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M.V. Seletsky, A.Y. Fedorchenko, P.V. Chistyakov, S.V. Markin, and K.A. Kolobova

Institute of Archaeology and Ethnography, Siberian Branch, Russian Academy of Sciences, Pr. Akademika Lavrentieva 17, Novosibirsk, 630090, Russia

E-mail: archmax95@gmail.com; winteralex2008@gmail.com; pavelchist@gmail.com; markin@archaeology.nsc.ru; kolobovak@yandex.ru

Percussive-Abrasive Stone Tools from Chagyrskaya Cave: Results of Functional Analysis

This article presents a comprehensive study of percussive-abrasive active stone tools from Chagyrskaya Cave, using experimental use-wear and statistical methods, supplemented by 3D-modeling. Experiments combined with use-wear analysis allowed us to determine the functions of these tools by comparing the working surfaces and use-wear traces in the Chagyrskaya samples with those in the reference samples. As a result, we identified 19 retouchers, four hammerstones for processing mineral raw materials, and one hammer for splitting bone, which indicates the dominance of secondary processing over primary knapping in the Chagyrskaya lithic assemblage. Using statistical analysis, we traced the differences in the dimensions of the manuports and lithics under study. These artifacts are a promising and underestimated source of information for identifying working operations associated with stone- and bone-processing; moreover, they can provide new data on the functional attribution of sites and the mobility of early hominins.

Keywords: *Chagyrskaya Cave, Middle Paleolithic, percussive-abrasive stone tools, experimental use-wear analysis, statistical analysis, 3D-modeling.*

Introduction

The category of percussive-abrasive stone tools includes artifacts of diverse appearance. Such tools were used in various working operations, including splitting, polishing, fragmenting, crushing, and grinding mineral and organic raw materials (Semenov, 1953; Beaune, 1989, 1993; Kuchugura, 2003; Grichan, 2006). According to the classification by S. de Beaune, active and passive stone tools have been identified (1989). The group of active tools includes hammerstones, retouchers, abraders, grinders, pestles, and pestle-grinders, while that of passive tools includes anvils, grinding plates, fat lamps, mortars, and pallets.

The percussive-abrasive stone tools have been reported from many Middle Paleolithic sites in the Altai (Okladnikov, 1983; Prirodnaya sreda…, 2003: 126; Shunkov, Kozlikin, Mikhienko, 2019). Specialized studies of such artifacts from the Paleolithic assemblages of the Altai and adjacent regions are currently rare (Belousova et al., 2017; Shalagina et al., 2019; Kharevich et al., 2020; Shalagina et al., 2020). The present study is aimed at the identification and functional analysis of the percussive-abrasive active tools among the artifacts from Chagyrskaya Cave.

Chagyrskaya Cave is listed among the main Middle Paleolithic sites in the Altai Mountains. The cave is situated at the steep left bank of the Charysh River, in

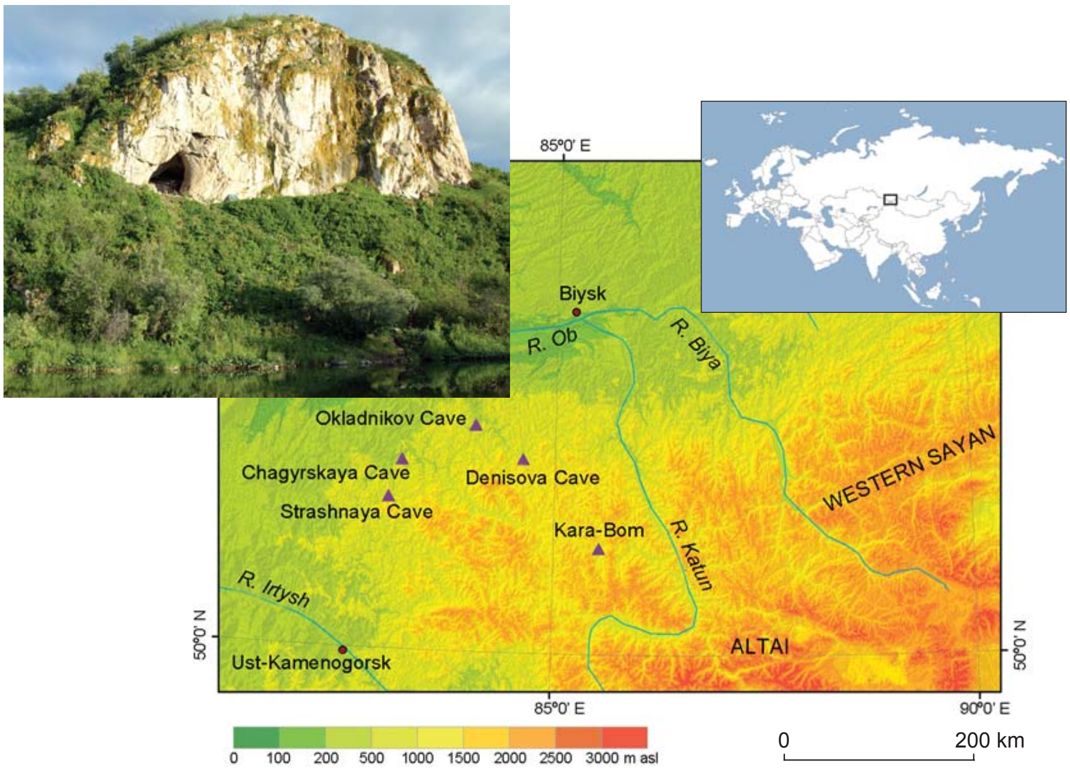


Fig. 1. Location of Chagyrskaya Cave (inset: southern view on the cave).

the southern part of the Altai Territory (Fig. 1). Remains of the Neanderthal material culture were recovered from layers 5–6c/2. According to the available stratigraphic and micromorphological data, layer 6c/2 was the source of artifacts that were accumulated in all culture-bearing stratigraphic units; therefore, we consider them as a single complex formed about 60–50 ka BP. In functional terms, the site is assessed as a Neanderthal base camp with an extensive complete cycle of stone tool processing, including all stages—from decortication of cores to modification of finished products (Kolobova, Shalagina, Chabai et al., 2019; Kolobova, Chabai, Shalagina et al., 2020).

The Chagyrskaya collection of hammerstones and retouchers is one of the most numerous among all the Middle Paleolithic assemblages in the region. The functional analysis of these artifacts makes it possible to reveal the unexplored aspects of ancient technologies associated with the economic and production activities of the late Neanderthals in the Altai.

Materials and methods

The study addressed the collection of percussive-abrasive tools and manuports (untreated pebbles brought by man) recovered from Chagyrskaya Cave. The study sample includes 58 items (see *Table*; Fig. 2) of granite, pegmatite, fine- and coarse-grained sandstone pebbles (determinations by M. Krajcarz, Institute of Geological Sciences, Polish Academy of Sciences).

In this study, we focused on determining the morphometric characteristics of artifacts, recording and interpreting use-wear marks through experimental use-wear analysis (Beaune, 1993; Zampetti, Lemorini, Massussi, 2007; Hamon, Plisson, 2008; Adams et al., 2009; Stepanova, 2015) and 3D-modeling (Grosman, Smikt, Smilansky, 2008; Porter et al., 2016; Benito-Calvo et al., 2018). All pebbles were examined at low magnification for the availability of use-wear traces, after cleaning in an ultrasonic bath. For identification of working areas and detailed analysis of macro- and microtraces we used an Altami CM0745-T microscope with a magnification of ×7–45; the photographic recording was performed by Canon EOS 5D Mark IV camera with an EF 100mm f/2.8 Macro IS USM lens, with further processing in the Helicon Focus software. In parallel with the functional analysis, experiments in stone- and bone-knapping were carried out. Pebbles of fine- and coarse-grained sandstone and granite collected in the alluvium of the Charysh River were used as hammerstones (40 spec.) and retouchers (10 spec.) (Kolobova, Chabai, Shalagina et al., 2020).

All the percussive-abrasive tools were subjected to 3D-modeling using a RangeVision Pro 5m structured illumination scanner (Kolobova, Fedorchenko, Basova

Percussive-abrasive stone tools and manuports from the Middle Paleolithic assemblages of Chagyrskaya Cave

Parameter	Tools		Manuports		Natural negative scars
	Intact	Fragmented	Intact	Fragmented	
Quantity	17	7	19	13	2
Length (mm)	31–89	50–99	25–94	31–45	34; 29
Width (mm)	30–82	37–76	16–77	23–31	29; 23
Thickness (mm)	10–44	20–34	10-48	8–21	7; 9
Mass (g)	17–421	53–312	9–530	3–46	9; 6
Volume (cm^3)	6.4–161	20.4–120.3	3.2–202.7	0.9–18.7	3.2; 2
Shape (number of spec.):					
oval elongated	5	3	5	1	–
oval slightly elongated	6	1	6	1	1
subtriangular	3	1	3	4	–
subrectangular	1	1	2	2	1
polygonal	1	–	2	3	–
ovoid	1	–	1	2	–
segmental	–	1	–	–	–

et al., 2019). The objects under study were installed on the platform and automatically scanned from several angles in the ScanCentre program. The resulting models were combined into one, which was exported to the RangeVision ScanMerge program. We used the ScanCentre, Geomagic Wrap, RangeVision ScanMerge software to determine the metric characteristics and cross-sections, build a mesh curvature map, and record the utilization macro-traces.

The differences in metric parameters and volume of percussive-abrasive tools and manuports have been determined through statistical analysis. The nonparametric Kruskal-Wallis test and the pairwise Mann-Whitney test were used to compare three samples for one variable (metric parameter or volume), because of the abnormal distribution of data in these samples, as determined through the Shapiro-Wilk test. In case of a statistically significant difference, the Bonferroni correction was applied to exclude type 1 error (Grzhibovsky, 2008). Statistical calculations were performed using the PAST program (Hammer, Harper, Ryan, 2001).

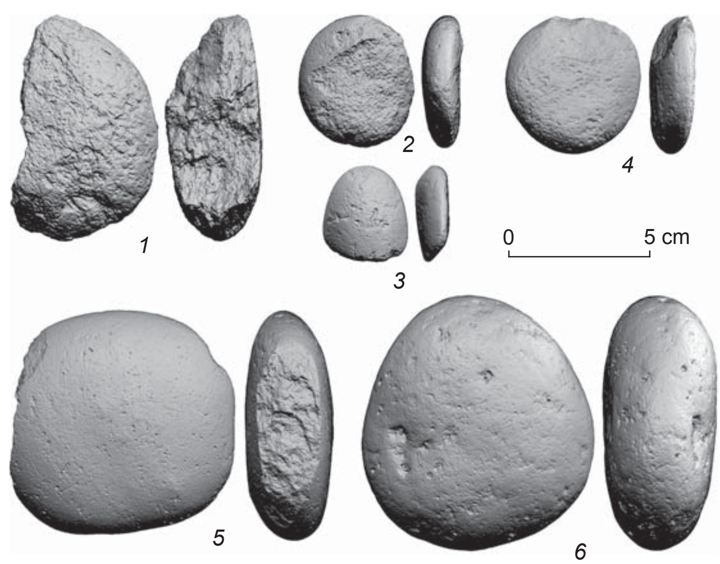


Fig. 2. Percussive-abrasive stone tools from Chagyrskaya Cave.
1, *5* – hammers for stone-knapping; *2–4* – retouchers; *6* – hammer for bone-splitting.

Nonparametric three-dimensional scaling was used to ordinate samples of percussive-abrasive tools and manuports by several variables simultaneously (metric parameters and volume). To unify the available data, we used the procedure of *z*-standardization of samples beforehand. Based on of ordination data, a graph was created, in which the coordinate scaling system shows the relative position of artifacts and manuports. At the same time, the distance between individual objects in the samples reflects their similarity or difference in the analyzed variables. To verify the obtained data, we applied the PERMANOVA nonparametric multivariate test to the scores of the main scaling coordinates. As a result, we obtained the detailed data, indicating similarity and difference of the analyzed samples for all four variables (Ibid.).

Study results

Experimental simulation. The experiment has shown several stages of formation of use-wear marks on simulated tools (Fig. 3). Pebbles of oval, ovoid, and subrectangular shape, 72 to 153 × 57 to 113 × 17 to 96 mm in size and weighing from 121 to 2107 g, were used as hard mineral hammerstones for processing stone raw materials (35 spec.). Working areas were located at the tops and edges of the pebbles; when exhaustion became heavy, the tool was reoriented. After half an hour of work, there appeared signs of microflaking, edge damage, and solitary rounded dimples on the contact surfaces of the hammerstones. At this stage, some pebbles subjected to primary reduction showed small cracks and solitary negative scars. One hour of work with a hammerstone led to extensive formation of dents and edge damage, which resulted in some smoothing of the rounded surface of the pebble's top. The areas involved in reduction of the simulated core showed small linear traces and smoothing of the surface. The hammerstones' efficiency dropped dramatically after an hour of operation. Use for an hour and a half or more led to the formation of heavy edge damage and dents, large negative scars or longitudinal fragmentation (Fig. 3, *1*; 4, *2*).

During the experimental bone-knapping, oval and ovoid pebbles, 124 to 142 × 81 to 115 × 52 to 81 mm in size and 946–1924 g in weight, were used as hard mineral hammerstones (5 spec.). Working zones of the tools were on the pebbles' tops. As a result of half an hour of

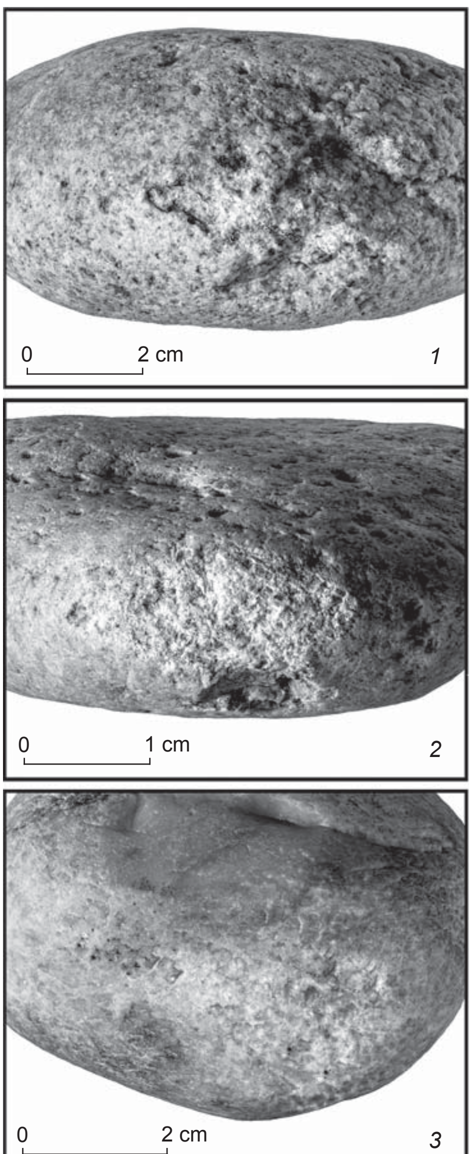


Fig. 3. Standard simulations.
1 – hammer for stone-knapping (2 hours of operation); *2* – retoucher (2 hours of operation); *3* – hammer for bone-splitting (1.5 hours of operation).

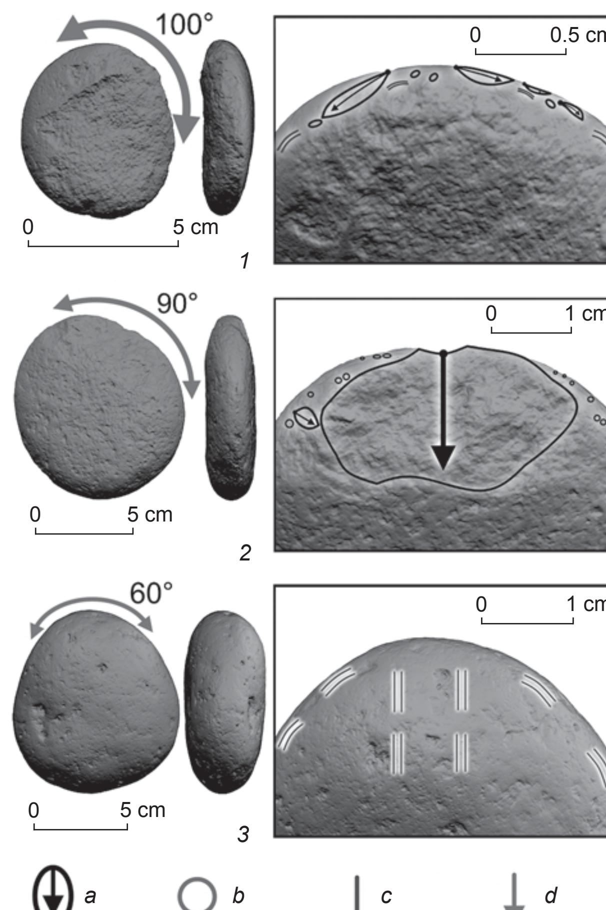


Fig. 4. Distribution of working zones and typical use-wear signs on percussive-abrasive tools from Chagyrskaya Cave.
1 – retoucher; *2* – hammer for stone-knapping; *3* – hammer for bone-splitting.
a – negative scar and its direction; *b* – dimples; *c* – linear traces; *d* – working edge width.

knapping of long bones, the experimental hammerstones showed weak microflaking and smoothing reminiscent of attrition; linear tracks were spread from the points of percussion to the edges of pebbles. The use of tools for over an hour led to a heavy leveling of the working surfaces and the formation of small dimples and dents; the associated linear traces became more pronounced (see Fig. 3, *3*; 4, *3*). The effectiveness of the mineral hammerstones in bone-splitting did not decrease after two hours of intense work.

Pebbles of oval, ovoid, and subtriangular shapes, 62 to 96 × 45 to 64 × 21 to 43 mm in size and weighing 117–355 g, served as retouchers for processing stone implements (10 spec.). Working zones were located in the same way as on hammers; only the long edges were used more often. After half an hour of retouching stone blanks, there appeared small rounded dents, weak microflaking, linear traces, and smoothing on the contact surfaces of the tools. After an hour of work, the retouchers showed weak microflaking, a greater number of dents subtriangular in shape, and denser linear traces; the working surfaces were heavily smoothed, and small negative scars were recorded. Further use of a tool led to more prominent and larger scars (see Fig. 3, *2*; 4, *1*). The effectiveness of stone retouchers decreased after 45 minutes of intensive work, when all the edges became worn out.

As a result of the experimental program, a representative collection of 50 standard models was formed. The traceological analysis of the standard samples identified a set of use-wear marks characteristic of each type of percussive-abrasive tool. Hard mineral hammers for stone-knapping had one, rarely three or more, worked-out areas of various shapes, with large oval dimples and dents, heavy microflaking and edge damage, and negatives scars (over 60 % of all specimens; see Fig. 3, *1*; 4, *2*). Working areas of the hammerstones, which were used for bone-splitting, were characterized by weak microflaking, dents, dimples, linear traces, and general smoothing of the surface (see Fig. 3, *3*; 4, *3*). Experimental retouchers had one wide (more than 60° archwise) or several narrower working zones with small elongated dimples and dents, weak microflaking, and linear traces. A total of 30 % of retouchers showed small negatives scars formed due to a counterblow during the processing of stone blanks (see Fig. 3, *2*; 4, *1*).

Study of working zones and use-wear traces on the experimental percussive-abrasive tools allowed us to establish the main distinctive features of the identified types of tools. Retouchers differed from hammers for stone-knapping by the following criteria: smoothing of working surface; oblong shape of dents; presence of clear linear traces, not overlapped by heavy microflaking, dimples and dents; rarity of large negative scars, which resulted only from cracks and other deformations in the used pebble. These distinctions were observed at all stages of utilization and can be explained by the functional purpose of these tools, and not by the intensity of their use.

Functional analysis. The traceological analysis of the collection of pebbles recovered from Chagyrskaya Cave revealed the following types of tool: retouchers (19 spec.), hammerstones for knapping of stone (4 spec.) and bone (1 spec.). Stone retouchers for processing mineral raw materials (19 spec.) are represented by intact (79 %) and fragmented (21 %) pebbles of granite and fine-grained sandstone (see *Table*; Fig. 5, *1*, *2*). These tools have one elongated subrectangular (53 %; Fig. 5, *1*), more rarely one (21.1 %; Fig. 5, *2*) or three (25.9 %) narrow oval working zones with rounded, elongated dents and dimples. The majority of retouchers (68 %) showed large dimples and small negative scars, and the percussion point located in the zone of weak microflaking and edge damage (see Fig. 4, *1*). Artifacts without significant mechanical damage (32 %) showed weak microflaking, edge damage, and dents on the convex surfaces. Macro use-wear traces in the form of dimples, dents, and negative scars were noted on all stone retouchers from Chagyrskaya Cave; these traces were directed mainly towards the center of the tool or parallel to its lateral sides (see Fig. 4, *1*).

Hard mineral hammers for stone-knapping (4 spec.) are represented by intact (50 %) and fragmented (50 %) pebbles (see *Table*; Fig. 5, *3*). These bear one wide elongated sub-rectangular (75 %) or narrow oval (25 %) working area heavy microflaking, edge damage, deep rounded dimples, one or several negative scars of large utilization removals. Macro use-wear traces are directed mainly towards the center of the tool and parallel to its lateral sides (see Fig. 4, *2*).

A hard mineral hammerstone for bone-knapping is an intact ovoid pegmatite pebble (see Fig. 5, *4*). A wide working area is located at the top of the artifact. Multidirectional linear traces, signs of microflaking, and small oval dents at the top and subtriangular dents at the edges have been recorded (see Fig. 4, *3*). The working area of the artifact is heavily smoothed.

Statistical data. To identify the main differences in the metric characteristics of the percussive-abrasive tools and manuports from Chagyrskaya Cave, a comparative analysis of the volume and massiveness index (width-thickness ratio) was carried out. The volume parameter was chosen as a variable that reflects all metric characteristics of the artifact as a whole. The massiveness index determines the main parameters of the working zones of pebbles: its increase means narrowing the utilized areas due to a decrease in the thickness of the product and vice versa. According to the presented graph (Fig. 6, *1*), the values of this parameter for all the tools and manuports fall into a wide range from 1.0 to 3.5. Comparison of the massiveness index of three groups of artifacts according to the Kruskal-Wallis test did not show any statistical difference ($H = 0.92$, $p = 0.62$).

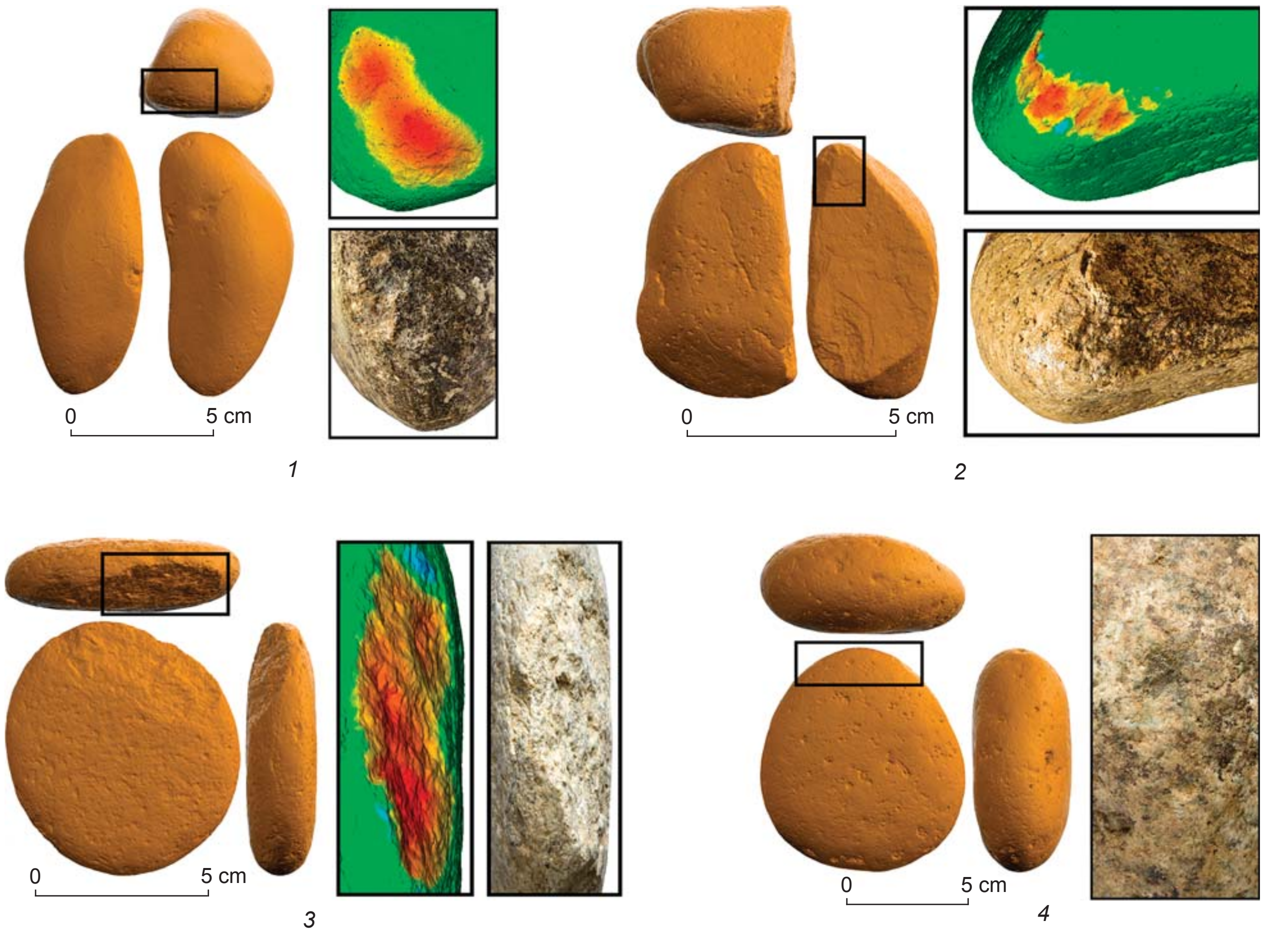


Fig. *5*. 3D-models, mesh curvature maps, and macro-photos of the use-wear signs on percussive-abrasive stone tools from Chagyrskaya Cave.
1, *2* – retouchers (No. 1229 and 1897); *3* – hammer for stone-knapping (No. 446); *4* – hammer for bone-splitting (No. 1510).

When comparing the samples by volume, the bone-knapping hammer was not included into the sample, because it was the only one. The Kruskal-Wallis test showed a significant difference in volume between the three analyzed samples (H = 17.08, p = 0.00019). At the same time, the pairwise Mann-Whitney test, used with the Bonferroni correction, showed that statistically the manuports differed significantly from the retouchers and hammerstones, which demonstrated the same values. It means that larger pebbles were selected to be used as such tools.

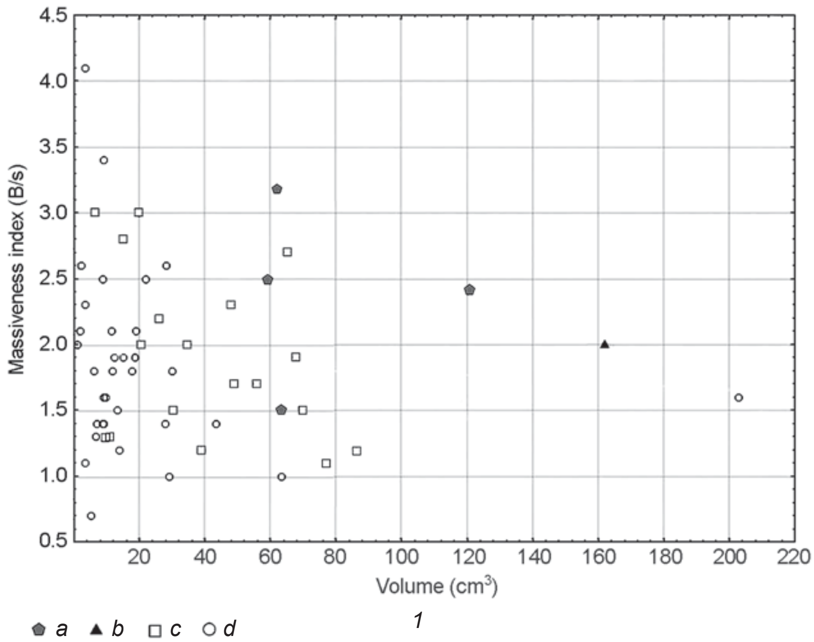
To verify the obtained data, we apply the nonparametric three-dimensional scaling to ordinate the samples by metric variables (length, width, thickness) and volume. A statistically stable result was obtained (stress level 0.0009). On the graph (Fig. 6, *2*), the relative distance between objects reflects the cumulative similarity or difference in the analyzed variables. Manuports are concentrated in the right part of the graph, and hammers and retouchers in the central. At the same time, manuports and hammers with extreme values of all variables are noted. To assess the similarity/difference between the samples, we applied the PERMANOVA nonparametric multivariate test to the scores of the main scaling coordinates. The test has shown a statistically significant difference (F = 10.74; p = 0.0001). Pairwise comparison indicated that manuports differed from retouchers and hammerstones by the aggregate of the variables. Thus, the percussive-abrasive tools and manuports from Chagyrskaya Cave are distinct in both the volume and metric parameters.

Discussion

Any comparisons of the Middle Paleolithic percussive-abrasive active tools from the Altai and adjacent regions is complicated because of the incompleteness of the available data: not all such finds have been identified as artifacts, analyzed, and described in publications. However, the typical microflaking, dimples, and negatives scars of removals noted on their surfaces make it possible to identify artifacts at the stage of field-studies.

A specific problem in the analysis of such tools is identifying of bone-splitting hammerstones, owing to the absence of evident macro-signs of utilization. Microscopic use-wear traces on such tools are visible with magnifying devices.

The primary method for studying percussive-abrasive tools is the experimental use-wear analysis based on the morphometric characteristics, macro and micro use-wear traces. The obtained analytical data made it possible to develop classifications based on these tools' functional determinations and dimensions (Semenov, 1953; Beaune, 1989, 1993; Zampetti, Lemorini, Massussi, 2007; Stepanova, 2015). At present, functional analysis is complemented by morphometric, petrographic, and statistical studies, as well as 3D-modeling (Benito-Calvo et al., 2018; Grosman, Smikt, Smilansky, 2008; Pop et al., 2018; Porter et al., 2016).



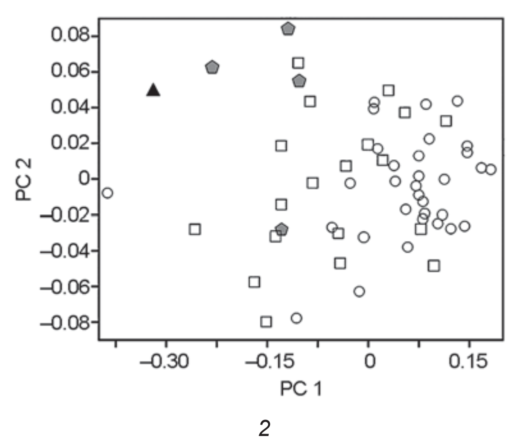


Fig. 6. Ratio of massiveness index and volume (*1*), and the result of nonparametric three-dimensional scaling of the metric characteristics (*2*) of the studied tools and manuports.
a – hammer for stone-knapping; *b* – hammer for bone-splitting; *c* – retoucher; *d* – manuport.

The executed comprehensive study provides information on the functional specificity of the Middle Paleolithic percussive-abrasive tools from Chagyrskaya Cave. The study method with the use of mesh curvature maps has been tested, which facilitates the identification and visualization of working surfaces with use-wear signs. All the identified artifacts were active tools (hammerstones and retouchers). However, the site collection contains one passive instrument—the anvil. This suggests a complex organization of the site-space. It was established that hard mineral hammers were used for the primary reduction of stone raw materials; retouchers were used in the preparation of bifacial tools, secondary working, and modification of the uni- and bifacial tools. This is consistent with the results of a preliminary attributive analysis of the Chagyrskaya collections, according to which about 60 % of the spalls were removed with hard hammers. About 30 % of the spalls indicate soft hammers, which is consistent with a large number of bone retouchers at the site (Kolobova, Rendu, Shalagina et al., 2020). Judging by the composition of the collection of percussive-abrasive tools, in which retouchers (19 spec.) prevail over hammerstones (5 spec.), we can assume that secondary working processes were far more active than the primary reduction in Chagyrskaya Cave. The Neanderthals probably split stones beyond the site, at the outcrops of raw material.

Conclusions

Until recently, it was believed that hammerstones and retouchers did not possess any specific set of features suitable for intra- and inter-regional correlation (Stepanova, 2015). The present study confirms this thesis, but the composition of the percussive-abrasive tools is indicative of the production processes that took place directly at the site. The abundance of rejected retouchers and hammers at the site results from the availability of raw materials for their production. Therefore, these tools might not have been regarded as valuable; they were not taken away from the site. Regarding other types of implement, a different attitude to these is recorded: bifacial tools made of high-quality material were used for a long time; these were transported from site to site intended for various economic activities (Uthmeier, 2012).

The experimental use-wear analysis of simulated tools made it possible to establish the functional distinctions between the main types of percussive-abrasive active stone tools, differentiating hammers for stone-knapping and retouchers by the characteristics of working zones with use-wear signs. Statistical comparison of metric parameters and volumes of the artifacts and manuports showed a significant difference. Pebbles larger than the manuports but of the same shape were chosen as tools. The revealed metric preferences of the Neanderthals from Chagyrskaya Cave for hammerstones and retouchers are exclusively functional.

This study has shown that percussive-abrasive tools, which have been greatly underestimated until now, are an important part of the archaeological assemblages of Chagyrskaya Cave. Analytical study of these tools from the Altai sites seems to be relevant and promising. The presence or absence of artifacts in this category, the degree of their utilization, and their position in the cultural layer may indicate the labor processes at the site, the reduction techniques used, and the functional attribution of the studied assemblages.

Acknowledgements

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