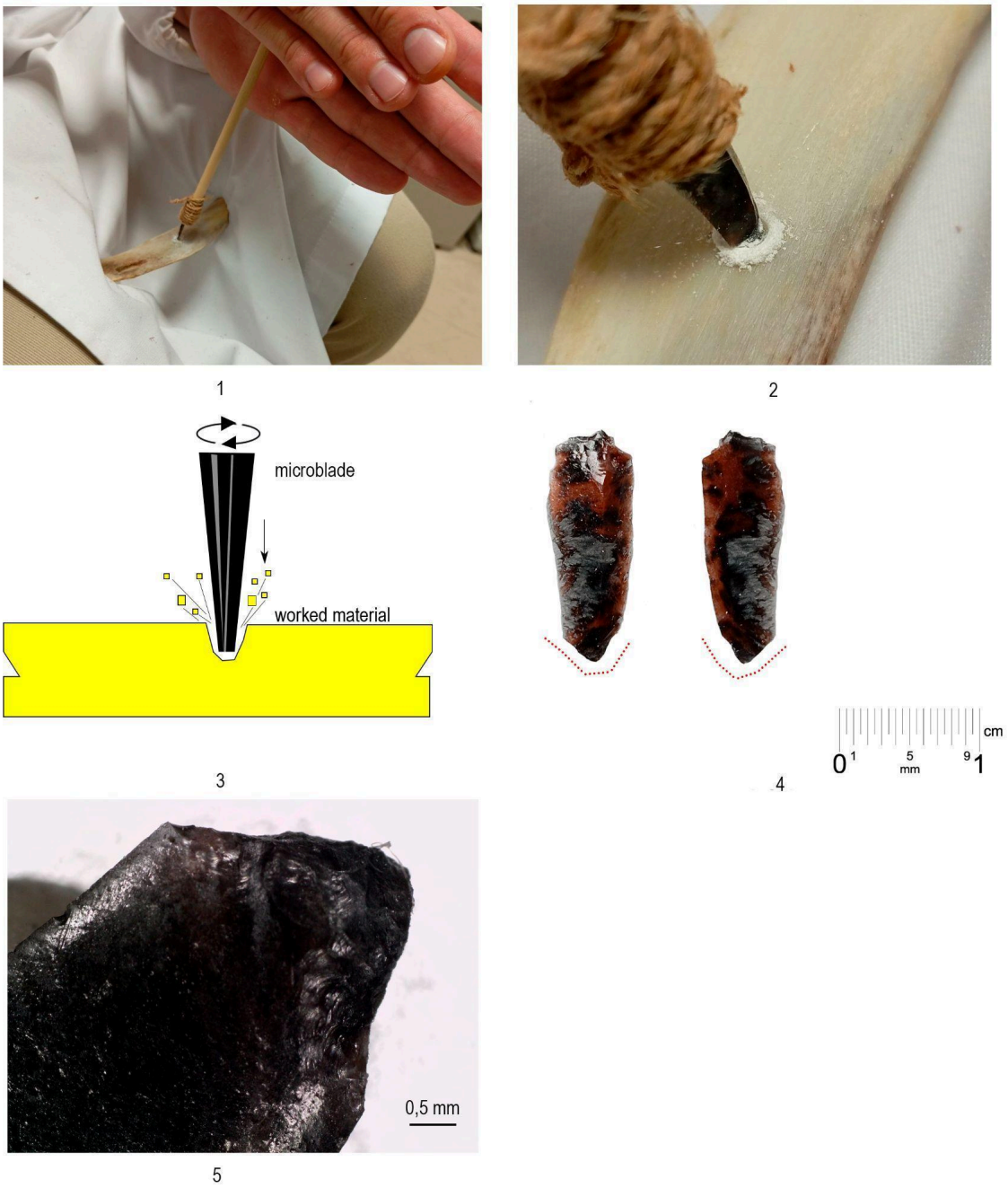
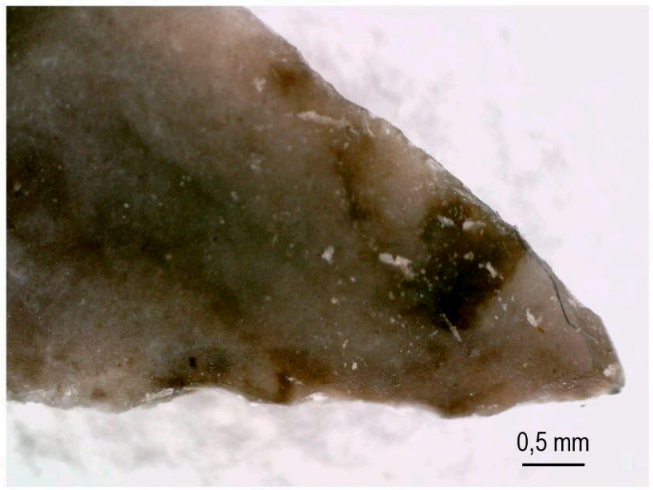


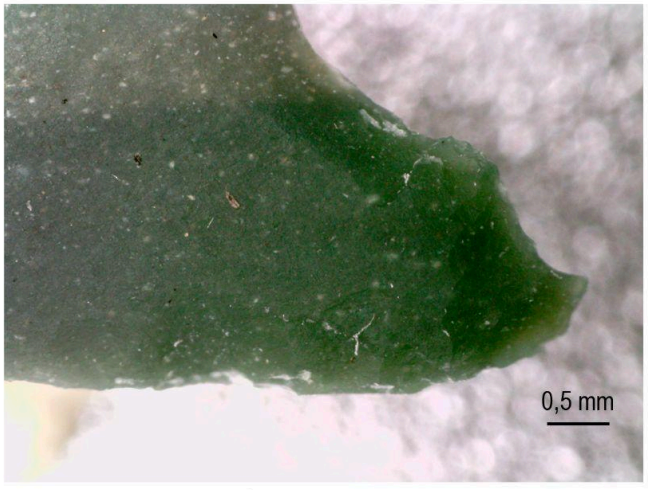
Fig. 32. Experiment with drilling: 1,2 – process of experiment; 3. - graphic scheme of micro-scraper`s working process; 4. - obsidian microblade used in experiment; 5,6 – use-wears – overlapped semi-circular scars with feather and scalar termination



1



2



3

Fig. 33. Use-wears of drilling: 1. - flint, 15 minutes; 2. - shale, 5 minutes; 3. - effusive rock, 5 minutes

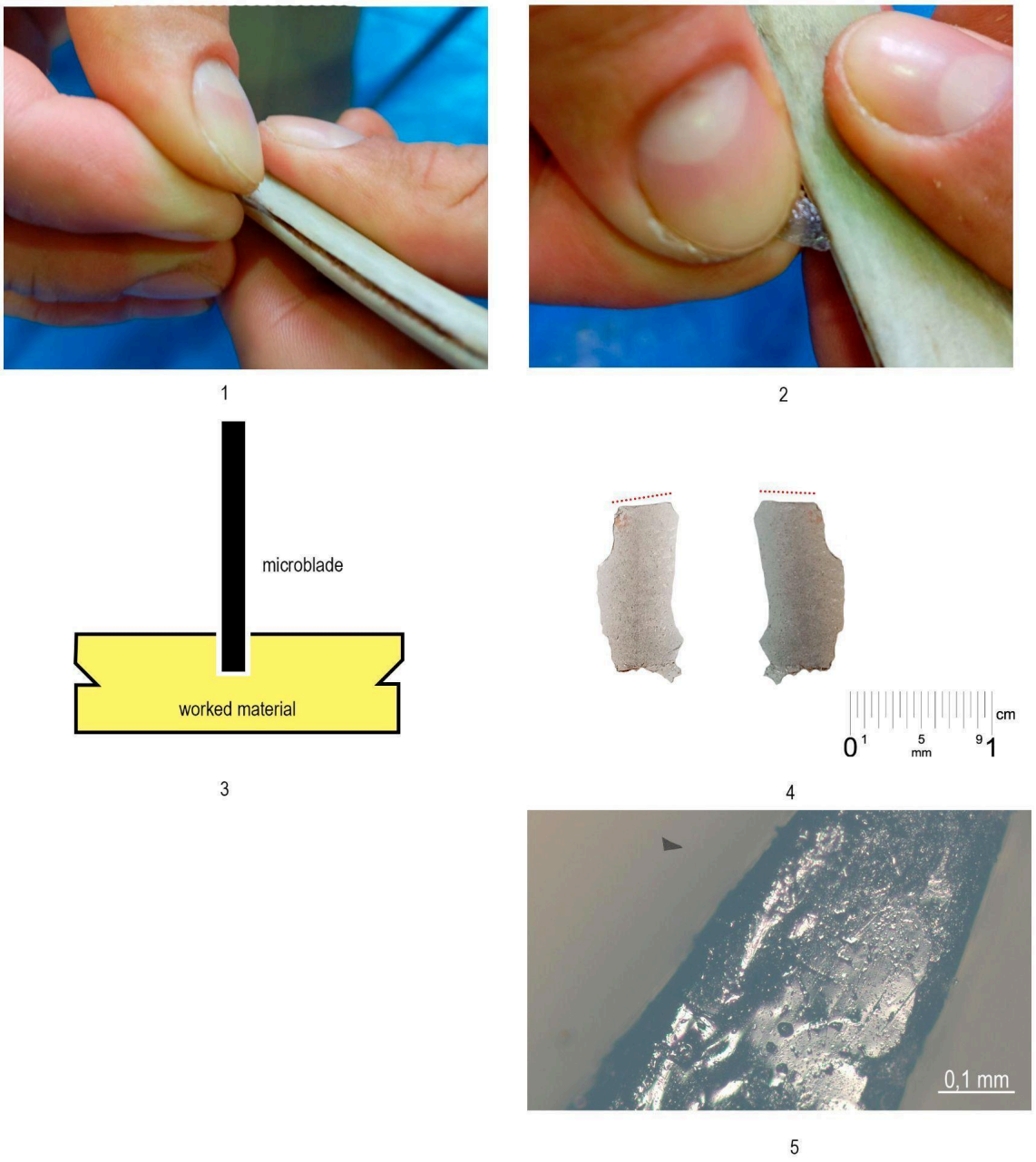


Fig. 34. Experiment with knife-carver: 1,2 – process of experiment; 3. - graphic scheme of micro-scraper`s working process; 4. - obsidian microblade used in experiment; 5,6 – use-wears with micropolish, aligned amorphous scars with scalar termination and striations

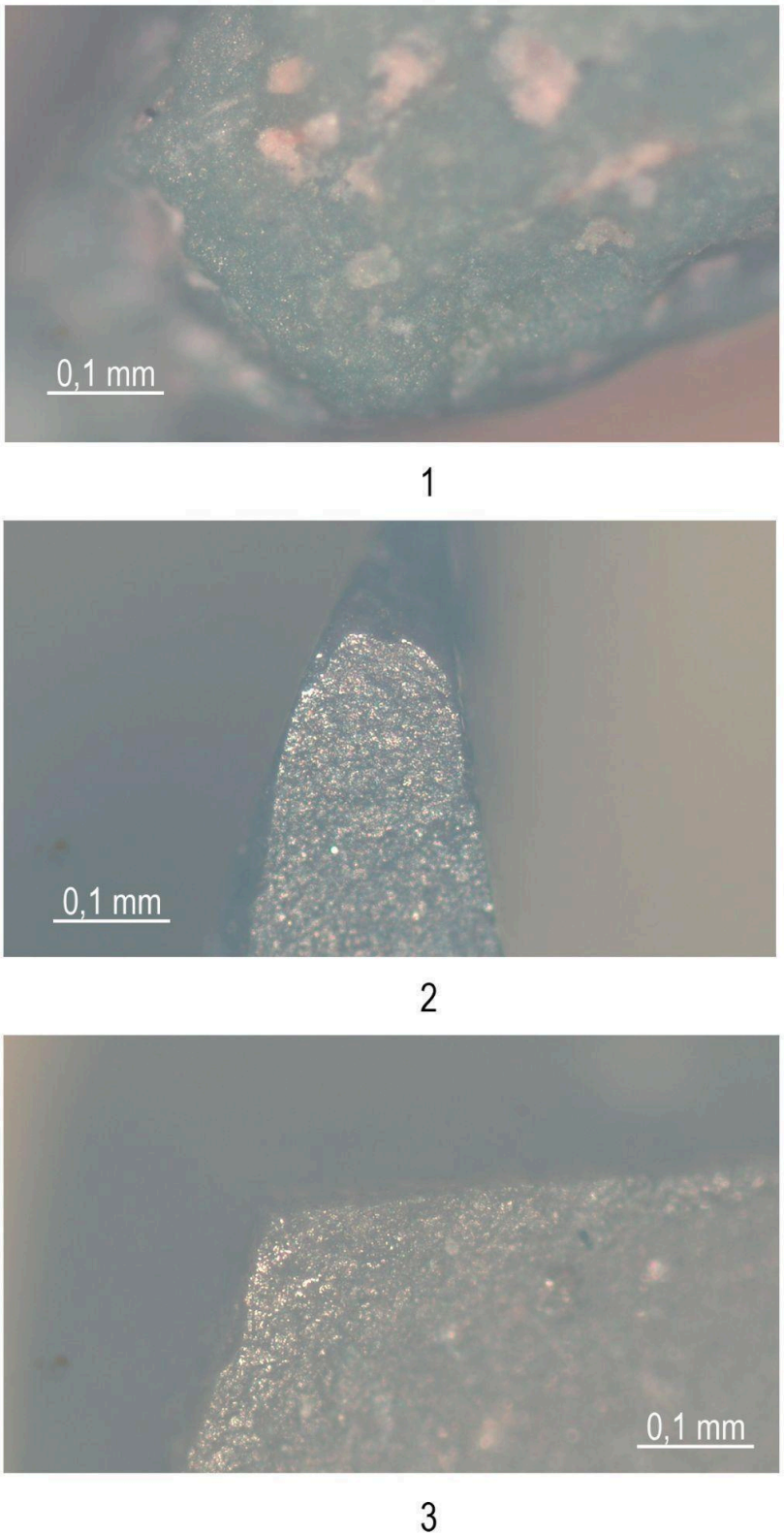


Fig. 35. Use-wears of knife-carver experiments: 1. - Effusive rock, 5 minutes; 2. - Flint, 5 minutes; 3. - Shale, 15 minutes

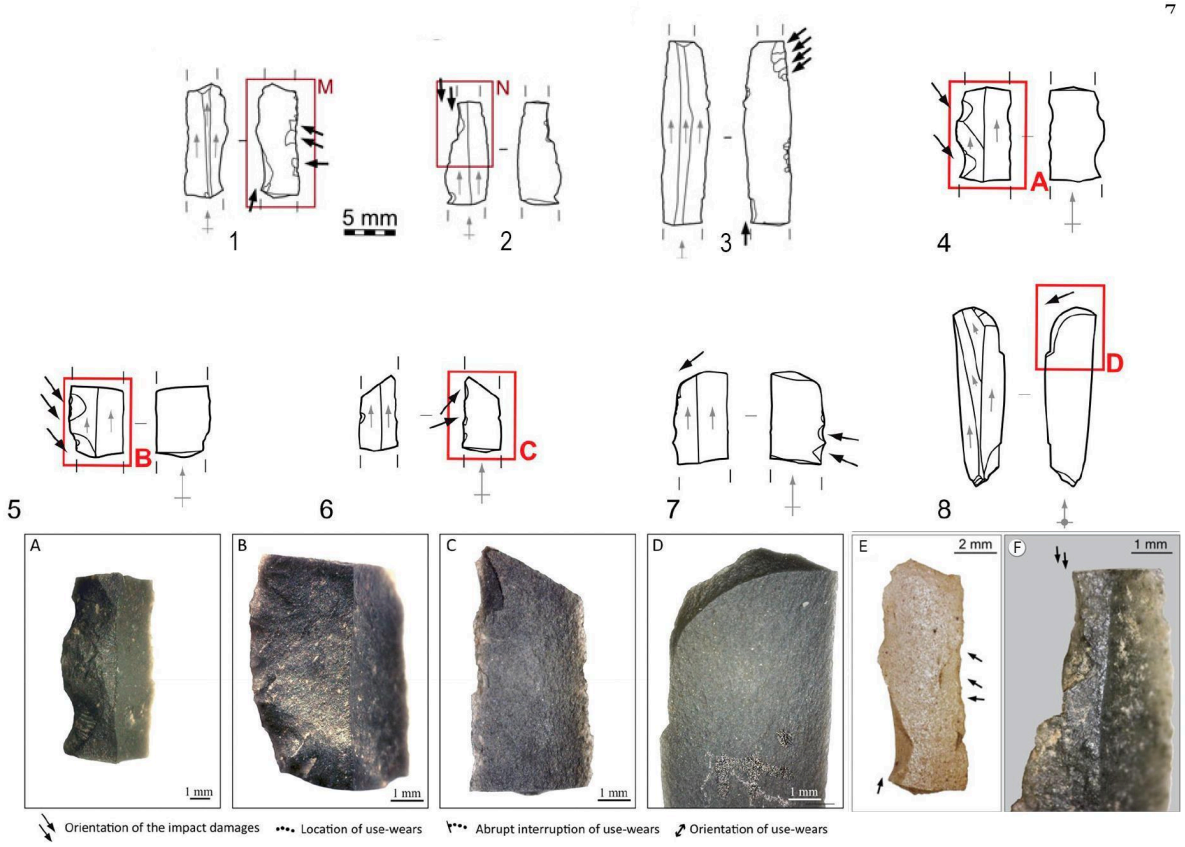


Fig. 36. Microblades with use-wears of impact: 1-3 Swan Point site CZ4b; 4-8 Kovrizhka IV site, level 6. Modified from (Roux et al., 2021; 2024).

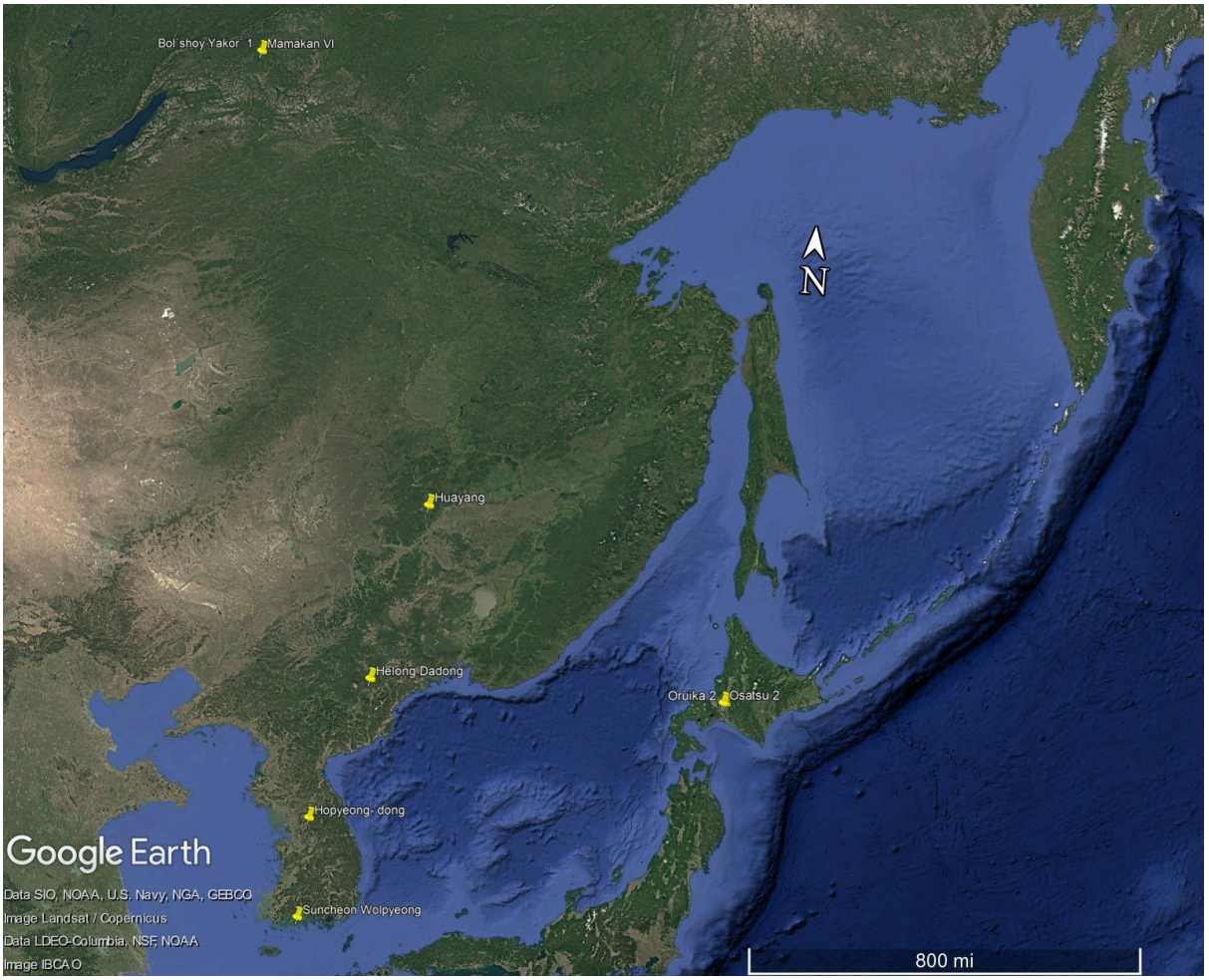


Fig. 37. Map of Northeastern Asia with indicated Paleolithic sites selected for the survey.

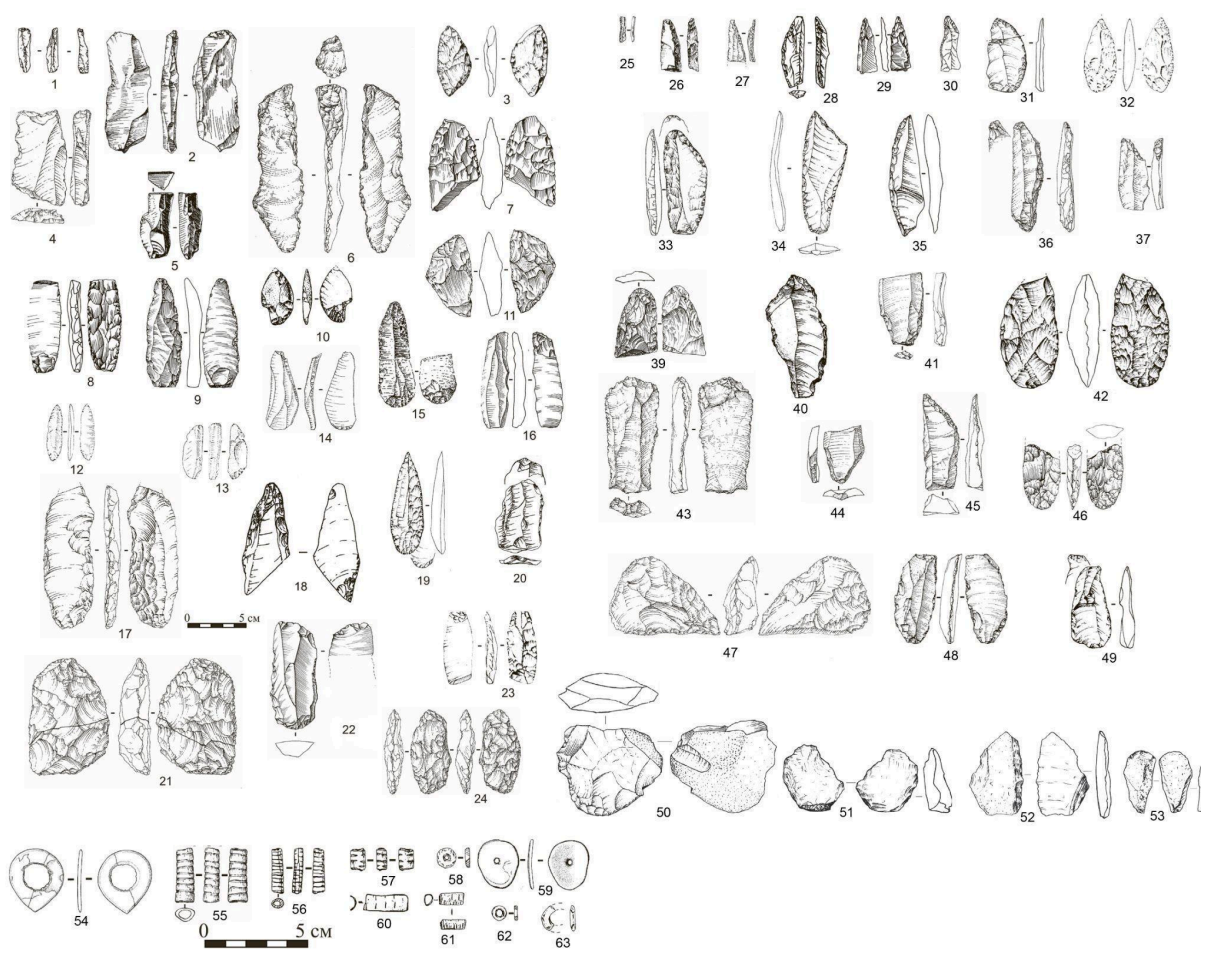


Fig. 38. Archaeological materials of Early Upper Paleolithic sites of Siberia and Central Asia: 1-54 – lithic artifacts; 54-63 – personal ornamentation artifacts. Modified from (Рыбин, 2014; Медведев, Новосельцева, 2011).

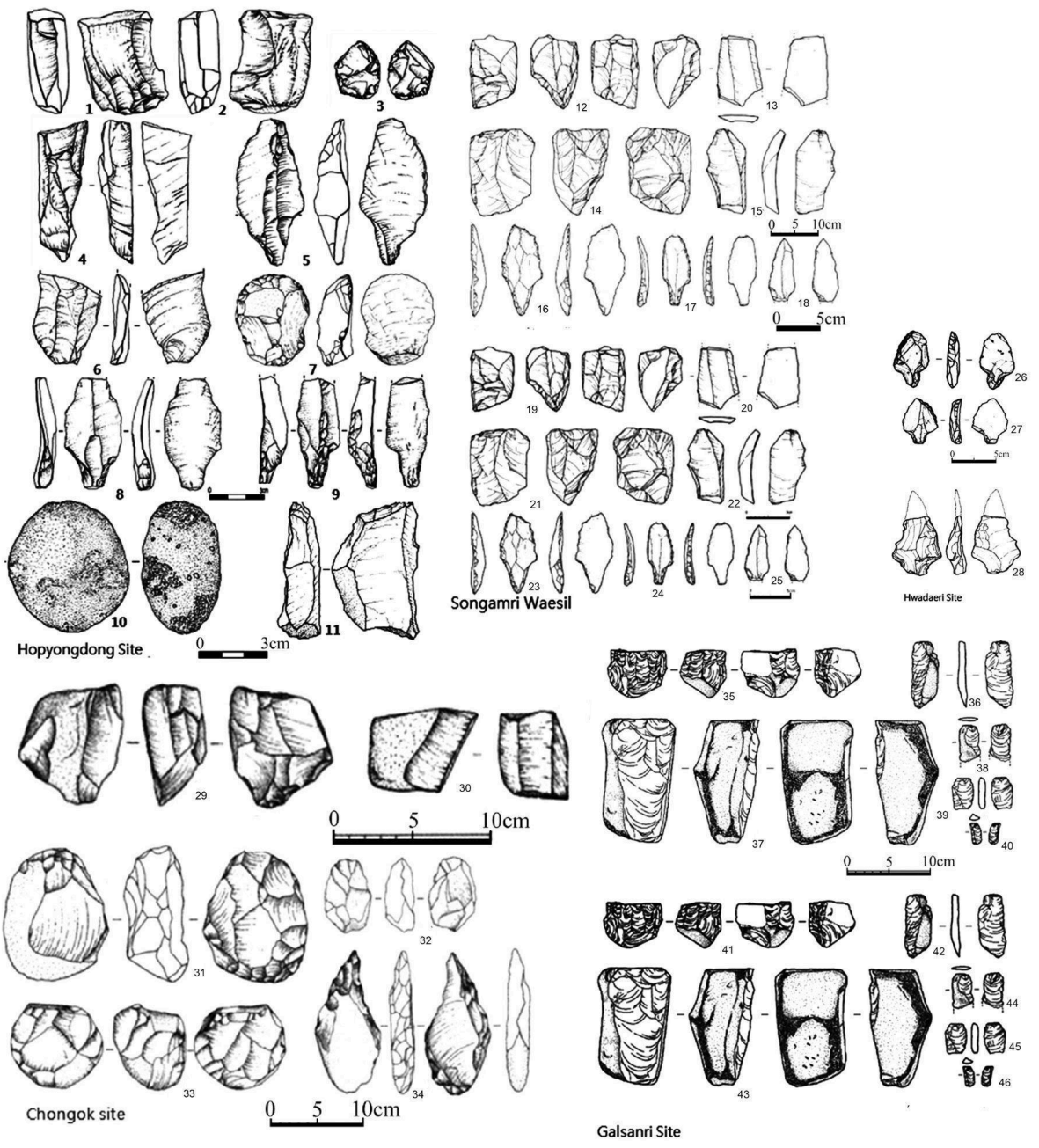


Fig. 39. Archaeological materials of Early Upper Paleolithic sites of Korean Peninsula: 1 -11 Hopyeong-dong; 12- 25 Songarmi Waesill; 26 - 28 Hwadaeri; 29 -34 Chongok; 35 -46 Galsanri (Heonjong, Sangseok, 2019).



Fig. 40. Archaeological materials of Early Upper Paleolithic sites of Hokkaido: 1-5: Kikyo 6-12: Shukubai-kaso (Loc. Sankakuyama) 13-18: Wakabanomori; 19-25: Kyoei-3; 26-33: Okushiarataki-1, Sb1-3 36-53: Kamishirataki-8, Sb1-13.. From (Terasaki, 2006).

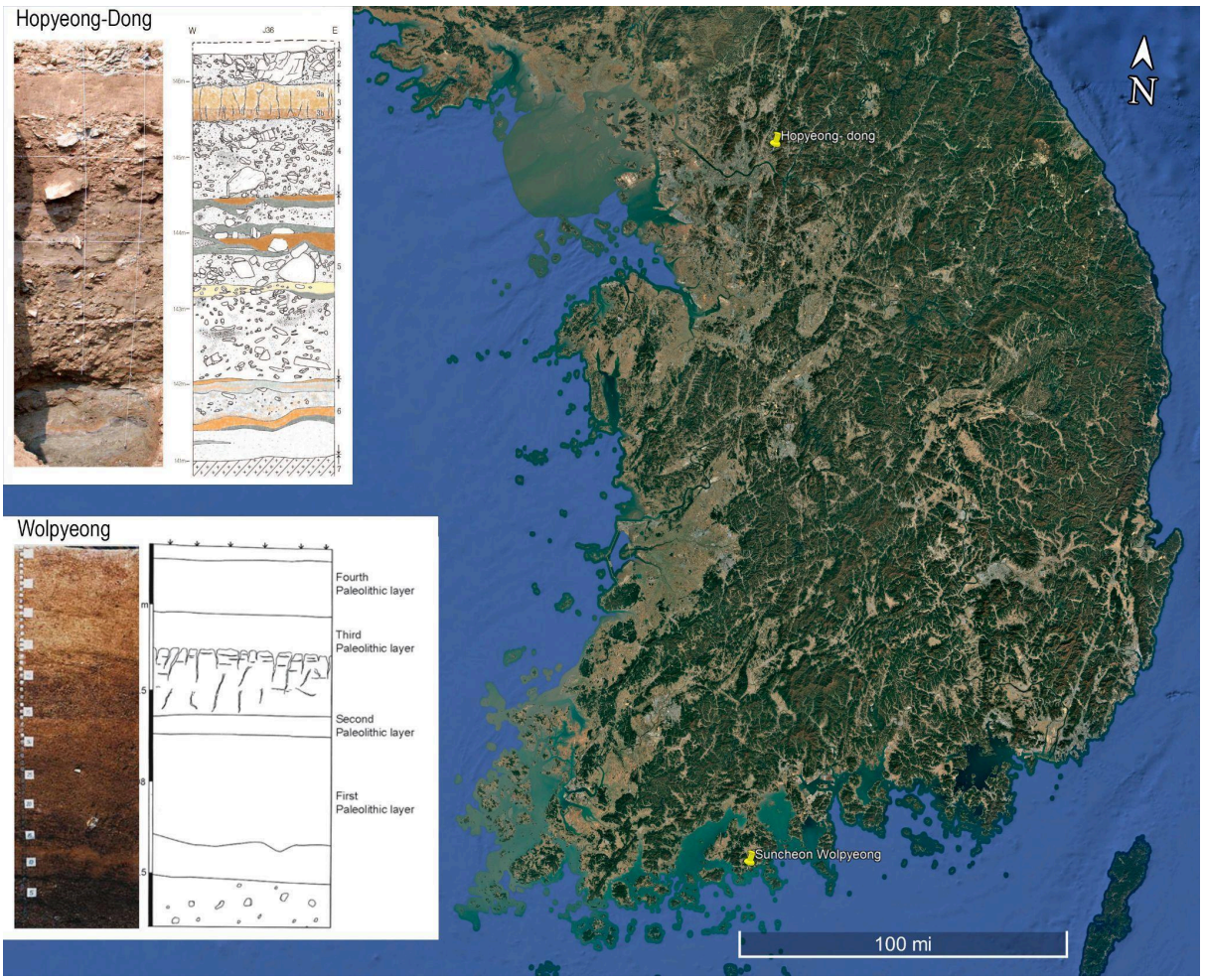


Fig. 41. Location of Hopyeong-dong and Wolpyeong sites. Stratigraphy modified from (Hong, Kononenko 2008; Lee, 2006).

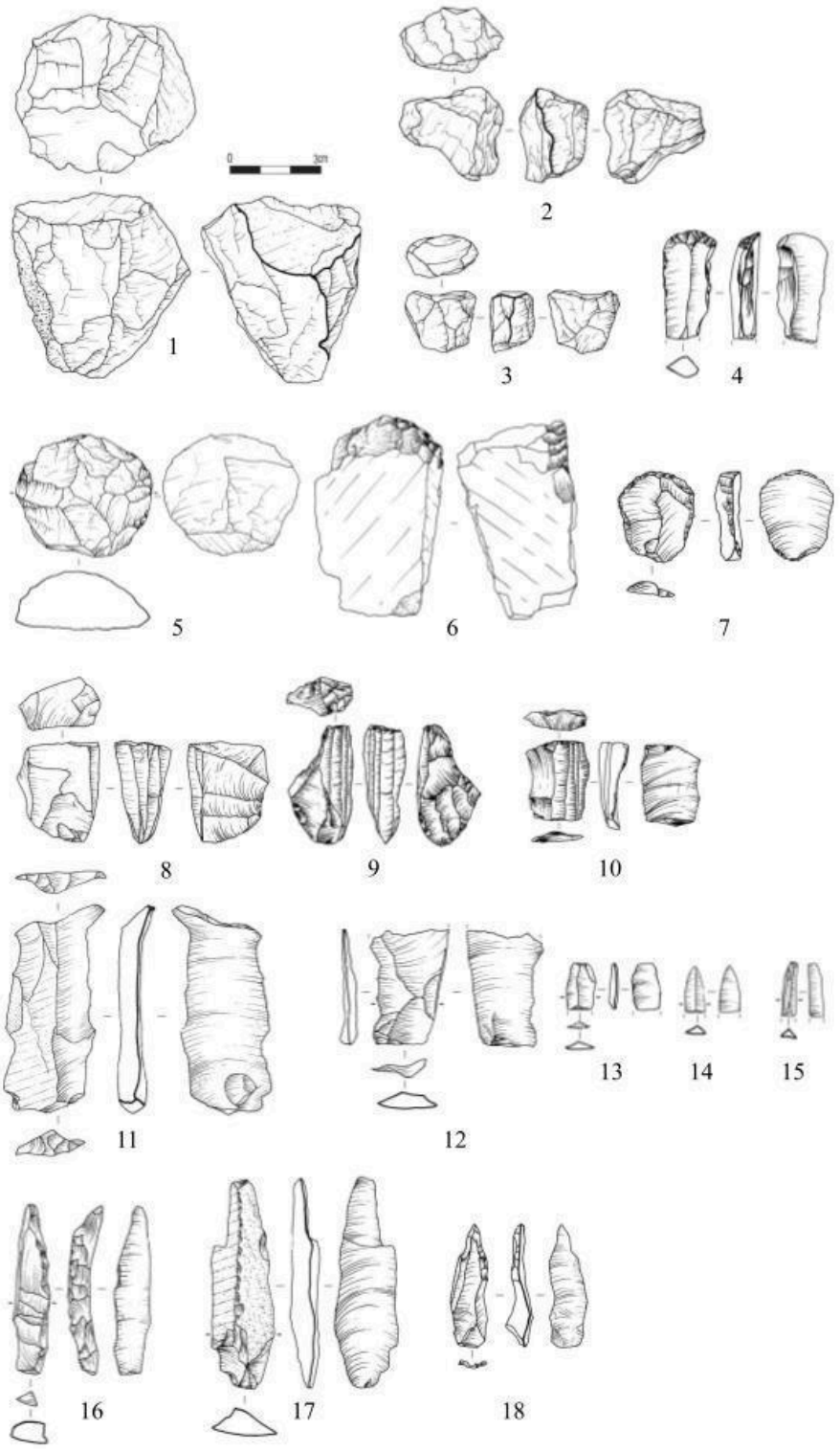


Fig. 42. Archaeological materials of Hopyeong-dong site, Cultural Layer 2: 1.-3. Quartz core; 4.- 7. Scrapers; 8.-10. Microblade cores; 11.-12. Blades; 13.-15. Microblades; 16.-17. Ridge Spalls; 18. Retouched bladelet. Modified from (Hong, Kononenko2008)

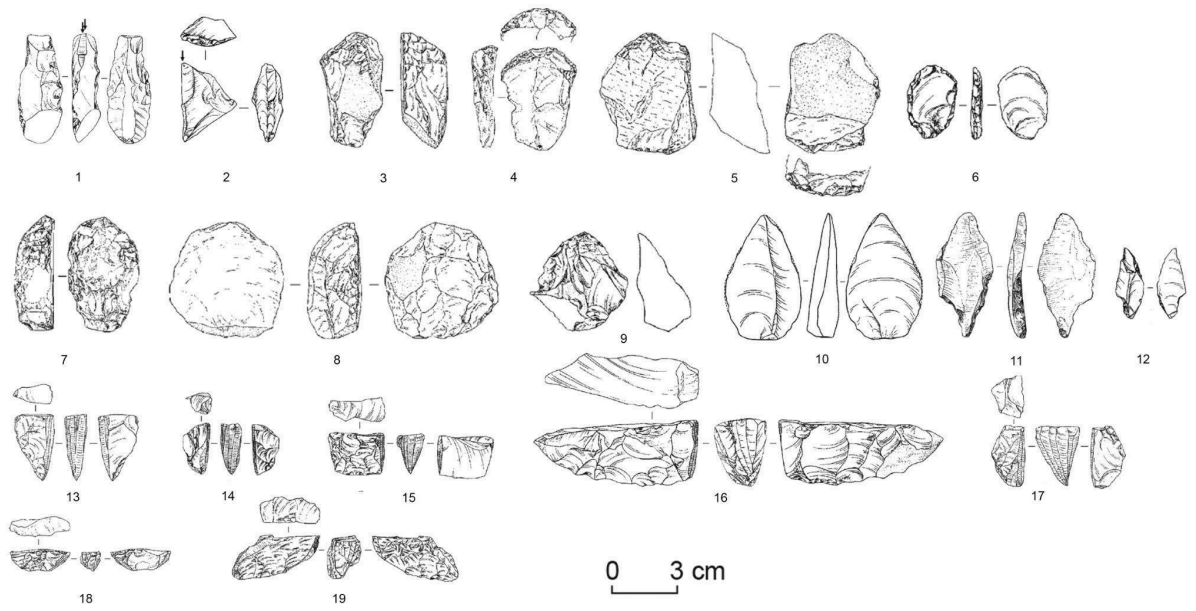


Fig. 43. Artifacts of Wolpyeong site: 1 – simple angle burin on transverse break; 2 – simple angle burin on truncation; 3-7 endscrapers; 8,9 - roundscrapers; 10-12 tanged points; 13-19 microblade cores. Modified from (Lee, 2006).

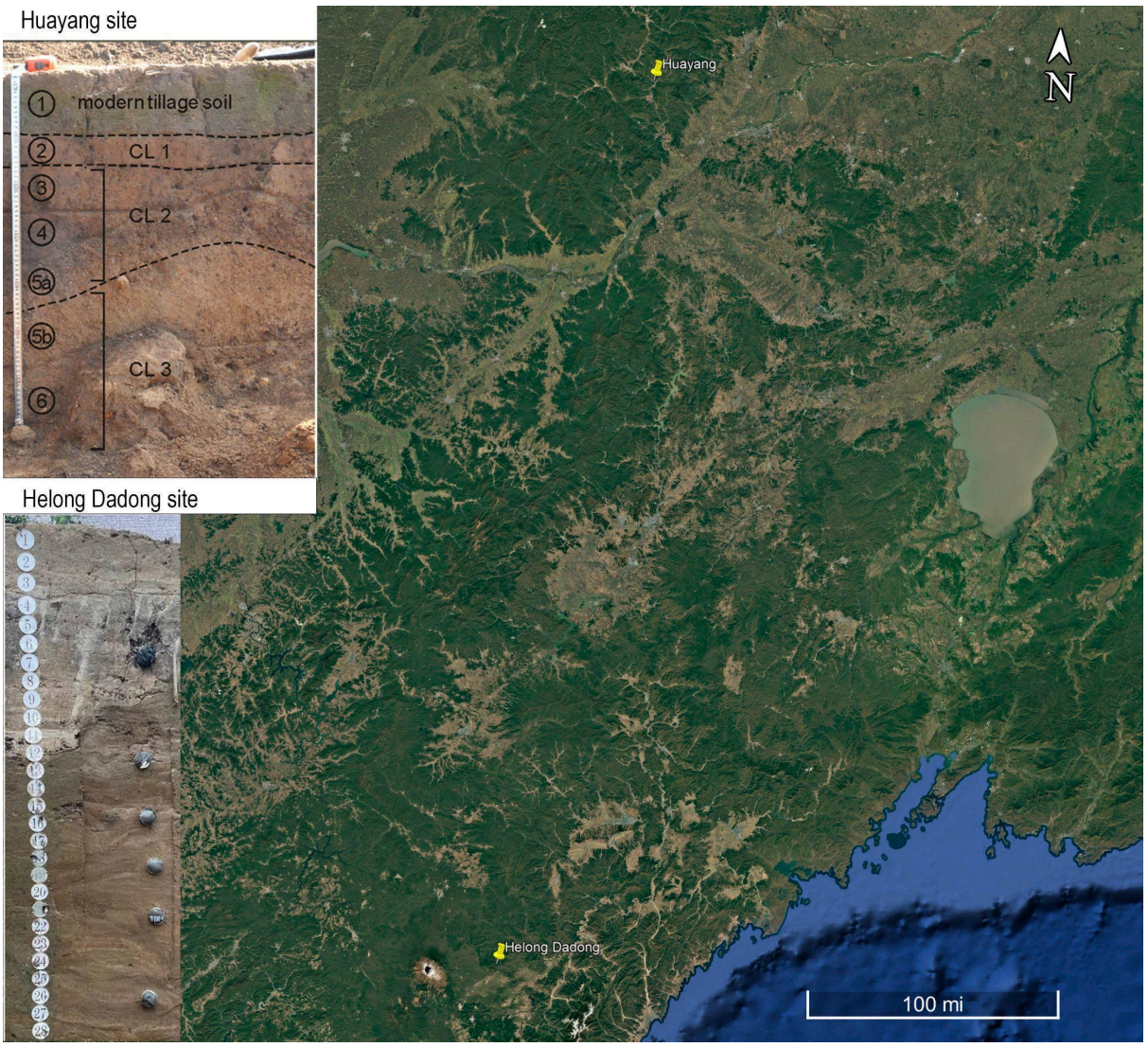


Fig. 44. Location of Huayang and Helong Dadong sites. Stratigraphy modified from (Lian et al., 2023; Yue et al., 2020).

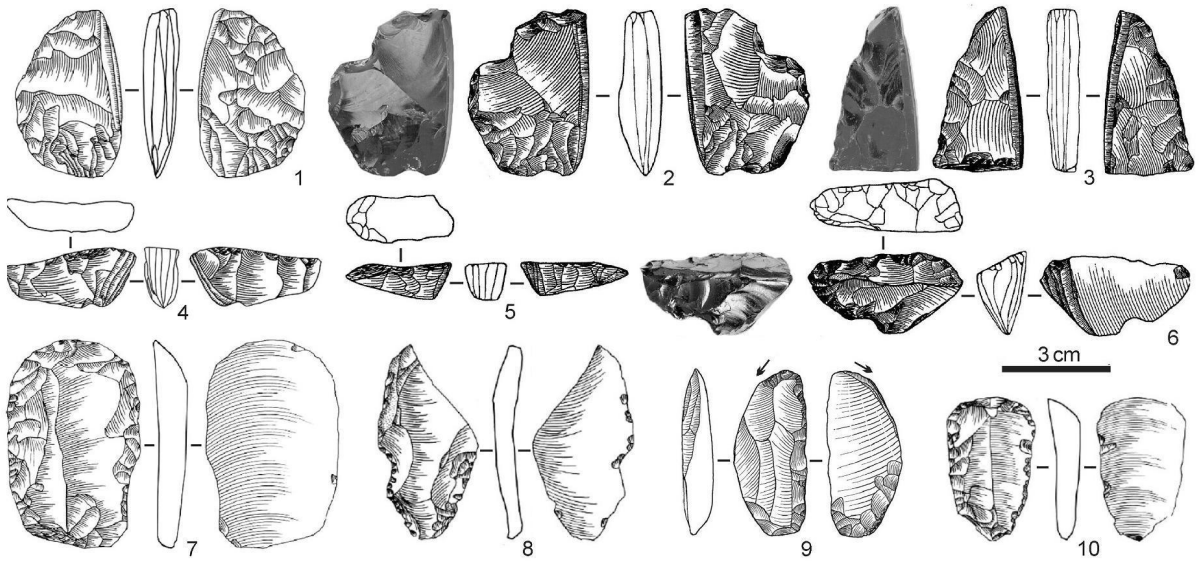


Fig. 45. Artifacts of Helong Dadong site: 1, 4, 7–8 Layer 3; 10 Layer 4; 2–3, 5–6, 9 surface collection. 1-6 Microblade cores; 7, 10 - scrapers; 8 - retouched blade; 9 - burin. Modified from (Yue et al., 2021).

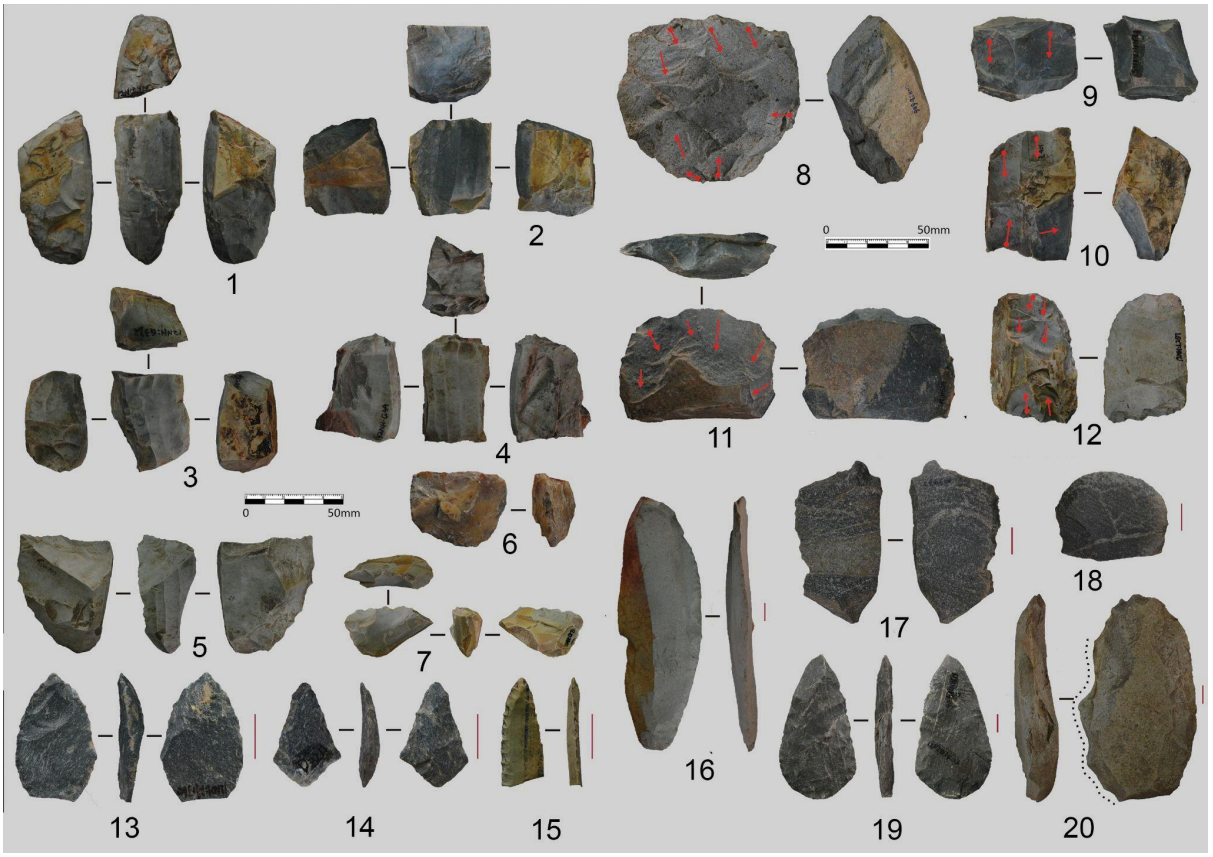


Fig. 46. Artifacts of the Huayang site: 1-5 bladelet cores; 6,7 - microblade cores; 8-12 cores; 13,14 arrowhead; 15 point on bladelet; 17 - borer; 16,18 - convex scraper; 19 - bifacial point; 20 - backed scraper. Modified from (Yue et al., 2019).

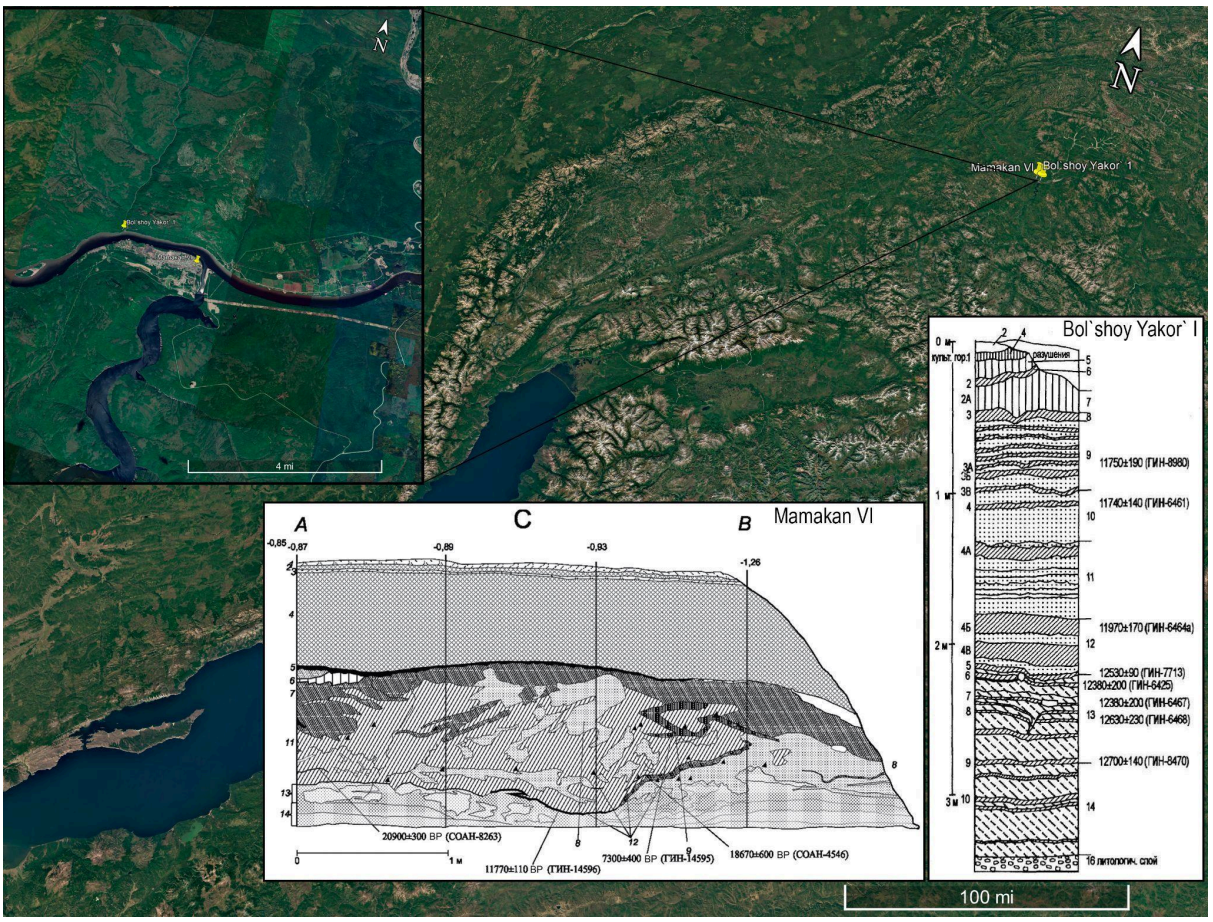


Fig. 47. Map of location of Bol`shoy Yakor` I and Mamakan VI sites in Eastern Siberia. Stratigraphy from (Тетенькин, 2014; Инешин, Тетенькин, 2006).

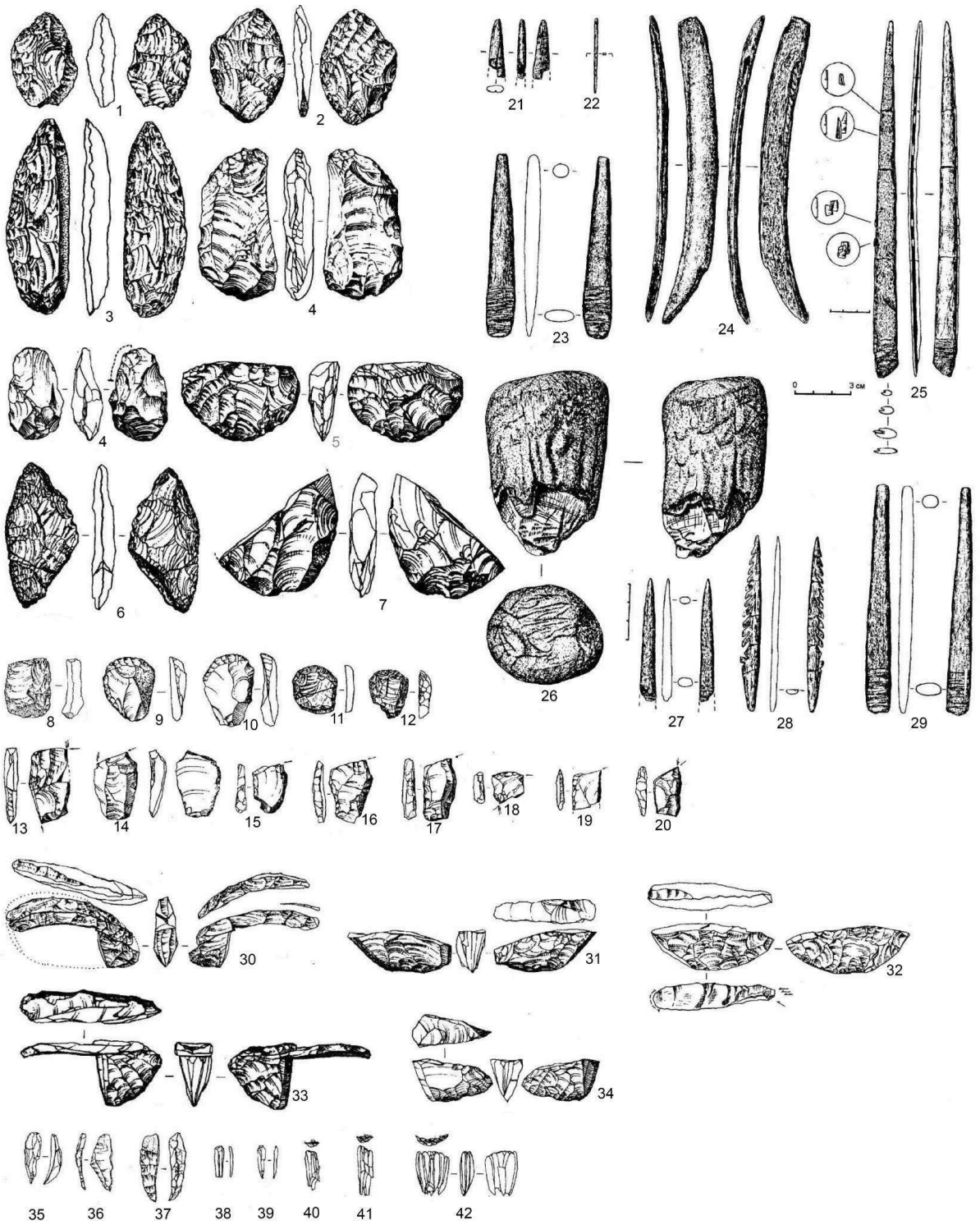


Fig. 48. Archaeological materials of Bol'shoy Yakor' site: 1-7 bifaces; 8-12 scrapers; 13-20 burins; 21-29 osseous artifacts; 30-34 wedge-shape microblade cores; 35-36 frontal spalls; 37 - ridge spall; 38-42 microblades refitting blocks. Modified from (Инешин, Тетенькин, 2006).

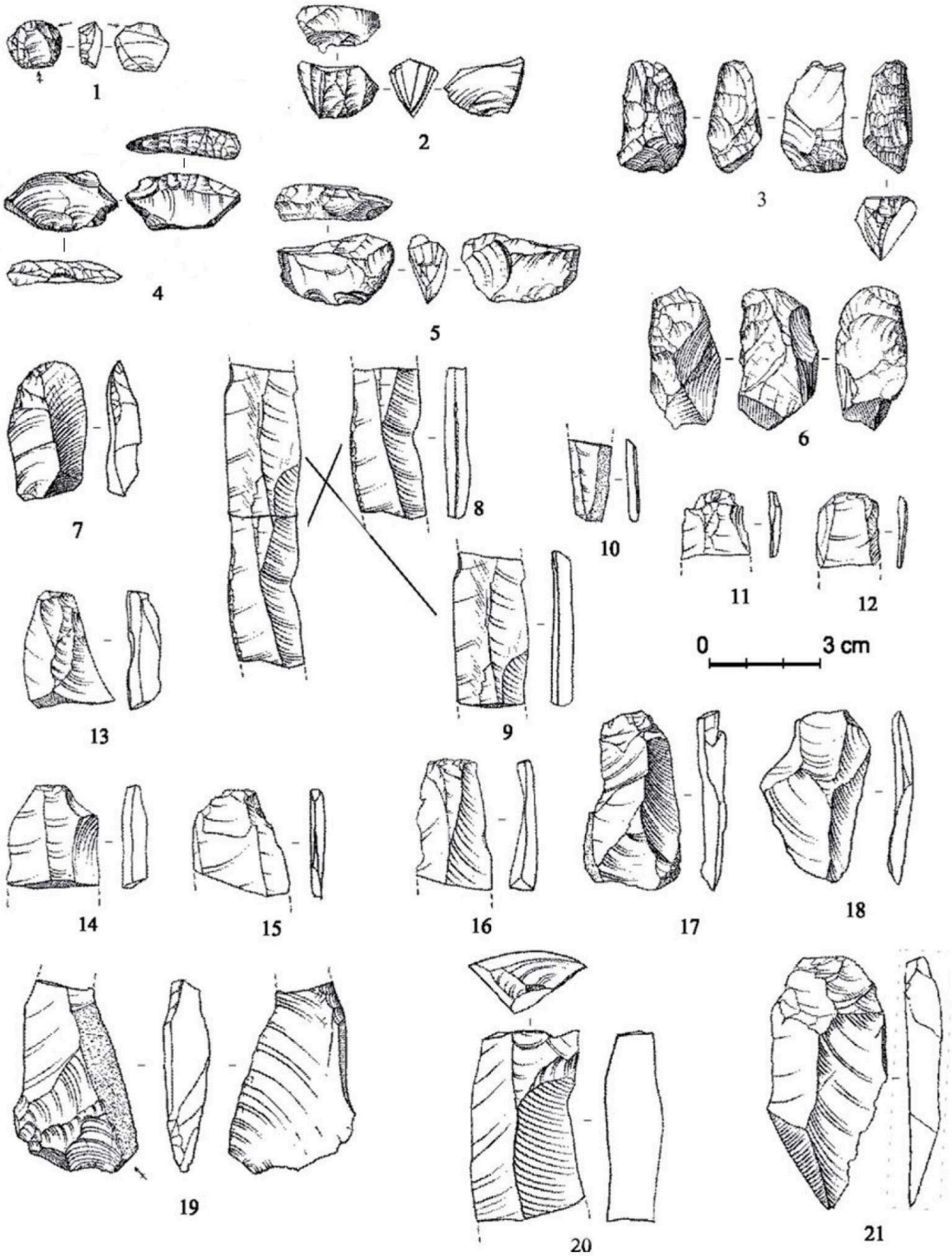


Fig. 49. Archaeological materials of Mamakan VI site: 1 - round scraper with transversal burin spall; 2, 4, 5 - microblade cores; 3, 6, 7 - scrapers; 8 – medial segment of retouched blade; 9 - medial segment of the blade; 10 - distal segment of the blade; 11, 12, 14, 15, 16, 20 - proximal segments of the blades; 13, 17, 18, 21 - blades; 19 – fragment of a flake with marginal retouch. Modified from (Тетенькин, 2014).

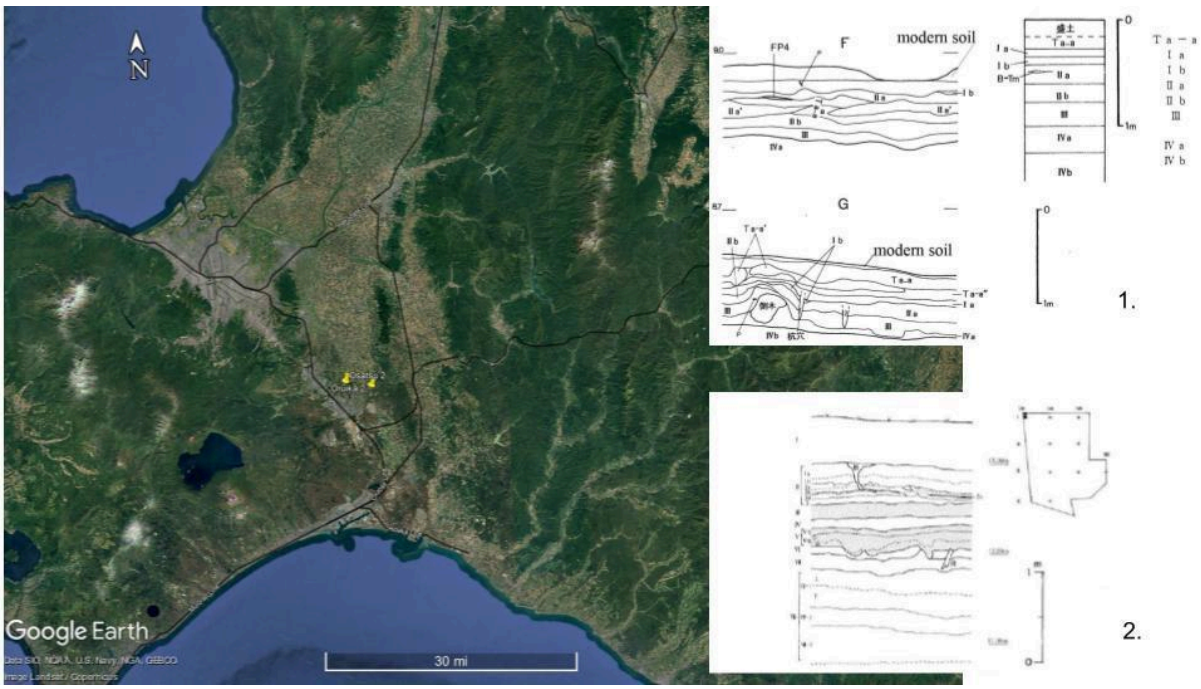


Fig. 50. Location and stratigraphic profiles of Paleolithic sites in Hokkaido Island, Japan: 1. - Osatsu 2 site; 2. - Oruika 2 site (Hokkaidō Maizō Bunkazai Center, 1996; Hokkaidō Maizō Bunkazai Center, 2005).

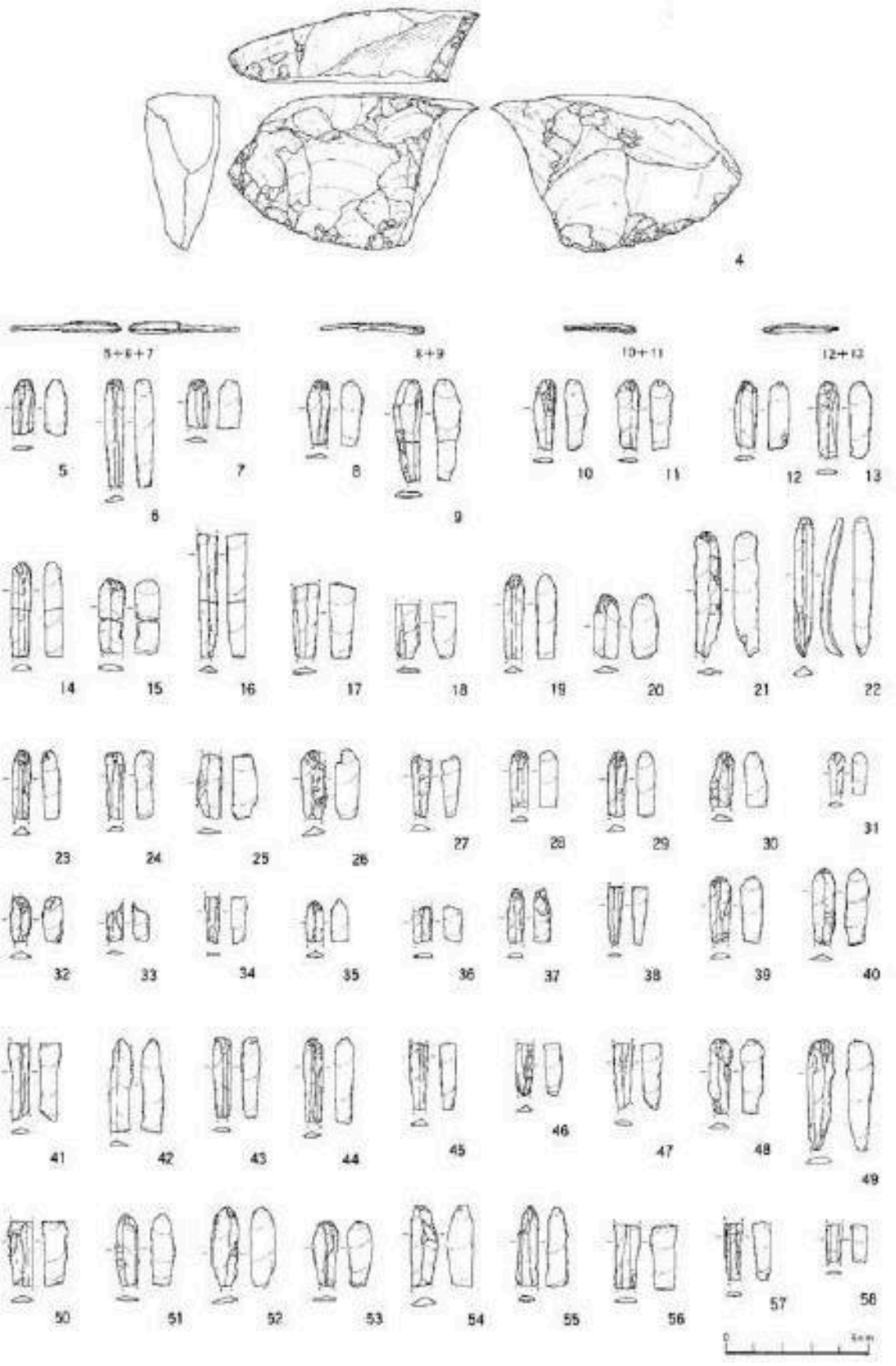


Fig. 51. Artifacts of microblade industries of Oruika 2 site. Modified from (Hokkaidō Maizō Bunkazai Center, 2005)

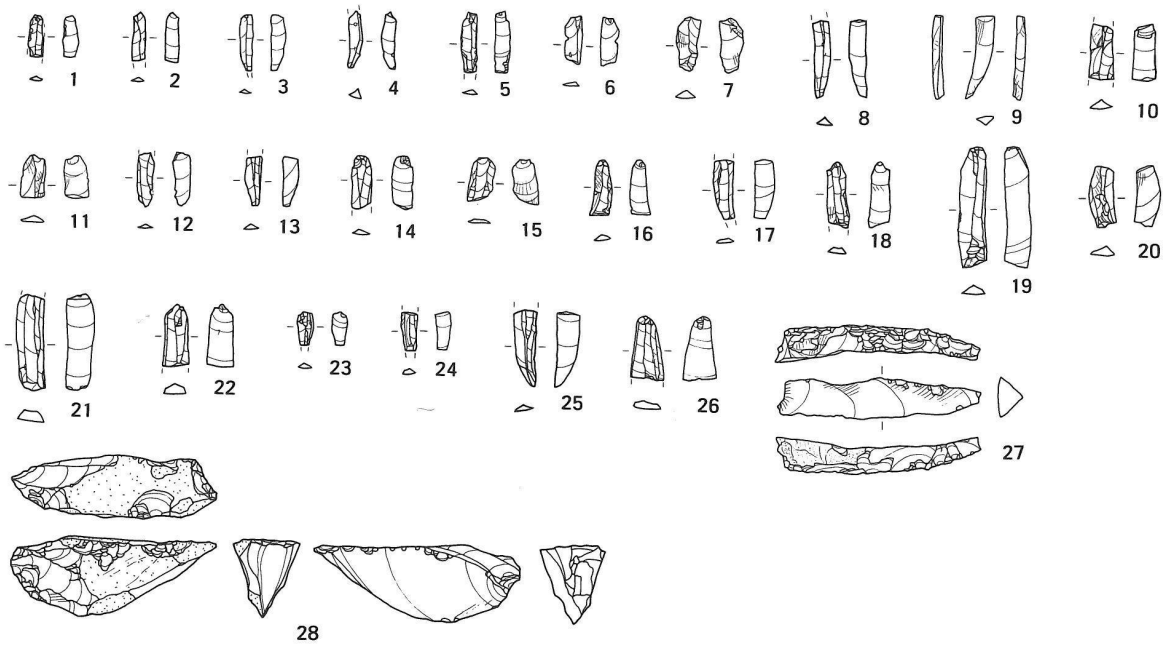


Fig. 52. Artifacts of Osatsu 2 site; 1-26 microblades; 27 ridge spall; 28 microblade core. Modified from (Hokkaidō Maizō Bunkazai Center, 1996)

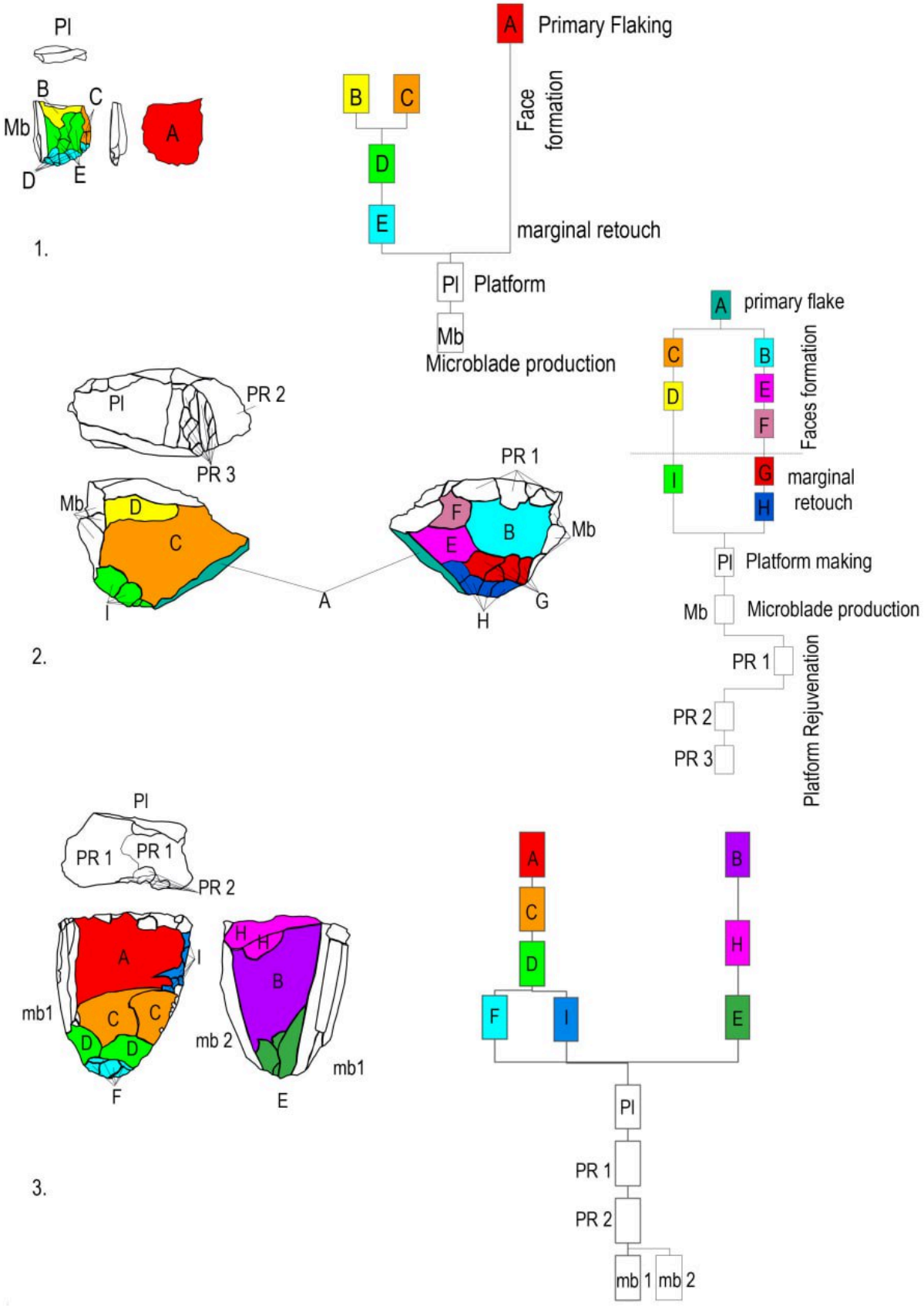


Fig. 53. Korean peninsula. Results of Scar Pattern Analysis: 1.-2. Tougeshita microblade cores; 3. Bifrontal microblade core

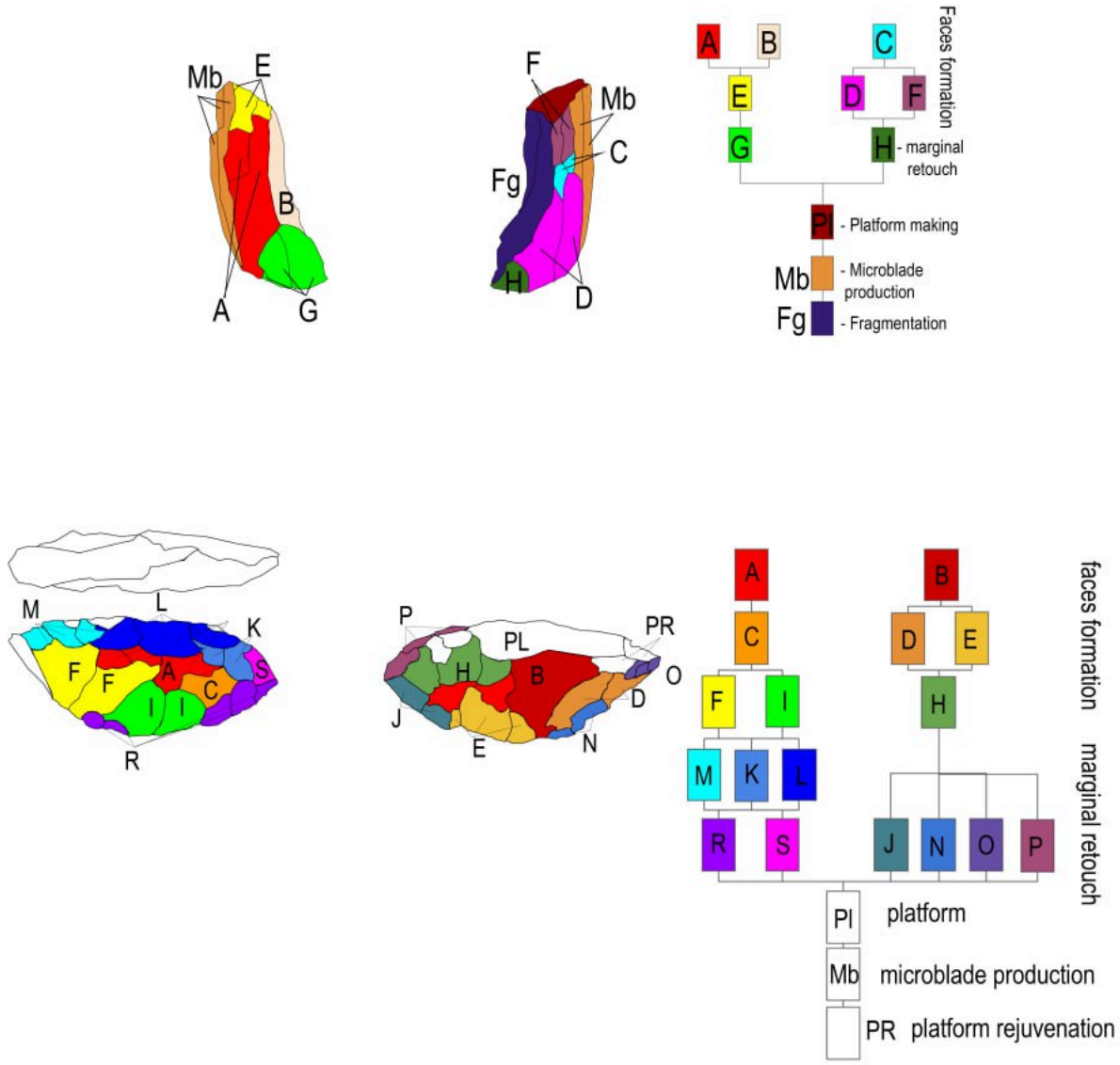


Fig. 54. Korean peninsula. Results of Scar Pattern Analysis: 1.-2. Yubetsu method microblade cores



Fig. 55. Huayang site, Northeastern China. Microblade core with twisted front

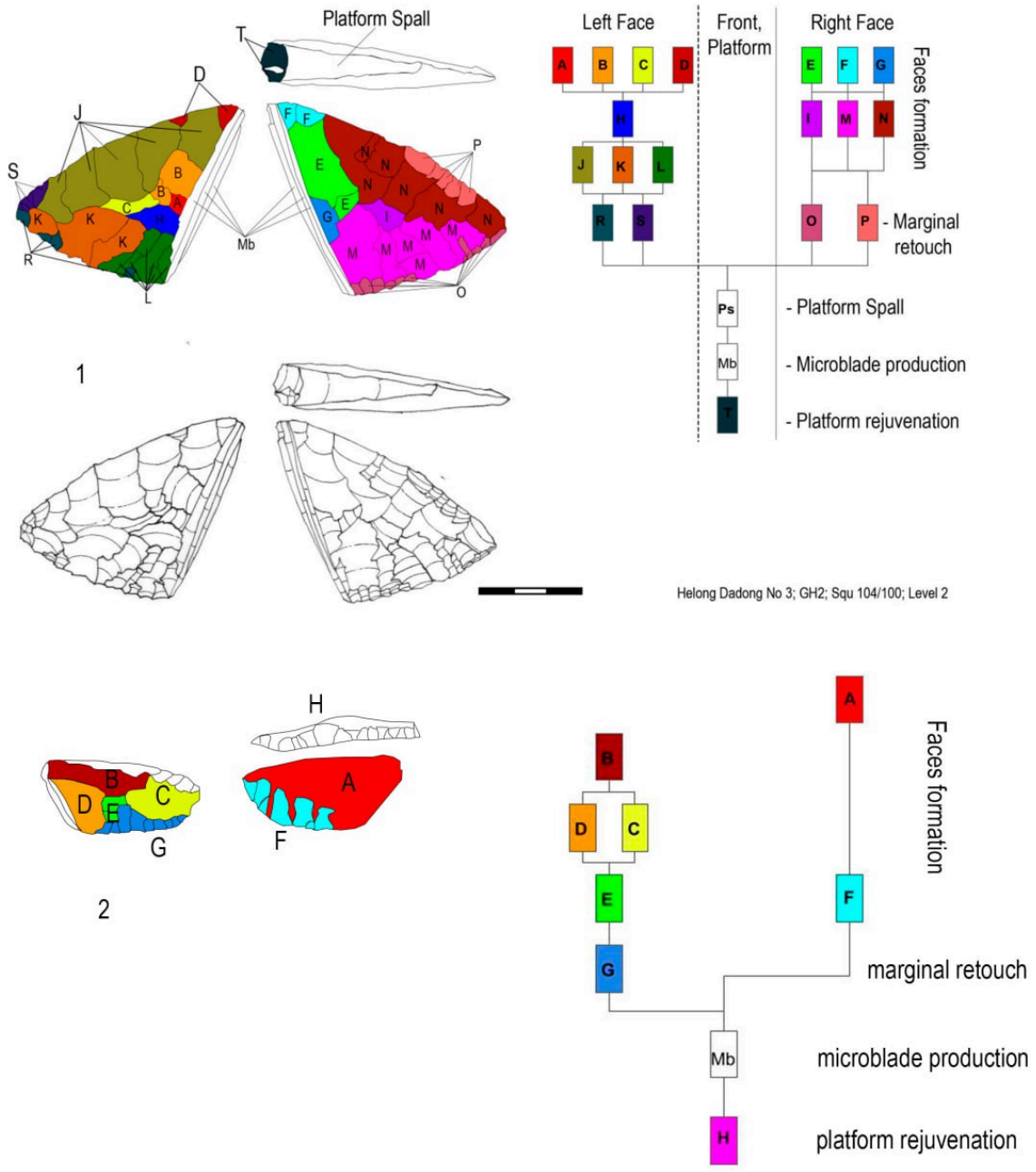


Fig. 56. Northeastern China. Results of Scar Pattern Analysis: 1.- Yubetsu method microblade core; 2. - Tougeshita microblade core

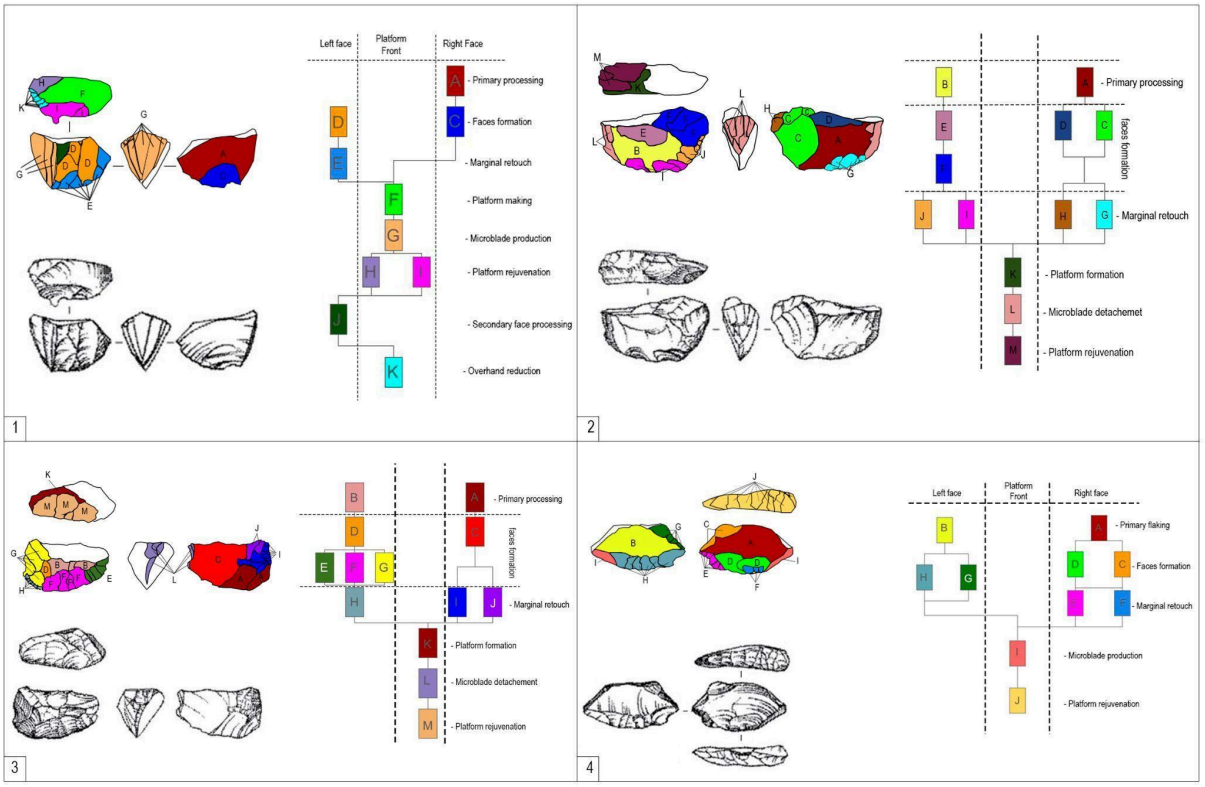


Fig. 57. Results of Scar Pattern Analysis of Tougeshita method microblade cores from Mamakan VI site, Eastern Siberia

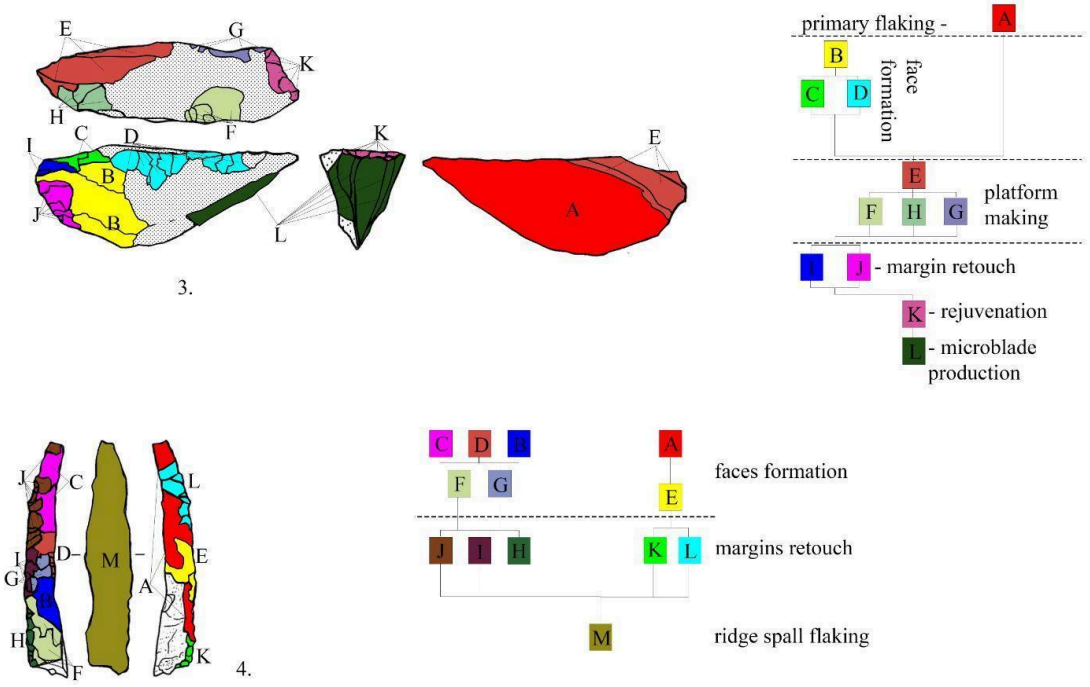


Fig. 58. Scar pattern analysis of Tougeshita method microblade cores from Hokkaido Island, Osatsu 2 site

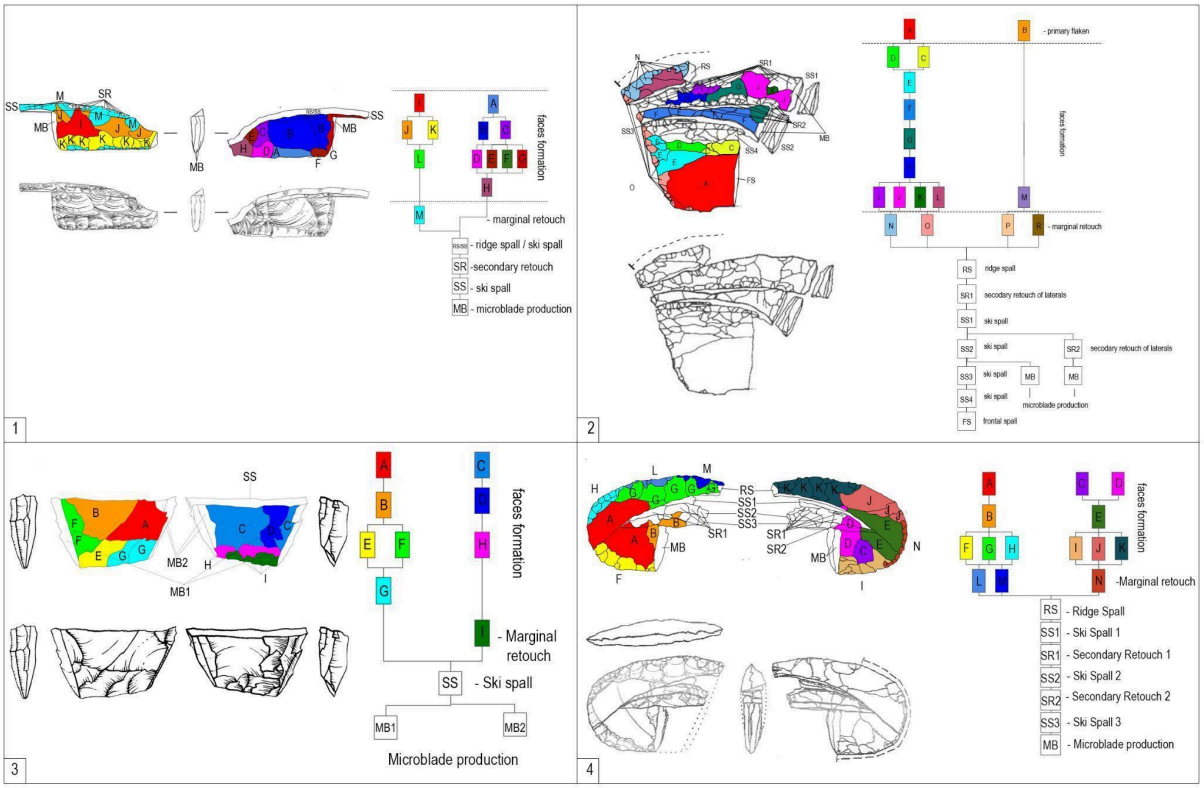


Fig. 59. Scar pattern analysis of Yubetsu method microblade cores from Bol`shoy Yakor` I site, Eastern Siberia

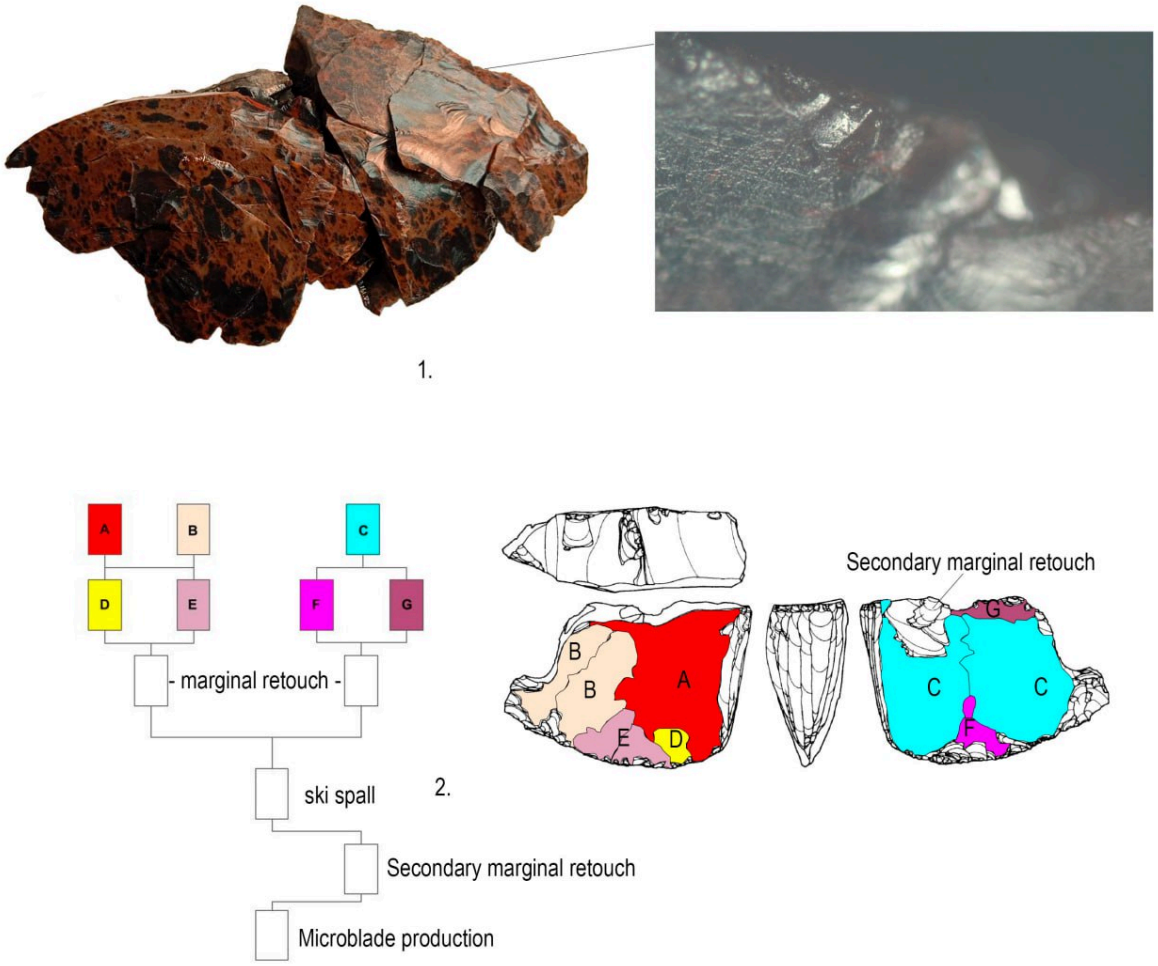


Fig. 60. Oruika 2 site, Hokkaido. 1. - Refitting block of Yubetsu method microblade core with use-wears on bifacial edge; 2. - Scar Pattern Analysis scheme of Yubetsu method microblade core



Fig. 61. Korean peninsula, Wolpyeong site. Use-wear analysis results of microblade core.

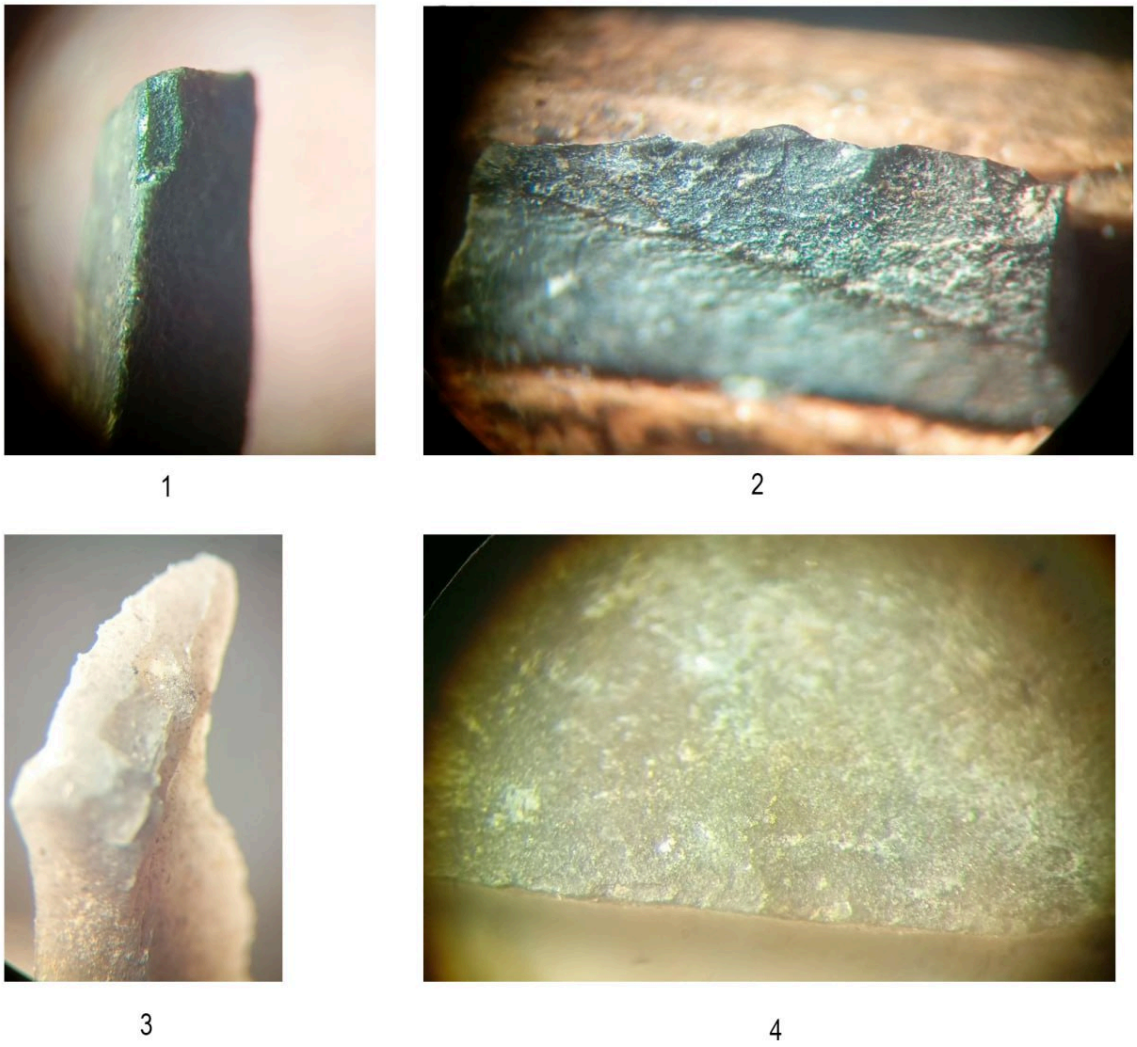


Fig. 62. Eastern Siberia, Bol`shoy Yakor` 1 site. Results of Use-wear analysis: 1. Impact fracture; 2. butchery knife; 3. borer; 4. scraper

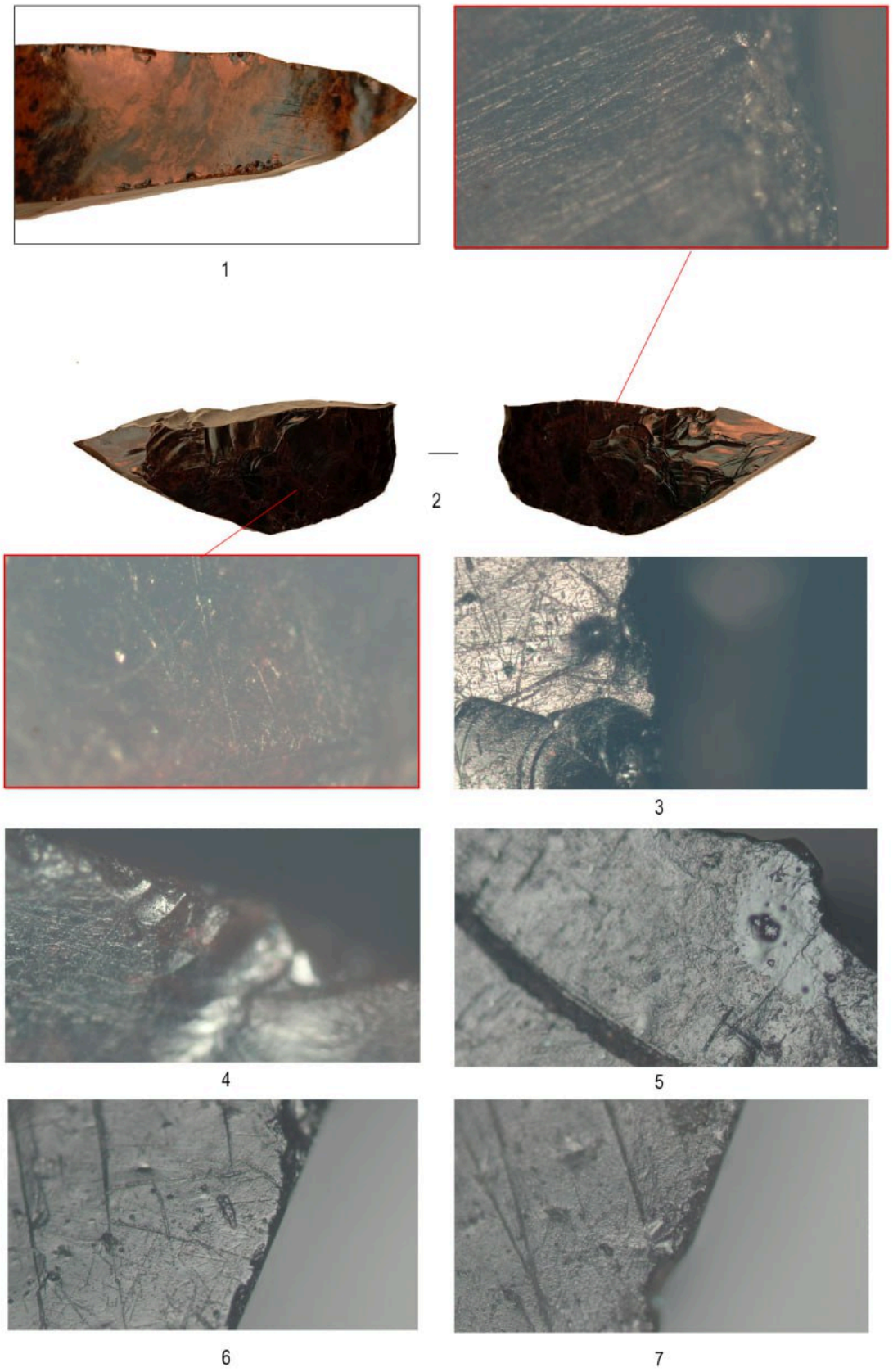


Fig. 63. Hokkaido island, Oruika 2 site. Results of Use-wear analysis: 1.-5. Use-wears located on microblade cores; 6.-7. Use-wears located on ski-spall

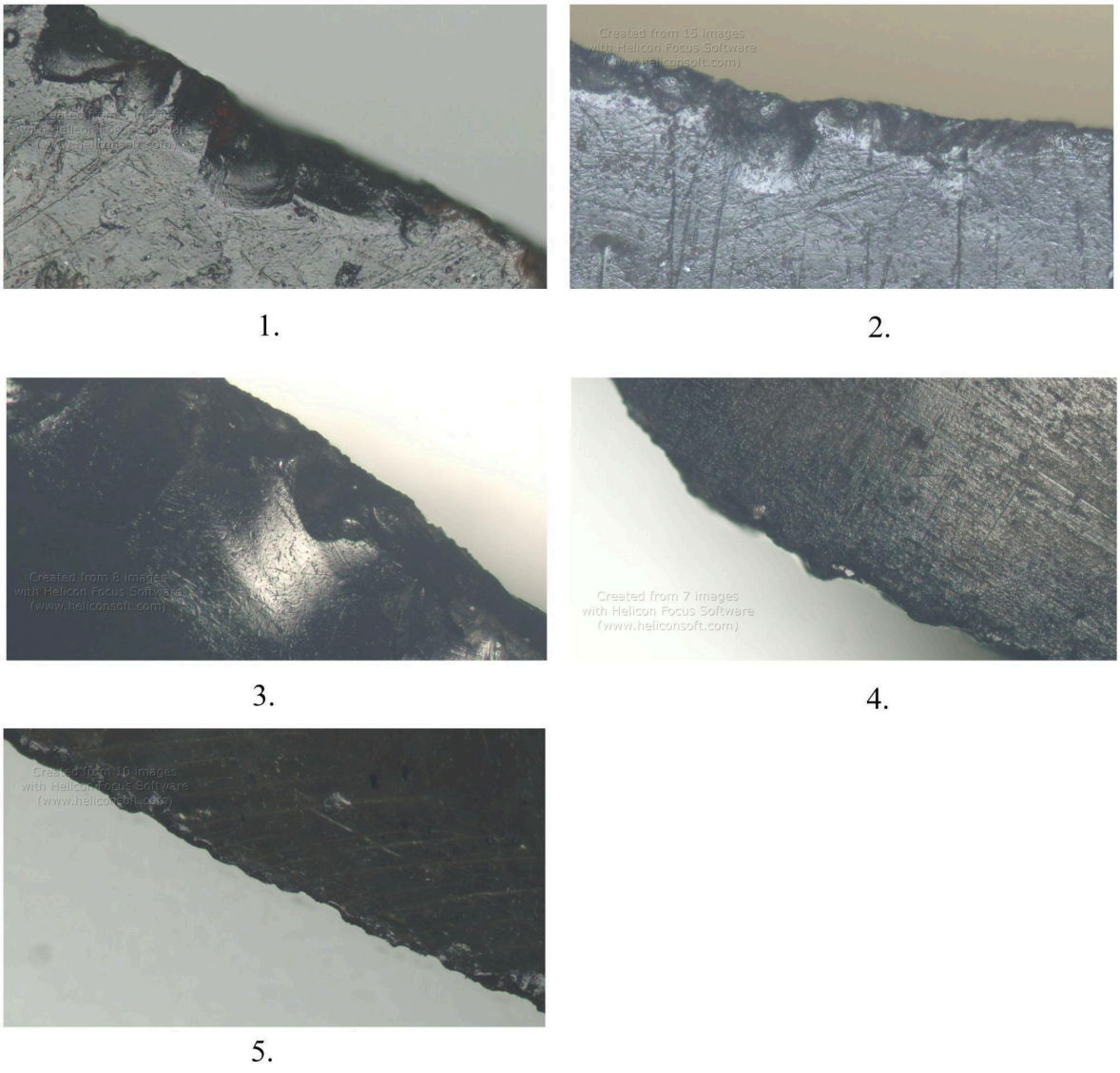


Fig. 64. Osatsu 2 site use-wear analysis result: 1 - butchery; 2 - scraping; 3 - shaving, dorsal face; 4 - shaving, ventral face; 5 - graving

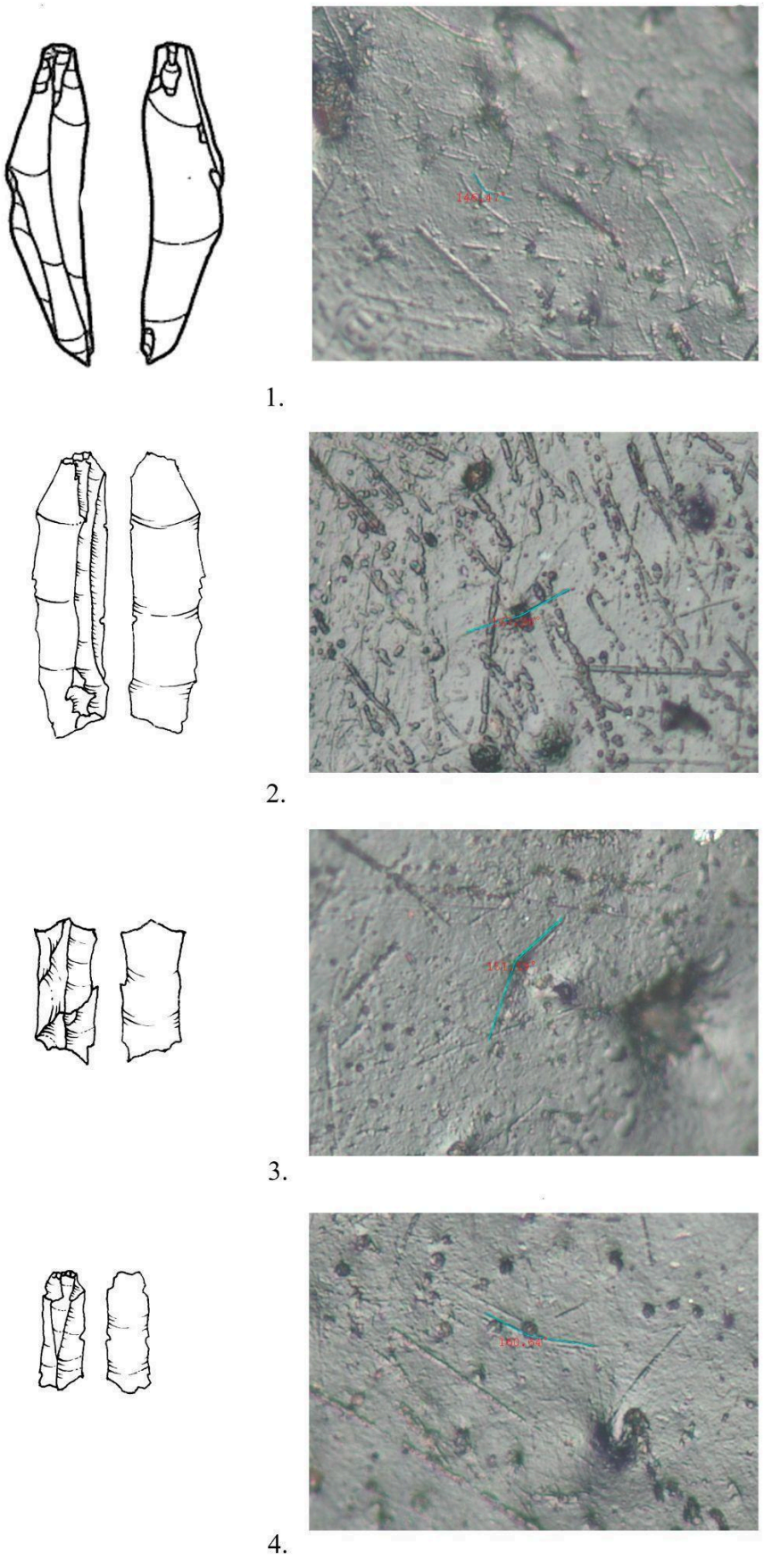


Fig. 65. Osatsu 2 site fracture wing analysis result

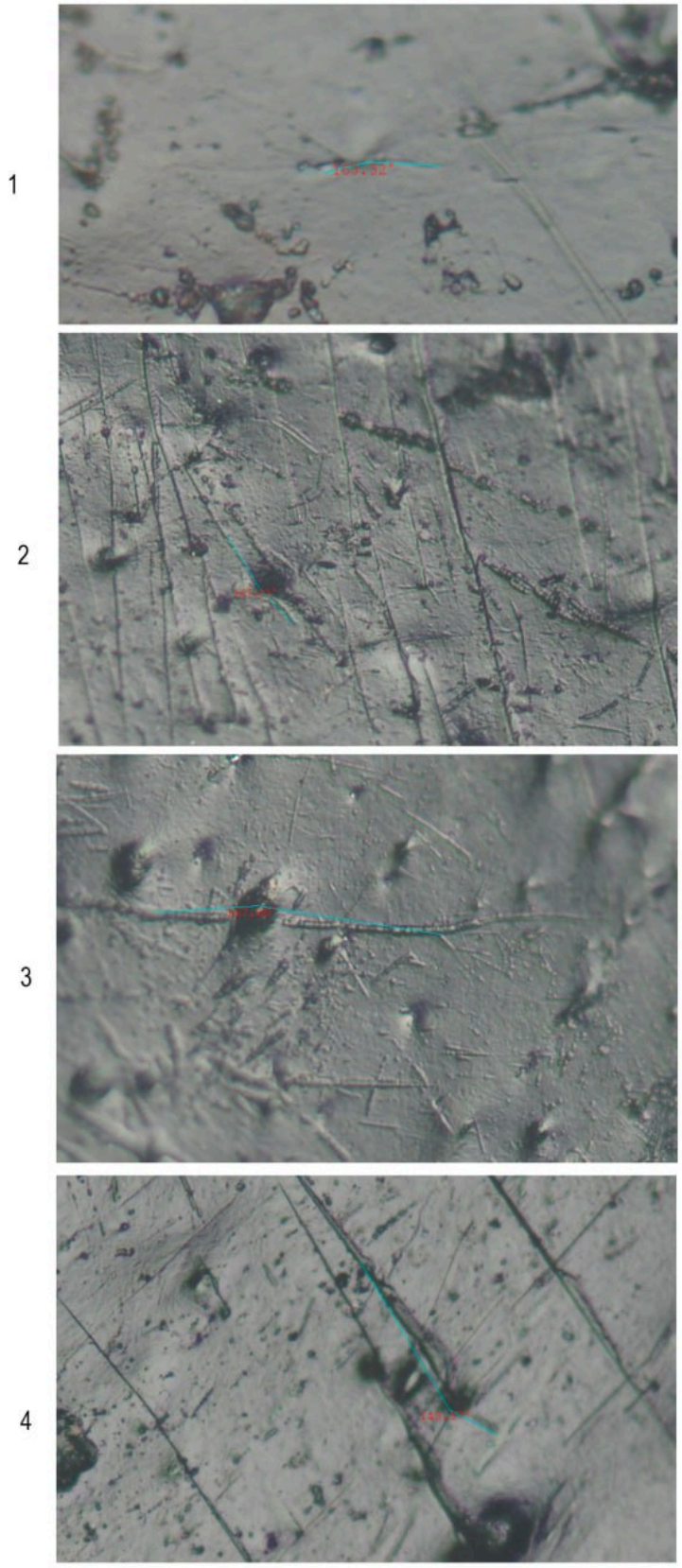


Fig. 66. Oruika 2 site, Hokkaido Island. 1 - negative of ski-spall detachment; 2-4 microblades

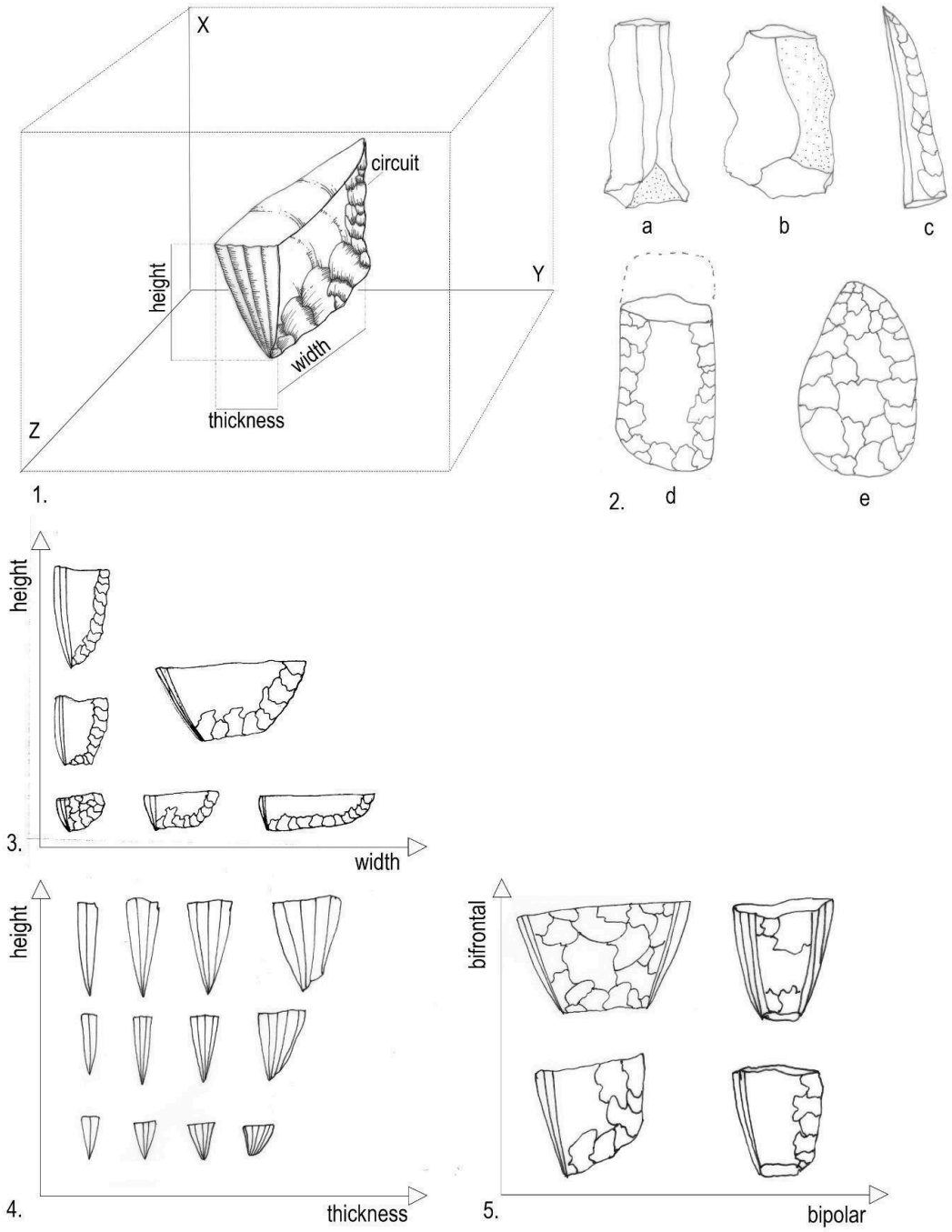


Fig. 67. Morphospace model of wedge-shaped core: 1. - general morphospace model; 2. - variability of core blanks: a. - blade, b. - flake, c. - ski spall, d. - broken tool, e. - biface; 3-5: morphospace range of microblade cores

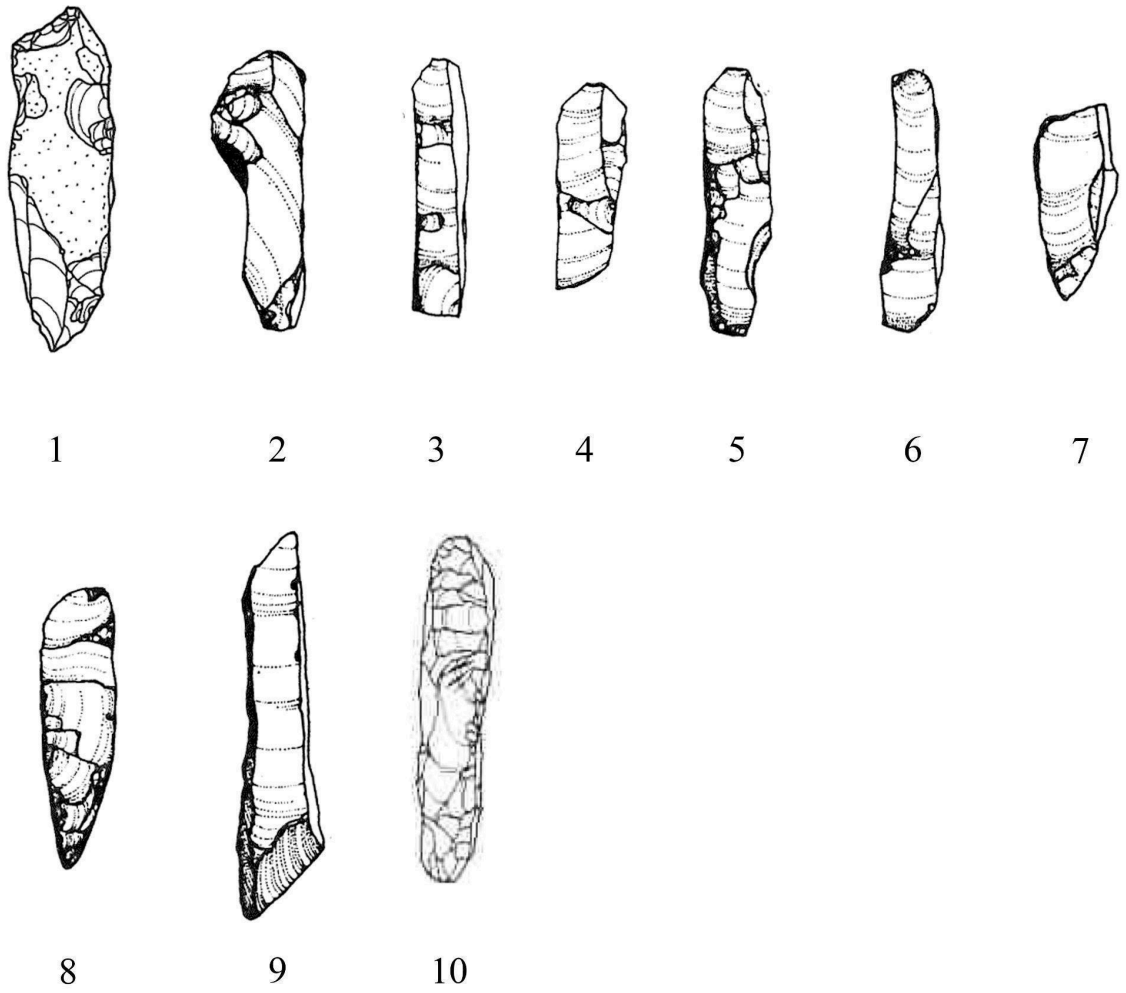


Fig. 68. Variability of Tougeshita microblade cores striking platforms rejuvenation; 1 - Osatsu 2 site (Hokkaidō Maizō Bunkazai Center, 1996); 2-9 - Taisho site (Ohi, 1963); 10 - Meboshigawa 2 site (Chitose-shi Kyōiku Iinkai, 1983)

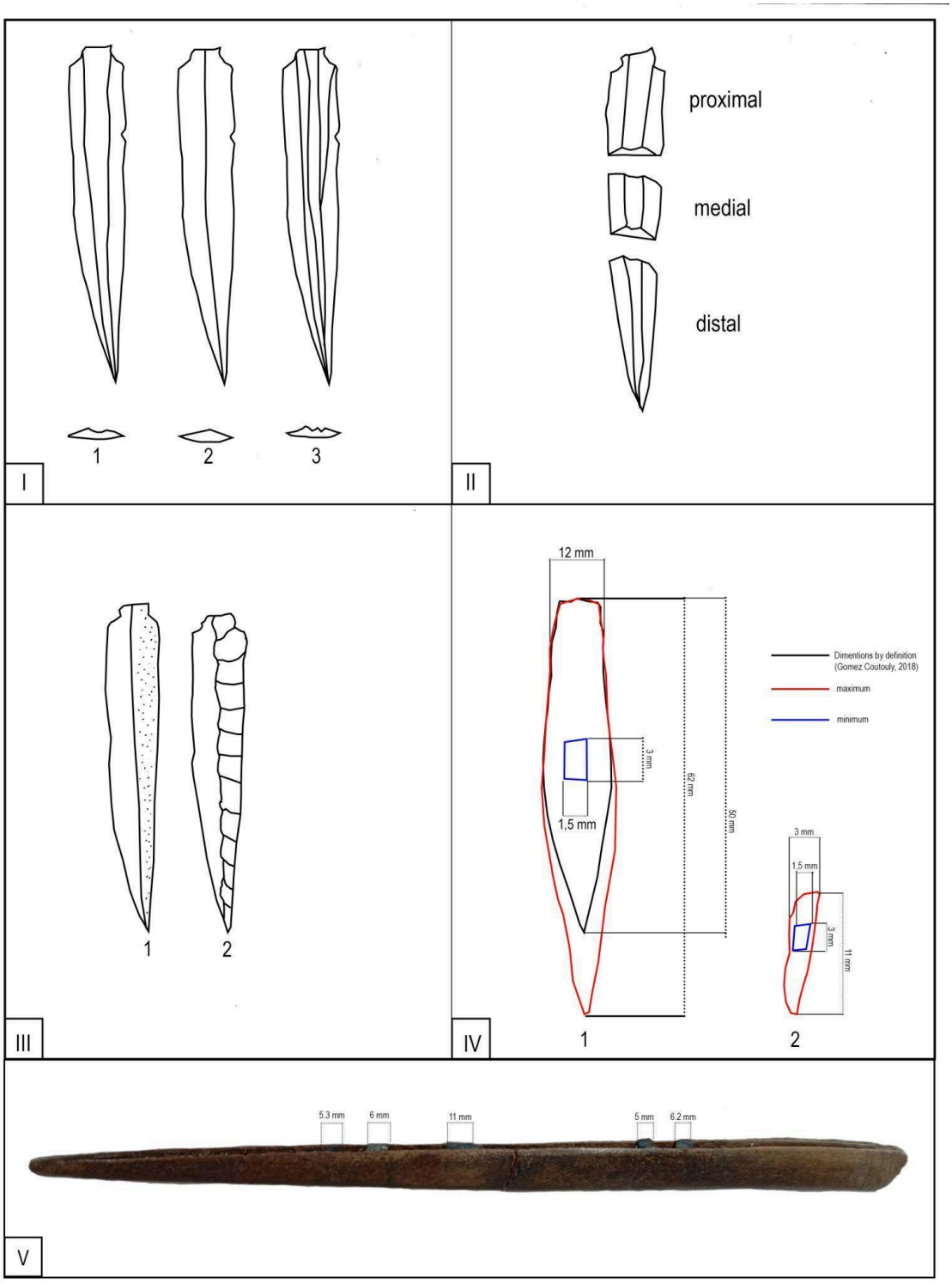


Fig. 69. Morphospace model of microblade: I - Cross-sections of microblades: 1. - trapezoidal, 2. - triangular, 3. - polyhedral; II - fragmentation of microblades; III: 1. - microblade with cortex, 2. - with rudiment of ridge; IV dimensional morphospace of microblades: 1. - with general functions, 2. - inserted in projectile point; V - sizes of microblades inserted in projectile point (Bol`shoi Yakor` site)

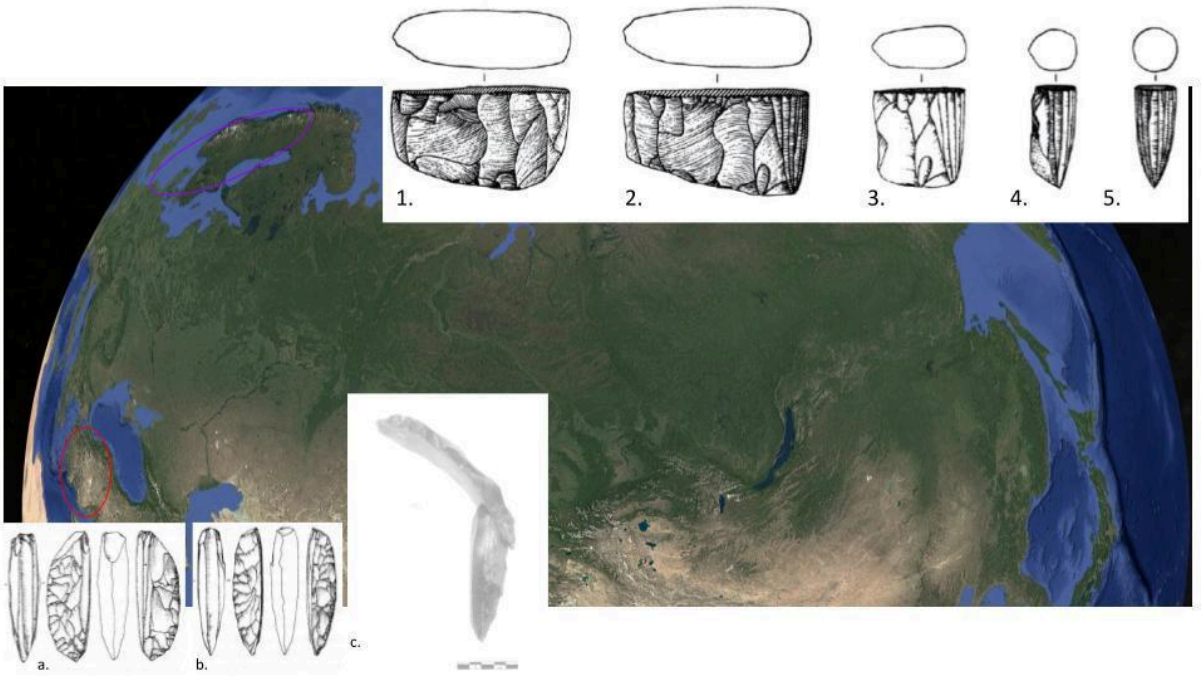


Fig. 70. Anatolia, Turkey: a.b.-(Binder, Balkan-Atli, 2001); c. (Balkan-Atli; Bender, 2002) Neolithic unidirectional bladelet cores from Keletepe site; Northern Europe: Sværdborg I: 1. - 2. Handle core without the blade scar front; 3. Keeled core; 5.-6. Conical cores (Söderlind, 2024)