IMPLICATIONS OF HEAT TREATMENT EXPERIMENTS ON LITHIC MATERIALS FROM THE ZERKALNAYA RIVER BASIN IN THE RUSSIAN FAR EAST

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ABSTRACT

At the transition between the Pleistocene and Holocene periods within the Russian Far East lithic tool assemblages expanded from that of microblade industries to that of bifacial points and knives. The raw material primarily used in tool manufacture in the Zerkal'naya River Basin was a silicified tuff. This material is relatively dense and difficult to flake in its natural state. The transition to bifacial flaking techniques in the site of Ustinovka 3 appears to coincide with the appearance of ceramics. Given an assumed knowledge of firing techniques for pottery it is hypothesized that simultaneous heat treatment techniques for lithic material s were developed. Field experiments in heat treatment of lithic material were conducted during the 1995 and 1996 field seasons in an attempt to validate this hypothesis.

INTRODUCTION

The life of man, during the vast period of prehistoric time, depended on suitable sources of raw material which could be used for the manufacturing of stone tools. The selection of raw material was based on homogeneity, hardness and tensile strength. Therefore the siliceous materials composed of minerals of chalcedony, flint, jasper, chert, quartz and volcanic materials such as andesite and obsidian were of significant value (Derevyanko et al. 1994). These kinds of raw materials were not distributed everywhere and sometimes were not easily reached. As archaeological evidence indicates, prehistoric man did not always use fine quality raw materials for the manufacturing of tools. He adapted to the sources of lithic materials within the limits of his seasonal rounds.

Some types of poor quality, coarse grained, lithic material can be improved by artificial means. As early as 1964, Don Crabtree successfully demonstrated that heat treatment altered the structure of siliceous materials, making them more suitable for flaking and retouch (Mandeville 1973). The utilization of lithic heat treatment has had a profound effect on the simulation of lithic technologies and the tracing of temporal and geographic distribution of specific lithic industries. Further, the process of heat treatment required the constant control of temperature, and implies an accumulation of knowledge and skill by prehistoric people.

ARCHAEOLOGICAL DATA

It is well known that heat treatment technology appeared very early, persisted until quite late and was widespread across North America (Shippe 1963, Flenniken and Garrison 1975, Mandeville 1973). Nevertheless, the origins of this technique are still unclear. Although the problem of heat treatment in the Old World is not as well studied as in America, there is some archaeological evidence that heat treatment of lithic raw materials were used in different parts of the world and at different times. Heat treatment means the intentional, controlled heating of lithic material in order to improve its ability to be fractured in a controlled manner through either percussion or pressure techniques. This technology may have been present in the Late Paleolithic period, and possibly even earlier, with the development of pressure flaking techniques. This usually requires high grade lithic material for the successful propagation of flakes. What is presently known is that heat treatment was employed in various parts of the world prior to the migration of the first people into North America. In an attempt to research the presence and distribution of lithic heat treatment techniques an analysis of the lithic assemblage from the Ustinovka 3 site in the Primorye Region of the Russian Far East was undertaken. This is a Late Pleistocene to Early Holocene transitional site which has been under investigation by a joint Russian and Japanese team of archaeologists for the past five years.

USTINOVKA 3

The Ustinovka 3 site is in the northeastern part of Primorye of the Russian Federation. It is situated on the east slope of the Shihote-Alin mountain range and is located in the Zerkalnaya River Basin approximately 30 kilometers from the Sea of Japan. The site occupies an alluvial terrace and is elevated about nine meters above the river. The Zerkalnaya River Basin is the source of a readily accessible outcrop of siliceous volcanic tuff. The quality of this resource is fair to poor for flintknapping and results in considerable debitage during the initial stage of reduction (Krupyanko and Tabarev 1996). The presence of this raw material appears to be a major reason why the area was repeatedly occupied throughout the Late Pleistocene and Holocene periods. At present there are over 20 Paleolithic and Neolithic sites identified within this area.

To date, over 260 square meters have been excavated at Ustinovka 3 and over 25,000 artifacts have been recovered (80% of which is debitage). Amorphous cores, nodule fragments, preforms in different stages of reduction and tertiary flakes amount to about 10 percent of the collection. Completed tools include various forms of bifaces, arrowheads, drills, borers, end scrapers, side scrapers and edge-polished adzes. Initially it was felt that this site functioned as an area for lithic reduction, but more recent assessments indicate that the site was most likely used as a seasonal base camp for hunting and fishing (Kononenko 1996).

A considerable quantity of artifacts exhibit the traces of firing such as surface color alteration and small surface fractures. Several points have pot lid fractures on their surface. A large quantity of debitage has a reddish color. The debitage exhibiting a reddish color is located in the upper part of the cultural layer and often exhibits micro-fractures and pot-lid fractures. This is likely the result of forest fires which frequently occur in this area. Another layer of reddish debitage comes from a basal layer of the deposits. This material exhibits a smaller quantity of pot lids and micro-fractures. These are concentrated around specific areas and appear to be in association with artifact assemblages. This has resulted in the identification of two lithic reduction areas within the site. It is thought that these areas were used for the secondary processing of bifacial tools, as well as the rejuvenation of worn out tools (Kononenko 1996). During the 1995 excavations two caches of large tertiary flakes were located. The caches amounted to 171 large flakes and appear to have been reduced from 2 or 3 cores. The flakes also appear to have been sorted by size. It is likely that these caches were set aside for future reduction and may indicate a preparatory stage prior to heat treatment (Kononenko 1996).

In spite of the poor quality of the lithic raw material, many of the finished artifacts exhibit a considerable degree of fine pressure retouch. Numerous experiments on the flaking of this raw material has determined that it is very difficult to replicate these tools with this raw material in its natural state. In spite of a lack of direct evidence for heat treatment within the site itself, the indications of fire affected rock, the caches of large flakes and the fine quality of pressure retouch exhibited on finished tools strongly suggest that the technique of heat treatment was being employed. In an attempt to test this hypothesis several heat treatment experiments were conducted using this raw material during the 1995 and 1996 field seasons.

THE IMPLICATIONS OF HEAT TREATMENT EXPERIMENTS

The heating of lithics is done to improve the flakability of silicious materials. The heat drives out the ambient water and increases the number of internal micro-fractures. This reduces the tensile strength of the stone by 40 to 60 percent and increases its brittleness. After heat treatment, fracture propagation is improved and the resulting surface flattens. Light is reflected from the fracture surface in a more uniform manner and exhibits a glossy luster. There is often an alteration of the color resulting from the oxidization of inherent minerals. This color change is often not uniform and may only penetrate a few millimeters.

On more porous materials the color change may be throughout. Color change will not occur in the absence of suitable minerals or if the material is heated in an oxygen reducing atmosphere. Thus, the absence of color change is not a reliable indicator of the lack of heat treatment.

Siliceous lithic materials will usually react to heat treatment between 250 and 650 degrees centigrade, but this range can vary widely depending upon the type of raw material. Generally, the coarser the material the higher the temperature will need to be in order to obtain the desired effect (Purdy and Brooks 1971, Mandeville 1973, Patterson 1979, Collins and Fenwick 1974, Olausson and Larsson 1982). The most critical factor is to control the gradual increase and decrease of the temperature in order to avoid thermal shock (Mandeville 1973).

Heat treatment field experiments were conducted by the authors in an attempt to replicate field conditions for this technology and to test the hypothesis that heat treatment was utilized by the occupants of Ustinovka 3. The raw material for these experiments were obtained from three quarry sites near Ustinovka 3. Geologic analysis confirmed that this material is similar to that employed at Ustinovka 3. This cryptocrystalline tuff is somewhat granular and sometimes exhibits a fibrous structure. It includes a large quantity of impurities and is formed with mineral grains up to .01 millimeters in size. The pervasive impurities are formed by quartz, plagioplaz and spar. A petrographic thin-section analysis showed that the structure of the lithic raw material from the Zerkalnaya River Basin is not essentially silicious. Natural flints formed with chalcedony and cryptocrystalline quartz contain about 97-99% silica, 1% water and admixtures of aluminum, ferrum, magnesium, calcium and other elements. The material from Ustinovka are 65-75% silica, 15-20% alumina, 10-15% oxide of potassium, sodium, calcium, magnesium, ferrous and 1-10% water. This type of material is similar to porcelain which includes 65% silica, 25% alumina, 7% alkalies and 3% water. It is likely that the technological qualities of the Zerkalnaya raw material are conditioned by this similarity (Zalistchak and Pahomova 1996).

Fifty-eight pieces of raw material were selected for heat treatment experiments. Twenty-five pieces were quarried from Ustinovka 1, 14 pieces from Ustinovka 6 and 19 pieces from Suvorovo-Masterskaya. Each piece was reduced into 4 flakes through direct percussion. One flake from each of the 4 was retained as a control sample and the rest were heated in 3 separate types of firing pits. Regrettably, we did not have the use of a pyrometer to record the temperature variation during the firing process. The firing intensity was gradually increased and then gradually permitted to cool during the entire process. The first pit was roughly 70 centimeters in depth and a fire was maintained in the pit until the coals reached a depth of approximately 20 centimeters. The coals were then covered with 3 centimeters of sand, upon which the flakes were placed. The flakes were then covered with another 3 centimeters of sand on top of which another fire was built. This fire was maintained for about 7 hours until another 25 centimeters of coals had accumulated. The pit was then covered with a layer of sand and left to cool for 34 hours. When the flakes were removed there were 17 fractured pieces as a result of thermal shock. The flakes that fractured were all from the Ustinovka quarries, while the Suvorovo-Masterskaya materials did not exhibit any alteration. The Ustinovka flakes that did not fracture exhibited pot lids, micro-fractures, and dramatically altered color and were quite brittle.

The second pit was 40 centimeters in depth and the flakes were put directly on the bottom and covered with a 3 centimeter layer of sand. A fire was built on top of the sand and was maintained for 24 hours. It was then left to cool for another 24 hours. The flakes from this pit only exhibited a slight color alteration and loss of weight. When compared to the control sample there did not appear to be any significant differences. It is assumed that the heat either did not penetrate through the layer of sand, or dispersed and did not reach a sufficient temperature among the flakes.

In an attempt to isolate the flakes better and improve the accumulation of the heat the third pit was lined with a layer of birch bark. The flakes were then placed directly on the bark and covered with 3 centimeters of sand and the fire was then built directly on top and maintained for 24 hours. The flakes were then removed from the pit after a cooling period of 24 hours. The Ustinovka flakes in this experiment changed color, took on a glossy luster and exhibited an improved fracture quality. However, the color change was substantially greater than that recognized among the artifact collection from the Ustinovka 3 site. The flakes from the Suvorovo-Masterskaya site remained unchanged.

A fourth firing was attempted utilizing a similar technique as that in firing number 3. In this pit a layer of sand separated the flakes from the birch bark liner and only flakes from the Ustinovka quarries were used. The results of this firing exhibited a less dramatic change of color alteration. Further experiments of placing flakes directly in the fire and beneath the ashes of open fires were also attempted but in most cases the flakes suffered from thermal shock.

THE RESULTS OF THE EXPERIMENTS

Color Change

A Munsell color chart was used to standardize the comparisons. The most obvious color changes were visible on the lithics from the Ustinovka I and 6 quarries. The lithics from Suvorovo-Masterskaya did not change in color after heat treatment. The colors took on a darker reddish tint as the result of firing. Flakes from the first experiment changed their color throughout. The flakes from the third experiment only changed their surface color to a depth of one to two millimeters. Essentially the color changes did not change in color so much as experiencing a decrease in value and purity. In experiment number one these measures diminished by 2 or 3 degrees on the Munsell chart. In experiment number 2 the flakes did not change in color in any measurable way. The color values in experiment number three altered by one or two degrees in value and purity. Based upon these measured changes we concluded that the lowest temperatures were obtained in pit number 2, pit number 3 was the next highest in temperature and pit number 1 experienced the highest temperatures. In comparing the color value and purity of the flakes from all three pits, it was obvious that the color of the flakes diminished from pit number 2, to pit number 3 and finally to pit number 1 respectively. Consequently the color became darker with the increase in temperature. Thus, these observations can be used to make subjective comparisons with the prehistoric lithic artifacts.

Weight loss

All of the heated flakes experienced a weight loss of approximately 3%. Such a high weight loss is presumably related to the unusually large quantities of water in the raw material. This water content is mostly eliminated during the process of heat treatment.

Flake Scar Luster

The flakes from experiment number 1 exhibited the most visible luster from fresh flake scars, while the flakes from experiment number 2 exhibited no increased luster and experiment number 3 resulted in some increase in luster. The increased luster of flakes from experiment number 3 was not consistent throughout all the pieces, but there was a marked improvement in the flatness of the scar surface noted. In summary, it was noted that the material from the Ustinovka quarries does not generally obtain a high or consistent luster as the result of heat treatment.

Ease of Flaking

Upon completion of the heat treatment experiments the flakes were tested for improved fracture propagation through the use of both percussion and pressure techniques. The materials from the Suvorovo-Masterskaya quarry did not evidence an improvement in fracture propagation and were determined to be an inappropriate material for heat treatment. In contrast, the samples from the Ustinovka quarries exhibited significant improvements in fracture propagation.

Use of direct percussion on the heat treated Ustinovka samples resulted in thinner and longer flakes than obtained from the control sample. The heated samples were more brittle and often resulted in perverse fractures when reduced by percussion. This may indicate that unheated materials were reduced to at least preforms prior to being heat treated. It is likely that heat treatment would be most advantageous when the artifact is in the preform stage and just prior to the use of a pressure retouch technique. Samples from experiment number 1 fractured easily with direct percussion, but crumbled upon attempts to apply pressure retouch. Samples from experiment number 2 exhibited no change from the control sample. The amount of force necessary to remove both percussion and pressure flakes from sample number 3 was substantially reduced. Also, the length of retouched facets obtained was significantly increased. The control sample yielded facets 7 millimeters in length, while the heat treated samples yielded facets between 12 and 15 millimeters in length.

In general, the heat treatment technique is more appropriate where considerable pressure retouch is required. It is recognized that heat treatment was selectively employed in the manufacture of tools which required considerable pressure flaking and which did not require particularly strong edges. This would be especially appropriate for tools that required sharp cutting edges. Thus, it was not desirable to employ heat treatment in the manufacture of such tools as drills, scrapers and adzes when stronger edges were desired (Ahler 1983, Olausson 1983).

Petrographic Analysis

A petrographic thin-section analysis of heat treated materials and their unheated control samples failed to reveal any alterations in individual cryptocrystalline grain structure. Both the heat treated samples and the archaeological artifacts exhibited the same dark spots of ferric oxide, which were absent from the unheated control samples.

Surface Features

Both the control and experimental samples were inspected through the use of an Olympus BHM binocular microscope at 200 power magnification. This level of magnification appeared to be adequate to examine the surface changes on a fresh flake scar. Attention was specifically paid to the comparison of flake scar surface texture of both the heated and unheated samples. Changes were not noted on the flake surfaces on samples from experiment number 2. Changes on the fresh flake scar surfaces from samples number 1 and 3 were apparent. The flake scar of the control samples and the same surface after heat treatment did not change, but the fresh flake scar surface after heat treatment demonstrated dramatic changes. The fresh flake scar surfaces of the samples from experiment number 1 became apparently flatter, the cavities and eminences were not so pronounced, ripple marks became apparent and new surfaces reflected light more uniformly. In group number 2 the surface became flatter and separate grains disappeared. This indicates that the force traveled through the crystalline lattice rather than around separate granular grains (Flenniken and White 1983). The surface of fresh flake scars of the second group after heat treatment did not reflect light well and there was little glossiness noted.

Comparison with Archaeological Collections from Ustinovka 3

Given that this was the first research into heat treatment techniques for archaeological collections in the Russian Far East, there was no precedent on the selection of specific artifacts for examination. However, it was decided that if we could find a series of contrasting flake scar surfaces on the same tool, that intentional heat treatment could be confirmed. Thus, we decided to examine a small collection of different tool types in different stages of reduction, with special attention paid to tools that exhibited substantial pressure flaking.

A collection of 22 artifacts was examined. The collection consisted of 10 bifacial preforms which fractured during reduction, 1 blade with a reddish luster indicating possible firing, 6 small arrow points with significant pressure retouch, 1 knife, 2 end scrapers, 1 drill, and 1 retouched flake. Five of the tools had pot lid fractures on their surfaces. The color of the tools differed slightly from the natural state to the color obtained from heat treatment experiment number 2. Some of the tools exhibited a reddish color as if they had possibly been fired. Most of the tools had no luster on their surface, or only a slight luster on one surface. This was probably the result of surface patination. The site deposits only reach a depth of 40 centimeters and indicates the soil sedimentation was extremely slow, and that the artifacts probably remained on the surface for long periods of time. The unexposed surface of the artifact probably retained the original color and luster. Altered surface luster can also be caused by other processes such as wind polish, soil sheen, weathering and bioturbation (Domanski and Webb 1992). It is not fully understood how the natural processes in the soil influence lithic artifacts, but it is apparent that artifacts can be altered by natural processes over time.

All of the collection was examined at 200 power magnification. There was no evidence that the end scrapers, drills, or retouched flakes had been exposed to heat treatment. The knife exhibited considerable pressure flaking and it has a pot lid fracture on one surface. It exhibited no contrasting surfaces and has a uniform greasy luster probably caused by surface patination. The bifacial preforms did not exhibit significant evidence of heat treatment. We were able to determine some contrasting surfaces on 5 small arrow points and 1 small bifacial preform. Heat treatment may have only been used just prior to the final stage of the reduction process. While the surfaces did not exhibit a lustrous surface, they did exhibit contrasting flake scar surfaces indicating possible before and after comparisons of heat treatment scars.

CONCLUSION

These heat treatment experiments have resulted in a number of conclusions. First, the Ustinovka lithic raw material appears to decrease in color value and purity with exposure to heat. Second, it appears that the Ustinovka material does not consistently acquire the glossy luster that is characteristic of chalcedony and chert. Third, the surface of fresh flake scars becomes flatter and smoother after heat treatment. Fourth, the Ustinovka raw material appears to consist of up to 10% of ambient water and looses approximately 3% of its weight when subjected to heat treatment. Fifth, the heat treated material becomes notably more workable for both percussion and pressure reduction techniques. Sixth, the heat treatment of this lithic material results in a substantial increase in brittleness and the frequency of perverse fracturing during percussion reduction increases substantially. This last conclusion implies that heat treatment would have been most likely reserved for certain classes of tools which required the development of sharp edges through pressure flaking techniques.

In terms of firing techniques, it was evident that a firing pit with a birch bark lining worked best for the accumulation and maintenance of heat. The other methods attempted resulted in unsatisfactory results, because either the temperatures became too intense or the heat accumulation was insufficient and not consistently sustained. This conclusion implies that the heat treatment of lithic materials was not a casual activity, but that it employed a specific series of technical knowledge and skills for the successful heat treatment of raw material.

Comparisons of the artifact collection to the experimental samples did not result in any specific conclusions. It may be necessary to examine the entire collection of tools from Ustinovka 3, paying special attention to the bifacal preforms and arrow points in order to identify consistent trends.

This has been a first step in an attempt to identify the presence of heat treatment technology among the prehistoric cultures of the Russian Far East. The initial results appear to be somewhat inconclusive and subjective, but this effort has provided an initial data base which can be applied to further attempts at heat treatment analysis.

NOTES

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