A Metallographic Analysis of the
Old Copper Osceola,Wisconsin Site : 1900 to 1200 B.C.E.

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There has been a hundred year controversy concerning whether ancient Midwest Native Americans could melt and cast copper. Melting metal is an important hallmark in man's advancement out of the Neolithic (new stone age) into the Calcolithic (copper age). Though Indians in Central America and Mexico melted copper, gold and silver alloys as early as 600 AD, there is little evidence of casting in the Upper Central Midwest until European contact. This report identifies cast, copper artifacts associated with a documented Old Copper Culture site in Wisconsin.

OSCEOLA SITE

In 1945, two local men (Ralph Turner and Victor Irish) found numerous Native American artifacts eroding out of a river embankment at what would be later known as the Old Copper Osceola Site. It was located along the Mississippi River shoreline, two miles south of Potosi (Grant County) at the southwest corner of Wisconsin. Later that year, Robert Ritzenthaler and John Douglas, of the Milwaukee Public Museum, excavated the site (Ritzenthaler, 1957) . This became the first of many Old Copper Complex sites found in Wisconsin.

The site was composed of a large cemetery and a five foot deep stratum filled with a variety of artifacts(Ritzenthaler, 1957). Many of the artifacts were copper. The estimated number of human burials at the Osceola site was 500. They consisted of a variety of different burial modes including flexed, extended, bundled, partial cremations, single and multiple interments, with no specific orientation or grave goods. The age at death of the people buried seldom exceeded 30 years. They all had a relatively short life span. Remains in the graves were of various ages and in various degrees of decomposition. This fact, along with the different modes of burial, implied that the people buried along the river bank had occupied the site over long periods of time and had different customs regarding the disposal of their dead. They had not died at the same time but over many years exhibiting numerous changes in culture. It is assumed that the cultural materials in the surrounding strata belonged to the people represented by the nearby burials (Smith, 2002).

The cultural material found consisted of lithics and a considerable number of copper artifacts (Ritzenthaler, 1957). This included: 33 copper awls (large, squared, some hafted), 1 tanged knife, conical points, 2 socketed spear points(or knives?), beads, 6 socket spuds, a ring, bracelet and fragments typical of the Archaic period. Stone tools were also found including: large, chert side-notched projectile (Osceola) points, chert drills, scrapers, hematite, 20 Galina (lead) cubes, smoothing stones, red ocher and grit tempered-cord marked pottery fragments (representative of the Woodland period) (Ritzenthaler, 1957).

The dating of bone and artifacts from the site showed an age range of 1900 BCE to 1200 BCE (Fogel, 1963, Martin, 1999). The Osceola site extended from the Mid-Archaic period to the Early-Woodland period. A span of approximately 700 years.

ANALYSIS OF THE COPPER

The Osceola copper artifacts were similar to that found at other Archaic period Old Copper Complex (OCC) sites (Ritzenthaler, 1957). The collection had numerous awls and spuds (many more than other OCC sites) but each artifact showed the usual design and signs of typical stone hammering methods of manufacture. Generally, the members of the Old Copper Culture used cold hammering of float copper (found in and on the ground) to shape the metal artifacts into useful goods. There is metallurgical evidence (twinning seen in microscopically etched samples) demonstrating the use of heat to soften the brittle metal (annealing) thus making it easier to shape without breaking (strain hardening) (Neiburger 1992, Schroeder 1968, Martin 1999). This can be done at 500 degrees F: campfire temperature. Copper can be melted only in a forced air furnace able to reach 2000 degrees F temperatures or more. A campfire/forest fire will only reach 700-1100 degrees F which will not usually melt the metal but bring it only to a cherry red color. (Martin 1999, Schroeder 1968)

Macroscopic examination of the Osceola copper artifacts shows a thick green-brown layer of carbonate-oxide patina.(Figures 5, 10, 11) This generally is acquired over long periods of time as the result of slow weathering/corrosion caused by the environment. Most of the site's copper artifacts showed evidence of a wrought working form of manufacture. Naturally pure (99%+) float copper, gathered from the ground, rivers or shallow pits, was shaped on stone anvils using stone hammers to produce the observed artifacts. A craftsman could make a copper knife or awl in a few hours which would last considerably longer and work more efficiently than a similarly shaped, fracture prone, stone tool. At a time when float copper, left by the glaciers, littered the environment, using copper metal was a boon to tool manufacture and eased the lives of the local natives.

Figure 1.A sectioned aluminum engine block showing two large casting porosity "bubbles" made by gases during the casting process.

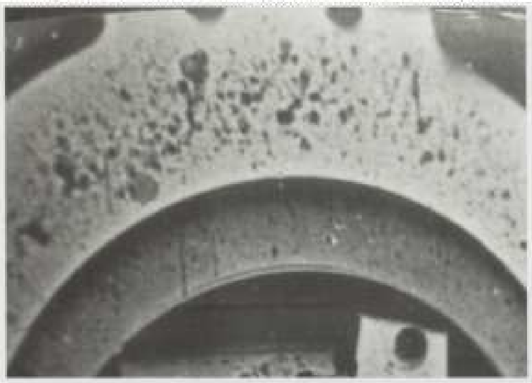

Figure 2. Xeroradiographic image of the above engine block demonstrating extensive casting porosity in the interior of the block. Note the many circular gas spaces typical of casting.

METALLURGY OF COPPER

The melting of copper metal (casting) by the prehistoric Native Americans is generally not observed until historic times (post 1492). This has been the position of most modern archaeologists (Martin 1999, Ritzenthaler 1957, Schroeder 1968). Until recently, there have been no clear casting molds or obvious culturally identified copper castings found in the Midwest until the coming of the Europeans. Only a few hundred OCC artifacts have been metallurgically tested for evidence of casting in their manufacture.(Martin 1999, Schroeder, 1968) There are several different tests that can be used:

1. The most common form of testing is a careful sight examination of the form and surface of the artifact. One looks for exposed casting porosity/bubbles, metal flow lines, shapes and contours that are difficult or impossible to make by hammering (loops, undercuts), cutting and polishing as well as weathering and corrosion. Identifying flow lines in the metal, which can only be produced by melting the copper, can (in many cases) be noted. Unfortunately, many copper artifacts, cast or wrought worked, received additional shaping AFTER CASTING by hammering and polishing where diagnostic bubbles and flow lines are easily obliterated, especially with thin artifacts.(Figures 9-11) Weathering and corrosion can change the surface of the metal eliminating some signs of casting. Thick areas of patination can obscure subtle signs of casting unless one is willing to polish the surface of the specimen, thus ruining its value.

2. A second traditional copper test usually requires the cutting of the artifact and polishing/etching of the cut surface for microscopic examination. The shape and size of the metal grains, as well as air pockets and inclusions (impurities along the grain boundaries) tell whether the object was cast or just hammered.(Figure 1) This analysis can become complex and difficult if a copper artifact was seriously hammered after casting since the pounding will change the grain structure and density of the copper and collapse any casting porosity/bubbles or flow lines so diagnostic of the process. The act of cutting and polishing the metal surface for microscopic examination in itself can easily alter the grain structure of the metal (if not carefully done) thus confusing diagnostic results.(Figures 9-11) Chemical or spectrographic analysis of the metal requires the cutting, dissolving or polishing of the artifact. This process identifies the different chemical elements in the artifact and determines whether the metal is an alloy (metal mixture = casting) or a naturally occurring lump of pure float copper. With all these processes, the artifact is damaged or often destroyed in the process so the number of expensive relics tested (sacrificed) remains small.

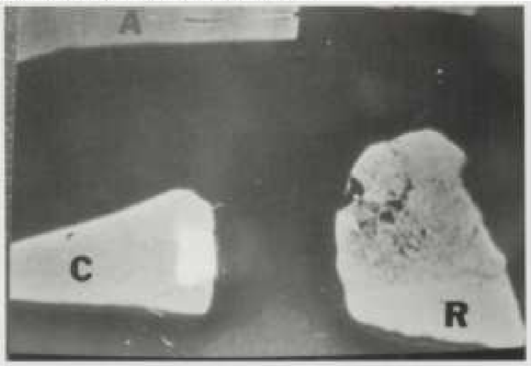

Figure 3. Xeroradiographic image of three float copper derived Old Copper Culture artifacts. Items 'A' and 'C' show little internal porosity implying that they were hammered to their desired shape. The copper artifact(R666) marked 'R' shows casting porosity. Other copper artifacts shown were not cast and appear solid without serious porosity. Artifacts came from the Riverside, MI Archaic (1000 BCE) site.

Figure 4. Riverside, MI copper artifact shown in Figure 3 and displaying a "normal" surface typical of the OCC. Internal porosity defines it as a casting.

Figure 5. A copper spear point MPM #53674/18962 from the Osceola, Wisconsin site. This point was cast but appears simply hammered and polished.

3. A third test is Xeroradiography (Figures 2,3,6,7). It is a non-destructive X-ray technique using an electrically charged, selenium plate placed below the X-rayed artifact. The X-ray exposed plate enhances the radiographic image and emphasizes casting porosity/ bubbles in the metal. This is called "edge enhancement" or "edge contrast" The image appears as dark, well-defined moth-eaten areas on the selenium plate image. Xeroradiography is infinitely more accurate than standard X-ray/film processes which, at best, leave fuzzy, difficult to interpret images. The xeroradiographic plate displays the radiographic image which is later photographed or transfered to paper and examined. The plate is then wiped, recharged and used again. Medical mammograms use xeroradiography. (Neiburger 1984,1992)

Evidence of multiple circular gas bubbles in the metal is diagnostic for casting since naturally occurring voids in the metal (e.g. float copper, wrought worked-folding laps) generally appear ovoid or longitudinal; seldom circular and never in quantity).(Figures 2,3,6,7) Round voids usually form from gases trapped in the molten metal as it solidifies.(Figures 2, 3,6,7) Copper is notorious for producing hydrogen bubbles from chemically reduced water associated with the mold and casting environment; especially in sand casting which uses damp sand and leaves no intact molds after the process. Xeroradiography is labor intensive and expensive. It requires a significant amount of skill to adjust the X-ray machine power settings (voltage, amperage) to get a clear image that can be interpreted.

A number of artifacts showing signs of casting using these analyses end up as being classified as clever fakes either because they were recently made or they have no provenance (e.g. found in a field with no cultural identification). Modern manufactured fakes (early 1800s-present) are always a consideration because of the high monetary value associated with all OCC relics.(Martin, 1999) The easiest way to make high quality fakes (reproductions) is to cast them. This is why it is important to identify the site and culture associated with the artifact.

To date, there are several dozen cases of prehistoric copper casting found in the Midwest and only two cases where the artifact has been connected with an established site (Neiburger, 1984, 1992):

1. A lump of copper was found at Turner Mounds, Ohio (Hopewell) which was cast "Hot Short" (hot enough to slightly flow).(Figure 8) The partial melting of this artifact was determined by sectioning, etching and microscopic analysis. (Martin, 1999)

2. A second artifact was a lump of copper found at the Riverside, MI (Archaic) site which appears to have been thoroughly melted-cast using Xeroradiographic analysis (Neiburger, 1984, 1992).(Figures 3,4) No other "documented" cases of prehistoric casting have been reported. *Until now.*

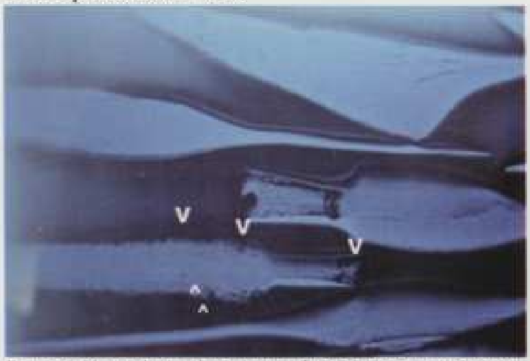

Figure 6. Xeroradiographic images of OCC copper implements. The 4th point from the top (arrows) is the #53674 Osceola point. It shows a "worm eaten", multi porosity (arrows), image consistent with casting as a mode of manufacture. The point above it contains the same type of casting porosity though it was a random surface find from another Wisconsin site. All other copper artifacts pictured appear wrought worked (hammered), solid and show little porosity. These were not cast.

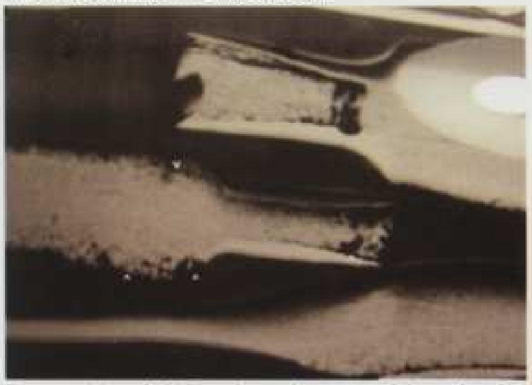

Figure 7. Magnified Xeroradiographic image of the surface find (top) and Osceola #53674 spear point (bottom). Note the many areas of porosity-bubbles and other defects attributable to casting.

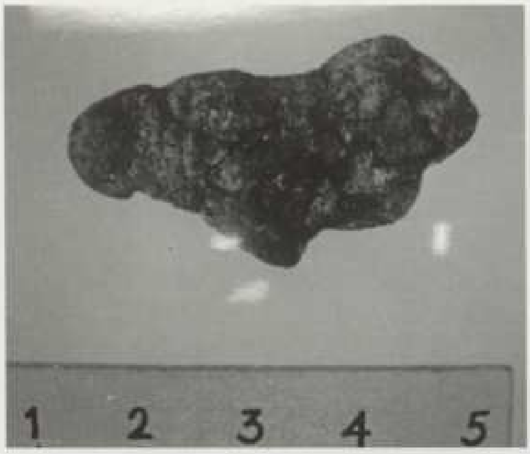

Figure 8. Turner Mounds, Ohio lump of copper. This artifact came from a Hopewell mound and was analyzed as being partially melted ---"hot short". This demonstrates that the Hopewell Indians had high heat technology and could melt metal.

OSCEOLA SITE COPPER CASTINGS

In the late 1970's and 1980s I had a wonderful stroke of good fortune. I became curator of anthropology at the Lake County Museum. Because of this connection, I had:

1. been offered the expertise of John Longabaugh, chief metallurgist for Outboard Marine Corporation and National Director for Die Cast Engineers Association and his Xeroradiography lab (one of the largest in the nation).
2. been given access to the entire Old Copper Culture collection of the Milwaukee Public Museum (MPM).
3. sufficient free time, funds and energy to make things happen.

Over several years, I officially borrowed large numbers of Old Copper Culture specimens from the MPM with the help of Nancy Lurie, department chairwoman. I took them to OMC's Waukegan, Illinois plant and had John Longabaugh Xeroradiograph them and analyze the images. Having trained as a metallurgist /microscopist myself, long discussions over the artifacts ensued. John's specialty was non-ferrous metallurgy (copper, aluminum, non-iron). OMC's outboard motors were made out of primarily cast aluminum alloys which suffered tremendous wear and stresses, thus the need for a metallurgical, Xeroradiography lab and an engineer of his talents.(Figures 1,2) My specialty, being a chemist and dentist, was with the noble-related metals (e.g. gold, silver, copper,). Artifacts were selected and X-rayed randomly. (Figure 6) Considering the prevailing archaeological theory, that the OCC people did not have the skills to melt metal, there were big surprises.

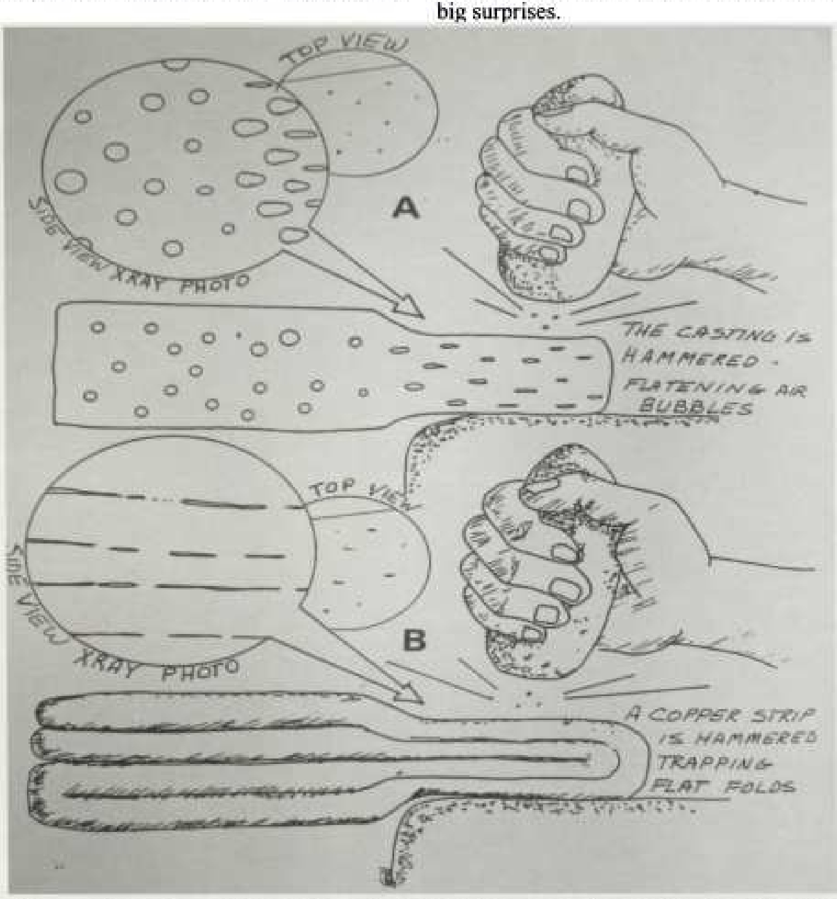

Figure 9. Artist's rendition of how casting porosity can be altered by hammering. A process done to many castings.(H. Gill)

SPEAR POINT 'G':

One of the surprises was the discovery of gas bubbles in a copper spear head/point from the Osceola site. (Figures 5,6,7) This porosity was identical casting bubbles found in some of OMC's cast aluminum engine blocks. The spear point, or tanged knife, was found at the site and given the MPM accession number of 53674/18962. Its accession card was missing from the files. The point was 15.5 cm (5 inches) long and 2.5cm wide (1-1/4 inch). It was 3mm thick at an elevated ridge running down the length of the blade with the copper sloping-thinning out towards each edge. The point was a socketed, ovate- shaped blade that was beveled on both edges. It weighed 45.9 grams. The artifact was covered in a thick greenish patina of copper carbonate-oxide showing numerous areas of corrosion and pitting similar in texture and color to other Osceola copper artifacts. It appeared to be a standard type of OCC, hammered, copper point or knife with no visual evidence that it was cast.(Figure 5)

The Xeroradiograph of the artifact tells a very different story.(Figures 6,7) Unlike other copper points, which show a hammer-only mode of manufacture (solid body with occasional oblong voids), this point was filled with porosity from gas bubbles; evidence of casting. The artifact showed a mottled, worm eaten-like appearance on the Xeroradiograph.(Figures 6,7) It appeared on the edges (an occasional visual artifact with Xeroradiography). It also appeared on the tang and well into the body of the metal point. Longabaugh and I recognized that the point was cast and then hammered and polished during a finishing process.(Figure 9)

BIG AWL 'H':

One of the numerous (33) copper awls was MPM 53281/18709. It was a large awl 21.4 X 1.0 X 1.0 cm. It weighed 90.3 grams. This artifact was a long, hefty tool with pointed ends and a thick cover of green copper carbonate patina over a brown copper oxide coated surface. The patina was similar to the other OCC artifacts found at the sight. It was unique because its cross sectional shape was square with four flat sides rather than the usual OCC rounded (bar-like) edges.(Figures 10,11)

On one end, about 3-4 cm from the tip, were a series of slightly curved, parallel elevations of metal extending out from the surface and running at a 45 degree angle to the length of the artifact. These were flow lines consistent with the progressive solidification (expansion and contraction) of molten copper metal as it cooled. These kind of flow lines are diagnostic for casting.

The flow lines were composed of approximately 10 elevated striations. They were slightly curved, and did not show any sign of wrought working such as cutting or filing.(Figure 11) They were positioned at an angle (45 degrees) to the long axis of the awl which precludes their creation by selective corrosion or weathering. "Worm tracks" are jagged, random shaped elevations of corroded copper that usually run along the long axis of a copper artifact. "Worm tracks" are often found on OCC artifacts. These flow lines were smooth, relatively straight and positioned at oblique angles to the artifact's axis. The flow lines were not "worm tracks". (Figure 11)

The appearance of two sets of multiple, parallel, striations, on opposite sides of the same end of the Osceola awl, suggest that the artifact was cast, allowed to harden in the mold and lightly finished (hammered, polished) thus preserving the flow lines which, otherwise, could have been easily flattened or smoothed away. Xeroradiographic analysis was incomplete.

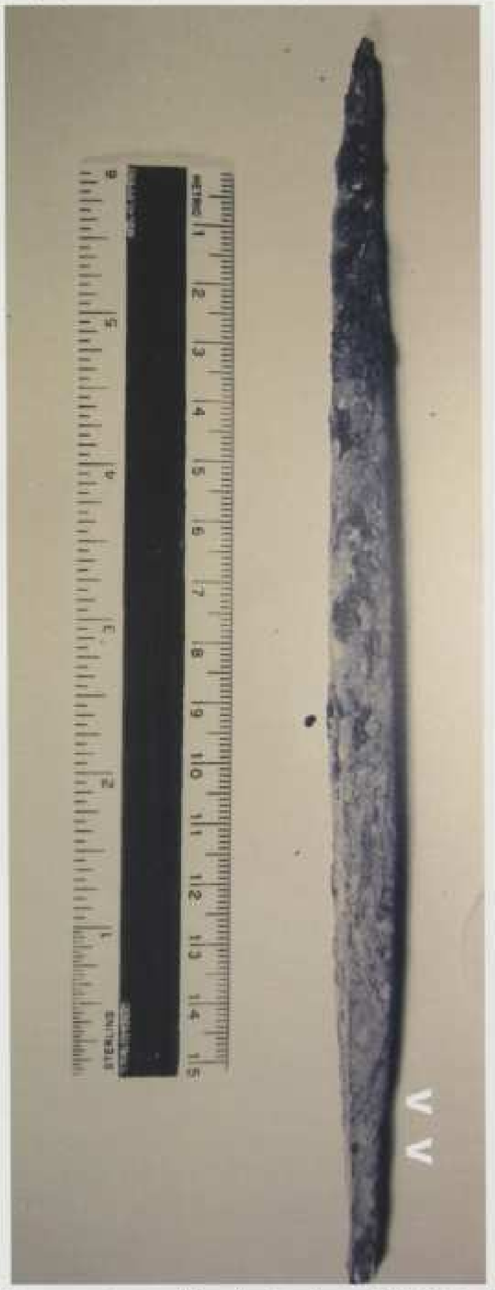

Figure 10. Copper awl from the Osceola site MPM#53281. Note the irregular shape of the corrosion caused "worm tracks" (center) as compared to the flow lines (arrows).

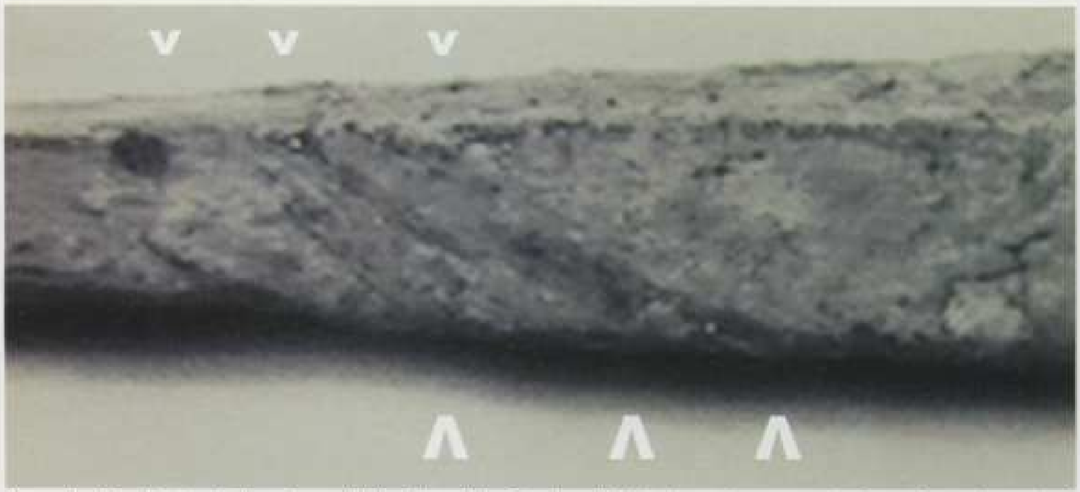

Figure 11. Magnification of elevated, parallel flow lines of the Osceola awl indicating casting as a mode of manufacture. (arrows) It is impossible to create these imperfections by wrought working only. Sawing or polishing will create only straight indentations in the metal, not curved elevations.

MANUFACTURE

No one will know exactly how the artifacts were made but this metallurgical analysis gives us good hints. Some artifacts possess a shape that is very difficult to produce using simple hammering/polishing. A recent study (Fregni, 2009) suggests that casting was the most practical way of making Wittry Type 1 socketed spear-heads; like the Osceola Spear-head #53674 artifact. To cast, copper blanks were probably made by pouring molten metal into depressions made in damp sand. After the metal solidified, the castings were easily hammered into the desired shape and then polished/sharpened. In this case, the hammering was not sufficient enough to flatten, thus obliterate the casting porosity (Figure 9) or flow lines. (Figures 10,11) Other OCC spear heads could have been made by wrought working only (Figure 6).

Casting is an easy way to make similarly sized tools. Producing copper blanks is an excellent way of artifact production because the technology need not be exact nor sophisticated. Sand for the molds is plentiful and, incidentally, leaves no record for it disintegrates immediately after use. The forced air furnace, needed to melt the copper, crucibles to hold the molten metal and tuyeres (fire-resistant tubes that lead the air stream into the furnace) present another question. They are fragile and easily decompose after use. They are rarely found in Wisconsin. They do not appear at Osceola. Where are they?

Why is there only two castings at the site? It is infinitely easier to make multiple tools while casting than just one or two. If you go to the trouble to make a furnace, collect the copper, melt it and then cast, its only a little more effort to make 20 or 100 castings yet we find only two at this site. Were they the only ones made or were they traded and found their way into the Osceola camp?

In earlier times, archaeologists like Hoy, Perkins, Hamilton, Moorehead, Cushing, Squire and Whittlesey maintained that prehistoric Indians cast copper. Today, many archaeologists clearly believe that the primitive natives of the Midwest did not cast metal (Martin 1999, Ritzenthaler 1957, Schroeder 1968).

This report documents several artifacts that seriously question that theory. More to come.

ACKNOWLEGMENTS

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Note: The only digital editing or manipulation this author has done to the illustrations was to crop, duplicate and place arrows on the photo. No other enhancements were made.

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