Evidence of Heat Affectation in 19th Century Ceramic Wares: An Experimental Study

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Archaeological Methods

Abstract.

The Market Street Chinatown Archaeological Project has been working since 2002 to catalog, analyze, curate, and publish the assemblage of materials collected from the former location of the Market Street Chinatown in San Jose, which was destroyed by arson in 1887. Unfortunately, the conditions of this archaeological investigation were not conducive to recording provenance accurately, and it is difficult to determine which materials may have been in standing structures at the time of the arson versus which would have been burned in regular, open-air, small-scale trash disposal fires. To provide tools for conducting this analysis, we have conducted an experiment subjecting ceramic sherds of two ware types (Asian Stoneware and Improved Whiteware) to temperatures approximating these conditions for different increments of time and analyzed the visible effects of these heat treatment trials. Our preliminary results document consistent changes in hardness and glaze surface bubbling across ware types. We demonstrate that little change overall can be observed in the Improved Whiteware sherds, but apparent color change in the Asian Stoneware sherds may be used to distinguish between contexts from a household trash pit versus those deposited in the arson event.

Background.

In the middle and late nineteenth century, the Market Street Chinatown in San Jose consisted of a settlement occupying two city blocks and housing about 1,000 Chinese men, women, and children. On May 4, 1887, however, the Market Street Chinatown was burned to the ground by an arsonist who was never identified (Yu 2001).

The remains of the Market Street Chinatown were rediscovered a century later when construction began for a new Fairmont Hotel in downtown San Jose. The Chinese-American community in San Jose objected to the unchecked disposal of the emerging artifacts, and in response, the San Jose Redevelopment Agency appointed Archaeological Resource Services to oversee the construction and to document—as much as possible—the features and materials being uncovered by bulldozer. Unfortunately, the excavation data and recovered materials were not analyzed or reported at the time; moreover, the conditions of this archaeological investigation were not conducive to recording provenance accurately (Voss 2004).

In 2002, the Market Street Chinatown Archaeological Project began in an effort to catalog, analyze, curate, and publish the assemblage. An ongoing problem for the team is attempting to understand collections of artifacts without knowing the depths at which they were found, or their relationships to each other *in situ*. This experiment is an attempt to provide additional analytical tools in this endeavor.

It should be noted that other experiments dealing with heating ceramics usually focus on thermal properties like heating effectiveness or thermal-shock resistance (Bronitsky and Hamer 1986, Schiffer 1990, Tite 1999, Young and Stone 1990), not on the visual markers exhibited by sherds that have been heated. This experiment therefore answers questions of broad relevance to archaeological sites with evidence of either large or small burning events.

Research Question.

With this experiment, we wish to determine whether the ceramics that were deposited as part of the arson fire in 1887 can be distinguished from those deposited before this event. Evidence of heat affectation, apparent on several sherds in the collection, seems a promising approach—but this fire-clouding, crackling, bubbling, and spauling could also have been conceivably produced by regular, open-air, controlled fires in the trash pits behind the tenements. This was a known method during the nineteenth century for ensuring the sanitation of household trash pits (Voss 2008). Therefore, the research question we hope to answer is whether the heat affectation we see was caused by arson fire, trash pit fires, or both, in order to gain insight into the depositional contexts of the many components of the assemblage.

Experiment Design.

Arson fires that burn down houses and small-scale, open trash fires burn at different temperatures and for different lengths of time. Past experiments have determined that the base of a small open fire burns at a temperature of about 1600°F (Audoin et al 1995; Cox and Chitty 1980; McCaffrey 1979; Smith and Cox 1992; Yuan and Cox 1996), whereas an arson-created room fire will burn closer to 1900°F (ASTM E 119; Babrauskas and Williamson 1978). Trash pit fires can burn for a wide range of time, and we are not certain of the duration of the arson fire; moreover, burning could have persisted for different ranges of time in different areas.

In order to determine whether these different conditions would leave observable traces on the ceramic sherds in the collection, we used a Thermolyne oven to heat several sherds of different ware types, at 1500°F, 1750°F, and 2000°F for 30 minutes and 2 hours, respectively.

The sherds were placed inside the oven as it reached temperature, and allowed to cool inside the oven completely to recreate realistic fire conditions.

Two ware types were tested: Asian stoneware (of two distinct thicknesses) and European improved whiteware. Sherds were created from larger sherds and made to weigh 3-4 g. Before this heat treatment, sherds were subjected to a visual inspection that included measuring the hardness of the paste, the color of the paste (according to Munsell), the color of the glaze and of any decoration, along with evidence of any color, crackling, bubbles, flaking, or spauling of the glaze or decoration. Mass, maximum length, and maximum thickness of each sherd were also measured and recorded. All of these attributes were then also assessed after the heating, along with an evaluation of microscopic changes to the glaze surface. Sherds were photographed both before and after the heating in the oven.

Approval for the experiment was obtained from all of the community partners involved in the Market Street Chinatown Archaeological Project. The experiment was conducted at the Stanford Archaeology Center over the course of two weeks in May 2013.

Results.

The results of this experiment are given in the tables and figures shown below. Table 1 summarizes the changes in color observed as a course of this experiment. Table 2 describes the evidence of change in the hardness of each ware type observed during this experiment. Table 3 shows the appearance of visible changes in the glaze surface.

The tables are followed by photographs illustrating some of the most significant changes observed, as well as microscopic evidence of change as a result of these different heat treatments.

Table 1. Summary of Changes in Color Measured by Munsell When Heating Ceramics to Different Temperatures at Two Time Intervals

	1500°F, ½ hr	1750°F, ½ hr	2000°F, ½ hr	1500°F, 2 hr	1750°F, 2 hr	2000°F, 2 hr
Thin Asian Stoneware (paste initially 2.5Y 5/2—grayish brown) (glaze initially R-Y 2/5YR)	paste: 10YR 4/3 (brown) glaze: 10YR 2/1 (black)	paste: mottling between 2.5Y 3/2 (very dark grayish brown) and 5YR6/6 (reddish yellow) glaze: 7.5YR 2.5/1 (black)	paste: three faces 5YR 5/6 (yellowish red), one face 2.5YR 3/6 (red) glaze: 2.5YR 3/2 (dusky red)	paste: shaded from 7.5 YR 4/2 (brown) on glazed edge to 7.5YR 6/6 (reddish yellow) on unglazed edge glaze: 7.5 YR 2.5/1 (black)	paste: mottling between 10YR 3/3 (dark brown) and 5YR 3/8 (yellowish red) glaze: 7.5YR 2.5/2 (very dark brown)	paste: 5YR 6/6 (reddish yellow) glaze: 2.5YR 2.5/2 (very dusky red)
Thick Asian Stoneware (paste initially 2.5Y 8/4—pale yellow) (glaze initially 7.5YR 3/4—dark brown)	paste: 10YR 8/3 (very pale brown) glaze: 7.5YR 2.5/2 (very dark brown)			paste: 10YR 8/3 (very pale brown) glaze: 5YR 3/4 (dark reddish brown)		paste: 7.5YR 8/3 (pink) glaze: 5YR 3/2 (dark reddish brown)
Thick Asian Stoneware (paste initially 2.5Y 6/2—light brownish gray) (glaze initially 7.5YR 2.5/2—very dark brown)		paste: 10YR 7/4 (very pale brown) glaze: 7.5YR 2.5/1 (black)	paste: 10YR 8/3 (very pale brown) with some splotches of 2.5YR 3/6 (red) glaze: 10R 3/2 (dusky red)		paste: 10YR 7/4 (very pale brown) glaze: 7.5YR 2.5/1 (black)	
Improved Whiteware (paste initially R-Y 9/10 Y) (glaze initially R-Y 9/10Y)	paste: one face changed from R-Y 7/5Y to 7.5 YR 8.4 (pink) glaze: no change	paste: three faces 7.5YR 8/2 (pinkish white); two faces unchanged glaze: no change	paste: no change glaze: no change	paste: no change glaze: no change	paste: some staining immediately below glaze 2.5YR 5/8 (red) to 5YR 7/8 (reddish yellow) glaze: no change	paste: one face became R-Y 9/5Y glaze: no change

Table 2. Summary of Changes in Hardness According to Mohs Scale When Heating Ceramics to Different Temperatures at Two Time Intervals

	1500°F, ½ hr	1750°F, ½ hr	2000°F, ½ hr	1500°F, 2 hr	1750°F, 2 hr	2000°F, 2 hr
Thin Asian Stoneware	+1	+2	+1	+3	+3	+1
Thick Asian Stoneware	+3	+2	+1	+2	+2	+1
Improved Whiteware	no change	+2	+1	+2	+1	+1

Table 3. Visible Macroscopic Changes in Glaze Surface As A Result of Firing Two Ware Types at Three Different Temperatures for Two Time Intervals

	1500°F, ½ hr	1750°F, ½ hr	2000°F, ½ hr	1500°F, 2 hr	1750°F, 2 hr	2000°F, 2 hr
Thin Asian Stoneware	some surface scratches more apparent than before firing	very minimal bubbling	no change	some minimal bubbling	some minimal bubbling	some minimal bubbling
Thick Asian Stoneware	some minimal bubbling	crackling, some minimal bubbling	some minimal bubbling	bubbling	bubbling	crackling, some minimal bubbling
Improved Whiteware	normal whiteware crackling became more apparent	some minimal bubbling	some minimal bubbling and possible flaking	some minimal bubbling	some minimal bubbling	bubbling

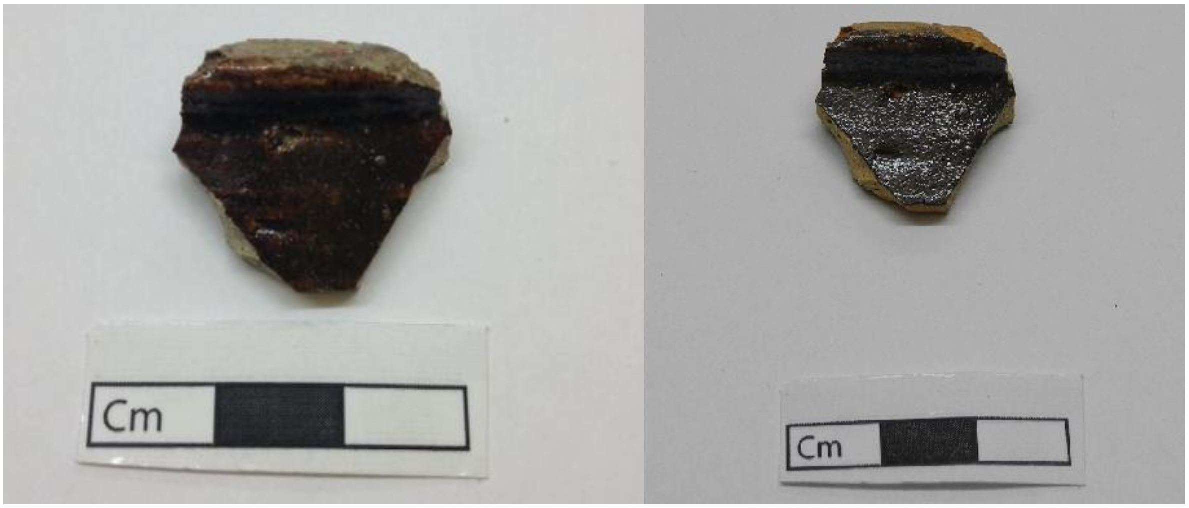

Figure 1. Thick Asian Stoneware Sherd before (left) and after (right) 1750°F, 2 hour trial. Exhibits evidence of darkening in paste and glaze.

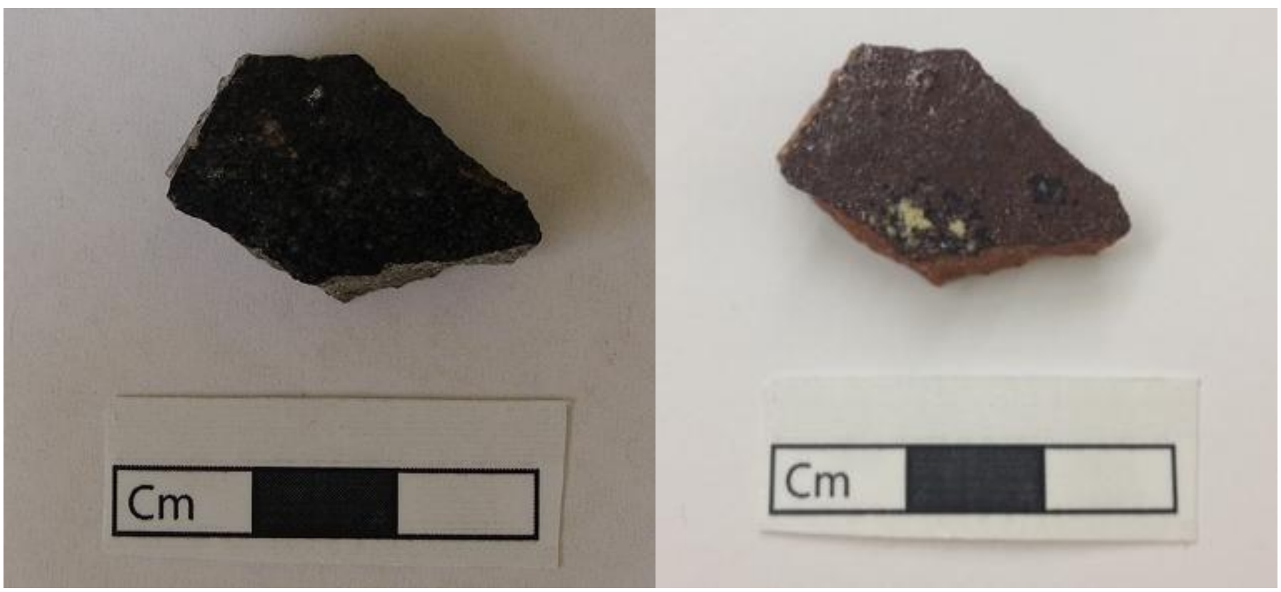

Figure 2. Thin Asian Stoneware Sherd before (left) and after (right) 2000°F, 2 hour trial. Exhibits evidence of reddening in paste and glaze.

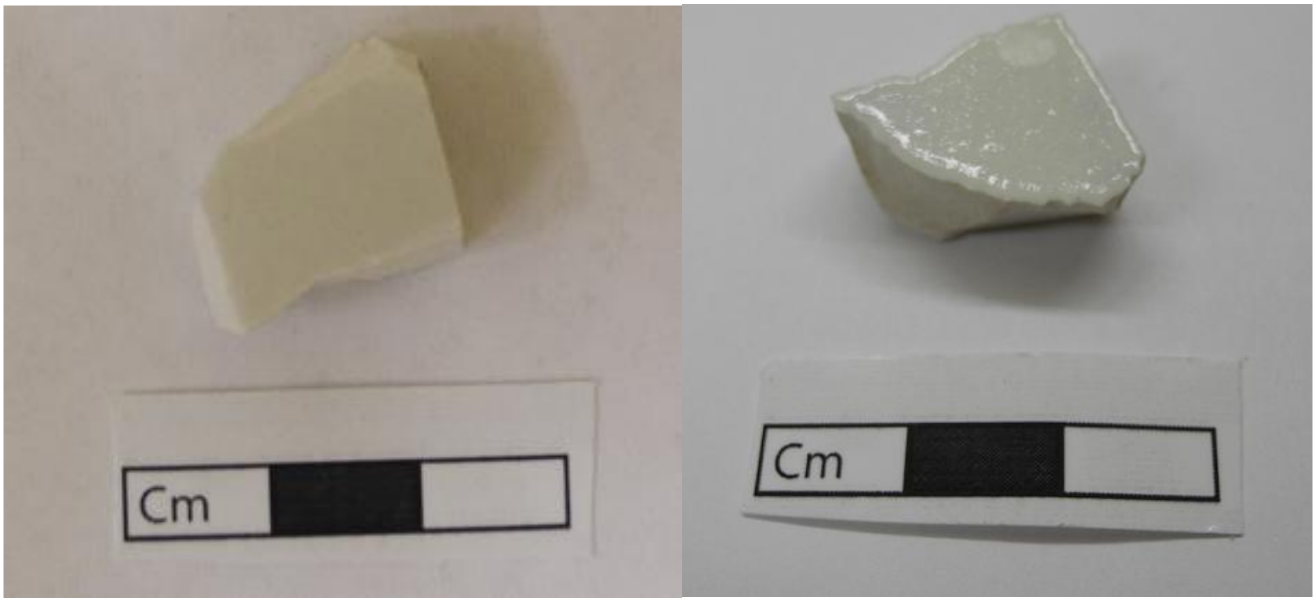

Figure 3. Improved Whiteware Sherd before (left) and after (right) 2000°F, 2 hour trial. Exhibits evidence of bubbling on glaze surface.

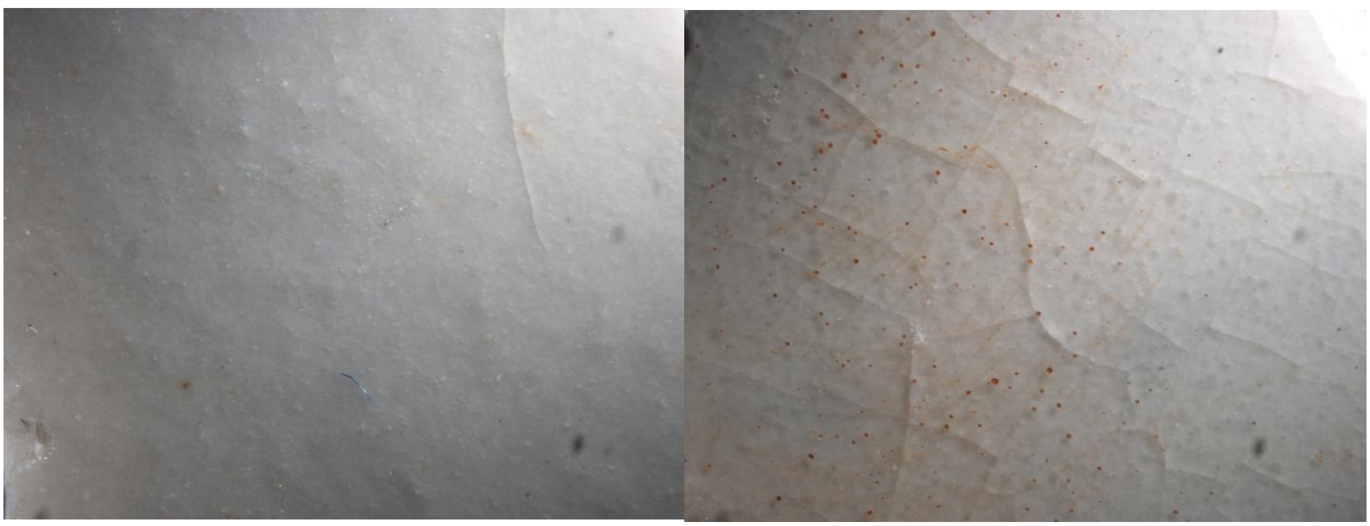

Figure 4. Improved Whiteware Sherd before (left) and after (right) 1500°F, ½ hour trial under stereomicroscope and magnified 7.5x. Shows evidence of orange speckling and crackling.

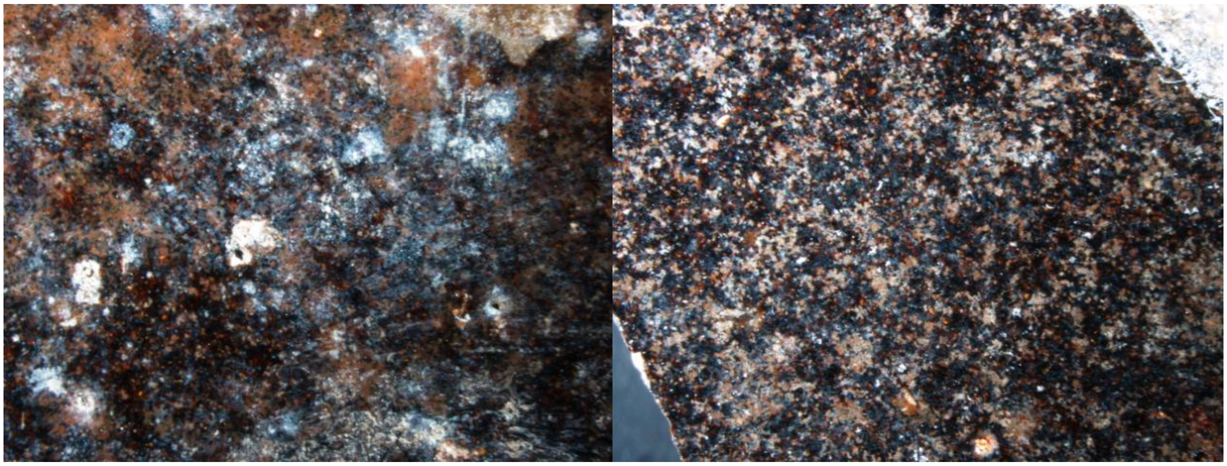

Figure 5. Thin Asian Stoneware Sherd before (left) and after (right) 1500°F, ½ hour trial under stereomicroscope and magnified 7.5x. Glaze appears more dispersed and less blended after treatment.

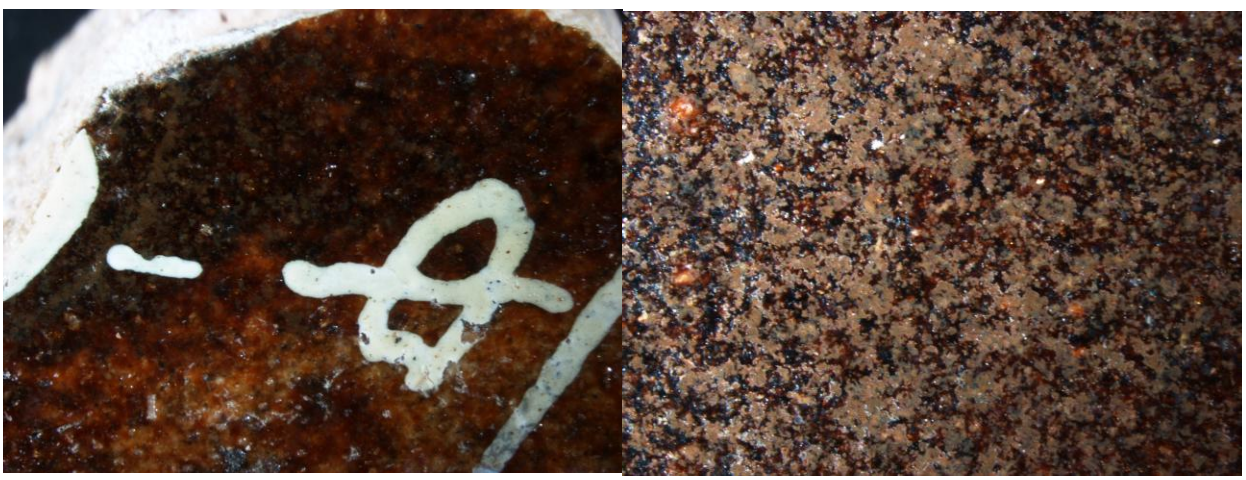

Figure 6. Thick Asian Stoneware Sherd before (left) and after (right) 1500°F, ½ hour trial under stereomicroscope and magnified 7.5x. Glaze appears more dispersed and less blended after treatment.

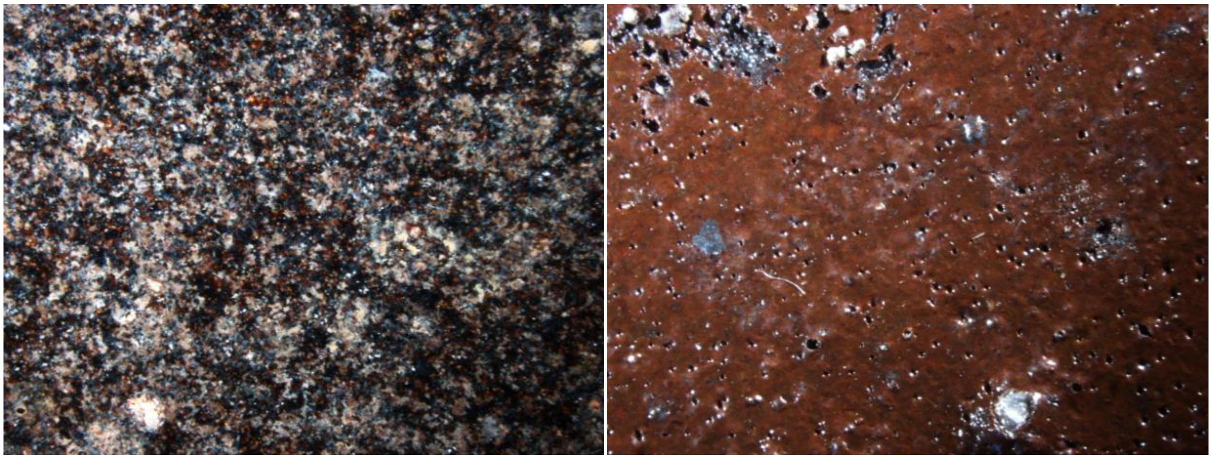

Figure 7. Thin Asian Stoneware Sherd after 1500°F, 2 hour trial (left) and after 2000°F, 2 hour trial (right) under stereomicroscope and magnified 7.5x. Glaze appears dispersed on the left, but blended and reddened on the right.

Discussion.

The results of this experiment suggest that the most obvious indicator of heat treatment for Asian Stoneware is color change, while heat treatment is overall extremely difficult to detect in European Improved Whiteware. The Asian Stoneware is furthermore a good indicator of differences in temperature, since the both the glaze and the paste darkened in the cooler trials and became redder in the hotter trials (see Table 1, Figure 1, Figure 2). In fact, when subjected to 1750°F (regardless of duration), which was our middle temperature, the thinner Asian stoneware tested exhibited mottling in the paste between darker brown color and reddish color. This likely represents an intermediate stage between a heat level that would turn the paste to a dark color (successfully achieved here at 1500°F) and a level which would turn it to a dusky red color (2000°F).

The Improved Whiteware, on the other hand, exhibited almost no macroscopic change overall in color in either glaze or paste, although in some trials selected faces showed some reddening. This alteration, however, is not predictable, as it occurred in both the coolest, shortest trial (1500°F for ½ hour) and the hottest, longest trial (2000°F for 2 hours)—and some but not all of the intermediary trials. It may have more to do with the random orientation of the sherd near a heating element in the oven, so that some faces heated up much more or at a faster rate than the others. When examined under a microscope, however, the whiteware exhibited orange speckling and crackling even at the heat trial with the lowest temperature and the shortest time (see Figure 4).

Hardness is a much more consistent indicator for heat treatment across ware types, as almost all sherds became at least somewhat harder after being fired (see table 2). Surprisingly, for all ware types, the least amount of change in hardness occurred when they were fired to 2000°F. This suggests that there may be a correlation between a hardening of the sherd and heating to a lower temperature. An alternative explanation is that between 1750°F and 2000°F, there may exist a sort of "flash point" at which the heat no longer works to harden the paste, but instead to enact other modifications in the ceramic body (e.g. the reddening visible in the Asian Stoneware). It is difficult to select between these analyses based on the evidence available, although the similarities between the results from the 1500°F and 1750°F trials do seem support the flash point explanation. More fine-grained experiment with heat treatments between 1750°F and 2000°F would need to be conducted in order to definitively make an assertion either way. Hardening, generally speaking, does seem to occur with heat treatment, however.

Bubbling of the glaze surface as well seems to be a consistent and predictable change that occurs with heating (see Table 3). In the case of the Improved Whiteware, bubbling seems to become more intense as either temperature or time is increased. The most extreme bubbling was observed when the sherds were heated to 2000°F for 2 hours (see Figure 3), and the least bubbling was observed in the half hour 1500°F trial. Minimal bubbling was observed in all of the less extreme trials, although it was always discernible under a microscope. For the Asian Stoneware, bubbling only seems to become more detectable as time is increased. In the sherds put through the half hour trials, the thin Asian Stoneware exhibits almost no bubbling and the thick Asian Stoneware exhibits only minimal bubbling. When we compare the two hour trials at the same respective temperatures, however, we see much more bubbling. An interesting phenomenon with the thicker Asian Stoneware is that at the 2000°F, two hour trial (the hottest and longest trial), we actually don't observe very much bubbling. Instead, we still only see minimal bubbling and instead the glaze starts to crack, something which also occurred in the 1750 °F, half-hour trial. This is not the pattern observed with the thinner Asian Stoneware; the difference may be explained by different glaze compositions or applications across the two vessels chosen for this study.

The Asian Stoneware exhibited additional glaze modification that was only visible under a microscope. In both the thick and the thin sherds, we can observe an evident change in the 'blendedness' or 'blurriness' of the glaze (see Figures 5 and 6). It appears that the heat may have caused some degree of separation between the components of the glaze, which then hardened when the sherd cooled. This was only true in the lower-temperature trials. In the 2000°F trials, the glaze appears smooth and uniform—even moreso than before firing, as well as exhibiting a distinct color change (see Figure 7).

Conclusions.

This study offers much in the way of better understanding the Market Street Chinatown assemblage, as well as having broader applicability for other historical archaeological projects looking to investigate the conditions of deposition of the ceramic sherds in their assemblage. The results presented here illustrate the difficulty of observing any evidence of heat damage in European Improved Whiteware. Increased hardness and bubbling in the glaze surface may be promising analytical traits for drawing these kinds of conclusions, but these characteristics are quite subtle and ultimately microscopic analysis is necessary in order to state with any certainty whether sherds of this ware type have been burned in a fire as part of their depositional history. For the Market Street Chinatown project, this suggests that the European Improved Whiteware sherds are unlikely to be very useful for identifying contexts subjected to the arson fire versus those burned as a part of normal trash disposal, since the changes in temperature and time do not provide us with solid analytical benchmarks by which to differentiate between the effects of a 1600°F backyard trash disposal fire versus a 1900°F arson fire on the Improved Whiteware. If the 'flashpoint' hypothesis regarding the lack of increased hardness in extremely hot fires is correct, this could be one potential future avenue for distinguishing between these contexts. Still, ultimately both hardness and bubbling necessitate comparative analysis between a controlled, untreated sherd and a heated one, which is not possible to do when the very research question is whether the sherd was heated or not.

Asian Stoneware, on the other hand, may be much more useful for identifying burnt assemblages within the Market Street Chinatown project and at other archaeological sites. Two different vessel types were tested in this study, and although they showed some different changes as a result of the same treatment, some broad generalizations can be made. As with the Improved Whiteware, harness may be a potential indication of the difference between these two burning contexts. The most dramatic changes in hardness appears to occur when Asian Stoneware sherds are burned at lower temperatures (1500°F or 1750°F). When they are fired at a higher temperature (2000°F) for the same amounts of time, there is instead apparent bubbling or crackling in the glaze surface, although the exact nature of these glaze surface changes varies by the characteristics of the glaze. This reduces its utility for distinguishing between the conditions of arson rather than those of regular trash disposal open fires.

A much more promising and predictable characteristic of the Asian Stoneware sherds is their changes in color according to heat treatment. Sherds from both vessels featured a distinct reddening of the fabric when heated to hotter temperatures, but exhibited a general darkening of the fabric at cooler temperatures. Mottling of colors in the paste occurs at the intermediate temperature, signaling that 1750°F is a point of change in how the heat affects the ceramic sherd. Since this temperature lies between the average temperature of a trash disposal open-air fire and that of an arson fire, this suggests that sherds with dark glaze and paste in the Market Street Chinatown assemblage would have been involved in normal trash disposal fires, whereas those with redder glaze and paste would have burned in the arson destroying the settlement.

Similarly, the glaze used on these vessels appears to darken at a lower temperature, but to become much redder at a higher temperature, no matter what the firing time is. This can be explained by microscopic examination of the sherds. At the lower firing temperatures, the glaze appears dispersed and heterogeneous (see Figures 5 and 6), suggesting that it has dissociated into different elements in its composition. When heated to 2000°F for the same amount of time, the glaze instead appears homogenous and red in color. This suggests that different physical transformations are occurring at these different temperatures, and that this could be a potential method for distinguishing between arson fire and trash disposal contexts. It seems that these microscopic changes appear to the naked eye simply as darkness or redness, but the difference is much starker when the sherds are magnified. For quick preliminary analysis, then, sherds can be sorted into hypothetical contexts according to darkness or redness, then the sorting can be easily confirmed with microscopic evaluation. Based on color change, hardness, and glaze surface modifications, therefore, the Asian Stoneware assemblage offers much in the way of giving evidence for provenience based on readily evident visual characteristics as well as changes that are microscopically discernible.

Another means of distinguishing between the conditions of an arson fire and those of smaller, personal open fires is based on observations we did not initially set out to record. In both of the trials where we fired the sherds at 2000°F, we found that the glaze of several sherds had melted and fused to the ceramic tray used with the Thermolyne oven. When we tried to remove the sherds from the tray, we discovered that a great deal of force needed to be used and in fact, a few of the sherds—especially the European Improved Whiteware—took off chips of the ceramic tray when they were finally pried off of it. Moreover, tiny pieces of the sherds sometimes broke off in the removal process. These changes recalled several sherds in the Market Street Chinatown assemblage which also have small pieces of ceramic from other vessels fused to them. It seems that heating the ceramics to 2000°F is sufficient to melt the glaze, and that in cooling, this glaze attaches extremely securely to objects with which it has contact. This was not observed when the ceramics were heated only to 1750°F, suggesting that this is an additional potential means of identifying contexts subjected to the very hot arson fire which destroyed the Market Street Chinatown in 1887.

Other unexpected difficulties in the experiment are also worth noting, although they are not significant analytically. The variation in the sherds used in this study, even within a single ware type, according to shape, curvature, and glaze application, could complicate the generalizations we are attempting to make based on this limited experiment. We have done our best to account for this variation by documenting each sherd individually before firing and by choosing sherds with nearly identical weight. Still, this is an important possible factor to remember when trying to generate broader conclusions from these single trials.

More trials would certainly aid in making more secure conclusions. However, because this experiment necessitated the destruction of historic artifacts, it might be more productive and justifiable instead to conduct tests that more closely approximate the conditions of these heat damage situations. Specifically, tests with open air fires would be helpful, to determine if the changes observed in the course of this experiment (in particular the dramatic color changes) were only produced under the conditions of the Thermolyne oven, which functions by surrounding the sherds in red-hot coils. It does not allow for the flow of air over the sherds, and it administers a constant heat throughout the trial. None of these accurately mimic the real circumstances of either a trash disposal fire or the arson of the Chinatown. Achieving a sense of how flames and the flow of air impact evidence of heat damage in Asian Stoneware and Improved Whiteware would offer even more to the Market Street Chinatown team in identifying heat-affected sherds and in distinguishing between those in standing structures at the time of the arson and those burned in backyard trash pits.

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