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MISSION STATEMENT

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Class Size Matters: An Examination of Size Classes in Ceramic Bowls from Classic Era Sites in New Mexico

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Introduction

As archaeologists, we rely on our ability to sort artifacts into categories. These categories allow us to see patterns, date the artifacts we find, and relate assemblages over large distances. However, archaeologists rarely create types based on quantitative separations, which makes evaluating the categories and conclusions based on those categories, difficult (Spaulding 1953). We compound these problems when classes, types, and categories also lack explicit definitions (Dunnell 1971). Such problems occur in all aspects of archaeology (Dunnell 1971), but "new" fields of inquiry within the discipline are more susceptible to this behavior.

This lack of explicit definition or examination of units directly affects the archaeology of childhood. As with many other sub-disciplines of archaeology, an explicit definition of the units of inquiry remains largely undiscussed (Ramenofsky and Steffen 1998). Kamp's (2001a) "Where have all the children gone?" encourages archaeologists to ask new questions but does not necessarily examine the ways we might answer those questions. This issue is important because an investigation of the units used to answer questions about childhood may demonstrate that we are not answering the questions that we thought we were.

This study addresses this larger question of units and definition by investigating if size classes existed at sites in the northern Rio Grande region. For this study, I chose to examine the size of ceramic bowls because they are one of the first and easiest shapes attempted by child potters (Crown 2001), it is a relatively easy-to-define type, and it is a common form for ceramics in the northern Rio Grande region. I hypothesize that if small or miniature bowls, possibly related to child or novice potters (Smith 2006, Kamp 2001b), were a class of artifacts separate from other sizes, size distributions will reveal multiple modes, with peaks for small or miniature bowls separate from other vessel sizes. When this pattern is present, I separate the assemblage into different distributions and assess each distribution for normality centered on a desired size. I draw the hypothesis that size classes should follow normal distributions from Kamp's (2001b) data display and the idea that experts minimize the variation in their creations because of muscle memory and practice.

Background

This work builds on initial research into the question of bowl size categories (Przystupa 2012, 2013a, 2013b). Initial investigations into the question of size classes looked to see if there were discrete size categories within sites or if they appeared to be continuous (Przystupa 2012). Based on the samples from Pottery Mound and Sapawe, I concluded that size categories were continuous rather than discrete. Building upon this, I looked to see if, based on the samples from Pottery Mound and Sapawe, separate categories of "small" and "miniature" vessels existed and tested if those categories were statistically powerful (Przystupa 2013b).

I explored this question because of the use of small and miniature categories as separate and distinct terms in Kamp (2001b) (Przystupa 2013b). Kamp (2001b) suggested that children created most miniature vessels, mean diameter 45 mm with a standard deviation of 17 mm, while a mixture of child and skilled potters made small vessels, mean diameter 76 mm with a standard deviation of 20 mm. However, she did not explain how she created those categories or investigate the overlap in size between miniature and small bowls (Przystupa 2013b). This work expands both questions by looking for the existence of size classes at seven sites from the American Southwest.

The importance of this question lies in naming these size categories. Many studies that investigate learning in the past use children as the explanation for miniature versions of material culture (Kamp 2001b). A dictionary definition of the term miniature is "a small or tiny copy of something." This implies that the object has to be small, but also is a replica of some regular or normal-sized object. This does not necessarily imply anything about usability, unlike what Kamp (2001b: 437) suggests, but it does suggest a connection in shape between size classes and that these objects are small. Another caveat with the use of the term miniature is that, while some take it to mean children, miniatures are and were made for many more reasons than for or by children (Flechsig 2004). They can be used in special ritual circumstances or be usable for unique purposes such as paint pots. These caveats suggest that size should not be the driving selector when looking for evidence for child potters.

Methods

The following outlines the methods used on the bowls recovered from the sites listed in Table 1. The distribution of bowls did not always warrant the methods outlined below, so I varied the methods based on the visual distributions of the data.

Site, artifact, and variable selection

The key variable in this study was bowl diameter as measured from the inside of the orifice. Therefore, I selected sites based on their occupation in time, location within the northern Rio Grande region, specifically looking for sites between Sapawe and Pottery Mound as northern and southern boundaries; the accessibility of collections, the presence of bowls, and specifically the presence of bowls under 100 mm in size. These considerations control for variations in time, in space, and discriminations in recovery practices for sites excavated in the early part of the 20th century. I examined the sites in order from north to south as seen in Figure 1.

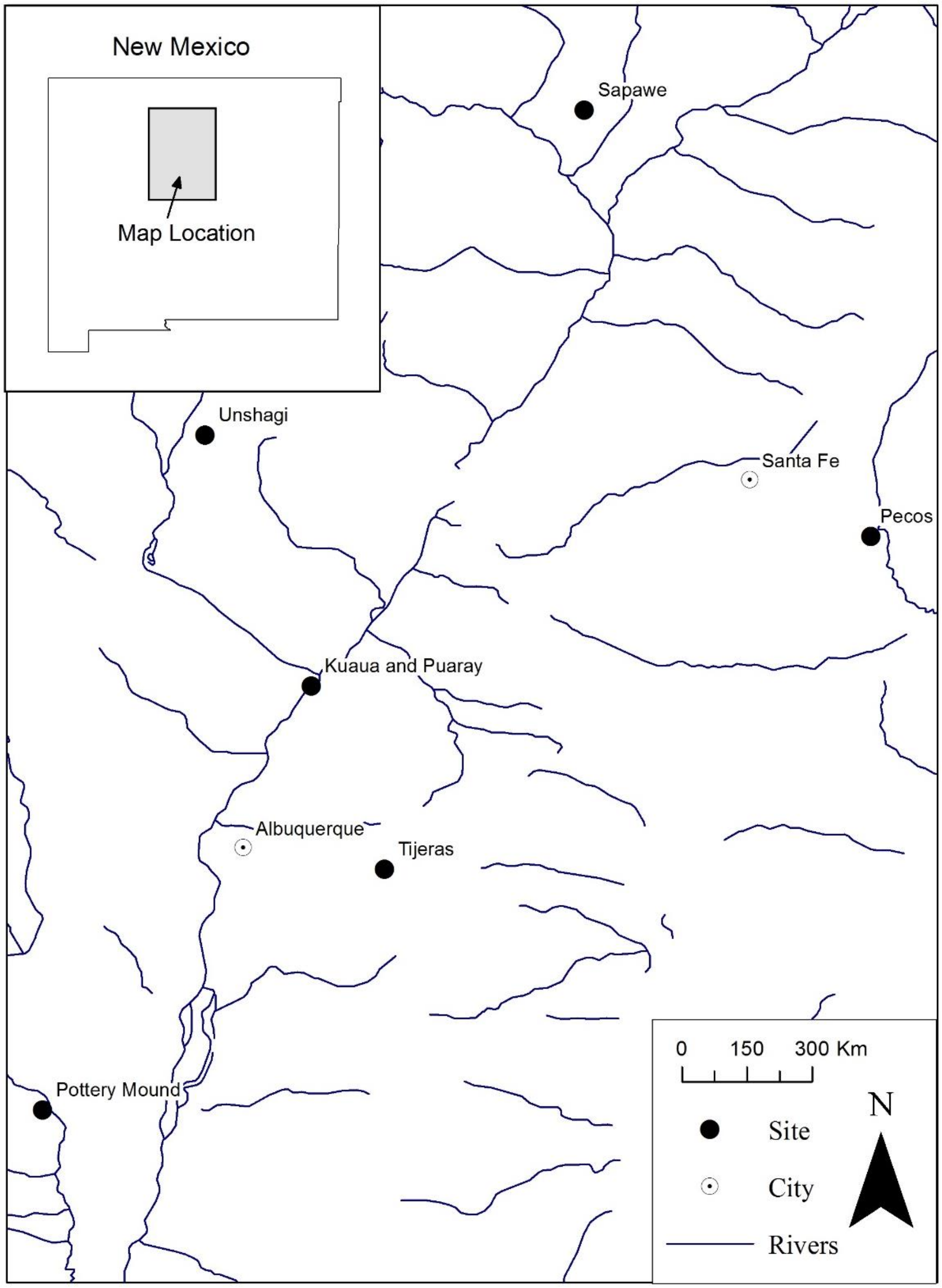

Figure 1. Map of study area.

Definition of size classes

For the purposes of this paper, the term small refers to any size class close to the minimum value of the entire distribution; large referred to the size class closest to the maximum value of the entire distribution, and medium was any size class between these two extremes or close to the halfway point between the minimum and maximum values. This paper focuses on the above three terms. I also applied the term miniature if there were two size classes close to the minimum value of the distribution and if the two followed normal distributions.

Based on the discussion of the size classes displayed in Kamp (2001b), I sought to define size classes as normal-like distributions. I determined the number of classes present in each assemblage based on visual assessment of the data and examining the number of modes in the histograms of diameter. I then used the different categories to construct means and standard deviations for the hypothetical normal distributions, which then defined those size classes. I took the existence of multiple modes as evidence for an underlying distribution based on multiple idealized size classes. If there was no clear pattern to the distribution, or if it displayed a normal distribution, I took this to indicate an absence of multiple defined size classes.

Multi-modal Distributions

I defined a multi-modal distribution as a distribution that had multiple modes of similar frequency. True multi-modal distributions have the exact same frequency for each mode but archaeological assemblages are rarely perfect representations of their populations so I consider all modes greater than half the first mode true modes.

Using these guidelines, I considered each mode the center of a normal distribution. Using this as a guideline, I divided the assemblage around these points including all the values that fell within an approximate normal distribution. I then used these ranges to separate the distribution into different size categories, to calculate a mean, and to calculate a standard deviation for each size category. After establishing the range for these categories, I used quantile-quantile plots to assess how normal the distribution was for a particular size category. If the distribution was multi-modal, and all modes demonstrated a normal distribution, I compared the entire distribution to an idealized distribution based on the calculated means and standard deviations.

I created this idealized distribution using a resampling program that iterates counting instances and returns a probability of how many times the idealized distribution will be indistinguishable from the observed distribution. The program created a hypothetical distribution based on a combination of values randomly picked from the multiple normal distributions. Then a Kolmogorov-Smirnov test compared the hypothetical distribution to the actual observations. The comparison between the hypothetical distribution and the observed distribution of diameters tested to see how likely the observed distribution was from a population that has a similar shape as the hypothetical distribution.

After the comparison, the program noted if the difference between the two distributions is significant at the level of 0.01. The program did this 1000 times and returned the number of times it was not significant over the number of iterations. This was the probability that the observed sample will be indistinguishable from a sample drawn from our hypothetical or idealized multi-modal distribution. Generally, the more similar they were the more likely that the observed distribution is a sample of this hypothetical population. The less similar they were, the less likely the observed distribution is a sample of the hypothetical multi-modal distribution. The program is an R-script and two versions, one for a bi-modal distribution and the other for a tri-modal distribution, are available by request from the author.

Following this assessment of the distribution, I assessed the statistical power of these size classes if there was overlap at one standard deviation between the classes. Statistical power assesses how easy it is to separate values between two different distributions by calculating β. β measures how likely a value from one distribution will be mistakenly identified as coming from a different distribution. The multi-modal distributions are compared to each other to see how "discreet" each size category from its next closest one. I calculated power using the normal distribution based on VanPool and Leonard (2010) and calculations using the student-t distribution were adapted from Llobera (2012). Alpha for all tests was set at 0.05 in order to balance a good value for alpha and to maintain a strong beta value in order to increase the power of all the tests. Figures and summary statistics were executed using Rstudio software.

Singularly modal Distributions

If the distribution was not multi-modal, I assessed its distribution for normality using a quantile-quantile plot based in order to compare size classes across sites, for example small to small. If the single mode is normal the distribution has only one size class.

Inter-site comparisons

I used the Kolmogorov-Smirnov rank sum test to assess similarity in distribution across all sites. This particular test was appropriate for this study because none of the overall distributions were normally distributed, they had small sample sizes, and I wanted to compare the different distributions at sites. I also compared size classes between sites using a paired student t-test. This test determines if the means from each site were drawn from the same population. I only tested between similar size categories, for example between the "large" vessels from each site, to see how the size classes at each site compared to one another.

Results

Entire sample

I measured 244 vessels from seven sites curated at the Museum of Indian Arts and Culture in Santa Fe and the Maxwell Museum in Albuquerque. The distribution of their diameters was very similar to the hypothesized distribution of small, medium, and large size of bowls as seen in Figures 2 and 3. There were three peaks, one at 55 mm, one at 190 mm, and one at 290 mm. These three peaks all appeared to have normal-like distributions and I used them to break the data into three separate normal distributions.

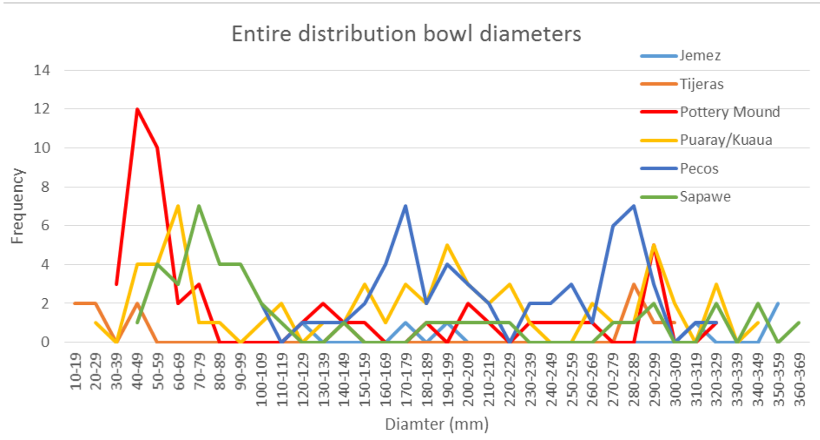

Figure 2. Line chart including all of the sites diameter distributions.

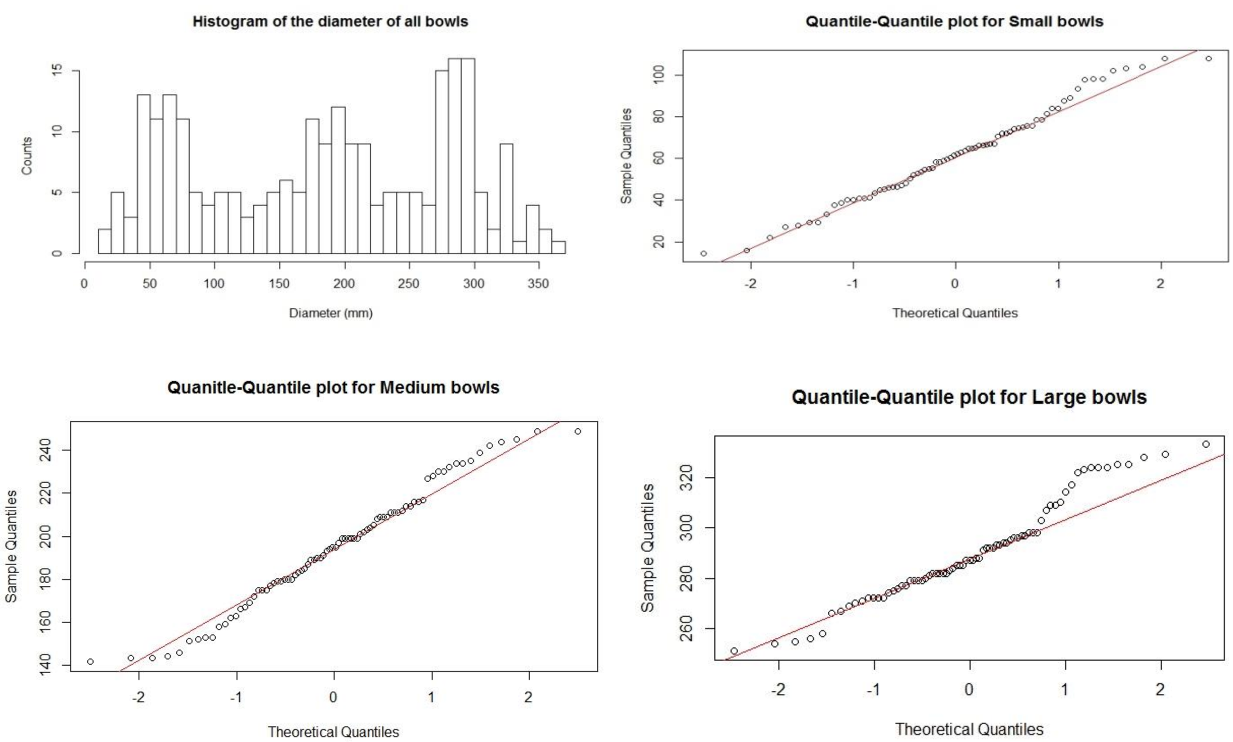

Figure 3. Whole distribution, histogram and quantile-quantile plots for large, medium, and small size categories.

The first distribution labeled here as “small” had a range of 14.31-107.97 mm, a mean of 61.77 mm, and a standard deviation of 22.57 mm. Using a quantile-quantile plot to assess its normality, seen in Figure 3, the distribution was very normal with slight skewing near the maximum and minimum values. The second distribution, medium, had a range of 141.55-249 mm, a mean of 194.37 mm, and a standard deviation of 27.92 mm. A quantile-quantile plot of the distribution suggests that it was very normal with slight skewing at the ends of the distribution as seen in Figure 3. The last distribution, large, had a range of 251-333 mm, a mean of 290.03 mm, and a standard deviation of 19.79 mm. A quantile-quantile plot of this distribution, Figure 3, was very normal at the center with heavy skewing at the edges. This suggested that the range selected was possibly too large, adding values that might not be part of the distribution.

Since the entire distribution was a combination of these three distributions, I compared them to a hypothesized distribution based on the above means and standard deviations. In comparison to this hypothetical distribution, about 98% of the time the two distributions will be indistinguishable from one another at a significance level of 0.05.

Sapawe

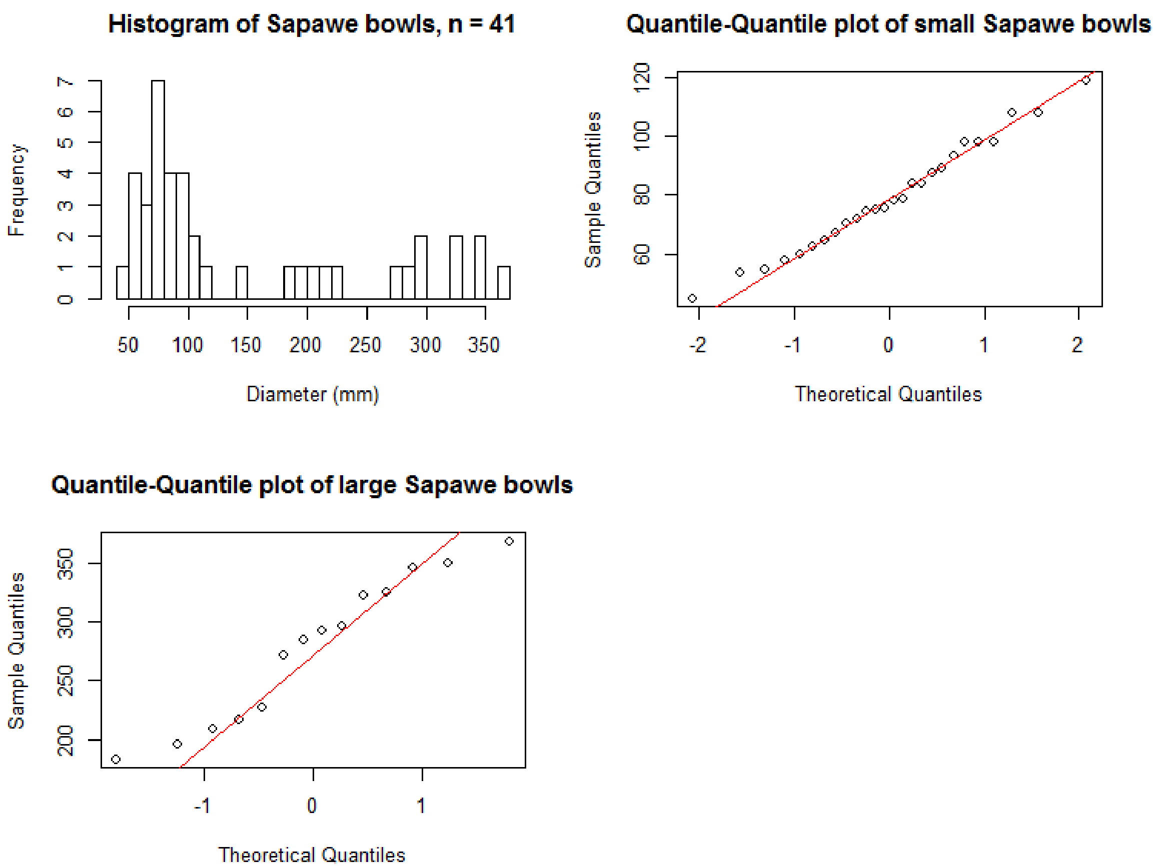

Figure 4. Sapawe bowl diameters, histogram and quantile-quantile plots for small and large bowls.

I measured 41 bowls from Sapawe, ranging in size from 45 mm to 369 mm in diameter. The majority of vessels were 70-80 mm in diameter, n = 7, and appeared to be the peak of a small normal-like distribution. There were no other peaks in the data as seen in Figure 4. Using this normal-like distribution as a guide, a “small” category ranged between 45 mm and 120 mm with a mean of 79.1 mm and standard deviation of 18.7 mm. Displayed in Figure 4 a quantile-

quantile plot demonstrated that the distribution was normal around the mean with skewing at the beginning and ending of the distribution. According to the definition of size classes defined above, Sapawe only had a small size class. Vessels over this size showed no discernable pattern and may reflect other behaviors at the site, excavation bias, or a lack of reconstructed vessels.

Unshagi

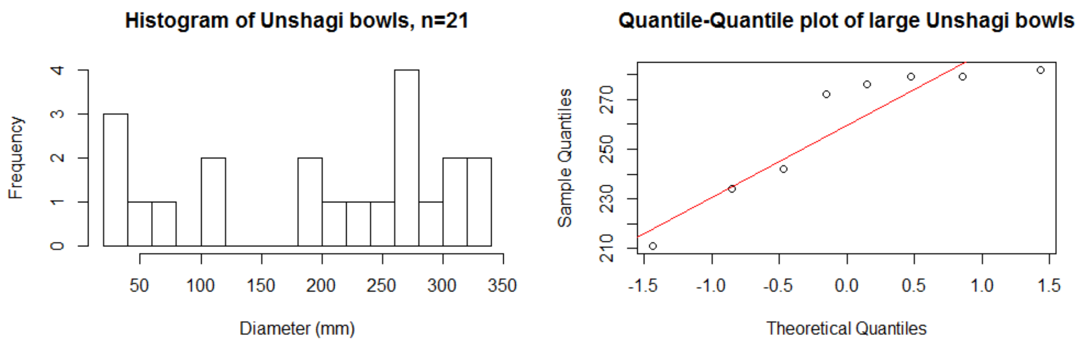

Figure 5. Unshagi bowl diameters, histogram and quantile-quantile plot of large size category.

I measured twenty-one bowls from Unshagi. They ranged in size from 27 mm to 325 mm. There were two modes, the first between 20 mm and 40 mm, n = 3, and another between 260 mm and 280 mm, n=4, as seen in Figure 5. Only the larger mode appeared normal like.

Using this normal-like distribution as a guide, a “large” category, ranged from 185 mm and 325 mm with a mean of 267.8 mm and a standard deviation of 46.5 mm. This category was tested using a quantile-quantile displayed in Figure 5 and demonstrated that the distribution is not very normal. It skewed across the normal quantile line seen in Figure 5. This suggested that this “large” size category was probably not reliable as a size category, as least as modeled by a normal distribution. This was probably an issue of sample size rather than a product of behavior at the site.

Other bowls from the Jemez region

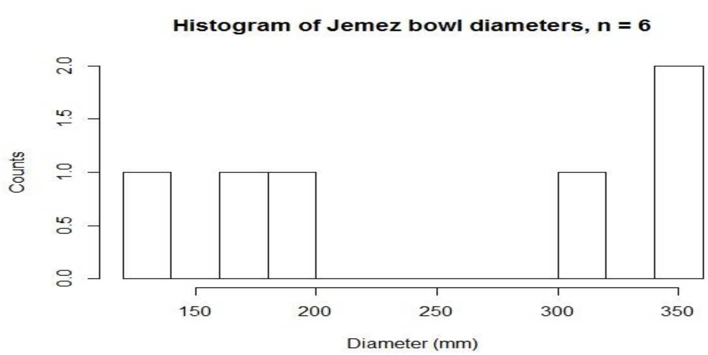

Figure 6. Jemez region bowls, histogram.

I measured six bowls from the region of Jemez Pueblo. There was one peak in the data between 340-360 mm, n = 2, as seen in Figure 6. The small sample size limited any patterning and no normal or normal-like distributions are visible in the data. This suggested that no size classes are identifiable at this site based on this sample.

Pecos

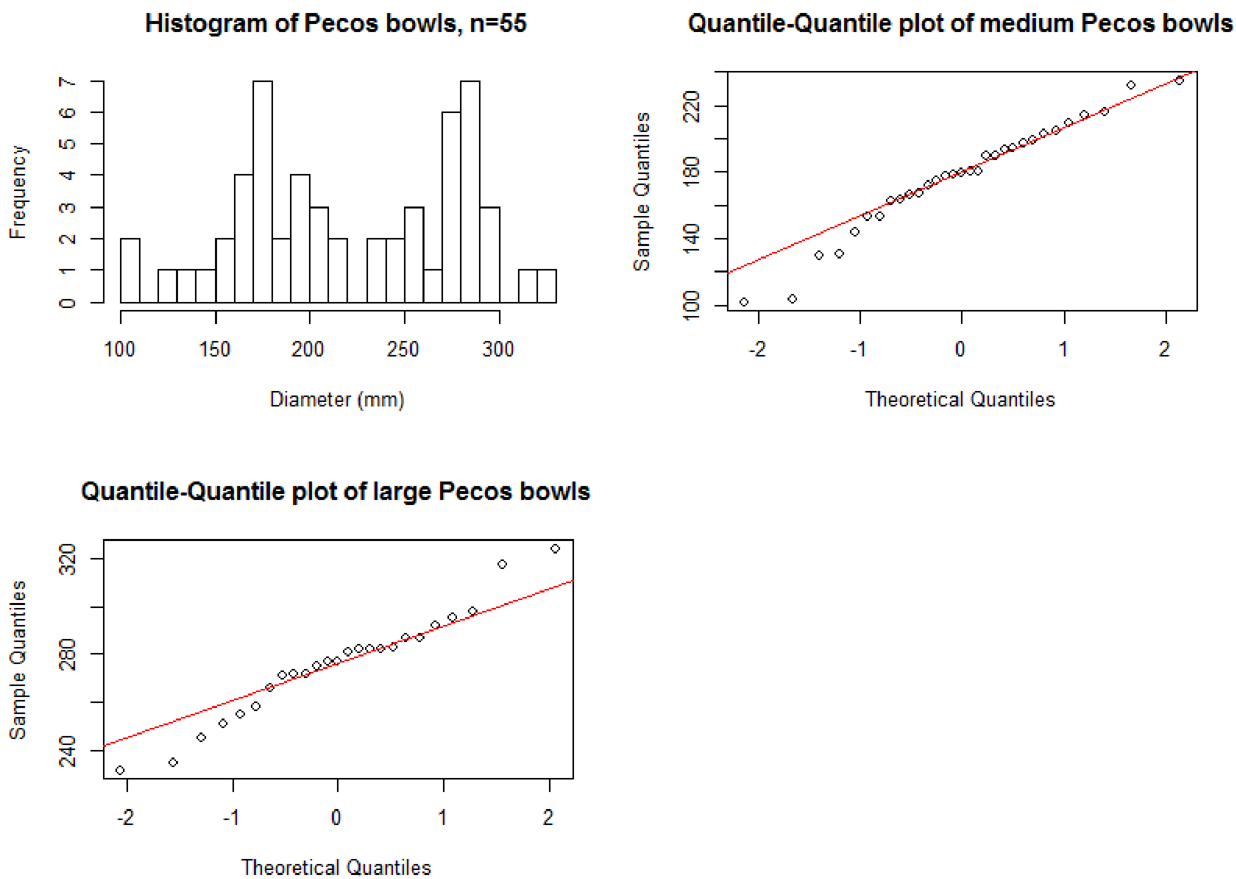

Figure 7. Pecos bowl diameters, histogram and quantile-quantile plots for medium and large bowls

I measured 55 bowls from Pecos. There were two peaks in the data, one between 160-180 mm, n = 11, and another between 280-300 mm, n = 10, as seen in Figure 7. Those familiar with Bagwell (2002) will note that this distribution was significantly different from the distribution displayed in Bagwell (2002: 105). This was because we used different collections. Bagwell's sample of vessels from Pecos included those from the Robert S. Peabody Museum of Archaeology and Pecos National Historical Park, with a focus on vessels in the Rio Grande Glaze Sequence (Bagwell 2002, personal communication).

Both distributions around these modes appeared normal-like and using this as a guide, there was a "medium" category, between 102 mm and 235 mm with a mean of 177.1 mm and a standard deviation of 32.6 mm. A "large" category lay between 245 mm and 324 mm, with a mean of 279.5 mm and standard deviation of 18.8 mm. Figure 7 demonstrated that these distributions were normally distributed especially closer to the mean with skewing occurring towards the edges. This suggested that these are reliable size categories.

To see how likely this sort of distribution was based upon two normal distributions with those calculated means and standard deviations the described resampling method was applied. The resampling method suggested that the observed distribution was a common sample of the hypothetical distribution, almost 100% of the time. Substituting the standard error for the standard deviation decreases this to about 73% of the time, which still suggested that these are reliable size categories.

Kuaua and Puaray

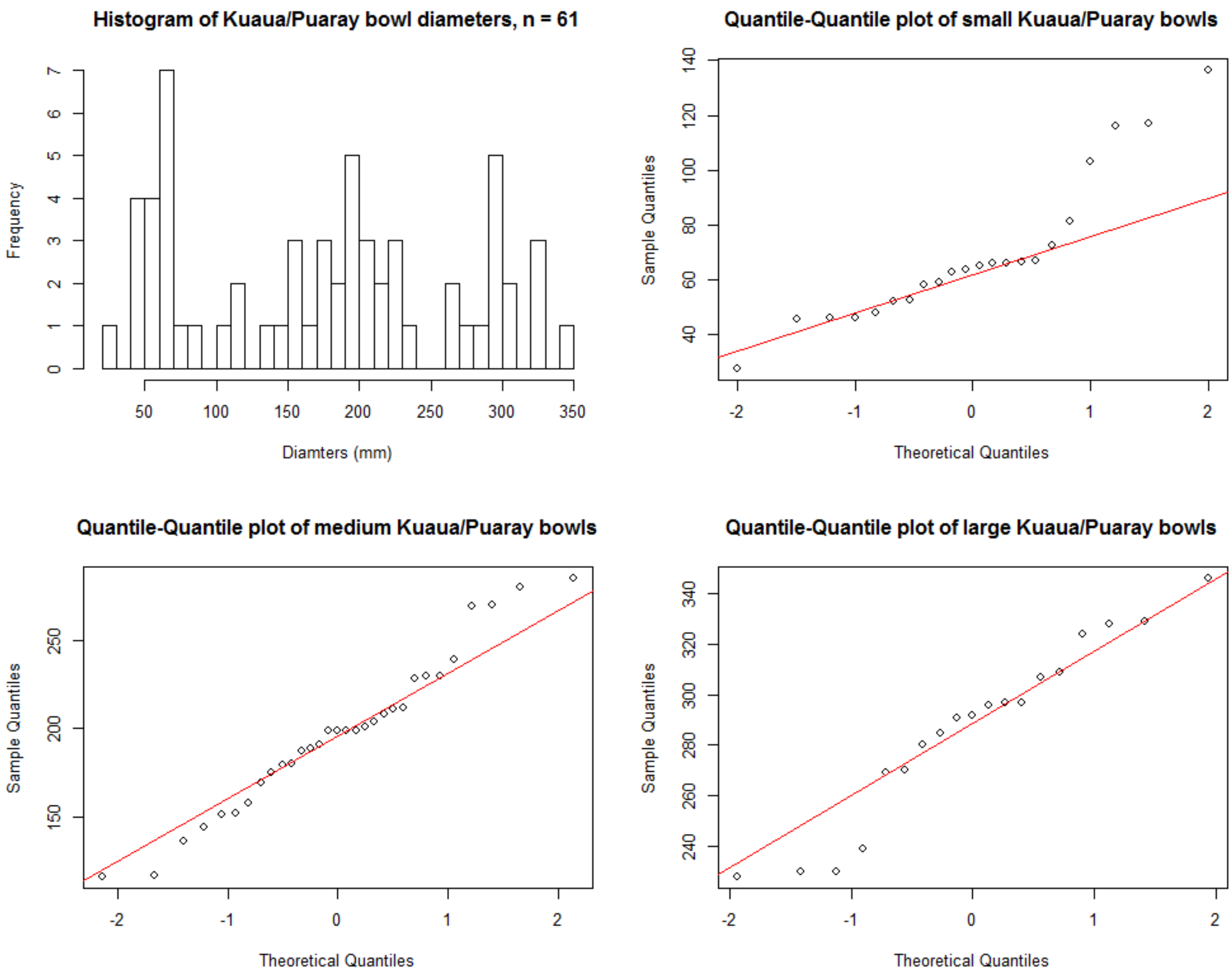

Figure 8. Kuaua and Puary bowl diameters, histogram and quantile-quantile plots for small, medium and large bowls

I measured 16 vessels from Puaray and 45 from Kuaua, but grouped the data because they were considered the same site. This assemblage showed a tri-modal, small, medium, and large distribution in bowl diameters. The small mode was between 70-80 mm, n=7, the medium was between 190-200 mm, n = 5, and the large was between 290-300 mm, n=5, as seen in Figure 8. All three appeared to be normally distributed around these modes.

Using the normal-like distributions, I defined small as between 27.7 mm and 103 mm with a mean of 60.6 mm and a standard deviation of 15.9 mm. I defined the medium category as between 116.1 mm and 239 mm with a mean of 185.3 mm and a standard deviation of 33.4 mm. Finally, I defined the large category as between 269 mm and 329 mm with a mean of 298.1 mm and a standard deviation of 19.5 mm. The three plots, seen in Figures 8, showed the most normally distributed size class was medium bowls followed by small and large bowls. All three were skewed towards the maximum and minimum values.

I then tested this distribution against the resampling technique to see how often such a distribution would be indistinguishable from an idealized distribution based on the calculated means and standard deviations. The resampling method suggested that the observed distribution was a common sample of the hypothetical distribution, almost 100% of the time they were indistinguishable. Substituting the standard error for the standard deviation decreased this to about 92% of the time. This supports the idea that this distribution was a sample of an idealized distribution with peaks at those means.

Tijeras

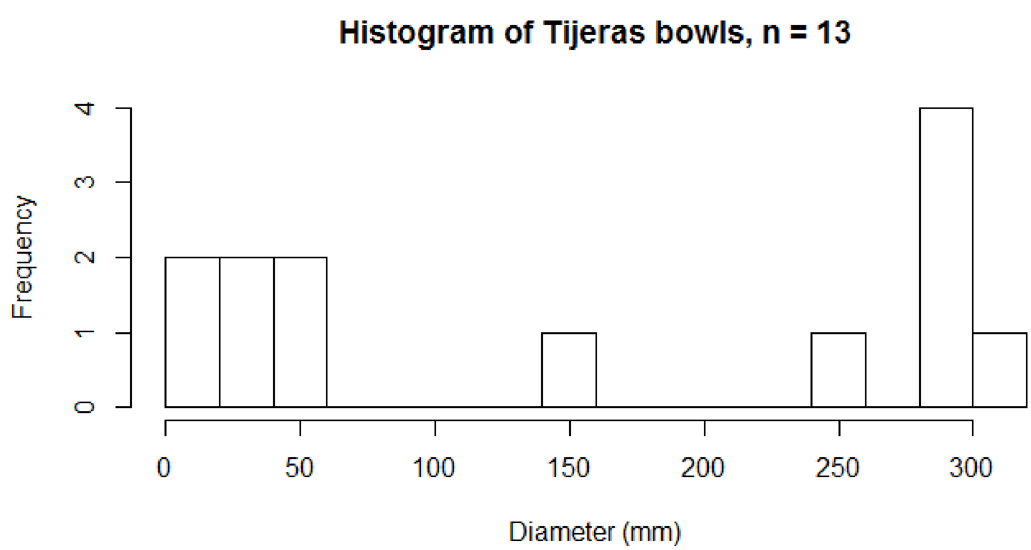

Figure 9. Tijeras bowl diameters, histogram.

I measured 13 bowls from Tijeras that range in size from 14.3 mm to 310 mm, with significant gaps between these two extremes. There was only one peak in the distribution, between 280 mm and 300 mm n = 4, as seen in Figure 9. The small sample size limited any patterning but no normal or normal-like distributions were visible in the data.

Pottery Mound

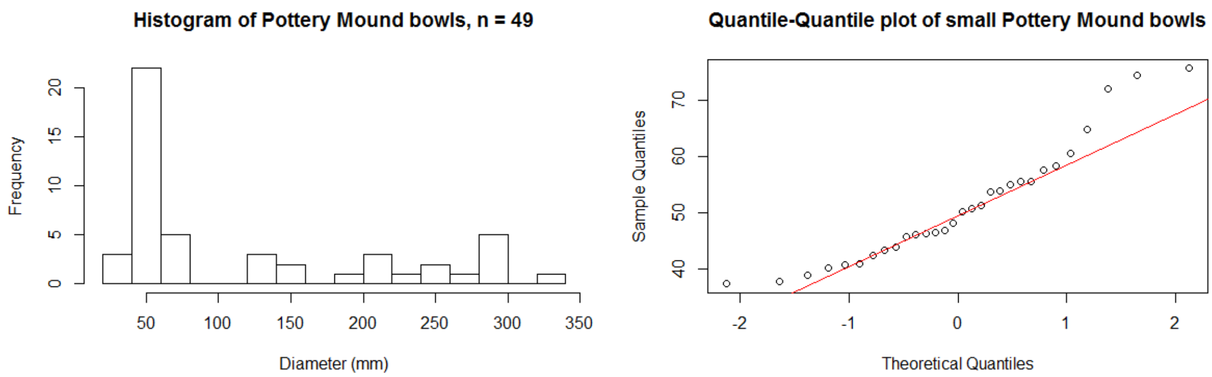

Figure 10. Pottery Mound bowl diameters, histogram and quantile-quantile plot of small size bowls.

In total, I measured 49 bowls from Pottery Mound. This increase in bowls from Przystupa (2012) altered the shape of its distribution. There were two modes to the data but the second was less than half of the first mode and did not appear normally distributed. The first mode was between 40-50 mm, n = 12, and the second was at 290-300 mm, n = 5, as seen in Figure 10.

Based on its normal-like distribution, I examined the existence of a "small" size category for this site. The small class ranged from between 37.4 mm and 75.6 mm, with a mean of 51.1 mm and a standard deviation of 10.5 mm. The quantile-quantile plot in Figure 10 suggested that this was a normal distribution but like the other distributions, skewed away from normal the farther the value was from the mean. According to the definition of size classes defined above, Pottery Mound only had a small size class. Vessels over this size showed no discernable pattern and may reflect other behaviors at the site or excavation bias.

Discussion

Size Categories

Each site showed a unique pattern for bowl diameter size with different numbers of modes, values for modes, peak counts, and overall shape. There did appear to be a correlation between the number of vessels measured and the number of size categories. Sample size could explain about 83% of the variation in the number of size categories. However, it was unclear exactly how new vessels would alter size classes. For example, I measured seven additional bowls from Pottery Mound between Przystupa (2012) and Przystupa (2013a, 2013b). While this altered the shape of the Pottery Mound distribution and changed its statistical relationship to Sapawe, it did not help to define an additional size class.

The existence of modes at many of the sites suggested that particular size classes were preferred at these sites. The sample sizes for two sites, the Jemez region and Tijeras, were too small to have visible patterns; one site, Unshagi, had modes but the distributions around them were non-normal; two sites, Sapawe and Pottery Mound, had one size class; one, Pecos, had two size classes; and Kuaua/Puaray had three size classes. Unshagi was the only site whose modes did not have normal distributions around them and, like Tijeras and Jemez, which had no visible patterns in their distributions, this is most likely due to sample size. An increase in observations may help to see if those modes have meaning, but at present Unshagi has no clear size classes.

The two sites that only had one size class were Pottery Mound and Sapawe. Both sites had small diameter modes with strong normal distributions. This conformed to our definition for size classes and suggested that a small size class of vessel existed at these sites. Przystupa (2013b) examined the existence of both "miniature" and "small" size classes at this site but concluded that it was not clear that both categories existed and concluded that "small" was the only reliable class. Both sites had vessels that were larger than this initial size but they did not display a normal distribution around any mode. This lack of patterning suggested that while large vessels did exist, different factors may have been operating on them to produce the current sample of bowls.

Pecos was the only site with two size categories based on two modes with strong accompanying normal distributions around each. Their separate quantile-quantile plots supported a normal distribution for each and iterative modeling supported the idea that they were samples from an idealized distribution made up of two normal distributions based on those means. However, the addition of Bagwell's (2001) data to this study could create a three-size class distribution. However, without her large sample of small vessels, the distribution appears to ignore small vessels and demonstrates a preference for medium to large size vessels. Lastly, Kuaua/ Puaray was the only site that had a tri-modal distribution. The assemblage had three modes, each of which had a normal distribution based on their quantile-quantile plots. Resampling helped to confirm the existence of this blended distribution.

While the use of iterative modeling in this context helped us to understand how these samples may relate to their population, there were some caveats to understanding the very high agreement between the resampling technique and our hypotheses. One of the problems with resampling that one is trying "to get something for nothing". This problem was definitely true of these data. Since I based the hypothetical distributions used in the resampling technique on the observed sample, it was highly likely that they will be similar to the observed sample. This means that when interpreting any of the values from the model the number of times the modeled distribution and the real distribution are considered "indistinguishable" actually happens fewer times than reported. For example by altering the number of observations in the hypothetical distribution, the likelihood that the observed distribution is indistinguishable from the hypothetical distribution decreases.

Inter site comparisons – distribution

Examining only the sites that had discreet size categories ignored the interesting information gained from including Unshagi, the other bowls from the Jemez region, and Tijeras in this study. Distribution assessments allowed me to contextualize the bowls that did not have discreet size classes. Although these sites lacked defined size classes, the comparison of their overall distribution to the other sites demonstrated that there are similarities between sites that are in spatial proximity, have historical ties, or were most likely from the same language group. The connection between, possible, linguistic groups suggested that there were cultural similarities in ceramic production at sites that shared a language. This similarity in distribution may imply that while the sample sizes for Unshagi, Jemez, and Tijeras were too small to say anything definitive about their own size classes they would have most likely been similar to Pecos and Pottery Mound, the sites within their spatial or linguistic group.

I compared the shapes of the distributions between all the sites using a Kolmogorov-Smirnov test of shape, as seen in Table 3. This non-parametric test looked to see if two distributions were drawn from populations with the same shape. Going north to south, Sapawe was not statistically similar to any site at $\alpha = 0.05$. However, Unshagi, p-value = 0.04314, was closest to being statistically indistinguishable and was the closest in proximity to Sapawe. Unshagi was statistically similar to Pottery Mound, p-value = 0.01755, and Sapawe, p-value = 0.04314. The other bowls from the Jemez region were statistically similar to all sites except Pottery Mound, p-value = 0.03636, and Sapawe, p-value = 0.01684. Both Pecos and Kuaua/Puaray were statistically indistinguishable from Unshagi and Jemez but were statistically distinct from each other. Tijeras was indistinguishable from Unshagi, Jemez, and Pottery Mound. Finally, Pottery Mound was indistinguishable from Tijeras. Overall Pottery Mound was the least likely to be statistically similar to any other sites in distribution according to the Kolmogorov-Smirnov test as seen in Table 3.

There appeared to be a weak spatial relationship between the distributions of bowl orifice size at these sites. Sapawe and Pottery Mound, the two sites with a predominance of small bowls, were statistically significantly different from all sites except the ones that were closest to them in spatial distance. While Sapawe and Unshagi probably belonged to different language groups, Tewa and Towa (Schroeder 1979), they may have had some sort of trading or traditional connection because of their spatial proximity but assessing whether they were similar or not depends on how one defines α. The fact that people occupied these sites for almost the exact same times supports this possible connection, see Table 1.

Unshagi and the other bowls from the Jemez region were most commonly the sites that were statistically indistinguishable from the other sites, which may be due to their sample size. However, this may not be the only discriminating factor since Tijeras, which also had a small sample size, n = 13, had a different relationship with the other sites. Tijeras was the only site that was statistically indistinguishable from Pottery Mound, which may reflect a connection between the sites because of their close proximity. While the two sites did not overlap much in time, Pottery Mound may reflect a possible destination for the people who formerly lived at Tijeras.

Unshagi and Jemez were the only sites that were not statistically significantly different from Pecos. While this may be because of their sample size, it may also reflect a connection between the pueblos that manifested when the remaining inhabitants of Pecos migrated to the Jemez region in 1838. Unshagi was one of the larger pueblos of the Jemez region and its similarity to Pecos may reflect connected ceramic traditions or trading between Towa speaking Pueblos.

The fact that Pottery Mound appeared so different from the other sites may be because of excavation strategy at the site. However, based on the current data this may be due to different cultural groups inhabiting the site. Pottery Mound was the farthest south of the sites used in this study and appeared to be most associated with Acoma Pueblo and Hopi (Philips, personal communication). This made it the only site that most likely spoke Hopi and Western Keres. This suggested that it could have a completely different ceramic tradition than the other sites. This is with the exception of Tijeras, which although inhabited before Pottery Mound was the closest site geographically to Pottery Mound and was not statistically significantly different in distribution.

Inter site comparisons - size classes

Two of the sites demonstrate a normal-like distribution for large bowls, Pecos and Kuaua/Puaray, with their respective means of 279.5 mm and 298 mm. Paired t-test results suggested that these means can be considered to be drawn from different populations, p-value = 0.008172. This suggested that slightly different behaviors or processes were affecting large vessels at both of these sites. This could be different potters, different trade connections, or just different needs for types of large bowls.

Two sites demonstrated a normal-like distribution for medium vessels, Pecos and Kuaua/Puaray. Their respective means were 177.1 mm and 185.3 mm. Paired t-test suggested that these two means can be considered to be drawn from the same population, p-value = 0.3493. This suggested that similar behaviors or processes may be operating on medium size class bowls at these two sites. This could be that they have similar trade connections, similar pottery traditions for this size, or similar needs for this size of bowls.

Three sites demonstrated a normal-like distribution for small vessels, Sapawe, Kuaua/Puaray, and Pottery Mound. I used a more restrictive significance level, $\alpha = 0.01$, for these categories in order discriminate between the smaller size differences between the means. Their means are respectively 79.1 mm, 60.6 mm, 51.1 mm. Paired t-test results suggested that small bowls from Sapawe and Kuaua/Puaray were draw from different distributions, p-value = 0.00089. Kuaua/Puaray and Pottery Mound were not significantly different from one another, p-value = 0.02922. Finally, the means for small bowls from Sapawe and Pottery Mound can be considered to be significantly different from one another, p-value = 5.33e-08. This suggested that Sapawe had different behaviors and processes acting on that sample than are acting on the other two sites. Kuaua/Puaray and Pottery Mound may have had similar processes and behaviors acting on them to create their samples of small bowls.

These calculations suggested that different behaviors affected extant size categories at each site and some size classes may connect sites through shared conceptions of bowl size-norms. The close proximity of Kuaua/Puaray and Pecos and the fact that their medium bowls were statistically the same has many possible explanations. They could share ceramic specialists, they could have had similar trade patterns for ceramics, the potters shared a ceramic tradition, or that they had similar needs for medium bowls at this site. Examination of the ceramic types from each of those sites and sourcing analyses may help to separate which hypothesis best explains this pattern. Similar explanations could be used to understand the similarity in small vessels between Pottery Mound and Kuaua/Puaray.

To compare the variation for each of these size classes I calculated the coefficient of variation across the different size classes as seen in Table 2. The coefficient of variation normalizes the variance around the mean in order to account for increasing error with size. Small vessels had the highest coefficient of variation, Kuaua/Puaray: 0.26, Sapawe: 0.24, and Pottery Mound: 0.21. Large vessels from Kuaua/Puaray and Pecos had the lowest coefficients of variation, both of which were around 0.06. While changing the arbitrary cutoffs between size classes may alter this statistic, there are large differences between the coefficients of variation, which supports the idea that a unique behavior is affecting small vessels.

Conclusion

So what can these size classes tell us about bowls and the people who made them in the northern Rio Grande region? At the most basic level this study demonstrated that particular size classes existed at some of these sites. Sapawe, Pecos, Kuaua/Puaray, and Pottery Mound had sample sizes large enough to identify at least one size class. The size classes had breaks between each class, if there was more than one in the assemblage, and adhered to a normal distribution. One site, Unshagi, had the possibility for two size classes, however; its small sample size affected our ability to recognize them as such since they were not normally distributed.

No sites utilized the classification miniature in this study. Previous work examined the existence of this category for Pottery Mound and Sapawe and concluded that there was a lack of discreet separation between these classes (Przystupa 2013b). Additionally, visual assessment of the data does not support that the idea that this additional small size variant existed at Kuaua/Puaray. Each distribution, seen in Figures 4, 8, and 10, appeared normally distributed around the mean rather than appearing as bi-modal distribution. However, this does not mean that child or novice potters were not present at any of the sites examined in this study. Furthermore, I did not calculate β for any sites since there was little overlap between size categories and none overlapped within one standard deviation.

Large sized vessels existed as a discreet class at Kuaua/Puaray and Pecos. Unlike medium sized vessels, these sites had statistically different sizes for their large vessels and maintained a low coefficient of variation. This suggested that the behaviors that influenced the construction of those large bowls at Kuaua/Puaray and Pecos were probably unique to those sites. This probably reflected different traditions for ceramic bowls based on practice or need for bowls of that size. Fewer people making larger vessels because they required more skill or a highly standardized tradition amongst potters for that size of vessel are the most likely explanations for the consistently lower coefficient of variation at both sites (Crown 1995, Stark 1995).

Medium sized bowls only existed at Kuaua/Puaray and Pecos. These bowls were also statistically indistinguishable from one another and had very similar coefficients of variation, Table 2. This suggested that the behavior that operated to create medium sized bowls at these two sites were similar to one another. The coefficients of variation, while similar to one another, do not reflect a standardized practice as they have coefficients of variation that were over 0.10, which was an arbitrary cutoff for "standardized" vessels (Crown 1995, Stark 1995). This suggested that an explanation similar to small vessels, of many potters or less skilled potters, explains the existence of a medium sized bowl class (Kamp 2001b). The slightly lower coefficient of variation for medium vessels, in comparison to small vessels, suggests that if similar processes were acting on medium sized vessels as well as on small sized vessels there was something restricting some of the variation between these two size classes, such as skill or number of individuals.

A small size class was the most common class at these sites, found at Sapawe, Kuaua/Puaray, and Pottery Mound. The addition of Bagwell's (2002) data would most likely have added Pecos to this list. The presence of this size class may demonstrate that behaviors or processes associated with small bowls were the most common at sites in the northern Rio Grande Region. However, it may also be a product of site selection. The two sites initially investigated by Przystupa (2012, 2013a, 2013b) were selected because of their large percentage of small bowls and the presence of bowls under 150 mm was considered a mandatory selection choice for the rest of the sites included in this study.

These small sized bowls were a discreet class of vessels at those three sites but probably were not products of the same behaviors or practices between those three sites. Small bowls at Sapawe were significantly different in size from those found at Kuaua/Puaray and Pottery Mound. This suggested that there were localized behaviors at Sapawe that governed the creation of small bowls. While Kuaua/Puaray and Pottery Mound may not be statistically different from each other, it was not clear exactly why they might be similar. Pueblo peoples occupied these sites at the same time, but they were quite spatially distant from each other. It is possible that they had similar uses for small bowls at these two sites or similar practices for teaching forming techniques.

Overall, small bowls had high coefficients of variation, which suggested that whatever behaviors governed their creation these also created variation within the size class suggesting that these small sized bowls were not standardized. This could be because they were the product of less skilled potters (Kamp 2001b), more potters were making this size vessel (Crown 1995), people received these bowls from many sources, and a combination of any and more possible behaviors. Either way further investigation of this size class at Sapawe, Kuaua/Puaray, and Pottery Mound examining forming technique and other skill level assessments *sensu* Bagwell (2001) and Crown (2001), will help us to understand this metric.

However, these may not be the only causes of variation in small and medium size bowls. Other studies that explore the meaning of the coefficient of variation have focused exclusively on single ware types (Crown 1995). The variation in size classes may exist because not all of the bowls are from the same ware type and they may reflect multiple potting styles aggregated at these different sites rather than tracking a specific potting tradition. Interestingly, large vessels, which also did not account for different ware types, did not have any larger coefficients of variation than might be expected from within a single ware type (Stark 1995).

While this might influence the variation at these sites, it is only by further analysis of the other attributes of bowls at Sapawe, Kuaua/Puaray, Pecos, and Pottery Mound that we can assess this variation further. Based on the distributions, Kuaua/Puaray was the site that had the largest sample size and the most evidence for three distinct size classes. This means that further research could investigate questions about whether learning potters were the creators of a particular size class. The large sample size would allow the application of a variety of techniques to the sample and comparison between distinct size classes (Crown 2001, Bagwell 2002). However, the presence of defined size categories does not necessarily imply that learning potters existed at the site. Without examining each vessel in the classes in relation to factors exclusive of size, we cannot be sure which behaviors influenced the construction of bowls at these sites.

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Tables

Table 1. Site background

Site	Dates	Possible modern affiliation	Sample size	Museums
Sapawe	AD 1350 - 1550 (Hawley Ellis 1968)	Tewa (Schroeder 1979)	41	Maxwell Museum
Unshagi	AD 1325 - 1574 (Reiter 1938)	Towa	21	Museum of Indian Arts and Culture, Maxwell Museum
Jemez Region	unknown	Jemez Pueblo, Towa	6	Maxwell Museum
Pecos	AD 1300-1838 (Bagwell 2002)	Jemez Pueblo, Towa	55	Museum of Indian Arts and Culture, Maxwell Museum
Kuaua/Puaray	AD 1300 - 1500s (NMDCA 2014)	Southern Tiwa (Schroeder 1979)	61	Museum of Indian Arts and Culture, Maxwell Museum
Tijeras	AD 1257-1395 (Cordell 1975)	Southern Tiwa (Schroeder 1979)	13	Maxwell Museum
Pottery Mound	AD 1370-1450 (Schaafsma 2007)	Acoma and Hopi, Western Keres and Hopi (Philips, personal communication)	49	Maxwell Museum

Table 2. Coefficient of variation for site size classes

	Pecos	Kuaua/Puaray	Sapawe	Pottery Mound
Large	0.067263	0.065436		
Medium	0.183455	0.180248		
Small		0.264559	0.237674	0.205479

Table 3. Non-parametric testing between sites, **bold** indicates no statistical significance at $\alpha < 0.05$

	Sapawe	Unshagi	Jemez	Pecos	Kuaua/Puaray	Tijeras	Pottery Mound
Sapawe	1	0.04314	0.01684	1.02E-07	0.02548	0.01832	0.0008621
Unshagi	0.04314	1	**0.4291**	**0.137**	**0.2357**	**0.5968**	0.01755
Jemez	0.01684	**0.4291**	1	**0.2951**	**0.2539**	**0.1976**	0.03636
Pecos	1.02E-07	**0.137**	**0.2951**	1	0.005569	0.02089	7.31E-09
Kuaua/Puaray	0.02548	**0.2357**	**0.2539**	0.005569	1	0.02862	0.000688
Tijeras	0.01832	**0.5968**	**0.1976**	0.02089	0.02862	1	**0.2851**
Pottery Mound	0.0008621	0.01755	0.03636	7.31E-09	0.000688	**0.2851**	1

What Mean These Mimbres Bird Motifs?

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Abstract

Birds are commonly depicted in Mimbres pottery. Some, such as macaws, can be identified based on physical details. Many are more generic, some are metaphoric, and still others are mythological. We discuss levels of identification, analysis, and interpretation of painted motifs and present two examples from Classic Mimbres bowls. Additionally, we briefly examine the perceived distinctions between representative, figurative, and geometric Mimbres motifs.

Introduction

It is told that a pilgrim once asked a sage, "What is the meaning of life." And the sage replied, "Life is like a river. Isn't it?" Others have asked: "When is a Kiva?" (Smith 1952) and "What, if Anything, is a Rabbit?" (Wood 1957). Here we attempt to address questions concerning content and meaning of prehistoric imagery in bowls and petroglyphs from the Mimbres River Valley of southwestern New Mexico. Specifically, we examine two examples of Mimbres motifs that include one or more birds. One depicts what appear to be real birds, including an exotic parrot, and another illustrates a mythical winged creature with knife-like wings or feathers.

Recently, we three published articles on aspects of Mimbres iconology in *American Antiquity* (Gilman et al. 2014) and *American Archaeology* (Thompson et al. 2014). The former presented evidence for and reasoned that the presence of scarlet macaws, their images in bowls, and Hero Twins imagery at about A.D. 1000, which was the beginning of the Classic period, coincided with the burning and lack of replacement of great kivas and significant changes in ritual behavior. Additionally, we posited that women, perhaps in the company of men, journeyed from the Mimbres River Valley to the Huasteca region, located in southern Tamaulipas and northern Veracruz, Mexico, to acquire young macaws for ceremonial purposes, long red tail feathers, and eventual sacrifice on or about the vernal equinox. It is also possible that instead people from Mesoamerica brought the macaws north to the Mimbres. We surmised that with the macaws came training for their care and the ideology of the Hero Twins saga as illustrated on Classic Maya pottery and described in the sixteenth century *Popol Vuh* of Guatemala.

In the second paper, Kristina Wyckoff illustrated Classic Mimbres bowls graphically depicting the birth, adventures, death, and resurrection of the Hero Twins, and we correlated the images with written episodes in the K'iche' Maya tale. Our conclusions were based on analyses of elements, icons, and motifs that correspond to similar motifs in both prehistoric and historic Mesoamerican and Southwestern media including iconography and folktales. We posited that cognate ideology from the Mayan speaking Huasteca region of Mesoamerica arrived with macaws in the Mimbres River Valley.

Our previous research concentrated on figurative imagery. By figurative we mean: as in figures of speech; not literal; metaphorical; symbolic or emblematic; of or relating to representation by means of animal or human figures; figural. Another term used to describe Mimbres painting is representational, i.e., of or pertaining to representation, especially realistic graphic representation, sometimes referred to as naturalistic. It has been a convenient custom to separate Mimbres designs painted in bowls and pecked in stone into two basic and descriptive categories: figurative/representational and geometric. According to this division, 35 percent of all Mimbres bowls are considered figurative, and 65 percent are classified as geometric. Distinguishing between representational (realistic), figurative (metaphoric), and geometric (rectilinear and curvilinear) motifs is difficult at best as the divisions of and between representational, figurative, and geometric are blurred by combinations of elements from all three modes in many bowls, as we will discuss below.

Many Mimbres figurative motifs appear to be narrative, such as those that depict the adventures of the Hero Twins. Some designs have mnemonic value, when a single icon brings to mind the attributes or activities of a mythic figure. Still other bowls exhibit chimeric creatures, such as fantastic animal hybrids with elements from more than a single species or taxon. These defy classification. Finally, many motifs are imbued with ambiguous dualities, and multivalent strata of meaning and symbolic expression. Mimbres art tells stories, expresses a visual mythology, and symbolizes a prehistoric cosmology. The motifs demonstrate little concern with the tropes of Southwestern archaeology: rainfall and water signs; kinship and clan symbols; farming and fertility; or kivas and *katsinam*.

Avian figures are the most common creatures painted in Mimbres bowls. Birds account for 20 percent of figurative/representational bowls. Below we present examples of two bowls, one with a representational motif and another with a figurative motif, as defined above. Both contain depictions of birds and illustrate contrasts and similarities in the expression of content and meaning.

***Is* a Bird in the Hand Worth Two in the Wood?**

Figure 1 is a rendering of what appears to be a representational motif with figurative elements that could account for an event, a process, and a mythopoeic (of or relating to myth-making) scene simultaneously. Here a Mimbres individual (based on the facial profile and diamond-shaped eye), likely a male (based on the hair style and presence of a bow and arrows), is climbing a tree to inspect chicks in a hollow nest. The birds in and on the tree do not appear to be parrots, but the immature bird in the capture device has mandibles characteristic of a macaw. The man, birds, bow and arrows are representational and recognizable as such. Plants, especially trees, are rare elements in Mimbres motifs, but the tree is a prominent figurative character here.

It is highly stylized, devoid of foliage (perhaps indicating it is dead), with exposed roots. It also exhibits three slightly anthropomorphic limbs, one behind the nest like an arm with a hand-like projection, one arm-like limb grasped by the man, and a third bifurcated limb split like legs upon which the man stands. A mouth-like cavity serves as a nest above two areas of eroded paint. Both the captive macaw chick and the tree roots suggest tropical habitat such as that in the Huasteca region. Immature macaws were brought from their natural environment that included trees such as the ceiba (kapok) that exhibit aerial roots systems, and macaws favor hollows in dead trees for nests. Next to the bow and arrows is a curved walking stick. This element may be associated with travel or movement and is often included with Mimbres motifs of women bearing immature macaws on burden baskets.

Figure 1. Mimbres Classic Black-on-white bowl. Provenience unknown.
Fine Arts Museums of San Francisco. Previously published in Robb (2014:Figure 7).

Our analysis and interpretation indicate this scene is representative of the dangerous task of acquiring young birds from trees in a Mexican tropical forest and may have been painted from a firsthand account. The representational depiction of the macaw in this bowl is that of a real bird with symbolic meanings. The red feathers of scarlet macaws were associated with the sun and the birds were sacrificed on the vernal equinox, a solar event (Thompson and Brown 2006). Although mostly representational, this painting also has figurative elements.

Knife-wing and its Ambit

The figurative Knife-wing icons appear in six percent of Mimbres figurative/representational bowls, making up about one-third of all birds. Knife-wing is typically recognized in the Southwest by the following elements and posture: 1) the wings are extended; 2) the wings or feathers are knife-like in appearance; 3) the figure is presented in anterior position (ventral facing); and 4) in later depictions, the icon often exhibits both avian and anthropomorphic features (Thompson 1999). In both Mimbres bowls and rock art, the head of Knife-wing is occasionally turned to the right or left with only one visible eye.

In a seminal article, David Kelley (1964) identified Knife-wing as a graphic motif represented in Mesoamerican media and correlated it with Southwestern folklore motifs. Kelley made the following observations: 1) Knife-wing is depicted at the Maya site of Chichen Itza and in later Mexican codices; 2) the icon is associated with death and warfare; 3) Southwestern folklore motifs include associations with war (and scalping, Acoma and Hopi); stealing women (Acoma, Pima, Zuni), and the zenith (Zuni). Additionally, he noted that stone knife glyphs on the wings of Mesoamerican Knife-wing depictions correlate with anthropomorphic eagle figures depicted with knife-like feathers on their wings at Zuni.

Subsequent research has also demonstrated that Knife-wing images appear in Mimbres Boldface, Transitional, and Classic (A.D. 800-1130) Black-on-white pottery (Thompson 1999). The dates on the stone Knife-wing reliefs at Chichen Itza are Yula, Lintel I: A.D. 873, and Temple of the Four Lintels, Lintel I: A.D. 881 (Kowalski 1989:174). These dates are coeval with those of Mimbres Boldface (A.D. 800/850-900/950) ceramics.

The central Mexican codices (e.g., Nuttall, Borgia, Borbonicus) are thought to have been painted between A.D. 1300-1519. Knife-wing icons in these screenfold manuscripts and Mixteca-Puebla codex-style ceramics are contemporaneous with Pueblo Knife-wing imagery in petroglyphs, ceramics, and kiva murals thought to date between A.D. 1300 and 1500. And, the painted figures in both Mesoamerican and Southwestern images are more animated and anthropomorphic than in previous depictions (Thompson 1999). Historic Knife-wing imagery, altar pieces, and folklore have been documented, the motif continues to exist as a symbol at Hopi and Zuni, and it is still depicted in modern pueblo jewelry (Thompson 1999). At Zuni, the icon is known as *A: chi: ya: latapa*, "with knife wings" and at Hopi as *Kwatako*, "Man Eagle" (Thompson 1999). Like Southwestern Hero Twins iconography, the Knife-wing icon was represented in imagery north, east, and west of the Mimbres region, but not to the south. A Knife-wing image was recently revealed by DStretch photography within an El Paso Polychrome crenelated bowl (A.D. 1300-1450) from a pueblo on Ft. Bliss, Texas (Myles Miller, personal communication, 2014). Despite geographic and temporal proximity, Hero Twins motifs that appeared with macaws in the Mimbres region and Knife-wing icons are absent in the ceramic inventory of Casas Grandes culture.

The Knife-wing icon varies stylistically through time and space. It is one of the few figurative motifs in Mimbres Boldface pottery, it increases in frequency in Mimbres Transitional Black-on-white pottery (A.D. 880/950-11020/1050), and the Boldface images share stylistic affinities with Hohokam avian figures. In Classic bowls (A.D. 1000-1130), the icon becomes more common with increased variability in individual depictions (Thompson 1999).

Figure 2 presents an example of the Knife-wing icon in a Classic Mimbres bowl. Prominent in this and many Mimbres depictions are triangular, knife-like wings with serrated edges. The serrated elements found on the wings in this bowl are repeated below the rim on either side of the icon. In this and other bowls, these elements appear to be a reiterative device. LeBlanc (2004:Plates 7, 24) has observed similar instances of elements representing larger entities with the appearance of paired fish tails. "Enough bowls have been found that show such minimal figurative elements that we can assume this was a deliberate rendering of an animal motif (LeBlanc 2004:98). We suggest that in both cases (serrated wing elements and fish tails) a single prominent attribute represents a more complex icon or motif. Recognizable abbreviations of icons may serve as attenuated parts that represent the whole. These essential symbols depart from literality to evoke something more than is there. In essence, a single element from a figurative bowl can appear in a geometric design, again blurring the division between figurative and geometric motifs.

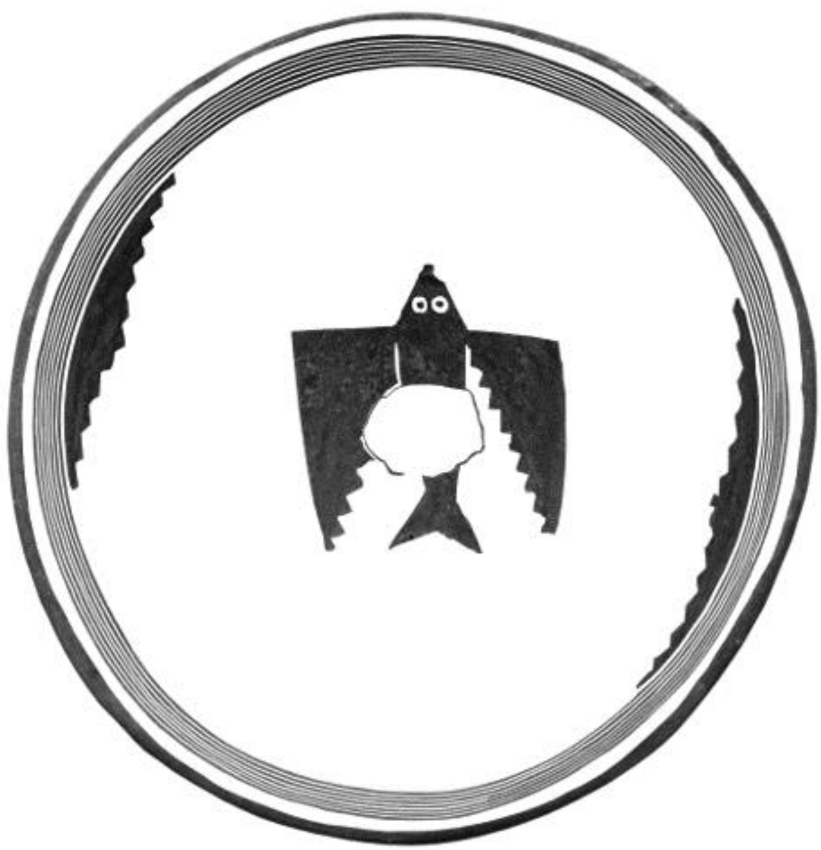

Figure 2. Mimbres Classic Black-on-white bowl. Galaz Site, University of Minnesota. Previously published in Anyon and LeBlanc (1984:Plate 65B).

The Knife-wing icon exhibited in this bowl is a figurative image of a mythical bird with metaphoric qualities. This bird with knife-like wings or feathers is emblematic rather than real. It stands for a complex set of associations including death and warfare, stealing women, and the nadir. In this case, an unreal bird symbolizes real concepts codified and subsumed by an iconic animal figure.

As an example of a figurative element representing a larger entity, consider Figure 2 without the Knife-wing icon. It would be classified as a geometric Mimbres bowl. This suggests that the division between figurative and geometric motifs may be more apparent than real. Hundreds of figurative Mimbres bowls contain geometric designs. Hundreds of geometric bowls may also contain figurative elements (see LeBlanc 2004:98-99).

Conclusions

The expressive content of Mimbres iconography is layered with strata of meaning, symbolism, and ideology. Combining representational, figurative, and geometric elements was part of the creative process, including the wedding of representational and conceptual symbols. The bowl in Figure 1 shows the combination of representational and figurative images. Knife-wing, a solely figurative image, appears early in Mimbres pottery before the time when Mimbres great kivas were no longer used, as described above. Boldface Black-on-white Knife-wing icons are thus present in Mimbres iconography before the arrival of macaws and the appearance Hero Twins iconography in Classic bowls. This suggests that Mimbres and Mesoamerican cultures were already sharing ideological symbolism, evidenced by ethnically distinct graphic depictions, before the arrival of macaws in the Mimbres region.

Geometric designs in Mimbres pottery predominate, although figurative motifs increase through time from Boldface to Classic Mimbres Black-on-white bowls. Our analyses and interpretations have concentrated on figurative elements, icons, and motifs. The recognition and identification of figurative elements in geometric bowls may indicate that an artistic and symbolic shorthand characterizes many geometric motifs. The inclusion of serrated wing designs and fish tails, combined with geometric elements, implies that some geometric bowls carry similar, but more highly encoded, messages such as those illustrated in figurative bowls.

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COMMENTS

A Comment on Swenson: Anasazi Organic Black-on-white Pottery: A New Paradigm

Owen Severence

I would like to make some comments on Rod Swenson's paper in Volume 30, "Anasazi Organic Black-On-White Pottery: A New Paradigm."

I agree with Rod about the lack of evidence for smothering the fire when it reached its peak temperature in order to produce reduced black-on-white pottery. I haven't seen any evidence of smothering at kilns in southeastern Utah.

Southeastern Utah kilns fall into three general categories: kilns that were used only once, kilns that were used more than once in the same kiln outline and kilns that were partitioned after their initial use to reduce the size of the kiln for any subsequent firing(s).

Figures 1, 2 and 3 are kilns that apparently had been used only once; they provide evidence that Rod's thesis is correct. All of the ashy soil appears to be within the outline of the kilns, and no excavated dirt or charcoal can be seen outside of the kilns. This indicates that these kilns were not smothered, that they were not excavated to remove the pottery, and that the pottery was removed by rummaging through the ashes.

Figure 1

Figure 2

Figure 3

Figure 4 shows a kiln that had been used more than once. After each use, the kiln was cleaned out and the ashes and kiln furniture were discarded. All of the pieces of rock in the foreground are discarded kiln furniture. (Apparently kiln furniture was only used once.) There is no evidence of charcoal in this "midden," and also there is no evidence that the kiln was excavated to remove smothering soil after each firing.

Figure 4

"The Kiln Site" (42Sa2160) on Cedar Mesa (Helm, 1973) is an example of a kiln that had been partitioned after its initial use. A wall was constructed about 5 feet from the west end, and the floor of the kiln was raised in that area. This created a much smaller kiln for a subsequent firing. This kiln supports another of Swenson's proposals. The initial kiln was about 2.5 feet deep. That is much too deep for firing just one layer of pottery. At least two or three layers could have been fired at one time, a much more efficient use of the firewood than firing one layer at a time.

It is obvious that a lot more work needs to be done before we can completely understand how the prehistoric potters fired their pottery. Rod is clearly on the right track in this effort.

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A Comment on Swenson: Anasazi Organic Black-on-white Pottery: A New Paradigm

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Rod Swenson's paper on how prehistoric potters from Mesa Verde may have produced organic painted Black on white ceramics states, "The central problem is that at firing temperatures organic paint simply oxidizes (or "burns off) and the design on the pot is destroyed, leaving at best only a faint ghost of the image rather than black" (Swenson 2014:5). He assumes that the presence of oxygen during firing is what causes the organic paint on carbon Black on white ceramics to be burned off and claims to control the availability of oxygen to the vessel itself – not to a fire or a combustion chamber (Swenson 2014:14). Swenson refers to this as the smothering paradigm (SP).

Swenson proposes a non-smothering paradigm (NSP) to prevent oxygen from coming in contact with the vessel during firing. He states that a crib fire constructed of 1 - 2 ½ inch diameter pieces of wood fuel, with small spaces between the pieces of fuel, limits the supply of oxygen to the interior of the fire where the vessels are located. However, previous laboratory research by the United States Forest Service (USFS) has indicated that any crib utilizing wood fuel greater than ½ inch in diameter is considered to be porous and will allow oxygen into the interior of the crib for combustion (McAllister and Finney 2013). Swenson suggests that 1 -2 ½ inch diameter pieces of wood will result in complete combustion. Complete combustion of a wood fire exists in theory. If a fire is producing smoke, it is not achieving complete combustion. A large part of smoke is unburned fuel (DeHaan & Icove 2012:502). Yellow luminous fires are diagnostic for incomplete combustion (DeHaan & Icove 2012:37). Research by recognized experts in fire behavior does not support Swenson's hypothesis.

The first step of any research on ceramic firing technology should be the analysis of the material used in ceramic production. The material used by potters is an assortment of different clays and other material (Shepard 1956:5; see also Grimshaw 1971). The composition of clay is variable; some clays require low levels of heat to sinter while others require higher levels (Grimshaw 1971:737). It is probable that there was no single firing technique in the Southwest due to the variety of available clays.

The second consideration should be the fire in which the vessels are placed. Basic information on fire behavior and heat transfer demonstrates that the fuel, fire environment, and rate of heat transfer from the fire to the pottery affect the firing of environment of prehistoric ceramics. At their simplest, these reactions involve fuel, oxygen, and heat. When organic material "burns off", the usually accepted explanation is excessive heat.

Heat from a fire is transferred by convection, radiation and direct flame impingement. Convective heat is usually considered to be about 70% of the total HRR (Drysdale, 2003:2-63).

It is controlled by gravity and rises in a convective column above the fire. That is best explained as the visible column of smoke and heat rising above a fire.

When heat from a fire hits a target, the temperature of that target tends to rise. The amount of increase is a function of the heat striking that object, the distance between the heat source and the object, and the material of which the object is made. Each material absorbs heat at different rates. Ceramic vessels made from different clays can experience different temperature increases when placed in the same fire.

Rachel Loehman, of the United States Geological Survey (USGS) in Alaska, Connie Constan of the Santa Fe National Forest, Rebekah Kneifel of the USFS Fire Lab, Anna Steffen of the Valles Calderas National Preserve, Alexander Evans of the Forest Guild in Santa Fe, and others are studying the effects of wildland fires on cultural material. They have found the surface and interior temperatures of prehistoric ceramic sherds are lower than the air temperature within the simulated wildland fire environment - in other words, because these artifacts heat more slowly than the air and conduct heat away from themselves, they don't achieve the upper limits of temperature measured within a fire. Preliminary results indicate organic painted Black on white sherds were less altered by the simulated crown fire environments than the mineral painted wares. (Loehman, personal communications 2015 and http://www.forestguild.org/Archburn)

Most of Swenson's inquiry was based on firing techniques utilized in and around Mesa Verde Park National Monument (elevation 6000 – 8500 ft.) on the Colorado Plateau. Swenson gathered clays from two sources near Mesa Verde National Park Monument and one at some distance (Pecos, New Mexico). He conducted tests in Apache Junction, Arizona (elevation 2000 ft.) to demonstrate his proposed firing techniques. That difference in elevation would have a meaningful effect on the results of his experiments. Fire behaves differently at higher elevations and produces less heat than at lower elevations (Li et al. 2009:2481-2488). Swenson should have considered differences in elevation during his experiments and when he suggested similar firing techniques for Salado Polychrome from the Tonto Basin and Mesa Verde White ware from the Colorado Plateau.

Swenson's paper is but one avenue toward understanding the complex process of prehistoric ceramic production. Additional research on ceramic materials and sources, the fire environments in which ceramics were produced, and the combustion and heat transfer characteristics of firing events needs to be undertaken to fully understand the processes employed in the production of organic Black on white ceramics.

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RESPONSE

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Owen Severance's comments (*Pottery Southwest* 31(2):30-32) on my paper "Anasazi Organic Black-on-White Pottery: A New Paradigm" (*Pottery Southwest* 30(1-4):4-33) further support the main claim of the paper that the production of Anasazi organic black-on-white pottery did not involve dirt smothering. Having at last count recorded well over 900 kilns, there is no other person, as far as I know, who has documented as many Anasazi kilns within the Mesa Verde Archeological Region as Severance. The work described in my paper grew from an uncertainty about the Smothering Paradigm ("SP"); this uncertainty was based upon parsimony principles and led to the conclusion that black-on-white organic paint could be achieved quite readily without smothering, the Non-Smothering Paradigm ("NSP"). Subsequently, we became skeptical of the theory that proposed that documented and excavated kilns provided evidence for smothering. My paper showed how incorrect this was. Severance's contribution here, as well as his three-kiln typology, and his support of the multi-layer firing strategy, is extremely valuable; it is the kind of hard scientific data that we need.

The following is a brief account of some, but not all, of the main disagreements or problems I have with Joe Lally's Comment (*Pottery Southwest* 31(2):33-35) on my paper:

- Lally begins by saying "He [Swenson] assumes the presence of oxygen . . . is what causes organic paint on carbon black-on-white ceramics to be burned off and claims to control the availability of oxygen to the vessel itself not to a fire or combustion chamber (Swenson 2014:14)." He continues that "Swenson refers to this as the smothering paradigm (SP)." However, Lally leaves out the entire process of smothering itself from his description. This is not a "claim" by me; this is a paradigm developed, promoted, and/or adopted by others (e.g., Swink 1993; 2004). In addition, the idea about not controlling oxygen "to a fire or combustion chamber" is erroneous. Smothering, or fire quenching with dirt, is by definition about cutting the oxygen off to a fire.

- When he gets to the NSP, Lally attempts to falsify it using the results of a study by McAllister and Finney (2013) showing the wood size used in the NSP would let some oxygen into the kiln on the way up (an extraneous issue to smothering or not). The study he says shows a crib built of wood "greater than 1/2 inch (such as used in the NSP) is considered porous and will allow oxygen" into the kiln. The study actually says a crib made of wood with a diameter smaller than 1/2 inch is porous (McAllister and Finney 2013:2). The study only addresses wood 1/2 inch to 1/16 of an inch and says nothing about larger diameter wood at all.

- The idea that if some oxygen gets into the kiln the NSP would be falsified is itself in error. The challenge is to limit the oxygen not cut if off entirely. If it were cut off entirely we would be doing a reduction firing rather than an oxygen-limited (reduction/neutral) firing and the result would be black-on-black instead of black-on-white pots. In fact cribs of any size wood will let some oxygen into a kiln. The smaller diameter wood used in the NSP, as argued in my paper, by simple general principles of physics, will naturally have smaller gaps and pack more tightly than used by the SP and make it easier to limit oxygen and avoid oxidation often seen with the SP. This is all that is said in my article and it is entirely true (Swenson 2014:14).

- Lally then states that when organic material (viz., paint) burns off "the usually accepted explanation is excessive heat." This is contrary to the opinion held by anyone who has had any experience trying to solve the challenge of Anasazi organic black-on-white or is familiar with the discourse (Helm 1973; Shepard 1939; 1956; Swink 1993; Toll et al. 1991). The whole issue of smothering stems from the challenge of limiting oxygen, not heat. Organic paint burns off just as readily at 600ºC as it does at 950ºC if too much oxygen gets into the kiln. Over this same temperature range excellent black-on-white is produced if the oxygen is appropriately limited.

- Next, Lally cites the results of a study showing the temperature of ceramic sherds is lower in a simulated wildland fire than the surrounding air, and that "organic painted black-on-white sherds were less altered by the simulated crown fire environments than the mineral painted wares." I have no disagreement with either of these claims, but neither contradicts my paper. The first is given by the general laws of thermodynamics and heat flow, and the second would be a hysteresis effect predicted from my paper (see detailed discussion on differential oxidation thresholds in the alteration of organic vs. mineral paint relating to Salado polychrome replication experiments [Swenson 2014:12-13]).

- Finally, Lally writes "Swenson should have considered differences in elevation" before suggesting "similar firing techniques for Salado Polychromes and Mesa Verde White Ware" since fire at higher elevations produces less heat. Lally assumes that we have not considered anything not explicitly mentioned in the paper like altitude, or other parameters (e.g., clay bodies and/or slips). The effect on heat production of the differential altitudes covered in the paper was not mentioned not only because it is outside the paper's scope but also because it has no measurably relevant significance – it is entirely swamped by ordinary local fluctuations in such variables as wind speed, and barometric pressure (Wallace and Hobbs 2006). The paper was about smothering vs. non-smothering. The case for the latter was demonstrated experimentally and further corroborated with evidence from the archaeological record (e.g., Hammack and Heacock 1991; Heacock 1995; Fuller 1984).

These demonstrations and data still stand. The additional corroboration such as the evidence presented by the elegant and fastidious work of Severance outlined in his comments presented here further substantiates them. Additional exploration of the many variables evident in ongoing research will likely produce more insights about the production of organic black-on-white ceramics.

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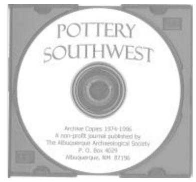

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