THE PRODUCTION AND DISTRIBUTION OF CLASSIC MIMBRES BLACK-ON-WHITE POTTERY

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Because the most abundant and finest quality Classic Mimbres Black-on-white ceramics are associated with large pueblos located in the Mimbres Valley, archaeologists have subscribed to a center–periphery model of exchange to explain the occurrence of these ceramics outside of the "heartland." Recent instrumental neutron-activation analysis based on 117 samples from six sites and supported by petrographic analyses demonstrates that separable production groups can be distinguished outside of, as well as within, the valley proper. Widely distributed production locales do not support a model of centralized control over production and distribution. The analyses thus raise questions about the purposes of such visually distinct pottery and the nature of its exchange.

Debido a que la mayoría de cerámica Mimbres Negro sobre Blanco de mejor calidad está asociada con grandes pueblos localizados en el valle Mimbres, varios arqueólogos han sugerido un modelo de intercambio de centro–periferia para explicar la ocurrencia de esta cerámica fuera del "área epónima." El reciente análisis cerámico por activación neutrónica realizado en 117 muestras provenientes de seis sitios y reforzado con análisis petrográfico, demuestra que existen grupos distintivos de producción cerámica tanto fuera como dentro del valle Mimbres. Locales de producción que se hallan ampliamente distribuidos no apoyan el modelo de un control centralizado sobre la producción y distribución cerámica. Estos análisis, por lo tanto, elevan preguntas sobre el propósito de la producción de cerámica tan distintiva visualmente y de la naturaleza de su intercambio.

Classic Mimbres Black-on-white pottery, which was manufactured between A.D. 1000 and 1150 in southwestern New Mexico, is famous for its naturalistic and geometric black designs painted on a white background (Figure 1). Most of the finest painted pottery and a high proportion of the naturalistic designs portraying humans and animals have been recovered from the Mimbres Valley, where Cosgrove and Cosgrove (1932) first defined the Mimbres pottery sequence. The greatest concentration of large Classic Mimbres sites—11 pueblos, each containing between 125 and 200 rooms—also occurs in the Mimbres Valley (Blake et al. 1986:458). The association of large pueblos and distinctive pottery has encouraged more excavation projects in the Mimbres Valley than in any other area yielding Mimbres pottery, and these projects, in turn, have depicted the Mimbres Valley as the heartland of the Mimbres region in southwestern New Mexico (Figure 2; LeBlanc and Whalen 1980).

The idea of a heartland from which all things Mimbres originated and emanated implies that people living in the Mimbres Valley had some sort of control over pottery production and distribution (Anyon and LeBlanc 1984:314). Since the processes by which Classic Mimbres Black-on-white pottery was produced and distributed have never been systematically investigated, these assumptions are questionable. For example, were the vessels made by a small group of localized specialists, or were they made by potters in many different areas? Were there elites present who used Classic Mimbres Black-on-white pottery as status symbols? Was the pottery's widespread distribution achieved through local production, through trade, or both?

In spite of the Mimbres Valley as heartland model, most archaeologists (Gilman 1989, 1990a; S. LeBlanc 1983:147–148; Shafer 1985:195) working in the Mimbres region today believe that Classic Mimbres society was noncentralized and nonhierarchical. Mortuary studies indicate that more than half of the people in the Mimbres Valley were buried with one Classic Mimbres Black-on-white

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Figure 1. Classic Mimbres Black-on-white bowl, height = 9.2 cm, diameter = 21.4 cm. Collected by E. H. Morris in a University of Colorado expedition to the Mimbres Valley. Courtesy University of Colorado Museum (catalog number #3158).

bowl, supporting the lack of a social hierarchy (Gilman 1990a:460). Classic Mimbres Black-on-white pottery, regardless of its artistic quality, appears to have been the product of a society with no full-time craft specialists (Gilman 1989:221), although a few individuals may have been responsible for the finest-quality vessels (S. LeBlanc 1983:138–139). Other evidence, including the relatively low population estimates per site and in the Mimbres Valley, the apparent lack of large pottery-production areas (firing facilities or concentrations of production tools, unfired vessels, and raw materials), and the lack of other kinds of craft specialists, also argues against the presence of a social hierarchy in the Mimbres region (Gilman 1989). Information about Classic Mimbres pottery production is badly needed to help explain the distribution of this visually distinctive pottery throughout southern New Mexico and southeastern Arizona relative to the "heartland" model and the "noncentralized and nonhierarchical" society model.

THE SOCIAL CONTEXT OF MIMBRES CERAMIC PRODUCTION AND DISTRIBUTION

Classic Mimbres pottery is an important component of ceramic assemblages from sites lying outside of the Mimbres Valley. For example, relatively high proportions of Classic Mimbres Black-on-white pottery have been found on sites along the Gila River west of the Mimbres River (Shaw and Bernard-Shaw 1986). These sites can be quite large; the Woodrow and Cemetery sites, which are on the Upper Gila River near the New Mexico–Arizona border, may number up to 500 rooms each (Lekson 1984:69). Classic pottery has been found as far away from the Mimbres Valley as the town of Alma to the north and El Paso on the east, south to the site of Casas Grandes, and west to the San Simon drainage (Figure 2; Gilman 1990b; Sauer and Brand 1930). In the San Simon drainage during the time contemporary with the Classic period in the Mimbres Valley, between 15 and 17 percent of the sherds are Mimbres whitewares, proportions considerably above the one to six percent representing the "locally made" San Simon Red-on-brown and the Safford variant of Hohokam Red-on-buff pottery (Gilman 1993). The relatively high proportion may be used to question the notion that not all Mimbres pottery was traded from the "heartland."

At least three heuristic models for the distribution of Classic Mimbres Black-on-white pottery may be constructed based on these observations.

1. All Classic Mimbres Black-on-white pottery was made in the Mimbres Valley where most of the large sites are concentrated; it was then traded to adjacent areas.

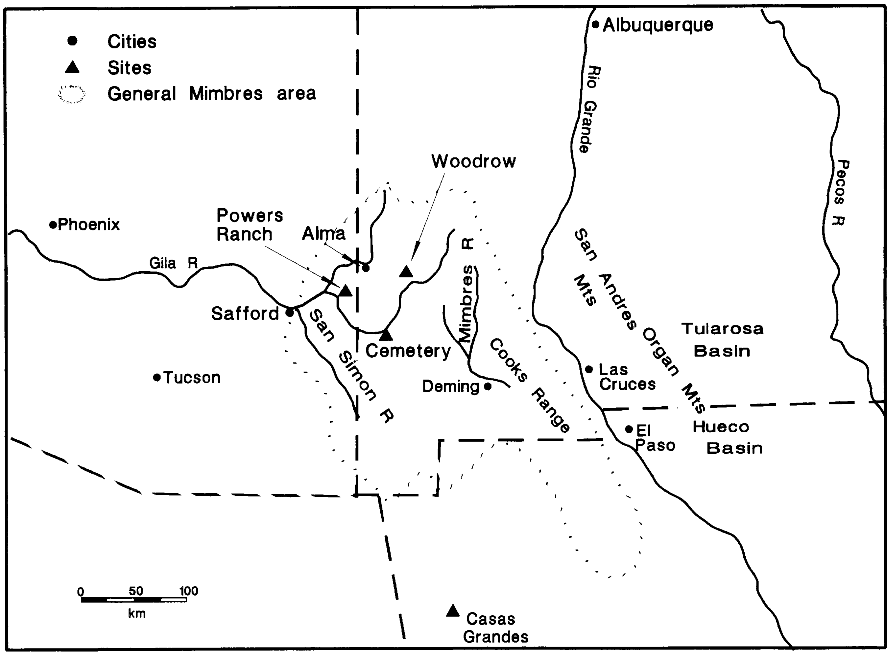

Figure 2. Area of the North American Southwest surrounding the Mimbres area.

2. The vessels were made locally across much of the southern Southwest. Little or no trade in ceramics occurred among different areas.

3. The distribution of the vessels represents movement over a period of years between the Mimbres Valley and other locales (Lekson 1988:141–142) or seasonal movement.

Each of these interpretative models implies certain social or economic organizational characteristics. The first suggests that people in the Mimbres Valley exerted some sort of control over the production and distribution of Classic Mimbres pottery such that people living in adjacent areas could only obtain this pottery through trade; this interpretation could imply the possible presence of an elite in the Mimbres Valley and the control of certain goods by the elite. The similarities in ceramic style and technology might suggest such control, as do the lower proportions of Classic Mimbres Black-on-white pottery outside the Mimbres Valley.

The second interpretive model implies some social interaction that does not involve social control. For example, the people in the Upper Gila may have been socially distinct from the people in the Mimbres Valley, but they may have maintained enough interaction to share the same technical and design repertoire used in the manufacturing process.

The third model assumes that people might have made pottery at any point during their proposed residential movements, accounting for the variable occurrence of Classic Mimbres Black-on-white pottery across much of the southern Southwest. This model cannot yet be evaluated adequately because of the lack of chronological controls that would make it possible to detect this kind of movement. Furthermore, if ceramics were made at the same locale in a seasonal or multiyear round, for example in the Mimbres Valley, the results would mimic those of the first model; the presence of multiple production locales would eliminate this kind of seasonal production as an explanation for the Classic Mimbres distribution patterns. However, if pottery were being made in many places by the same group during the year or over a period of years, the geographic results would parallel the second model, and a production locale centered in one small area would negate this model.

Evidence of the geographic extent of pottery-production locales is critical for evaluating the three models. As discussed next, several petrographic analyses have been recently performed on Classic Mimbres sherds, but the results, though suggestive of widespread production, are inconclusive.

PREVIOUS PETROGRAPHIC COMPOSITIONAL ANALYSES

Compositional characterization, either to match archaeological ceramics with likely sources of raw materials from which the pottery was made or to delimit areas of production, requires an analytical technique that is sufficiently sensitive to reflect potentially subtle differences among source areas and/or differences due to production techniques. Petrographic (mineralogical) analysis is a commonly used and relatively inexpensive technique to demonstrate production locales. A few small samples of Classic Mimbres Black-on-white sherds have yielded limited petrographic data. These data are reviewed here because the original reports are not widely circulated, because they have offered the initial suggestion that Classic pottery production occurs beyond the Mimbres Valley, and because the petrographic analyses and the compositional analysis presented here augment one another.

Petrographic analyses of Mimbres Black-on-white pottery from both the Classic and earlier periods in the Tularosa Basin and the Hueco Bolson, more than 100 miles east of the Mimbres Valley in New Mexico and Texas, indicate that at least some of the pottery was made in those areas rather than in the Mimbres Valley (Miller 1990; Rugge 1985a:135, 1985b, 1986). In fact, Rugge (1985b) hinted at as many as six distinct production locales based on the substantial diversity he observed in the temper of nine sherds from the Hueco Bolson. At least some of these temper types appear to have been derived from locally available materials in the nearby southern Organ Mountains. Hill (1991) found the same diversity in 11 sherds from the San Andres Mountains west of the Tularosa Basin.

Stoltman (1987) analyzed both plain and painted Mimbres sherds from Classic and earlier periods at the Wind Mountain site on the Upper Gila River in western New Mexico. Although the study was not specifically designed to determine production locales, Stoltman speculated that locally produced as well as nonlocally made vessels might be represented in his sample of five Classic Black-on-white sherds.

Petrographic studies of pottery from the Mimbres Valley itself have failed to differentiate production locales except for some corrugated ollas (Meinardus 1988; Rugge 1976; the latter is discussed in Anyon and LeBlanc [1984:169–171]). Because the black-on-white painted vessels were manufactured using broadly similar stream sand as temper, they have not been as easily distinguished on the basis of their nonplastic inclusions. These stream sands are derived from a rather complex geology, including alluvial, sedimentary, and igneous deposits, surrounding the Mimbres Valley (Elston 1957; Jones et al. 1967; Kuellmer 1954; Pratt 1967). It is thus not surprising that archaeologists have been unable to detect Classic Mimbres Black-on-white pottery-production locales using petrographic analysis.

The corrugated ollas, in contrast, exhibit two different types of temper, one volcanic and the other plutonic (Rugge 1976). When Rugge plotted the frequency of the plutonic-tempered olla sherds from sites located at various distances from the singular, localized source in the northern Cooks Range, he found that the greater the distance from the outcrop, the less frequent the number of plutonic-tempered sherds. Considering the amount of time required for an individual to travel to the outcrop, Rugge concluded that either the ollas or the temper alone were being traded to the more distant sites.

Thus far, the petrographic analyses demonstrate a wide diversity of temper materials appearing in Classic Mimbres Black-on-white pottery. Although this diversity is the likely result of localized production, the samples have been too small to form viable compositional groups. Furthermore, the analyses conducted to date have not been sensitive enough to distinguish among possible production locales within the Mimbres Valley, assuming they exist. There is, therefore, no basis for comparing pottery from specific valley production sites with pottery thought to have been made elsewhere.

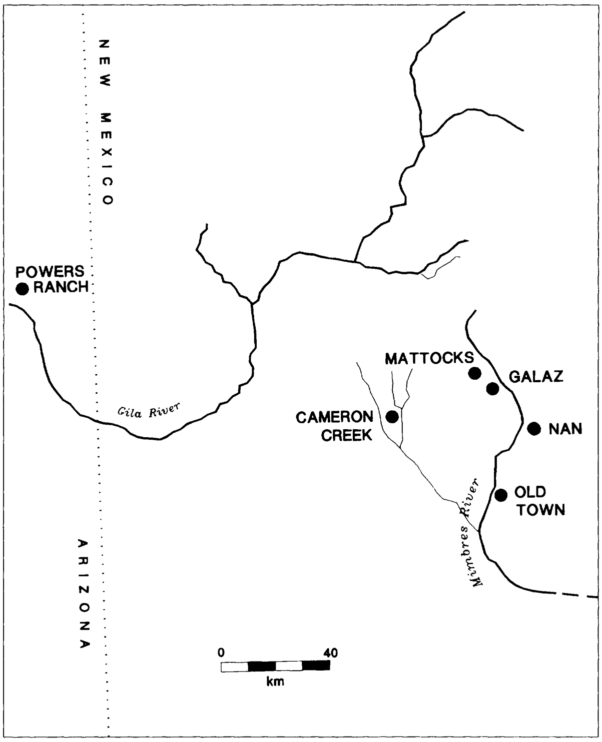

Figure 3. Detail of area where Classic Mimbres Black-on-white pottery is common. Sites discussed in text are labeled.

COMPOSITIONAL ANALYSIS OF CLASSIC MIMBRES BLACK-ON-WHITE POTTERY

Because the petrographic studies have not differentiated possible production locales within the Mimbres Valley, a chemically based compositional approach using instrumental neutron activation analysis (INAA) was selected. The primary objective of this INAA research was to assess the compositional variability of Classic Mimbres Black-on-white pottery as an indicator of the relative number of source and/or production units. In order to meet this objective, three questions had to be answered. One, what was the magnitude of chemically expressed compositional variability in the Mimbres ceramic pastes? Two, did the variability in pastes within the Mimbres Valley permit a more detailed investigation of intravalley production? And three, was the Mimbres pottery recovered at sites outside the valley compositionally similar to the pottery from the Mimbres Valley?

INAA combines great sensitivity with precise, simultaneous determinations for approximately 20 major, minor, and trace elements under routine conditions. The actual analytical precision for the determination of many elements is better than five percent (at one standard deviation), with some elements determined with better than two percent precision. The principle on which INAA is based involves a stable atomic nucleus that when irradiated with neutrons undergoes a nuclear transformation producing radioactive isotopes. Radioactive decay of certain radionuclides emits gamma rays of unique or characteristic energy that may be sorted, counted, and used to determine the elemental content of the sample. General discussions concerning the INAA procedure that was used can be found in Bishop et al. (1982), Blackman (1986), Harbottle (1976, 1982), and Perlman and Asaro (1969).

Although previously observed petrographic heterogeneity in the volcanic-derived temper might be expected to generate a considerable amount of noise in the chemical signatures of the Mimbres ceramic pastes, recent research on heavily tempered pottery suggests otherwise (Neff et al. 1988,

Table 1. Elemental Abundances Showing Differences Among the Sherd Samples.

	Mimbres Valley Compositional Units								Compositional Units Outside Mimbres Valley			
	Central Mimbres (n = 43)		Valley Variant 1 (n = 7)		Valley Variant 2 (n = 16)		Old Town (n = 7)		Powers Ranch (n = 11)		Salado Samples[a] (n = 27)	
Element	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Na	1.53%	17	1.09%	4	1.41%	12	1.24%	8	1.64%	14	1.56%	7
K	2.73%	8	2.87%	5	2.67%	10	2.95%	5	2.64%	11	2.63%	6
Sc	7.49	11	5.91	11	9.99	15	8.14	6	10.9	23	13.2	10
Cr	22.4	14	22.6	7	35.5	12	44.2	7	52.5	27	63.6	41
Fe	2.37%	16	1.99%	11	2.48%	13	2.42%	7	3.01%	16	4.09%	17
Co	12.3	27	17.0	32	12.8	33	27.4	31	13.3	40	19.0	18
Rb	160	25	215	22	184	17	252	10	145	18	120	27
Cs	4.93	13	7.08	9	19.3	36	7.26	6	8.55	43	6.69	20
Ba	736	18	520	18	525	21	534	26	692	22	794	22
La	52.7	18	40.8	8	49.3	15	39.6	5	52.9	12	47.5	11
Ce	86.8	18	62.9	10	76.6	15	70.8	7	95.4	12	84.2	12
Sm	6.47	22	3.26	10	5.69	15	4.41	6	8.51	21	7.79	14
Eu	1.21	17	.63	8	1.08	20	.91	8	1.47	11	1.47	22
Yb	3.57	14	2.81	11	3.76	9	3.24	3	4.17	30	3.74	17
Lu	.49	18	.39	22	.52	12	.45	16	.57	25	.50	24
Hf	7.44	19	7.66	13	7.34	13	7.19	8	8.40	10	7.73	24
Th	22.9	17	30.0	8	22.3	9	19.8	5	15.2	26	13.0	10

Note: Mean elemental concentrations are given as parts per million except where indicated as percent. S.D. = one standard deviation of the mean concentration expressed as percent of the mean. Data are reported as three significant figures.

[a] The Salado Polychrome samples are from the Gila Valley (Crown and Bishop 1991) and are presented for comparative purposes.

1989). Despite such heterogeneity, differences among various clay resources can still be ascertained if the temper does not constitute an extremely high percentage (e.g., more than 40 percent) of the ceramic paste and if reliance during stages of numerical analysis is placed on the characteristics of grouped specimens. A combination of petrographic and chemical analysis is easily a more powerfully discriminating approach than either technique used separately. Nevertheless, the heterogeneous, yet broadly similar mineralogical assemblage constituting the nonplastic components of Mimbres pottery suggests that chemical analysis is necessary to identify microregional variation in production locales.

A sample of sherds from six sites in the Mimbres and Upper Gila valleys (Figure 3) was selected for analysis. Four sites in the Mimbres Valley were chosen in order to assess compositional variation in ceramic production within the valley. They included the Mattocks site, which is the northernmost large site in the valley (Gilman and LeBlanc 1993; S. LeBlanc 1983; Nesbitt 1931), the Galaz site (Anyon and LeBlanc 1984), the NAN Ranch site (Shafer 1982, 1987, 1990, 1991a, 1991b), and Old Town (Creel 1989, 1990), the largest southernmost site in the valley. The site of Cameron Creek (Bradfield 1931) was used because it is located on a tributary that drains the backside of the mountain range separating the site from the central Mimbres Valley. The Powers Ranch site (Shaw and Bernard-Shaw 1986) completed the sample. This site, located on the Upper Gila River west of the Mimbres Valley, represented the farthest geographical location from the Mimbres Valley included in the analysis; if there is a periphery to the Mimbres Valley heartland, this site represents it.

A total of 117 sherds was analyzed: 26 sherds from the Mattocks site, 9 from Galaz, 20 from NAN Ranch, 23 from Old Town, 25 from Cameron Creek, and 14 from Powers Ranch. For this initial inspection of chemical variation in Mimbres ceramic paste, the lesser number of sherds analyzed from the Galaz site is not significant, due to the fact that the site is located only about three miles from the Mattocks site and was, therefore, not expected to be compositionally distin-

Table 2. Discriminant-Function Coefficients by Element.

Variable	DF 1	DF 2
K	−3.9	6.83
Sc	−13.0	−10.10
Fe	5.29	.37
Cr	−5.17	15.32
Co	.62	−2.60
Rb	−1.18	.39
Ba	1.82	.66
Cs	−10.00	−6.76
La	−2.08	−9.80
Sm	11.94	27.23
Yb	−12.58	2.33
Eu	−5.00	−10.59
Lu	1.99	−6.66
Hf	−1.09	−5.49
Th	6.91	−8.74

guishable if local resources were being used in ceramic production. Bowl forms in the total sample were better represented than jars, 108 to 9, and all of the 117 sherds analyzed were unambiguously classified as Classic Mimbres Black-on-white.

An evaluation of the initial cluster analysis of the raw elemental concentrations suggests that 84 (72 percent) of the 117 sherds form five major partitions of the data set. Four of these compositional units—Central Mimbres, Valley Variant 1, Valley Variant 2, and Old Town—are located in the Mimbres Valley, and one, Powers Ranch in the Upper Gila Valley, is outside of it (Table 1; the raw analytical data are available on request). The Salado samples included in Table 1 are from the Gila Valley and are later than the Classic Mimbres period. They are included on Table 1 for comparative purposes and are discussed near the end of this section, but they are not part of the Classic Mimbres compositional analysis.

The clusters were obtained by a complete linkage cluster analysis of a mean Euclidean distances matrix calculated from log-transformed elemental concentrations. The elemental abundances used included those that are determined with relatively high analytical precision and are relatively free of post-discard formation-process effects.

Samples that were not part of the initially formed groups were also evaluated as to their likelihood of belonging to any of the five clusters. No additional compositional profiles were found to lie within the 99 percent confidence interval, thus leaving 33 analyzed specimens unplaced. Whether or not these ungrouped specimens are members of yet unrecognized compositional groups, or whether they represent outliers to the currently recognized groups remains the subject of additional analyses and interpretation. The balance of our present discussion centers around the recognized groups that represent clusters of relative compositional similarity within the compositional space of Mimbres pottery.

The five groups of samples deemed to be compositionally similar by the cluster analysis were subjected to statistical evaluation of within-group membership. Starting with the largest group of 43 samples (which forms the Central Mimbres compositional unit described below), the probability of group membership was determined for each sample in the unit (Bishop et al. 1982). These calculations consider the particular pattern of interelemental variance and covariance relationships for the specific reference group under consideration; the probability of a given sample actually belonging to a reference group, given that sample's Mahalanobis distance from the multivariate group centroid was adjusted using Hotelling's T^2 to compensate for the small number of samples-to-variables ratio. Evaluated in this manner, for example, all samples that were not already within the largest reference group (i.e., Central Mimbres) were found to lie outside of a 99 percent confidence interval.

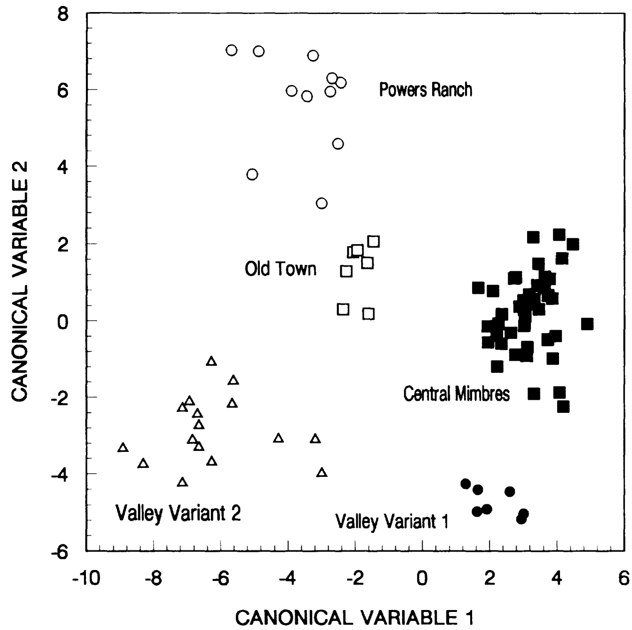

Figure 4. Discriminant analysis of Mimbres pottery compositional reference groups relative to Canonical Variables 1 and 2. Elemental loadings on the axes are given in Table 2.

A similar evaluation of the other groups was also made, but because a reasonable ratio of number of group members to the number of variables is needed (Rao 1948), a reduced number of five elements, in different combinations, was used as the basis for group evaluation. One rationale for the use of as many elements as practical is that you will be more likely to find differences among clay resources than if only a few elements are used. It can be shown, however, that if a sample fails to achieve an acceptable likelihood of group membership in a reduced elemental space, it will be similarly excluded in the expanded elemental space. Within the existing data set, statistical evaluation of the resulting groups supports the compositional distinctiveness of the derived reference units even when based on a reduced elemental space.

Membership in the five statistically evaluated groups is described below. While some of the groups can be shown to be fully separated from other reference units when bivariate plots of principal components or other ordination procedures are used, several such plots are necessary to demonstrate that all of the identified groups are separated from each other in a chemically defined space. For graphical simplicity, the compositional differences among the groups are illustrated by reference axes derived by a stepwise discriminant analysis; the elemental loadings on the axes are listed in Table 2. The discriminant analysis is used here only as a convenient manner of showing tendencies of compositional differences among several groups in a low dimensional space (for a discussion of discriminant analysis in compositional data handling, see Bishop and Neff [1989]; for comments on the distortions that can arise in stepwise discriminant analysis, see Bishop et al. [1989:Note 2]; see Hocking [1983] for a discussion of general regression techniques).

Eleven sherds from the Powers Ranch site constitute a group that is observed to be markedly different in composition from those groups with a provenience in the Mimbres River valley (Figure 4; Table 3). Even among the Mimbres Valley samples, where the use of compositionally similar clays is expected, six sherds from Old Town and one from NAN Ranch deviated from the patterning in the other Mimbres samples. Both the Old Town and the Powers Ranch samples formed strongly site-specific clusters and hence are referred to as the Old Town and Powers Ranch compositional units, respectively.

Table 3. Membership in Mimbres Compositional Groups by Sites and Vessel Form.

Site	Vessel Form	Central Mimbres	Valley Variant 1	Valley Variant 2	Old Town	Powers Ranch	Not Grouped	Total
Mattocks	Jars	2	1	0	0	0	0	3
	Bowls	12	3	0	0	0	8	23
Galaz	Jars	0	0	0	0	0	0	0
	Bowls	2	0	4	0	0	3	9
NAN Ranch	Jars	3	0	1	0	0	0	4
	Bowls	7	1	4	1	0	3	16
Cameron Creek	Jars	0	0	0	0	0	0	0
	Bowls	13	0	5	0	0	7	25
Old Town	Jars	0	0	1	0	0	1	2
	Bowls	4	2	1	6	0	8	21
Powers Ranch	Jars	0	0	0	0	0	0	0
	Bowls	0	0	0	0	11	3	14
Total		43	7	16	7	11	33	117

The largest cluster from pottery recovered within the Mimbres Valley is made up of 43 samples representing the Mattocks, Galaz, NAN Ranch, Cameron Creek, and Old Town sites (Figure 4; Table 3). This reference group is designated as the Central Mimbres compositional unit. Although Cameron Creek is located on a tributary to the Mimbres River, many of the samples from the site cannot be separated from the Central Mimbres compositional unit at this time. It may be that the potters were drawing on commonly available clay sources or that much of the Classic Mimbres pottery at the Cameron Creek site was traded from the Mimbres Valley. Alternately, Cameron Creek drains through the same complex geology as the Mimbres River (Elston 1957; Jones et al. 1967; Kuellmer 1954; Pratt 1967), and the geological overburden through which both flow probably imparts a similar compositional signature to the clays.

The fourth cluster, designated Valley Variant 1, comprises seven samples from Mattocks, NAN, and Old Town that showed marked deviation from all other samples (Figure 4, Table 3). A second "valley variant" (Valley Variant 2; Figure 4, Table 3) is also identified; it differs from the Central Mimbres and Valley Variant 1 compositional units in not containing any samples from the Mattocks site.

The distinctly different compositional pattern of the Powers Ranch site sherds may reflect the different geology of the Upper Gila drainage. Using the same elemental abundances as in the cluster analysis, support for this distinct Upper Gila composition may be gained through a Q-mode factor analysis (Joreskog et al. 1976:86–115) when later-manufactured Salado Polychrome pottery analyzed from the Upper Gila Valley sites of Riverside and Willow Creek (Crown and Bishop 1991) is combined with the Classic Mimbres compositional groups. In Figure 5, the Powers Ranch site specimens occupy an intermediate area, away from the Mimbres Valley specimens and toward the Salado ones located near the A-apex of the triangle. Factor scores constituting the Q-mode axes are listed in Table 4. This plot does not imply that the Salado and the Powers samples are produced from the same specific resources, but only that they share compositional characteristics that are most likely derived from the geological substrata of the Upper Gila drainage.

Also of interest in Figure 5 is the somewhat weaker tendency of the Old Town specimens and those of the Valley Variant 1 group to occupy a compositional space toward the B-apex. As two members of the latter group are also from an Old Town provenience, these patterns may suggest a southern valley production location for the specimens within Valley Variant 1.

From the standpoint of distributional patterns, given that all the sherds selected for this analysis are Classic Mimbres Black-on-white, the relationship between the site from which the sherd was recovered and its possible production locale should indicate directionality and distance in ceramic movement, if such exists. But at the present time, evidence for trade among these Classic Mimbres sites remains somewhat ambiguous. For example, all 11 samples in the compositional unit for the

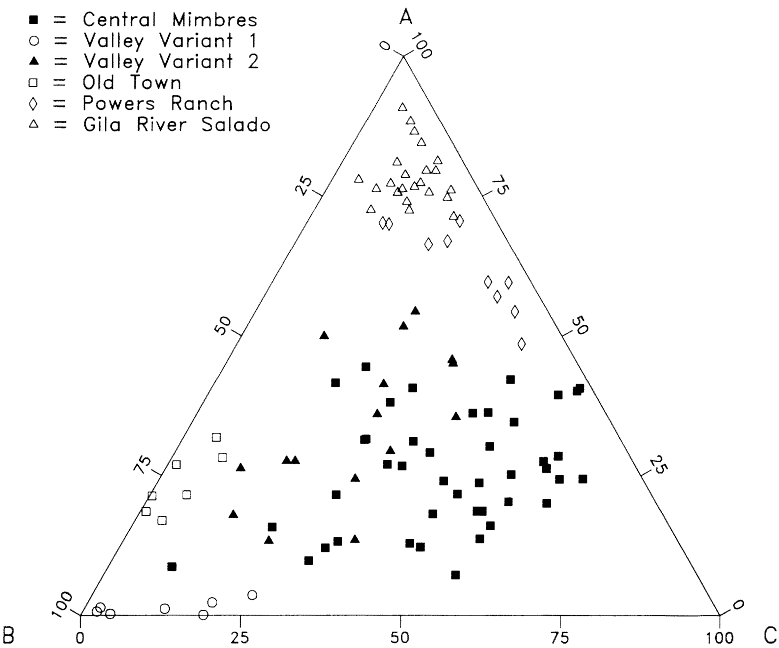

Figure 5. Q-mode factor-analysis plot of analyzed Mimbres and Salado pottery. Mimbres reference-group symbols are retained from the cluster and discriminant analysis. Unlike the discriminant analysis that attempts to calculate axes that maximally separate the groups, the Q-mode analysis focuses attention on the major structural relationships among samples. These relationships are summarized with regard to hypothetical "end members," and the samples are plotted with regard to their percentage of each respective end-member apex of the plot. Elemental loadings constituting the end members are given in Table 4.

Powers Ranch site have an exclusively Powers Ranch provenience, and no other defined compositional unit includes pottery from the Powers Ranch compositional unit. The apparent interaction between people living at this site and people living in the Mimbres Valley is based solely on similar technologies and designs. With only four sherds from Old Town included in the Central Mimbres compositional unit, any attempt to identify the direction or extent of trade within the valley would be premature at this time.

SUMMARY AND DISCUSSION

The compositional analysis and interpretation show that ceramic production was not limited to the Mimbres Valley. Equally important, these data refute that aspect of the "heartland" model that would have pottery production and distribution controlled by peoples living in the Mimbres Valley. Some portion, perhaps the majority, of Classic Mimbres pottery made in the Mimbres Valley stayed there; some portion, again perhaps the majority, of Classic Mimbres pottery made outside of the Valley was used locally. This pattern would appear to align with the second model proposed earlier, which posited essentially local production with little exchange. The local production and use of Classic Mimbres pottery by people moving over the landscape, as outlined in Model 3, could affect interpretations of exchange behavior, but not the widespread distribution of production locales.

If pottery production is not being controlled, what impact does this information have on the continued characterization of the Mimbres Valley as "heartland" or core? Although it is increasingly likely that Classic Mimbres society was nonhierarchical, that elites were not present, and that different groups acted relatively autonomously in the production of Classic Mimbres pottery, the Mimbres Valley does contain more large Classic Mimbres sites than any other drainage, including the Gila River. Sites outside the Mimbres Valley also have fewer Mimbres Classic vessels than sites in the

Table 4. Scaled Varimax Q-Mode Factor Scores.

Variable	Factor 1	Factor 2	Factor 3
K	.11	−1.88	−.23
Sc	1.93	−.17	.54
Fe	1.64	−.17	.58
Cr	1.15	−.16	.71
Co	1.10	−1.34	1.13
Rb	−.08	−2.35	.10
Ba	.87	−.31	−.74
Cs	3.11	−.57	.26
La	.02	.27	−1.92
Ce	.47	.30	−1.51
Sm	1.26	.36	−1.23
Yb	.69	.05	−1.03
Eu	1.45	.24	−1.01
Lu	.58	−.11	−.95
Hf	.56	−.64	−.14
Th	−1.09	−1.96	−1.55
% of variance	79.7	8.3	3.6

valley (Gilman 1980). One might thus still argue that the Mimbres Valley functioned as a core, but such arguments must hinge on the specific environmental and social conditions that obtained in the Mimbres Valley and the surrounding drainages.

Not only do nonceramic indicators suggest that Mimbres social organization was nonhierarchical, so do the ceramic indicators of production. But other aspects of production relating to the artistic and/or technological particulars of the pottery remain unanswered. Building on this new evidence of Classic Mimbres pottery production, the question of the context and use of such visually distinctive pottery in a nonhierarchical society can now be examined.

As Shafer (1985) has noted, a hierarchical society may not be necessary for the presence of craft specialists. Specialists at the household level could certainly practice their craft part-time, but regularly enough to maintain their painting skills. To test the possible existence of part-time specialists, C. LeBlanc (1977) examined the quality of the design execution on Classic Mimbres bowls. She assigned comparative grades of excellence to bowls from seven sites that included large and small sites as well as sites in the Mimbres Valley and those on tributaries. After plotting their distribution, LeBlanc found that all seven sites had some of the better-graded vessels (i.e., the highest of the four assigned grades). The smaller sites and those sites lying on tributaries of the main valley, however, exhibited a more uneven distribution, having a higher proportion of poor-quality vessels. Two of the largest sites in the valley, on the other hand, showed a more even distribution across the four grades. If there were part-time specialists present, they were more likely to produce their wares at the larger sites. That potters were making Classic Mimbres pottery from clay sources outside the Mimbres Valley is no longer arguable: They were. Unless evidence is forthcoming that the better-graded vessels circulated differentially, the contrasts in the quality of the painting may reflect only the artistic talents of the individual painters at each site, and not the appropriation of the part-time specialist's vessels for use by an elite.

If Classic Mimbres pottery was not being used to signify the social distance and power of elites, the painted designs may have had some meaning for families, clans, lineages, or other similar social groups. Perhaps, in fact, the designs were symbols of group membership, and their very elaborateness was to make membership in such groups quite clear. C. LeBlanc's (1977) preliminary study of the distribution by site of animal motifs on black-on-white pottery initially supports this idea in that specific naturalistic motifs were differentially represented in site assemblages. For example, the bighorn-sheep motif was most common at the Swarts site in the Mimbres Valley, whereas the horned-toad motif predominated at the Baca site to the south of Swarts. However, the simple fall-off pattern, obtained when Brainerd–Robinson coefficients of motif similarity were compared with the distances between sites, suggested to LeBlanc that the exchange was based on simple reciprocal ties that did not relate to particular social segments of the population. Regardless of the possible causes of the design-motif distributions, the association of specific designs with specific sites again supports the model of production at different sites within the Mimbres Valley.

LeBlanc did not rule out the possibility that the naturalistic motifs could still carry information of "national" significance. Shafer and Taylor (1986) explore this possibility on a communal scale. They hypothesize that the motifs reinforced communication among communities engaged in cooperative agricultural pursuits. They further suggest that the artistic changes between the earlier painted pottery and Classic Mimbres Black-on-white may have been correlated with new residential patterns, which they infer from changes in the architectural complexity at the NAN Ranch site. This interpretation focuses on the mutual understanding that could be realized, in part, through elevating the level of redundant information contained on the vessels.

The new evidence presented here that ceramic production and distribution were not determined solely by residents of the Mimbres Valley and the lack of any other evidence for a centralized hierarchy of elites both tend to support simpler models of Classic Mimbres production and distribution. The long-term objective of this research program is to define further production locales within and outside of the Mimbres Valley. In spite of the variable nature of Mimbres pottery temper and its effect on the pottery's compositional profiles, the demonstrable separation between most sherds from Old Town and the other Mimbres Valley samples suggests a rich area for future compositional research. Once production sites can be established on the basis of compositional analysis, in combination with petrographic studies, then their correlation with design styles and resulting distributional patterns can form the basis for refining models of exchange relationships.

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STRENGTH TESTING ARCHAEOLOGICAL CERAMICS: A NEW PERSPECTIVE

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The measurement of ceramic strength is an important source of evidence for assessing any pottery technology. However, the adoption of strength testing within comprehensive ceramic analyses in archaeology has been hindered by the absence of a reliable format for testing archaeological specimens. This paper presents results of research undertaken to develop the ball-on-three-ball test, which measures the tensile strength of archaeological, ethnographic, and experimental ceramics in biaxial flexure. Laboratory experiments demonstrate that the test produces reliable and accurate results largely unaffected by the irregularities of sherd-shaped specimens. In an example from the prehistoric Southwest, strength tests are used to investigate technological change in the Cibola White Ware sequence and the role of strength in the formation of archaeological assemblages. It is suggested that the development of a versatile, dependable technique can help to move strength testing out of experimental laboratories and into mainstream ceramic analyses.

La medida de resistencia de materiales cerámicos es una importante fuente de evidencia para evaluar cualquier tecnología cerámica. Sin embargo, la adopción de pruebas de resistencia dentro de un análisis cerámico comprensivo en arqueología ha sido impedida por la ausencia de un formato confiable para analizar especímenes arqueológicos. Este artículo presenta los resultados de una investigación realizada para desarrollar la prueba de bola-sobre-tres-bolas, la cual mide la resistencia tensora de cerámica arqueológica, etnográfica y experimental en flexión biáxica. Experimentos de laboratorio demuestran que esta prueba produce resultados confiables y acertados que no son afectados por las irregularidades de especímenes curvos como son los fragmentos cerámicos. En un ejemplo de la prehistoria del suroeste norteamericano, pruebas de resistencia son utilizadas para investigar cambios tecnológicos en la secuencia de la cerámica blanca Cíbola y el rol de la resistencia en la formación de conjuntos arqueológicos. Se sugiere que el desarrollo de una técnica versátil y confiable puede contribuir a movilizar las pruebas de resistencia del campo experimental al campo del análisis cerámico de rutina.

In *Ceramics for the Archaeologist*, Anna O. Shepard (1965:130) proposed that strength "is a significant property that would be useful in comparative studies if it could be measured satisfactorily." Shepard argued that the strength characteristics of ancient pottery would supply information useful for many research questions. In two general areas strength plays a dynamic part in ceramic technology and thus broadens the range of topics to which it may apply. First, strength properties are a product of most processes of ceramic manufacture, including clay and temper selection, forming, drying, and firing (Grimshaw 1971). By providing information on production techniques, strength measurements are a window for viewing past technological developments. Second, strength is an important component of certain vessel-performance characteristics, such as durability. In this way, strength measurements may pertain to intended vessel function, actual performance during use, use

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