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# Experimental and Traceological Studying the Use Of Stone Tools in Blacksmith's Work

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*The article presents results of experimental studying the use of stone tools in blacksmith's work. This research has contained thorough examination of problem of their efficacy in work with metal. Authors have compared measures of exposures on working material of stone tools with metal ones. The main part of the studying became use-wear analysis of peculiarities of traces formation on experimental patterns. It has allowed distinguishing types of use wear-traces for iron, copper and operations of their treatment. These results are very important for future differentiation of functions of archaeological artifacts. Moreover they significantly increase set of stone tools of latest times available for traceological determinations and thus open new perspectives for studying technologies of metal working on Siberia territory in Iron Age.*

*Keywords: experimental methods, traceological analysis, use-wear traces, stone tools, metal treatment, blacksmith's work, Middle Siberia, Iron period.*

## Introduction

Traceological analysis of stone tools of Iron period encounters distinguishing subjects set of subjects connected with metal treatment on settling and production complexes one way or another. Its results on the one hand allowed studying level of development this manufacture. On the other hand number and variety of stone tools for metal treatment can be base for investigation of technology aspects of ancient blacksmith's work especially when metal instruments with the same functions in Middle Siberia are found rarely.

As a result of conducted use-wear analysis of stone tools from settling complexes on territory of the Middle Yenisei and the Lower Angara of Iron period (hill-fort Ust-Shilka 2, settlement Prospikhinskaya Shivera IV) the set of instruments connected with metal treatment was revealed (Korobkova et al., 2008; Knyazeva et al, 2010). There were sledge-hammers, anvils, smoothers, grindstones and whetstones among them. They had probably been used in different stages of treatment of metal implements and could play not last role in blacksmith's work.

Meanwhile found out use-wear traces on subjects formed from contact with metal traceologist meets with necessity of their differentiation, exploring of their formation

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and correlation with definite work operations and sooner or later turns to experiments. Just empirical investigation has specific methods and allows deciding problems of interpretation of archaeological data, checking results made by analytic way, and also creating data system for verification and proofs the results of traceological examination (Korobkova, 1994; Grigoriev, Rusanov, 1995; Volkov, 2010).

Experimental and traceological studying stone tools used for treatment of nonferrous and precious metals (copper, bronze, gold and etc.) was made for material of Early Metal period from European part of Russia (Korobkova, Sharovskaya, 1963; Kileynikov, 1984; Korobkova, 2003). But experiments for investigation iron treatment with stone tools have not been conducted before. Though it is well known that ironworks had been one of the most important parts of economy of ancient Siberian population in later periods (Zinyakov, 1998).

A purpose of this investigation was experimental and traceological studying the use of stone tools in blacksmith's work. Fundamental circle of solvable issues included problem of efficacy and measures of exposures of stone tools on working material, comparison these parameters with features of traditional metal instruments with similar functions, and also peculiarities of formation use-wear traces as the results of realization different operations during treatment of cold and hot metals.

## Methods

Solving of these problems was made on base of complex empirical investigation and included both technological and traceological aspects (Semenov, 1959; Korobkova, 1994; Matyuhin, 1999; Volkov, 2010). The main part of experimental works on blacksmith's treatment of metals with use stone tools was realized in Laboratory of Artistic Smithery of Institute of Non-ferrous Metals and Materials Science of Siberian Federal University. Choice of form and weight of experimental patterns was founded mainly on examples of subjects for metal treatment from archaeological collections of the Middle Yenisei and Lower Angara of Iron period (Korobkova et al., 2008; Knyazeva et al., 2010).

The experiments included hot smithery iron and copper billets with use of stone sledge-hammers and anvils (Fig. 1). Cold smithery was made only for copper. Important part of works was correlation use-wear traces on archaeological smoothers for black metal with definite operations and kinematics of movement and also examination of their place and role in technological process of hot iron treatment. In addition experiments on smoothing copper billets in hot and cold state were made for comparative analysis use-wear traces and studying character of exposure and efficacy of such tools. Final part of works was studying abrasive treatment of metals which included grinding implements, sharpening edges and blades.

Holding experiments is only beginning phase of empirical investigation. Its following part has principal significance. It concludes in establishment of external and inside correlations of studied effects by analysis experimental results with distinguishing typical for them features and systematization experimental data (Semenov, 1959; Korobkova, 1994). In this context every experimental research of ancient technologies is inseparably connected with traceology (Volkov, 2010). It has not only constitutive role in generalization of the results of conducted experiments but primary examination of archaeological artifacts and presentation of necessary information for realization these experiments.

Traceological analysis received in course of the experiments patterns allows distinguishing

Fig. 1. Process of experimental smithery of hot metal with use of stone tools

main use-wear characteristics and directly correlating them with definite operations, character of working material and kinematics of movement. For studying use-wear traces on archaeological tools for metal treatment these data are the most valuable material. Mainly they are necessary for new workable methods of functional determination of stone tools for Middle Siberia of Iron period.

All these data allow talking about possibility and efficacy degree of use of stone tools with definite characteristics for metal treatment, place of the tools in blacksmith's work of ancient population of Middle Siberia and also about appointed specific of used technologies.

## Results

*Sledge-hammers*

In the course of the experiments on hot smithery pebbles weighting 950 – 1900 g. were used. They had ellipsoid or prismatic form and corresponded to archaeological finds from medieval settlements of the Lower Priangariye (Fig. 2). Archaeological specimens of sledge-hammers often contain on their surface special surrounded riffle made by point technique (Gladilin, 1985; Knyazeva et al., 2010]. It allowed supposing system of tool fastening to T-shaped handle as the most acceptable in this case (Sunchugashev, 1969; Kileynikiv, 1984) and using it for making experimental patterns.

Such stone sledge-hammers proved themselves during hot treatment of small iron billets very effectively. The tools with rounded bulging working end are handier for spreading of billet (Fig. 3 – 2). They penetrate into working material deeply and ensure quick flattening of it. The sledge-hammers with flat working end are the best for lengthening and shaping the billet (Fig. 3 – 1).

Visible for naked eye traces of stuck metal and scale appear immediately on the tool surface

Fig. 2. Experimental stone sledge-hammer

which touches hot iron billet directly. As since rounded bulging end of the sledge-hammer penetrates into material deeply than flat one then square of direct contact its working parts with metal is more sizeable. It also talks about large modification of working surface of the tool (Fig. 4 – 1). The metal scale always forms during hot iron treatment. That is conditioned by its chemical features. The scale is situated on the tool surface as areas of thin metal crust. Moreover metal in the form of rough, uneven and sometimes flaky formations gradually sticks on zones of constant contact with working material. It should be noted that they are often located on prominent parts of micro-relief of working surface and do not touch natural hollows and cavities. Meanwhile areas free from metal elements both central and outlying darken probably as the result of thermal influence. They contain some crushing and melting outlines of micro-relief. The latter represents flattening of separate prominent tops and their fuzzy contours. In spite of the darkening looks as united spot it touches not all waves of micro-relief and keeps light inclusions with sharp boundaries inside itself. On outlying parts of the spot their number increases and finally the darkening comes to naught.

Use-wear principle of sledge-hammers with flat edge has the same features but it differs by character of their location (Fig. 4 – 2). As since such form of working edge of the tool does not penetrate into metal deeply then its use-wear does not take solid square as in previous case and depends on sizes of working billets and implements. The metal scale is situated by far apart separate areas on prominent parts of micro-relief. The flaky knolls of suck metal are fixed rarely. The darkening encircles areas around them and zones of scale crust. It is also uneven and does not make solid formations. The darkening has sharp boundaries and is characterized by crushing and melting outlines of micro-relief which are the same as in the case has referred above.

Effect quality of stone sledge-hammers without handle on hot metal billet differs from described examples not much. As a whole such use of the tool during the smithery is possible (Fig. 3 – 3). But concentration of power efforts changes from forearm to wrist. Hits are shaped more directly and in some cases more effectively. But it is difficult to work in that way for a long time.

Similar sledge-hammers (weighting 880 – 1560 g.) with handle and without it were used for hot and cold smithery of copper billets (Fig. 5). As since according to its features the copper is softer than iron then its hot treatment takes lesser efforts. But the methods of treatment are the same as well as using form peculiarities of working edges of the tools.

During hot smithery of copper solid crust of metal scale does not form on the surface of stone

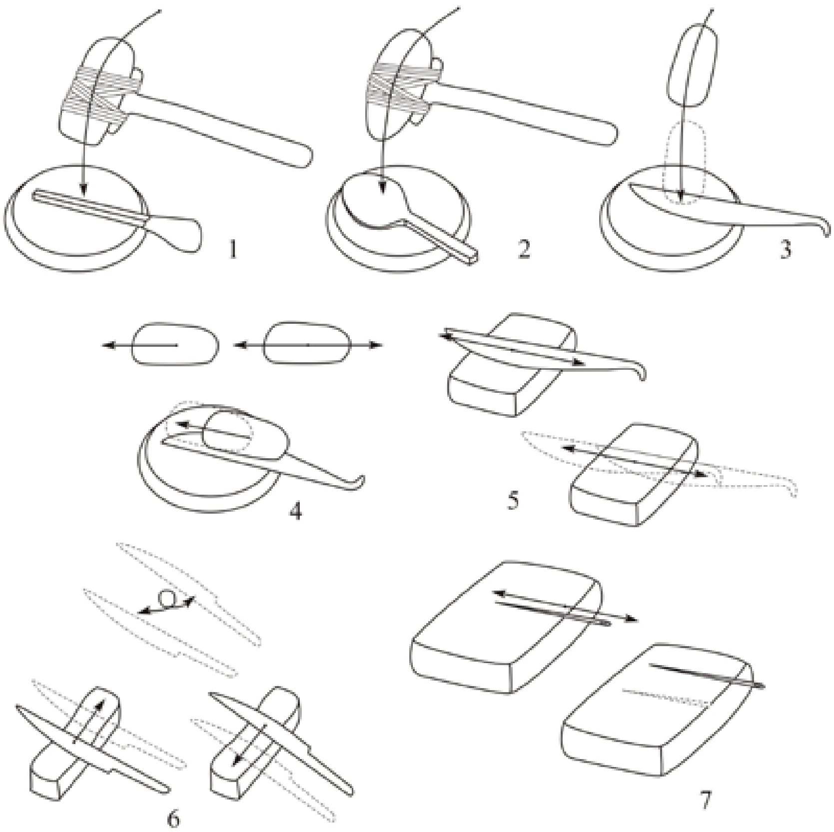


Fig. 3. Schemes of metal-working processes with stone tools and movement kinematics of them and working implements: 1 – lengthening of metal billet by sledge-hammer with flat end and handle; 2 – spreading of metal billet by sledge-hammer with bulging end and handle; 3 – smithery with sledge-hammer without handle; 4 – smoothing of metal implement by stone smoother; 5 – grinding of metal implement; 6 – sharpening of metal knife; 7 – grinding of metal needle

sledge-hammers. Metal elements on them are not visible (Fig. 4 - 3). They are fixed only in the time of microscopical investigation of tool surface and represent very small separate flakes of stuck metal. The solid rough and uneven formations as in case of iron treatment do not arise. The tool wears very slowly. Except metal flakes use-wear traces are characterized by irregular darkening of surface which is accompanied with slack crushing of micro-relief. All described use-wear features are connected exclusively with prominent parts of plane.

Cold copper in the process of treatment takes an application of heavier sledge-hammers then during hot smithery. But use of stone tools for that is very effective. Surface of them in this case crashes more intensively. It is expressed in flattening of micro-relief tops. Metal traces on it represent tiny specks of copper which cover of working areas evenly. They are easily and quickly effaced, so it is unlikely they could remain on the surface as a result of archaeologizing of such subjects.

*Anvils*

Massive pebbles of flat forms with even surface from 9,4x11,2x4,0 to 13,2x14,8x6,4 cm by size (weighting 880 – 2410 g.) were used as anvils in course of the studying. If the tools are fixed in immovable state then their use does not

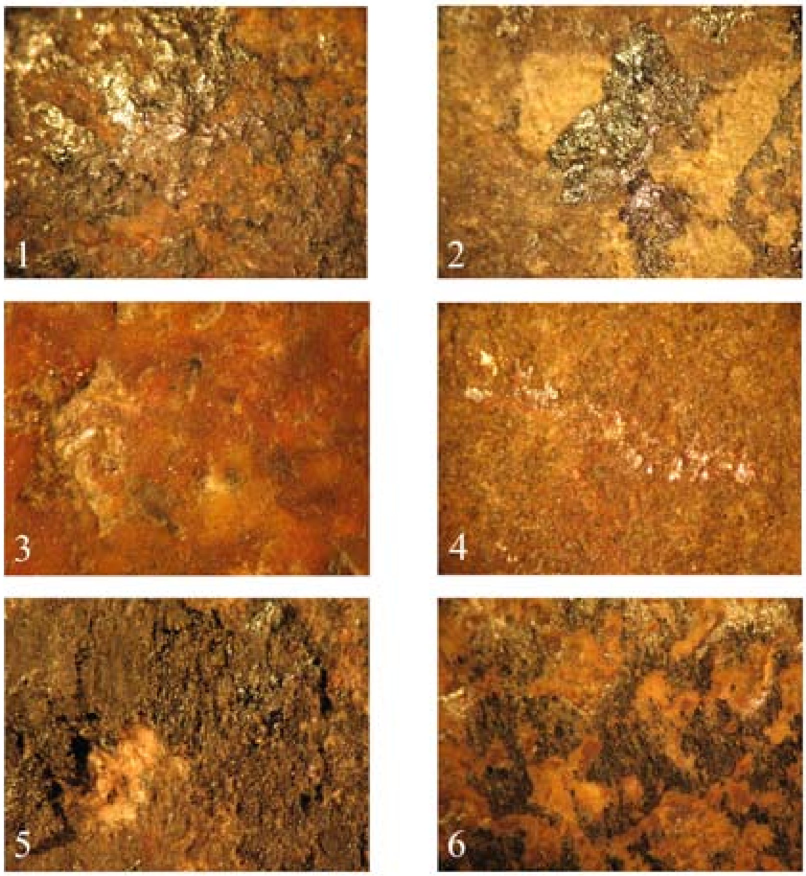


Fig. 4. Use-wear traces on surfaces of experimental tools (microphotos[1], 20×magnification): 1, 2 – sledge-hammers for hot smithery of iron; 3 – sledge-hammer for hot smithery of copper; 4 – anvil for hot smithery of copper; 5 – anvil for hot smithery of iron; 6 – smoother for hot iron

differ from similar metal implements. Use-wear features from treatment of copper and iron are different.

During hot iron smithery numerous traces of stuck metal and scale form on anvil surface (Fig. 4 – 5). They are the same as on sledge-hammers for iron. Moreover large prominent parts of micro-relief crash and flatten intensively. Rare wide point impressions appear on its surface.

Use-wear traces on anvil as a result of hot smithery of copper billet look otherwise (Fig. 4 – 4). Copper elements on its surface represent separate flakes of stuck metal and are fixed only under a microscope. Working surface darkens; prominent tops of micro-relief flatten, melt and get fuzzy contours. If during iron treatment only the most bulging far apart areas changes their shape and crashing of the surface under small magnification looks coarser and more irregular then it is in the case of copper treatment. At this point major parts of bulging tops of micro-relief become deformed; in this connection flattening area looks evener and with common darkening of surface reminds old deep-seated greasy spot.

As a result of smithery of cold copper the metal accumulates on anvil surface by separate tiny elements which disappear quickly. Features of micro-relief crush and melt more intensively than during hot treatment. According to degree of flattening evenness such tools hold intermediate

Fig. 5. Process of experimental smithery of hot copper billet

place among anvils for hot smithery of iron and copper and probably gravitate to the first kind of use-wear (i.e. for iron).

*Smoothers*

For final shaping and smoothing sheet metal modern blacksmith's workers use metal planishing hammers. These are tools of percussion which fulfill role of intermediary between hammer and billet (Shapiro, 1967). Archaeological artifacts with similar functions differ from them very much. Character of use-wear traces on archaeological subjects called in traceology smoothers is not correlated with such way of application too.

Typical smoothness of micro-relief, rarely fixed line traces and scratches on working surfaces of stone tools of flat sub-rectangular form (Knyazeva et al., 2010) exclude percussion completely. They are also similar to smoothers for burnishing of foil and metal sheets neither of form nor of use-wear character (Korobkova, Sharovskaya, 1963; Korobkova, 2003). Meanwhile because of metal scale on working surfaces archaeological smoothers differ from abrasives. It also witnesses about their application during hot treatment of iron.

In course of the work hypothesis about hot finishing iron surfaces by smoothing (with rectilinear forward movement) after smithery appeared (Fig. 3 – 4). Such thought had been expressed by V. V. Kileynikov during examination problem of use of stone tools for treatment of bronze implements (Kileynikov, 1984).

Form of ancient pebbles and also character of use-wear traces location do not allow talking about any variants of strengthening the tools to handle. So during selection of experimental patterns following points were taken into account: convenient configuration of pebble for it can be held without contact with red-hot billet; presence of even wide plane and also correspondence of it to measurement of working billet. The latter condition was revealed in course of the work since treatment of small billet with large pebble was not handy and so not always effective. As in this case principle of the work does not lean on percussion then necessity in big weight of the tool disappears.

In course of the experiments pebbles with even planes from 6,5×6,8×4,8 to 7,2×15,5×7,8 cm by size were used as smoothers. The first attempts of smoothing hot billet showed their effectiveness and expediency at once. The pebble smoothes

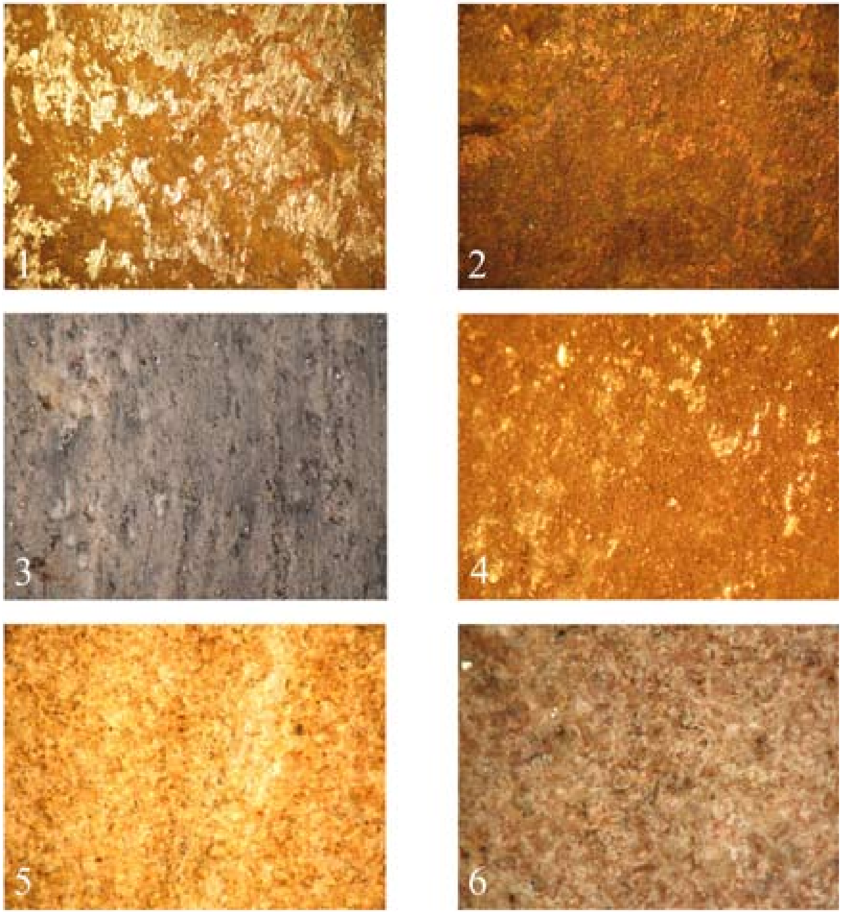


Fig. 6. Use-wear traces on surfaces of experimental tools (microphotos, 20×magnification): 1 – smoother for hot copper; 2 – smoother for cold copper; 3, 5 – grindstones for iron implements; 4 – grindstone for copper implements; 6 – whetstone for sharpening iron blades

unevenness on hot metal well at that bright luster appears on the billet. The tool does not touch hollows of micro-relief therefore they remain in original state. For complete smoothing of iron surface it is necessary to repeat the operation several times with periodic heating of the billet.

In first minutes of work metal brilliance appears on the tool. It takes place because of forming scale on prominent parts of micro-relief (Fig. 4 – 6). Then smoothness and groups of mutually parallel line traces arise on them. Parts directly contacted with hot metal darken.

Treatment of hot copper billet is more effective. All unevenness are smoothed much sooner then on iron surface. The tool on the contrary changes weakly. Black metal scale and lighter foliated copper flakes appear on working surface (Fig. 6 – 1). The parts bounding them darken. Polishing and parallel line traces are fixed under microscope.

Surface of cold copper billet is smoothed slowly but also enough effectively (Fig. 7). Surface of the tool has metal glitter but it penetrates in waves of micro-relief weakly (Fig. 6 – 2). Copper elements are situated on surface as separate large inclusions or groups of single irregular ones. Darkening does not form. Prominent parts of micro-relief of working plane are smoothed intensively. Groups of mutually parallel line traces form on them.

*Abrasives*

Abrasive treatment of metal implements is final, concluding stage of technological process of metal-working. It includes grinding and finishing things in cold state after smithery. Some scientists distinguish this process from blacksmith's work into metalwork proper [Kolchin, 1953]. This thought can be correct for high level of metallurgy on stage of division on separate crafts. However if the matter is about societies with diversified economy lived in taiga of Middle Siberia in Iron Age it is difficult to affirm about some specialization in this field. Moreover consideration of every technological process of metal treatment on that territory should not be in isolation from whole complex of operations of metallurgy which had occurred on settling sites [Knyazeva et al., 2010]. Exclusion can be only for whetstones as tools for sharpening implements in course of their use but probably in case of absence some traces of metallurgy on sites.

In course of the investigation set of experiments on grinding and sharpening of iron and copper implements by sandstones was hold. The latter are often found on settlements of Iron Age. Their effectiveness and wide spreading of use in ancient times are beyond doubt. Tasks of the work in this case were in studying peculiarities and character of sandstones use-wear as the result of treatment of different metals during operation of grinding and sharpening.

The grinding of iron implements showed that abrasive wears out quickly (Fig. 3 – 5, 7). In course of the work big quantity of dust appears as since the sandstone crumbles out intensively (Fig. 6 – 3). Moreover traces of metal remain on the tool surface. Presence of the dust complicates the treatment process and it must be washed off with water. Distinctive deepening of use-wear forms of sandstone surface. At that some unevenness and aliasing on its sides allow indicating width of the working implement. Grains of sandstone are lapped weakly because they crumble out quickly and get renewed (Fig. 6 – 5). Line traces and scratches on abrasive surface form only in case of presence of burrs on working implements. When blades of knives are sharpened sandstone crumbles out less intensively (Fig. 3 – 6). Its surface is burnished; line traces and scratches form rarely (Fig. 6 – 6).

As a result of abrasive treatment of copper implements metal elements appear on sandstone surface at once (Fig. 6 – 4). But as since this metal is soft enough grinds are lapped better and process of crumbling is slow. Line traces do not form.

## Conclusion

Thus conducted investigations have shown big effectiveness in use of stone tools in course of different operations during iron and copper treatment. Obtained data can be evidence that use of stone tools in blacksmith's work of Iron Age could be wide as since they have same characteristics as iron implements.

It is convenient to use stone sledge-hammers for treatment of hot and cold metals. Their effectiveness in different operations of smithery changes depending on working edge form. Smoothing of hot billet with stone smoothers could have big significance. Ancient technology of this operation in blacksmith's work apparently differed from modern one. In Iron Age smoothing was made by rectilinear frontal movements with tool of elongated form. Such use of smoothers probably came from ways of treatment of nonferrous metal as since there are tools with such function and special traces on sites of Early Iron Age [Korobkova et al., 2008].

Use-wear traces on tools from similar operations are deferent for iron and copper treatment. Hot iron tracks more noticeable and large traces of metal crust and scale on sledge-hammers and anvils. Copper traces on such tools are fixed weakly and only under microscope.

Fig. 7. Copper billet and smoother for its cold treatment

Copper scale formed only on smoothers as the result of hot treatment. Intensity of deformations of natural surfaces of tools working parts is also different that is conditioned by physical features of these metals.

Distinguished in course of the investigation types of use-wear traces for iron, copper and operations of their treatment allow revealing function of archaeological artifacts more differentially. Moreover it significantly increases set of stone tools of latest times available for traceological determinations and thus opens new perspectives for studying technologies of metal-working on Siberian territory in Iron Age.

1 The photos (figures 4, 6) were made in Laboratory of natural-science methods in archaeology and history of Humanitarian Institute SFU with microscope Stemi 2000-C.

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# Экспериментально-трасологическое исследование использования каменных орудий в кузнечном деле

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*Статья представляет результаты экспериментального изучения использования каменных орудий в кузнечном деле. В частности авторами были исследованы проблема эффективности и меры воздействия каменных орудий на обрабатываемый материал, в сравнении с традиционным набором металлических инструментов, а также особенности следообразования в результате выполнения различных операций по обработке холодных и горячих металлов. Выделенные в ходе исследования типы следов износа для железа, меди и операций процесса их обработки позволяют выявлять функции археологических артефактов более дифференцированно. Это значительно увеличивает набор каменных орудий поздних эпох, доступных трасологическим определениям, и таким образом, открывает новые перспективы для изучения технологий металлообработки на территории Сибири в эпоху железа.*

*Ключевые слова: экспериментальные методы, трасологический анализ, следы износа, каменные орудия, металлообработка, кузнечное дело, Средняя Сибирь, железный век.*