Microanalysis of North American Woodland-Period Pottery

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INTRODUCTION

Around 3,000 years ago, a new technology was developing in the northeastern United States. This innovation, known as pottery, involved utilizing a highly pliable substance that could be molded into a broad spectrum of forms, textures, designs, and functions. Prior to 1000 BC, the ancient inhabitants were laboriously scraping and hollowing out vessels from soapstone or sandstone blocks [1, 18]. Now clay was being tempered, fired, or heated in the sun to produce a material that proved so durable, that today it is amongst one of the most important forms of archaeological evidence [11].

The Woodland pottery shards we examined were found in Monmouth County, New Jersey, which is located in the central part of the state. Since they were broadly dispersed on farmland, no definite dates can be associated with them - all that is known is they belong to one of the three Woodland Periods, a term used by American archeologists when referring to areas extending from Manitoba, Minnesota, Iowa, northern Missouri, eastward across the United States and Canada [18]. American archeologists often subdivide the Woodland Stage into three different periods to help distinguish the development of pottery technology and cultural changes [18]. At around 1000 BC the Early Woodland Period begins [6]. It is a time marked by the first significant use of pottery, which plays a critical role in the early inhabitants' culture. Soon after the production of pottery, an agricultural lifestyle centering around village life begins to form, mortuary ceremonialism being practiced, and the tobacco pipe and bow are invented [6, 18]. The earliest northeastern vessels are thick-walled, heavy, and easily broken when heated [6]. In contrast, Middle Woodland Period (1000-1500 AD) vessels are often thinner-walled, and more break resistant (Fig 1)[6]. Pottery from this period is being used to cultivate seeds, and is often decorated with classic Woodland styles of cord or net impressions [6]. By the time the Late Woodland Period (1500-2000 AD) ends, every human population in the Eastern Woodlands is relying heavily on wild vegetable foods, and usually only a small constellation of plants for most of their vegetable diet [6]. Such vegetables as corn, beans and squash are being cultivated, and large villages are flourishing with populations dwelling in longhouses [18].

Microanalyzing Woodland pottery shards gave us some very interesting insights, and a greater appreciation for what went into creating these ancient vessels. After closely studying the pottery, there is no doubt that the early inhabitants had a deep understanding of this ancient technology - it was not something arbitrarily created. The Indians of America were experts in the various clay bodies; they knew that clays cannot be worked in a pure state, and were likely to crack, or even burst during firing if they dried too rapidly [10]. To prevent cracking during firing, they used fillers (or temper) such as mica, crushed pottery, and shell fragments [10]. The inhabitants had to know exactly how much temper to add - too much would result in weakening the vessel after being fired, and too little would result in the pottery breaking while being fired. Interestingly, they seemed to have had an understanding of modern-day structural composites.

THE CONSTRUCTION OF WOODLAND VESSELS

Archeologists are often surprised by the lack of evidence for the potter's wheel in the Woodland culture [10]. Without the potter's wheel, the early inhabitants designed their vessels by first washing, pounding, and mixing clay with crushed stone, sand and shell, which acted as a binder or temper [4]. Central New Jersey tempers consisted of shale, feldspar, quartz, chert, and mica [4]. Temper has two main functions; when a vessel is being constructed, and clay is in its wet, plastic state, temper acts as a strengthening agent, and prevents the walls from collapsing in on themselves [7, 15]. During the early stages of fir-
ing, temper also facilitates drying by allowing water to evaporate more easily from the clay vessel in the form of steam, which reduces drying shrinkage [7,15]. It is critical that exact amounts of temper are determined while creating a vessel, because once the pottery has undergone firing, it interrupts the bonding of day particles by forming voids at the clay/temper interface, and therefore it has a weakening effect [7,15]. This is why coarse clay pots containing large amounts of temper are more prone to breaking than those of finer-composed temper [7,15].

Once temper was added, clay was then rolled into thin strips which were coiled and built up to form the vessel walls [4,6]. The coiling method was a common technique applied to most New Jersey pottery [4]. When the desired shape was obtained, the coil marks were obliterated by the use of a paddle (or beater) in conjunction with an anvil [4]. The paddle was a wooden tool that was used for shaping and smoothing vessels by a people who did not have the potter’s wheel [4]. Signs of this method can be detected by X-ray radiography, because it can impart characteristic particle orientation [4]. The pottery was then placed in bonfires, pits, or sun baked [4].

WOODLAND POTTERY SHARD MICROANALYSIS

To the unaided eye, the surface of the vessel appears extensively oxidized, as evidenced by red-coloring on the outer surface (Fig 2a). Energy dispersive spectroscopy (EDS) shows an Fe/O ratio of 0.6 (Fig 2b), in comparison to the freshly generated fracture surface, which had a ratio of 0.2 (Fig 2c). The higher Fe/O ratio on the shard surface suggests the oxidative environment known to exist where the samples were discovered. Over time, groundwater would leach out iron oxides from the surrounding soil and transport them on the shards’ surface. Since lower concentrations of iron oxide were detected on the fracture surface, this may simply be mirroring a concentration gradient, or it may be an indication that iron oxides were present as a contaminant when the vessel was constructed. The sample was also subjected to X-ray diffraction (XRD), which showed the vessel shards were composed of three phases: illite (KAl\textsubscript{4}(Si\textsubscript{4}O\textsubscript{10})(OH)\textsubscript{8}), quartz (SiO\textsubscript{2}), and magnetite (Fe\textsubscript{3}O\textsubscript{4}).

Optical microscopy showed the presence of large, angular grains randomly dispersed in a fine-grained matrix. Theses large grains, which ranged in size from approximately 200 μm to 2 mm in diameter, functioned as the temper (Fig 3a). By utilizing X-ray microanalysis in the spot mode (resolution 1 μm) along with XRD data, we were able to determine that the temper was composed of quartz, and the surrounding matrix was made up of illite and iron oxide.

We performed quantitative image analysis (QIA) to find the percent area coverage of temper on the shard surface. Figure 3b shows a binary image superimposed on an optical image, which shows the percent area coverage to be around 16% temper. Since the distribution and size range appeared similar on all fracture surfaces examined, we extrapolated to three dimensions, and concluded that the 16% temper area coverage translates to approximately 16% temper by volume.

In order to find out the degree of heating the shards were exposed to, we resorted to scanning electron microscopy (SEM). Prior to examination by SEM, the fracture surface was coated with approximately 100 angstroms of gold for electrical conduction. As seen in figure 4a, we found the matrix to be composed of flake-like particles ranging from the nm to μm range. In many areas we observed the presence of numerous large pores. In most of the areas we examined, the grains were layered and compacted, however, some sample areas may have experienced enough heating to produce grain fusion (Fig 5). In Fig 5 we can see μm-sized grains that appear to be composed of “sintered” subgrains. The margins of both grains are not sharply defined, which we interpreted as an indication that sintering took place. Based on the microstructural evidence, we think sintering was limited to local regions, due to high amounts of porosity that inhibited the grain fusion process (Fig 5). Other important factors known to affect sintering are non-uniform, irregular heating patterns that the shards were exposed to, which is a characteristic of the open-firing methods the early inhabitants utilized.

Advanced firing methods utilizing kilns were being used in Europe contemporaneously with Woodland pottery that was being placed in bonfires, pits, or sun-baked [7,4]. The open-firing methods of bonfires and pits are characterized by high heating temperatures that often fluctuate (due to outside elements), and last less than an hour (depending of the type of fuel used) [9]. Pit firings normally last longer than surface bonfires because they are usually ignited from the top or side, and the fire takes longer to burn to the bottom of the fuel stack [7]. Also, the walls of the pit retain heat, which ensures a longer cooling period than what occurs in surface firing [7]. If such open-firing methods were used, the shards would have probably been exposed to temperatures in the range of 650-900°C [7,15]. This temperature range would ensure the removal of the hydroxyl groups from the chemically combined water in the clay molecules [7,15]. Once this occurred, the clay would irreversibly harden [7,15].

MODERN-DAY EARTHENWARE MICROANALYSIS: A COMPARISON

As a means of comparison, we examined a fracture surface on a modern piece of earthenware to compare the grain structure and chemical composition with that of the ancient vessel. XRD shows the shards contain kaolinite (Al\textsubscript{4}(Si\textsubscript{4}O\textsubscript{10})(OH)\textsubscript{8}) and quartz (SiO\textsubscript{2}), and small quantities of magnetite (Fe\textsubscript{3}O\textsubscript{4}). Since kaolinite becomes plastic with the addition of water, and it has the ability to be fired into a dense, hard mass in the presence of fluxes, it is often a prime ingredient in many of today’s ceramic products [9].

EDS analysis was also performed on the fracture surface and compared to the Woodland vessel. The modern ceramic had a much lower...
(a) SEM images from the fracture surface of the ancient vessel shard. The platy morphology is consistent with a clay composition.

(b) SEM images obtained from the fracture surface of a contemporary earthenware showing extensive sintering as well as porosity.

CONCLUSIONS

Microanalysis of the pottery shards has brought us a step closer into understanding how Woodland-Period vessels were constructed. Not much work has been done on the microstructure of Woodland pottery, and there is no doubt that more studies relating to the level of technology the early inhabitants reached with ceramics will bring many new surprises.

The most interesting fact is the ancients created sophisticated "composite materials," if we consider the established definition of a composite as materials in which the volume fraction of the minor phase is at least 10 or 15% [1]. Remarkably, the percent area coverage we studied with the Woodland shards falls close to the modern-day range.

REFERENCES


