The Formation of Ceramic Analytical Groups: Hopi Pottery Production and Exchange, A.C. 1300–1600

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The formation of ceramic analytical groups based on compositional, technological, and stylistic analyses enables us to begin modeling the conditions of production and exchange that affected Hopi potters between A.C. 1300 and 1600. The present study indicates that intervillage and intravillage production units can be isolated for pueblos located on adjacent mesas in NE Arizona. Exchange of vessels between sites on and off the Hopi mesas suggests directionality, but there is little direct evidence that bears on hypothesized intervillage alliances of either potters' groups, kin groups, or elites.

Introduction

The demographic upheaval and realignment that occurred in the American Southwest during the 13th and 14th centuries clearly had a bearing on the emergence of traditional Hopi society (Dean et al. 1985; Ellis and Colton 1974). Recent interest in assessing the complexity of Western Pueblo reorganization in terms of increased population pressure on traditional subsistence strategies, expanded alliance networks, and resultant inequalities in the distribution of materials or information has fostered the development of new models of late prehistoric adaptation. Whether proposing new considerations of leadership in community decision-making (Upham 1982) or the efficacy of long-distance networking to minimize subsistence risks (Braun and Plog 1982; Hantman and Plog 1982), these models require new theoretical orientations and methodological applications for interpreting the present data base.

Archaeologists rely to a large extent on the widespread distribution of pottery types in developing models of social interaction. In the case of the Hopi yellow-firing ceramics, which stand in sharp contrast to the preceding gray/white-firing and orange-firing ceramics, their manufacture corresponds closely with the inception of social or sociopolitical realignments (Upham 1982); their wide distribution has been noted as a hallmark of exchange (Schaefer 1969), and their potential symbolic value is underscored by the striking differences in design and technology from the previous Anasazi ceramic tradition (Shepard 1971; Smith 1971: 474–475).

Reports of the frequency and distribution of yellow wares off the Hopi mesas (Schaefer 1969; Upham 1982; Adams, Dosh, and Stark 1987) and archaeological data recovered more recently from sites also off the Hopi mesas (Upham 1982; Adams 1985) form one of the principal data bases for developing models of alliance and exchange involving the Hopi. For example, Upham (1982) proposes a 14th-century "Jeddito" alliance on the Colorado Plateau, with the Hopi pueblos forming an important polity in a system linking settlement clusters in the areas of Anderson Mesa, the Middle Little Colorado, Puerco, and Verde. Upham suggests that the Hopi or Jeddito yellow wares functioned as status markers and were exchanged by the elite throughout the region.

Because Upham's contribution rests chiefly on data from outside the Hopi country, inferences about Hopi participation in the proposed alliance and about its structure and operation would be vastly improved by data on pottery production and exchange from the Hopi mesas. Likewise, a closer examination of the technical and stylistic variation in the yellow wares, glossed in Upham's (1982:125–126) analysis of broadly formed, but technologically distinct wares, would prove most helpful in assessing behaviorally or contextually significant differences in ceramic production and exchange.

In order to provide these data, an interdisciplinary investigation was undertaken that entailed a compositional, technological, and stylistic analysis of Hopi yellow-firing pottery recovered from sites both on and off the mesas. Taking as our baseline the pottery manufactured between ca. A.C. 1300 and 1600, we have been able to distinguish regional, village, and intravillage patterning in the compositional data. Variation in technology and design style, corresponding to these patterns, has also been identified, although these analyses have not progressed as far as the compositional analysis on which they are based. Nevertheless, the emergent patterns of covariation or divergence among the different data sets, while presenting more complex data configurations, serve to enhance the interpretative potential of each data set.

Although the investigation is still underway, we are reporting the results of our initial studies for two reasons. First, analytical data from selected Hopi villages on Antelope and First mesas document pueblo-specific pottery production that bears on issues raised by Upham's model of Western Pueblo alliances. Second, these data force the consideration of the multicomponent nature of a ceramic-analytical group construct, a necessary first step toward developing a model of the conditions of production affecting the manufacture and exchange of Hopi pottery both on and off the Hopi mesas. The results illustrate the way that physical scientific analyses, quite apart from improving on the description of traditional archaeological data sets, can be used to identify ceramic variation across several dimensions and to assess the significance of this variability *vis-à-vis* production/artistic groups and exchange networks.

Feasibility Study

An initial study was conducted to assess whether there was sufficient elemental variation in the clays and ceramics to form compositionally discrete groups (Bishop and De Atley 1984). Impetus for the investigation was provided by Alfred Qöyawayma who, as a Hopi potter, had systematically and extensively collected clay samples in order to evaluate their utility for producing his own contemporary pottery and the ancient yellow wares (FIG. 1). Over 130 clay samples taken from these locales, including multiple samples from single lenses, and 132 yellow-firing sherds from the sites of Awatovi, Kawaika-a, Sikyatki, and Oraibi were analyzed for their trace-elemental content using the Instrumental Neutron Activation facilities at Brookhaven National Laboratory.

The results of the clay analyses revealed sufficient elemental variation in the sampled clays to permit discrimination among clays found on the mesas (Bishop and De Atley 1984). Interestingly, the analyses of clays from a single mesa do not have sufficient chemical similarity to form a single compositional pattern that is mesa specific. Even though repeated sampling from along a given exposure may yield a characteristic pattern, it can differ significantly from other clay lenses or clay ponds in the same geologic formation. Far from presenting problems for a compositional analysis, however, the presence on a given mesa of several clay chemical signatures means that a "match" between a group of pottery and a clay source is more resource specific.

In contrast to the weak "between-mesa" patterning in the clays, separation of the ceramic samples was strongly patterned. The differentiation of the compositional groups was found to be site specific and, by virtue of the sites' locations on different mesas, mesa specific (Bishop and De Atley 1984). Within the site-specific compositional groups there occurred occasional sherds from other sites. The similarity of chemical profiles of vessels recovered from different proveniences suggested that material exchange could also be monitored. Subsequent sampling and analysis have expanded group membership and strengthened the initial inferences about production loci and exchange.

The Formation and Use of Ceramic Reference Groups

One of the basic premises underlying the use of chemistry in a ceramic analysis is that clay sources can be differentiated if an adequately sensitive analytical technique is used. Furthermore, these differences can be used to form ceramic compositional groups because vessels manufactured from a given clay source will be more similar to one another than to vessels manufactured from a different source (Bishop, Rands, and Holley 1982: 301). The use of paste compositional analysis, then, allows us to monitor production and exchange behavior by 1) attributing the pottery of interest to a procurement source or region, 2) describing the spatial patterning of exchanged materials, and 3) reconstructing the organization of exchange with attention to directionality or symmetry of flow of goods. The variability encountered along these dimensions, however, is affected by technical and social behavior involved in pottery production and the context of exchange. In

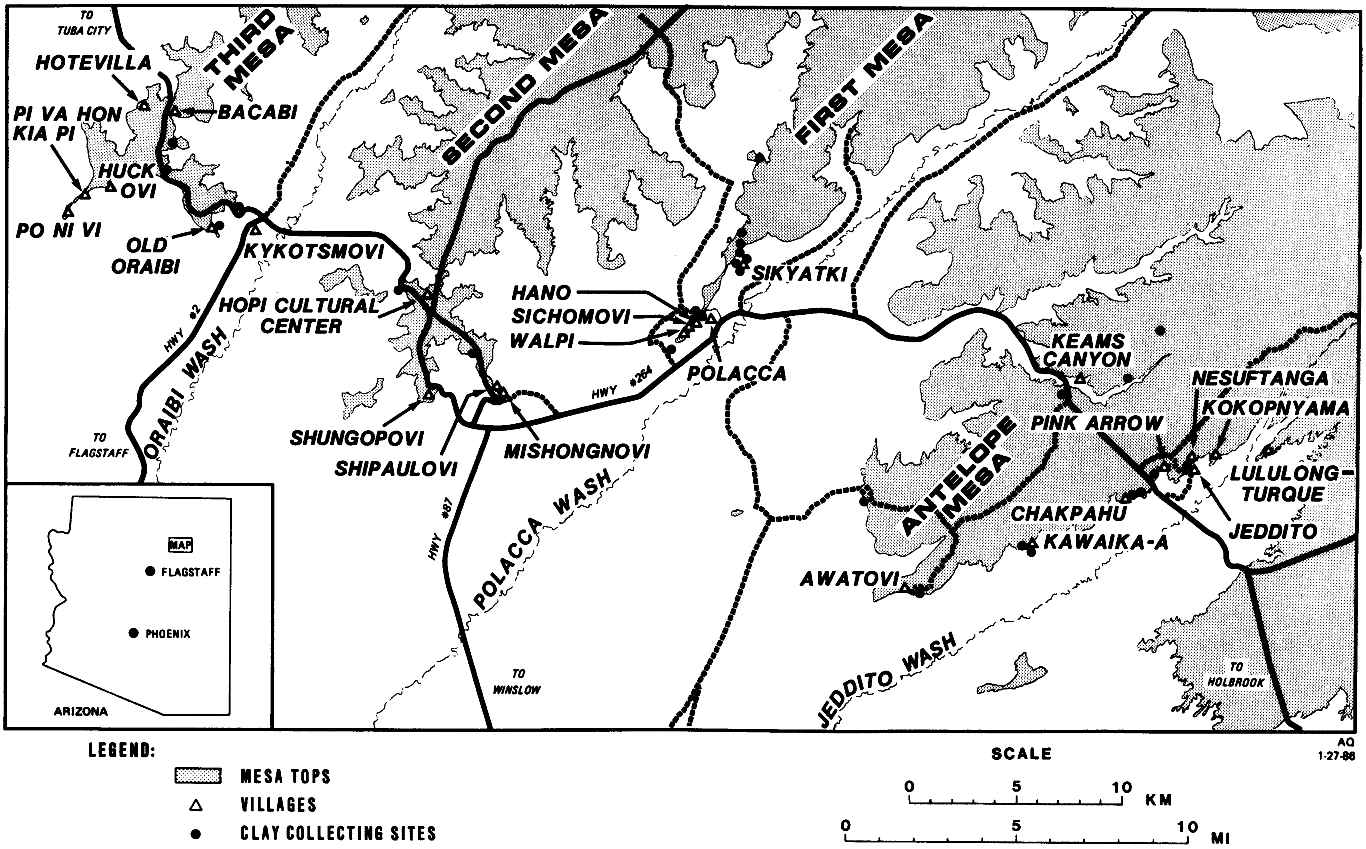

Figure 1. Locations of clay samples collected from the Hopi mesas. Inset shows location of the Hopi mesas in Arizona.

order to determine the degree to which the compositional properties, apparent in the feasibility study, covary with the physical differences resulting from technical manufacturing processes, as well as with differences occurring in the decorative system that reflect learning and/or signalling behavior, subsequent ceramic sampling for chemical analysis has both guided and been guided by complementary technological and stylistic analyses. This combination of analytical approaches provides the basis for a more integrated picture of Hopi social boundaries and exchange networks than that available from density/distribution maps of raw materials or finished products.

The Analytical Sample

The cooperation of collaborating institutions has enabled us to analyze over 650 ceramic samples and 130 clay samples. Most of the sampled ceramic collections have a long and diverse archival history, which biases efforts to sample the collections systematically. To overcome some of these difficulties, sampling has proceeded in multiple stages. In the initial stages, sherds and clay possessing the requisite properties were collected from several sites, broadly situated in the Hopi area, in order to assess paste composition relative to provenience. Supplemental materials were analyzed to increase our confidence in the initial ceramic reference groups and to broaden geographical coverage. As patterns emerged, samples were added to augment the comparative base. For example, sherds that could be unambiguously identified as Sikyatki Polychrome (Colton 1956) were selected initially to control for temporal and stylistic variability. Subsequent sampling has extended coverage to other types of yellow ware to assess temporal, geographic, and stylistic variation. Bowls and jars have received primary analytical attention in order to assess, and also to minimize, the effects of technical/functional manufacturing requirements in the interpretation of ceramic variability. The analysis of multiple vessels from the same burial or room context and the analysis of vessels with similar designs have provided comparative data on stylistic and resource contemporaneity and circumscription.

Obviously, the size of the sample is dependent on the pottery types and proveniences represented in the collections, which in turn are dependent on the history of archaeological investigations. Within any data set, the sample size is also affected by the type of analysis and nature of the instrumentation. Our analysis requires the selection of both whole vessels and sherd materials that are subject to different kinds of analytical procedures. For example, chemical spectrographic analysis and structural analysis are used in combination: only those samples that correspond to an identifiable paste group are investigated with a microprobe or scanning electron microscope.

Even though the sample is being drawn from a biased population, it does provide distributional information for numerous sites on and off the mesas and limited contextual information. The latter provides some control over "consumer context," which is important for design and technological comparisons. Because we are still analyzing the materials, the data presented in this discussion do not represent, uniformly, the distributional or contextual information that is available in the sample or even the totality of the analytical methods employed. The following data have been selected 1) to demonstrate differential resource selection between and within villages, 2) to assess the degree of technical and decorative information exchange, and 3) to trace the movement or trade evinced by the yellow-firing vessels. Special consideration has been given to samples from site assemblages that have already been characterized in the literature and, therefore, allow us to evaluate general inferences about production and exchange. For this reason, the presentation focuses on ceramic materials from the sites of Awatovi and Kawaika-a located on Antelope Mesa and the site of Sikyatki on First Mesa (FIG. 1; Smith 1971; Huse 1976; Fewkes 1898).

Compositional Analysis

The Hopi project, with its site locations relatively closely spaced in a similar geological environment, requires a ceramic paste compositional technique that is highly sensitive not only to subtle differences in the chemical profiles of differing raw material sources but also to manufacturing procedures that might alter the clays. Accordingly, Instrumental Neutron Activation Analysis (INAA) was selected as the technique of choice (Bishop, Harbottle, and Sayre 1982; Harbottle 1982). Although several techniques can be used to determine the chemistry of the ceramic clays, INAA combines great analytical sensitivity with relatively small sample requirements; this is an important consideration when the sampling of whole vessels constitutes a major part of the analytical program.

For samples more recently analyzed at the Smithsonian Institution, irradiation and counting procedures are those described by Blackman (1986). The samples which formed the earlier "feasibility" study were analyzed at Brookhaven National Laboratory according to the procedures described by Bishop, Harbottle, and Sayre (1982). As different analytical standards are employed at the two laboratories, the Brookhaven data have been normalized to the SRM1633 (Coal Fly Ash) standard used by the Smithsonian Institution's Conservation Analytical Laboratory (see Harbottle [1982] for a discussion of interlaboratory standardization; specific Brookhaven-to-Smithsonian data conversion factors have been reported in Olin and Blackman [in press: table 1]).

Binocular microscopic examination reveals that the yellow wares (Jeddito Black-on-Yellow and Sikyatki Polychrome) were predominantly formed from fine clays to which no apparent tempering material was added. These findings agree with earlier observations made by other investigators (e.g., Hargrave 1932: 28–31; Shepard 1971: 182–183; Smith 1971: 588–592). The nonplastic, silt-sized fragments scattered throughout the paste are of such quantity and in such a weathered state as to suggest that they are naturally-occurring inclusions within the clay matrix. Pottery from certain sites, such as those on Second Mesa, appears to have more abundant silty inclusions, which may correlate with specific resource, or possibly manufacturing, differences. Because of the lack of temper and the sparseness of nonplastic inclusions in most cases, the observed elemental concentrations predominantly reflect the elemental patterns of the utilized clay resources. This patterning is still quite variable, reflecting as it does the chemical-geophysical formation of clays, but the patterning is far less variable than would be encountered if the pottery were heavily tempered (Bishop 1980; Neff, Bishop, and Sayre 1988).

Data from 169 ceramic samples from the sites of Sikyatki, Awatovi, and Kawaika-a were log transformed, using the elemental concentrations for which reliable determinations were obtained: Na, K, Sc, Cr, Fe, Rb, Cs, Ba, La, Ce, Sm, Eu, Yb, Lu, Hf, and Th. Next, an average linkage cluster analysis was carried out on a matrix of mean Euclidean distances (Sokal and Sneath 1973). "Groups" of compositionally similar specimens were summarized by a hierarchical dendrogram and were found to reveal a pronounced tendency for patterning by site provenience as well. Such summarizations, however, while providing a reasonably quick guide to the grouping tendencies in the analytical data, are subject to varying degrees of "distortion" due to strongly-correlated elemental pairs and the averaging of point to point distances in the clustering process.

The distortion in the cluster analysis precludes direct interpretation from the resultant dendrograms although some reliance can be placed in the lower level linkages. Even though Everitt (1979) has shown that a "large" change in the dendrogram linkages may be a *necessary* condition for a major cluster break, it may not be a *sufficient* condition. Other kinds of metric relationships must be considered. For example, the patterns of elemental correlations within a group may be more diagnostic of a resource procurement area than are the patterns based upon absolute concentrations (Bishop, Rands, and Holley 1982). Therefore, the largest dendrogram groups with strong tendencies for a single site locus were selected for more detailed examination. Any sample that was recovered from a site other than the single site locus being considered was removed, and the remaining samples were re-evaluated as to their statistical likelihood of group membership.

The technique used for assessing compositional group membership was based upon a sample's Mahalanobis distance from the multivariate group centroid, expressed by Hotelling's T^2 statistic; the latter is a multivariate generalization of the well-known Student's t (Bishop, Harbottle, and Sayre 1982). Proceeding iteratively, a group's variance-covariance properties were determined and its eigenvectors and eigenvalues extracted. Probabilities of group membership were calculated for each sample that was placed within the group initially. Samples found to lie outside of a 95% confidence interval were excluded and the group properties recalculated. When no further samples could be removed, the probability of "nongroup" samples belonging to the group was determined. Nongrouped samples that were found to have a projection probability of group membership within the 95% confidence interval were added to the group and the process repeated until additional samples could neither be removed nor added. The resulting group was then used as a chemically-based compositional reference unit. The compositional reference unit forms a conceptual entity that may be subject to further modification in order to achieve stronger concordance with nonchemical data or may be used directly for inferences pertaining to ceramic production and exchange (Bishop and Rands 1982; Bishop, Rands, and Holley 1982: 302–306).

Village Ceramic Production on the Hopi Mesas

Studies of ceramic distributions and comparisons of different styles yield differences that are generally assumed to reflect different cultural groups. Such cultural groups are archaeological units that require further investigation before specific types of social interaction uniting them can be hypothesized (e.g., kin, residential, or work groups; clans, elites, or trading partnerships; etc.). In the absence of a paste compositional analysis, pottery production is usually assumed to correspond to site provenience. In areal studies of production and exchange of a single ware, the introduction of nonsite materials has to be distinguished from onsite materials before local potter/painting groups can be identified with confidence. Both the scale of production and the identification of these different production groups are important for assessing the nature of the variability in ceramic pastes and style that may relate to possible intervillage alliances of production and/or consumer groups.

Information about paste differences that would distinguish among the various production locales in the Jeddito Valley or on the Hopi mesas has not been forthcoming until now. From the compositional evidence, we conclude that the manufacture of yellow wares was site specific for the three pueblos discussed here. The separation between production occurring on First Mesa and Antelope Mesa, as well as variation in production on the same mesa, is consonant with the expectations based on the feasibility study.

Three separate, primary compositional groups have been formed: two representing pottery from Antelope Mesa at the sites of Kawaika-a (KAW-1) and Awatovi (AW-1) and one representing pottery from the site of Sikyatki (SIK-1) on First Mesa (TABLE 1). Compositionally distinct, but less numerous groups from Sikyatki (SIK-2, SIK-3, and SIK-4) and Kawaika-a (KAW-2 and KAW-3) are also represented (TABLE 2). Figure 2 illustrates the distinctions between ceramics from First Mesa and Antelope Mesa. The major compositional divisions that will serve in subsequent discussion are illustrated with sample positions plotted relative to lanthanum and thorium concentrations. When viewing this figure and the next, it should be remembered that the groups have been derived and refined *multivariately*; the group separations are shown here *bivariately*, in the original elemental space, for ease of data presentation.

While the ability to discern between the pottery produced on First Mesa and Antelope Mesa is readily apparent, having the analytical sensitivity to differentiate between the ceramics produced at closely-spaced sites on Antelope Mesa tends more toward the remarkable. Were the resources more generally characterized, either because of broadly similar clays exposed over a wide geographic extent or because of less sensitive detection parameters,

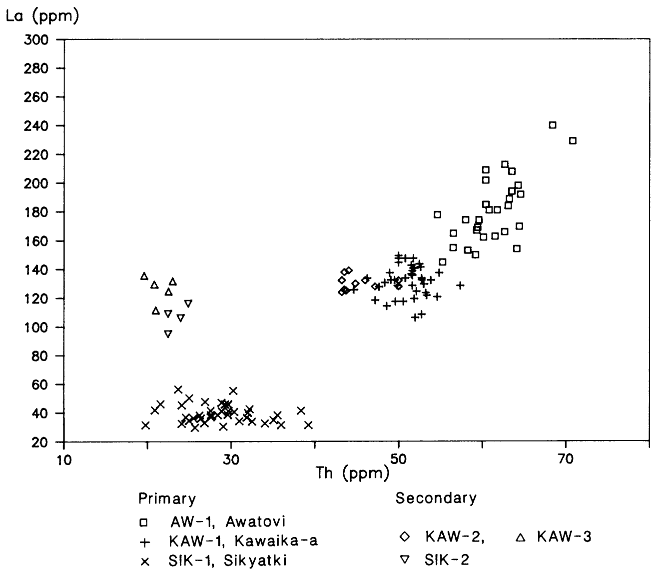

Figure 2. Primary ceramic compositional reference groups for the sites of Awatovi, Kawaika-a, and Sikyatki. The cases are plotted relative to their elemental concentrations of lanthanum and thorium.

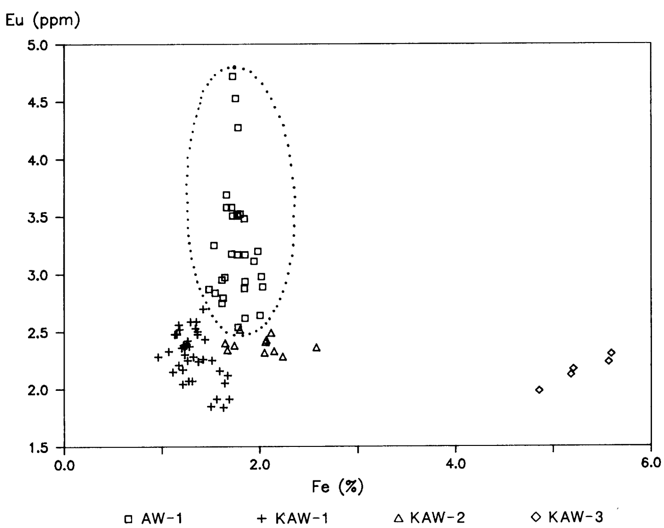

Figure 3. Ceramic compositional reference groups for the sites of Kawaika-a and Awatovi on Antelope Mesa. Samples representing production at the site of Awatovi (AW-1) have been encircled with a 95% confidence interval. The cases are plotted on two elements, europium and iron.

the analytical separation of pottery produced at the closely-situated sites of Awatovi and Kawaika-a would be unlikely. As presented bivariately in Figure 3, samples with Awatovi proveniences, enclosed in a 95% confidence ellipse, are seen to be distinct from pottery from Kawaika-a even though the pueblos are only 8 km apart! Future analyses

Table 1. Mean concentrations for Primary Compositional Groups. Data listed in parts per million except for Na, K, and Fe, which are listed in percent. Numbers in parentheses represent one standard deviation expressed as percent of mean value. Elements used for forming and evaluating the groups are noted by an asterisk.

	AW-1 $n = 30$	*KAW-1* $n = 40$	*SIK-1* $n = 33$
Na	0.152 (30)	0.132 (17)	0.114 (25)
K*	2.11 (11)	2.36 (13)	0.781 (11)
Sc*	20.8 (6)	18.0 (8)	11.1 (9)
Cr*	58.7 (8)	52.1 (8)	46.0 (11)
Fe*	1.76 (9)	1.31 (14)	1.77 (11)
Rb*	146. (10)	168. (14)	78.8 (17)
Sb	0.602 (33)	0.658 (33)	0.656 (32)
Cs*	8.89 (16)	9.13 (14)	7.72 (18)
Ba	556. (29)	689. (23)	294. (34)
La*	180. (14)	124. (9)	38.7 (18)
Ce*	327. (14)	229. (11)	58.5 (17)
Sm*	21.6 (15)	15.1 (10)	3.87 (17)
Eu*	3.22 (17)	2.28 (10)	0.547 (16)
Th*	60.9 (6)	51.9 (5)	27.8 (14)
Yb*	8.21 (13)	6.86 (10)	4.27 (17)
Lu*	0.984 (15)	0.911 (14)	0.577 (24)
Hf*	10.5 (16)	14.0 (18)	14.3 (24)
Ta	3.92 (13)	4.25 (11)	3.80 (12)
Th*	60.9 (6)	51.9 (5)	27.8 (14)

will determine whether a model of such site specific production will continue to hold for the other major villages located on each of the Hopi mesas.

With respect to the secondary groups within pueblos, important chemical variations do exist for Kawaika-a and Sikyatki (TABLE 2). That is, chemical groupings with minor but demonstrable differences in their respective compositional profiles make up the Kawaika-a and Sikyatki assemblages. Therefore, more than one reference unit is necessary to represent the raw resource procurement for the sites. These secondary groups contain fewer samples and are consequently less able to be rigorously evaluated than the primary groups.

The compositional data illustrate specific conditions of clay formation as well as the repeated utilization of these specific resources by village members. Given that distinctive compositional groups of yellow-firing pottery can be constructed, the interpretive potential of ceramic reference groups goes beyond mere chemically-based constructions. The chemical data reflect cultural variability as well as the particular geochemical and analytical variability encountered in modeling the compositional reference units (Bishop and Neff in press). Although separation between and within village ceramic production has been demon-

Table 2. Mean concentrations for Secondary Compositional Groups. Data listed in parts per million except for Na, K, and Fe, which are listed in percent. Numbers in parentheses represent one standard deviation expressed as percent of mean value. Elements used for forming and evaluating the groups are noted by an asterisk.

	KAW-2 *n = 11*	*KAW-3* *n = 5*	*SIK-2* *n = 4*	*SIK-3* *n = 8*	*SIK-4* *n = 4*
Na	0.151 (10)	0.131 (14)	0.150 (7)	0.131 (14)	0.100 (30)
K*	1.86 (10)	2.43 (13)	1.61 (12)	1.43 (32)	0.888 (18)
Sc*	16.8 (11)	23.3 (6)	18.1 (7)	14.6 (16)	11.6 (5)
Cr*	50.4 (15)	112. (7)	51.9 (7)	52.3 (11)	46.1 (7)
Fe*	1.99 (15)	5.29 (6)	2.56 (7)	1.74 (23)	1.86 (6)
Rb*	134. (11)	146. (19)	110. (35)	100. (18)	94.6 (12)
Sb	0.809 (26)	0.702 (31)	1.43 (8)	0.907 (38)	0.602 (141)
Cs*	8.37 (10)	7.70 (7)	9.06 (12)	9.11 (30)	8.50 (10)
Ba	531. (28)	732. (29)	319. (26)	412. (30)	330. (31)
La*	130. (4)	127. (8)	106. (9)	44.4 (18)	37.3 (20)
Ce*	235. (4)	126. (6)	228. (8)	71.9 (17)	55.2 (26)
Sm*	15.0 (5)	15.4 (7)	16.6 (7)	5.42 (23)	3.68 (4)
Eu*	2.40 (3)	2.18 (6)	2.69 (6)	0.793 (25)	0.511 (18)
Th*	45.2 (6)	21.3 (7)	23.3 (5)	28.4 (26)	31.1 (17)
Tb*	7.49 (11)	6.80 (8)	5.13 (4)	4.47 (15)	2.92 (22)
Lu*	0.938 (12)	0.879 (10)	0.642 (13)	0.622 (11)	0.427 (22)
Hf*	13.7 (17)	6.78 (7)	7.56 (8)	11.1 (20)	8.52 (9)
Ta	4.19 (19)	1.58 (7)	1.88 (8)	3.23 (14)	3.15 (10)
Th*	45.2 (6)	21.3 (7)	23.3 (5)	28.4 (26)	31.1 (17)

strated, the *meaning* or *utility* of the separations for modeling social aspects of pottery production and exchange must evolve within a broader perspective where stylistic and technological information are compared against the compositional data. The technological and decorative operational categories are more preliminary relative to the paste-compositional reference units; however, the research to date suggests that there are observable differences between and within village ceramic assemblages.

Village Interaction: Stylistic Considerations

Measuring and weighting stylistic variables in order to develop models of social interaction has proven to be a difficult exercise. Recent studies concerned with the way in which stylistic information is shared suggest that there are two aspects to the behavior governing stylistic similarity (Plog and Braun 1984). One is measured by ratio-scale data that relate to the frequency and duration of the interaction. The other relates to structural levels of the design. Decisions about details of designs at discrete structural levels relate to appropriate choices made in a wider context of group membership or exclusion.

Data on designs from bowls recovered from Sikyatki on First Mesa and Kawaika-a on Antelope Mesa indicate that residence affected certain aspects of stylistic similarity more than training or trading relationships between potters from different villages. Ratio-scale data pertaining to that portion of the vessel's circumference covered by a singular, large geometric or abstract, exterior motif provide support for stylistic differences on a scale that is comparable to compositional differences relating to Hopi village production. These large geometric or abstract, exterior motifs, which are found on the upper rim of ceramic bowls, are highly variable, so much so that Fewkes (1898) stated that no two exterior motifs were the same on the bowls he recovered from Sikyatki. In contrast, Huse (1976) found sufficient repetition in the occurrence of similar exterior motif designs in the Kawaika-a assemblage that she considered the type of exterior motif to be the best predictor of her potters groups. Keeping in mind that the extent of stylistic redundancy within assemblages caused by individual production/artistic units or kin groups could influence the range of variability, the exterior motifs on the Sikyatki bowls appear to extend almost half way around the bowls, whereas the Kawaika-a motifs appear smaller relative to bowl size.

To test this observation, 43 vessels for which we had metric data on diameters and exterior motifs were compared. In order to control for some of the variability that might be associated with stylistic or temporal differences, bichromes with interior geometric design fields and interior-paint spattered bichromes with simple geometrics were excluded in the initial selection. This selection procedure primarily affected the collection from Kawaika-a.

Although the representativeness of the sample is ques-

Table 3. Sikyatki polychrome bowls: size ratios of the exterior motifs.

Catalog number	*Analytical identification*	*Paste group*	*Diameter**	*Circumference*	*Motif**	*Ratio*
Kawaika-a						
3482	-	-	25	78.50	27	.344
3484	-	-	29	91.06	20	.220
3488	-	-	21.5	67.51	22.5	.333
3491	HPQ473	3	26	81.64	32	.392
3492	-	-	27	84.78	29.5	.348
3495	HPQ453	1	27	84.78	22.5	.265
3497	HPQ482	1	25.5	80.07	30	.375
3498	HPQ478	3	21.5	67.51	24	.356
3504	HPQ485	1	21.5	67.51	29.5	.437
3508	-	-	24	75.36	19.5	.259
3518	-	-	26.5	83.21	19	.228
3522	-	-	26.5	83.21	20.5	.246
3525	HPQ490	-	25.5	80.07	20.5	.256
3527	-	-	29	91.06	18.5	.203
3536	HPQ496	1	24.5	76.93	27	.351
3537	HPQ467	-	26.5	83.21	34	.409
3541	-	-	23.5	73.79	16	.217
3548	HPQ450	1	26.5	83.21	26	.312
3554	-	-	20.5	64.37	24	.373
3555	-	-	27	84.78	22	.259
3557	HPQ459	3	27.5	86.35	26	.301
3558	-	-	26.5	83.21	30	.361
3633	-	-	22.5	70.65	26	.368
3694	HPQ466	-	25	78.50	42.5	.541
n = 24			*x* = 25.23			*x* = .323
			s.d. = 2.36			s.d. = .081
Sikyatki						
155408	HPS010	1	23†	72.22	23	.318
155450	HPS011	-	21†	65.94	29	.440
155480	HPS006	-	25‡	78.50	40	.510
155490	HPS018	1	23	72.22	22	.305
155492	HPS032	1	23	72.22	22	.305
155505	HPS048	-	21.5	67.51	18	.267
155507	HPS042	1	23.5	73.79	26	.352
155547	HPS031	1	25†	78.50	22	.280
155549	HPS009	-	22	69.08	28	.405
155552	HPS037	1	23.5	73.79	23	.312
155553	HPS039	-	25†	78.50	24	.306
155558	HPS034	3	24.5	76.93	16.5	.214
155564	HPS046	1	24	75.36	25	.332
155569	HPS013	-	23.5	73.79	30	.407
155573	HPS038	-	24	75.36	23	.305
155607	HPS021	1	23.5	73.79	30	.407
155609	HPS049	1	23	72.22	30	.415
155610	HPS007	-	22.5	70.65	25	.354
155628	HPS012	-	21.5†	67.51	27	.400
n = 19			*x* = 23.26			*x* = .349
			s.d. = 1.20			s.d. = .071

T-Test for Diameters
Separate Variances T=3.543; df=41; p=.001
Pooled Variances T=3.302; df=41; p=.002

T-Test for Ratios
Separate Variances T=1.118; df=41; p=.27
Pooled Variances T=1.100; df=41; p=.278

* Measurement taken to the nearest 0.5 cm.

† Vessels slightly warped and diameter is an average of the minimum and maximum measurements taken to the nearest 0.5 cm.

‡ Measurement at shoulder because of sharply incurving rim.

Table 4. Distribution of size ratios of exterior motifs at the sites of Sikyatki and Kawaika-a.

Site	Exterior motif: Quarter .20–.29	Third .30–.39	Half .40–.55	Total
Sikyatki	3	9	7	19
Kawaika-a	9	12	3	24
Total	12	21	10	43

X^2=6.89; df=2; $p < .05$

tionable, Kawaika-a bowls appear to be larger; an extra 2 cm in diameter on the average translates into a significant visual difference of about 6 cm in circumference (TABLE 3). Despite the difference in size, the exterior motif covers about a third of a bowl's circumference in both assemblages. Yet slightly over one-third of the exterior motifs on the vessels from Sikyatki cover 40% or more of the circumference; in contrast, one-eighth of the motifs cover this much of the circumference on the vessels from Kawaika-a (TABLE 4).

These results indicate possible dimensions of significant variation, but they should be viewed as tendencies only since there are a number of biases caused by the uncertainty over production locale and the number of potters involved. Only those vessels that have been assigned to one of the primary compositional paste groups, thus far, can be assumed to have been locally produced. When the sample is limited to those 14 vessels that comprise the primary compositional reference groups, the difference between the expected and observed distribution of ratios of the motifs is insignificant. As the analysis is refined, more of the vessels, which are included in these assemblages on the basis of provenience only, may be assigned a source provenience on the basis of paste attributes.

Kawaika-a vessels reflect several paste compositional reference units that do not covary with motif ratios (TABLE 3). Huse (1976) considered these 24 vessels to be the result of 12 potters groups that again do not covary with the motif ratios. Thus, no one paste group or no one potter appears to have contributed significantly to motif ratios smaller than .30 or larger than .40 in the Kawaika-a assemblage. Most of the Sikyatki vessels are essentially from one large paste group, but there is still enough compositional and stylistic variability within this group to suggest the output of more than one production/artistic unit.

Within-Village Potters Groups and Paste Groups

Multiple compositional groups appearing in a ceramic assemblage from a single pueblo may represent either differences due to exchange or differences due to constraints and choices in the production process, conceived of in the broadest sense. Consideration of the fundamental production processes is not merely an exercise in the reconstruction of manufacturing and decorative techniques. The choices made by potting groups are intimately linked with the successful execution of form and design, and they reflect the subtleties of attempting to balance the demands of the consumers with the constraints of the technology and organization of production.

Again, it is not sufficient merely to identify distinct compositional groups but rather to assess the extent to which social correlates may exist. Features that indicate shared technical skills, such as clay selection and preparation, are more likely to be affected by close interaction between potters than by exchange or alliance considerations. Until we are able to evaluate the technical skills and artistry of the potters, however, an equation that links discrete paste groups with distinct potting groups within a pueblo is just a hypothesis.

Because of the potential for the paste groups to represent temporally-distinct periods of resource exploitation, evidence of contemporaneity was sought from the provenience information at the site of Kawaika-a. Even though all three compositional groups were used in the manufacture of Sikyatki Polychrome type pottery, the time span for this type ranges over 200 years, A.C. 1400–1625 (Colton 1956). Most of the vessels analyzed from the site of Kawaika-a were associated with burials. If different paste groups are represented by vessels from the same burial, such co-occurrence would establish contemporaneity of use, excluding the possibility of a heirloom effect. In fact, many of the burials had ceramic containers that represent more than one of our paste groups. For example, Burial 5 (Talus B) had vessels with compositions representing KAW-1 and KAW-3, and Burial 36 (Talus F) had vessels representing KAW-2 and KAW-3. At the present time, we have no data showing the presence of KAW-1 and KAW-2 in the same burial assemblage. All three compositional groups, however, are represented in vessels recovered from two spatially distinct burial locations: 1) Talus slopes B and C, separated by a gully, located on the SSE side of the mesa; and 2) Talus F, located on the opposite side of the ruin on the west side of the mesa (Huse 1976). At some point, then, these three, distinctive resources were probably being used contemporaneously.

If the paste groups are contemporaneous, this increases the possibility that paste reference units covary with potting groups. Contemporaneous exploitation of these clays, however, could also crosscut potting groups, reflecting alternative possibilities: 1) lack of control over access to specific clay resources; 2) nondiscrimination among gray clays as technical resources for yellow wares; 3) appreciation of aesthetic or technical differences that could be obtained with each clay; and 4) utilization of particular clay lenses for specific classes of objects by all or only a few potting groups. The comparisons of paste groups in vessels grouped along other stylistic or technological dimensions will enable us to assess the possibility of differential resource selection and use.

Stylistic Considerations

As noted, both ratio-scale measures and evidence of similarity in the choice of design have been used to measure the degree of close social interaction. Using whole vessels from the Kawaika-a mortuary assemblage, Huse (1976) performed a stylistic analysis that incorporated aspects of size and shape and similarity of designs, but not burial context. From this analysis, she formulated 34 potters groups that corresponded to groups derived from a preliminary stylistic analysis by Carlson (1976), who was guided by the burial data.

Although more recent studies of style address the substitution of design elements or the width of the lines in more detail, Huse's analysis compares favorably with the more recent studies. The nature of her results, that is the number of individual potters or, preferably, potters groups (see Muller 1977 for a discussion of analytical individuals) is more difficult to assess independently of the stylistic evidence. Demographic data, as determined by the burial population, by the number of domestic units or building episodes, and by the duration of the occupation, from which numbers of potters might be estimated, are incomplete. If we rely solely on ceramic data, we cannot even begin to consider the scale of production until we examine the full range of variability in the ceramics. Huse's stylistic analysis of the Kawaika-a materials, however, does provide a point of departure for evaluating the association between potters groups and paste groups.

Since Huse hypothesized that vessels with similar motifs were produced by single potting groups, decorated bowls with the same types of exterior motif were compared in order to assess their paste-compositional similarity. Even though Fewkes (1898, 1919) could group types of motifs according to continuous bands of step frets, the use of double triangles, or abstract bird designs, the criterion of motif similarity for this analysis (after Huse 1976) was based on exact replication of the configuration of the motif. The motifs that were duplicated at least once range in complexity from simple to intricate constructions (FIG. 4). Some leeway in the typology was permitted relative to reverse symmetry, size or proportional differences, and slight stylistic differences. While there is more repetition in the entire sample than has been analyzed in the present study, the number of repetitions per any one type of motif is limited, often to two occurrences, and the occurrence of motifs that repeat at different sites is extremely rare.

The compositional reference groups correlate closely with the exterior motifs in four types, Types 3, 7, 8, and 9; two types, Types 5 and 10, are ambiguous because the analyzed vessels cannot, as yet, be assigned to a compositional group (TABLE 5). The stylistic similarity of vessels within the same type (i.e., Types 3, 7, 8, and 9) also tends to suggest production by a single artistic unit. Using other criteria, including control over brushstrokes, color similarities and differences, and interior design layouts, Huse identified two or more potters groups who painted the same exterior motifs on their vessels. Because of this diversity and because different potters' bowls having the same exterior motifs occurred in the same burial, Huse suggested that the similarity in the exterior motifs might reflect a kin association, which could be expected in a context where ritual offerings were placed with a kinsperson who had died (compare Fewkes 1897). Further examination of the Kawaika-a ceramics shows that compositional clustering, though linking some of the exterior motifs together with the potters groups formulated by Huse, crosscut some of the hypothesized linkages between potter and motif.

Actually, these results are encouraging, for complete covariation between clay, motif, and potter would not reflect the interaction potential in which individuals could manipulate resources according to their skills or respond in an advantageous manner to social obligations. What the patterning *does* suggest is that clay sources were used by more than one potting group, and that certain potters consistently exploited one clay source.

In order to assess the degree of stylistic and compositional covariance irrespective of the exterior motif, decorated bowls showing close chemical linkages were examined. Two vessels from Sikyatki (FIG. 5), which are not chemically similar to any ceramic compositional group formed thus far, show elemental concentrations that are virtually identical; this similarity is closer than can be expected in two samples from the same vessel when analytical errors are considered. Initially, the two vessels had not appeared visually similar because of differences in the exterior and interior motifs, but upon closer inspection they proved comparable with respect to their lighter weight, larger size, slightly incurving rim, and color. The interior designs of the two vessels also revealed some structural similarity in the use of an encircling line with ticking and the use of spiraling feather designs. These two vessels are artistically pleasing, as are the four vessels that

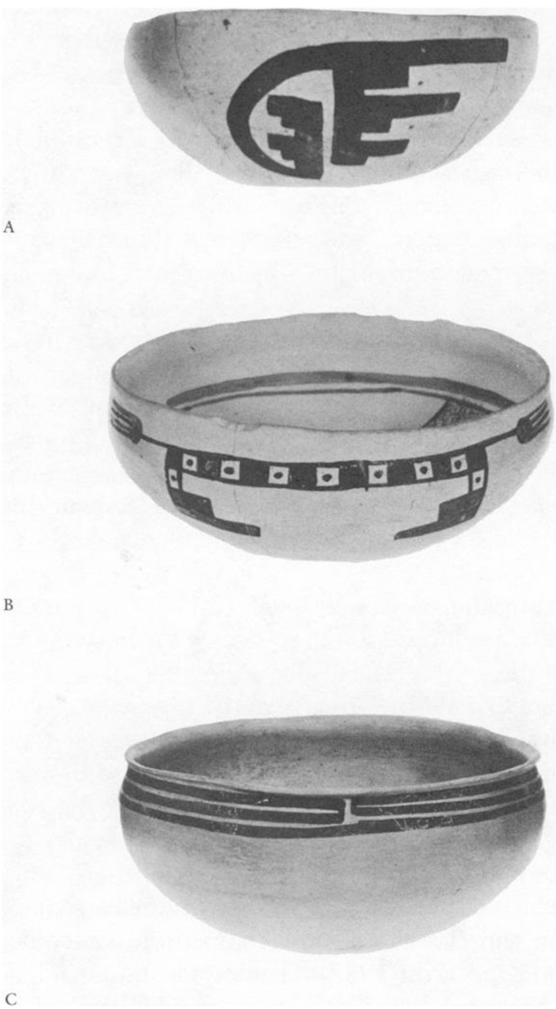

Figure 4. Examples of exterior motifs: a) Type 1, HPQ460, D. 17.5 cm [Cat. No. 3648, University of Colorado Museum]; b) Type 2, HPQ473, D. 26 cm [Cat. No. 3491, University of Colorado Museum]; and c) Type 8, HPS029, D. 22.5 cm [Cat. No. 155570, Smithsonian Institution].

Table 5. Correlation of exterior motifs and production/artistic units.

Type of motif/ analytical identification		*Burial provenience**	*Compositional group*	*Stylistic similarity†*
Type 1:	HPQ451	Kawaika-a 51	-	10+
	HPQ460	51	-	10+
	HPQ462	29	1	30−
	HPQ469	51	-	10+
	HPQ472	51	-	11+
	HPQ475	51	2	11+
Type 2:	HPQ453	5	1	29+
	HPQ456	5	1	32+
	HPQ468	5	1	32+
	HPQ473	5	3	29+
	HPQ478	5	3	31+
	HPQ482	5	1	31+
	HPQ485	5	1	31+
Type 3:	HPQ464	50	2	3+
	HPQ470	50	2	3+
	HPQ479	50	2	3+
Type 4:	HPQ450	19	1	19+
	HPQ459	24	3	19+
	HPQ496	16A	1	25
Type 5:	HPQ471	36	-	1+
	HPQ479	34	2	1+
	HPQ481	34	2	1+
Type 6:	HPQ483	36	3	4+
	HPQ484	36	2	4+
Type 7:	HPQ480	5	1	30+
	HPQ487	5	1	30+
Type 8:	HPS023	Sikyatki -	2	A
	HPS027	-	2	A+
	HPS029	-	2	A+
	HPS035	-	2	A+
Type 9:	HPS005	S	1	B
	HPS024	S	1	B
Type 10:	HPS015	-	1	C
	HPS019	S	-	D

*The vessels from Kawaika-a were recovered from individual burials in the talus slopes below the site; the Sikyatki vessels were also recovered from burials, but the provenience information is limited to fragmentary notes that identify burial areas south and west of the site.
†Stylistic similarity in the Kawaika-a material is based on the identification of individual potters by Huse (1976). In all but two cases, in Type 1 and Type 2, the identification by Huse matches an earlier analysis by Carlson (1976). The similarity of the Sikyatki vessels is based on an assessment by Canouts. The "+" equals a strong stylistic association and a "−" equals a weak association as assessed by the analysts.

comprise compositional group SIK-2 in the Sikyatki assemblage (TABLE 2; TABLE 5, Type 8). The artistic excellence of these pieces and their unique compositional profiles suggest that some potters may have selected clays that were either not available to other potting groups or were not used by them.

Technological Considerations

The significance of stylistic and paste group correlations must be determined within the context of the production process. The inception of yellow ware production necessitated a number of technological changes: chief among these was the major alteration in firing technology. The adoption of coal fuel was essential to achieve the yellow-firing potential of the ceramic clays; only with the higher temperatures sustained over long intervals could the characteristic base color of the bichromes and polychromes be obtained (Shepard 1971: 180–182). Thus, clay utilization

Figure 5. Sikyatki Polychrome vessels from Sityatki: a) HPS057, D. 28.5 cm (max.) [Cat. No. 155479, Smithsonian Institution]; and b) HPS025 D. 26.5 cm (max.) [Cat. No. 155468, Smithsonian Institution].

and firing technology were interdependent variables in the design and production of these important decorated ceramics. The question arises, then, to what extent was clay selection constrained by the potters' ability to control the firing process?

In the relatively simple pyrotechnology available to the Hopi, firing conditions, which are affected by the atmosphere, volatiles in the fuels, and temperature, are difficult to reproduce consistently. Control over the firing process is seldom given much credence, particularly in light of variation observed in monitored historical firings (Colton 1951). Nonetheless, we cannot evaluate the abilities of the ancient potters solely on the practices of their modern descendants who produce pottery in very different contexts. Besides, there are other examples of potters who show great consistency in their technical expertise, including firing. For the period A.C. 1300–1700, Nobles (1978) suggests that the firing temperature of each succeeding ceramic type, Jeddito, Sikyatki, and San Bernardo, was distinct, the highest-fired being Sikyatki Polychrome. The conclusion of progressive technical excellence followed by a decline in craftsmanship is drawn. While the sampling and methodological weaknesses severely limit the reliance one can place on Nobles' conclusions, they at least suggest limited control over coal firing that may have occurred in consort with limitations imposed by differences in the clay compositions.

An initial assessment of the relationships between firing processes and clay selection has been based on color measurements made on fired yellow-ware vessels from the site of Kawaika-a. Since vessels within one paste group have similar iron content, and presumably share other immeasurable characteristics such as initial organic content, the variability in color for the vessels should be due chiefly to firing variations.

Color determinations were made using a tristimulus chromameter to measure value, hue, and chroma, expressed in the L*a*b* color system (Hunter 1975; Minolta Camera Co. 1986). The use of the chromameter has several advantages over direct use of Munsell charts: it can be standardized; it is free from error introduced by variable light conditions; it is reproducible; and it can deal systematically with colors that fall between the referenced color chips in the soil color chart. The use of the L*a*b* system (which can be converted to the Munsell system of description and classification for comparison with other data [Simon and Frost 1987]) enables statistical manipulation of the results, and the values can be graphed to facilitate color communication.

Color readings for a single vessel were averaged, based on multiple readings, with three readings at each of three locations on the exterior of the vessel. Figure 6 shows the L*a*b* color for vessels within the three major compositional groups. Despite its low iron content (mean concentration 1.3%), KAW-1 had the widest range of colors—from very pale browns, through white and pale yellows, to red-yellow. KAW-2, with only slightly more iron—approximately 2.0%—has a narrower range of color: yellow to red-yellow.

The emphasis on the yellow color is likely due to firing consistency rather than the slightly-higher iron values since the yellow and red-yellows were also obtained with KAW-1 clays. This interpretation is also borne out by the samples for KAW-3. Although pots in the last group have an average iron content of 5.3%, they show a similar range of colors to those in KAW-1, including the pale white to

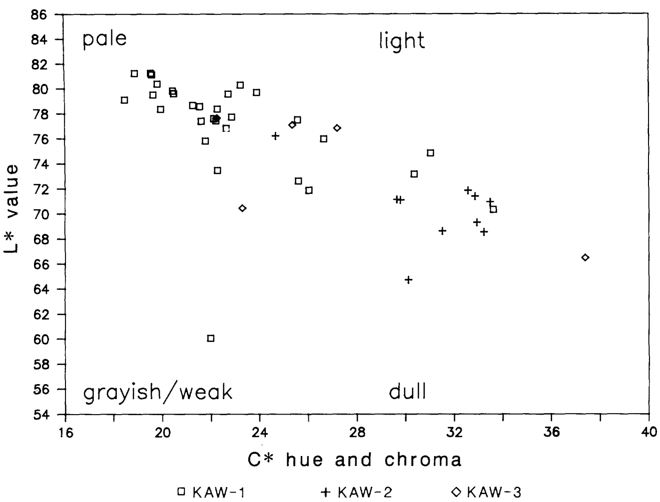

Figure 6. Colorimetric data for Kawaika-a compositional reference groups. L* is value, and C* ($\sqrt{a^{*2} + b^{*2}}$) is hue and chroma. For comparative purposes, the Munsell color readings that Huse (1976) obtained for 39 of the 45 vessels represented here are given with the approximate L* and C* values obtained by extrapolation from the color chips in a 1975 edition, Munsell Soil Color Chart:

Soil Color Names	*Munsell*	*L**	*C**	*No. of Cases*
Reddish-yellow	7.5YR 7/6	71.0	37.4	1
Pink	7.5YR 8/4	80.4	25.4	1
Very pale brown	10YR 7/4	69.8	26.9	4
Very pale brown	10YR 8/3	80.4	20.8	15
Very pale brown	10YR 8/4	80.6	26.9	7
Yellow	10YR 8/6	81.0	39.6	3
White	10YR 8/2	80.4	14.6	8

yellows. Thus, while each compositional group shows different iron concentrations, potters could use each clay to get the same range of colors. Preliminary results from recent work with the scanning electron microscope also support firing consistency. A high degree of vitrification in some samples, which results from longer firing and higher firing temperatures with complete oxidization, is consistently correlated with darker orange pastes and black cores. Selection and use of clays, then, seems not to have been constrained by desired final color; rather, it appears that color was achieved through variation in firing conditions.

But were the firing conditions tightly controlled? Patterning in the distribution of colors at the site suggests that they were. Figure 7 shows the distribution of the bichromes and polychromes, excluding plain yellow bowls (uncorrugated and undecorated) and paint-spattered bowls (i.e., Kawaika-a Spattered [Huse 1976] or Jeddito Stippled [Colton 1956]). In Kawaika-a, taken as a whole, variation in color is greatest for the bichromes, which range from the pale colors to the yellows and red-yellows. On the other hand, polychromes are generally confined to the pale color spectrum. This makes sense in terms of subtle paint colors employed on some of the pots; color contrasts would be lost if the pots were fired yellow. This more limited range of fired color for polychromes helps support the contention of greater firing control since the painting decision for any given pot was made prior to firing.

Another aspect of firing control is evident if we examine each of the paste groups separately. Each paste type could be used to produce bichromes and polychromes. Pots of paste KAW-2, however, were consistently fired to the yellow and red-yellow colors, while those of KAW-1 were more often fired to the pale spectrum, regardless of type. Patterning for KAW-3 may be similar to that of KAW-1, but at present the sample size is too small to do more than note the dichotomy between fired color and decorative type. These patterns are consistent with group-specific resource selection rather than with functional or aesthetic specificity of clays. They also suggest that within the stylistic canons held for yellow wares by the pueblo as a whole, potters exploiting a particular resource shared firing skills and preferences for particular final shades. Polychromes, however, were more narrowly constrained with respect to final color.

Material Exchange Networks On and Off the Hopi Mesas

Within the restricted groups that comprise the primary ceramic reference groups for the sites of Awatovi and Kawaika-a are samples that were recovered from other

Figure 7. Distribution of colorimetric data for Jeddito bichromes and Sikyatki polychromes from the site of Kawaika-a.

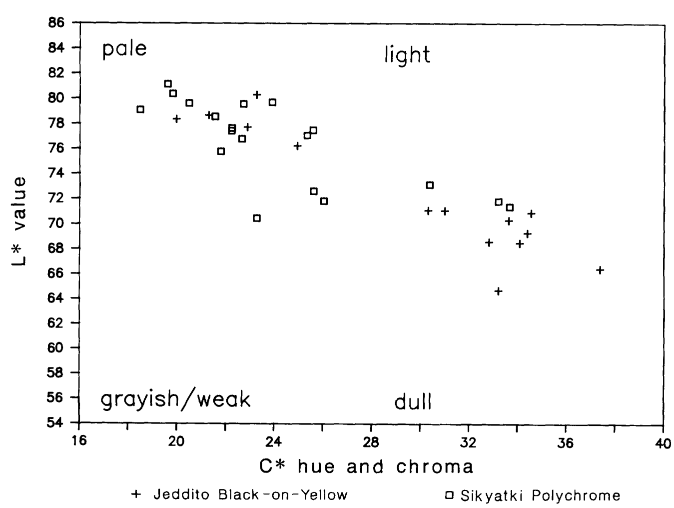

Table 6. Compositional groups with samples from other sites.

	Compositional reference group			
Provenience	*AW-1*	*KAW-1*	*KAW-2*	*SIK-3*
Antelope Mesa				
Awatovi	31	3	0	1
Kawaika-a	2	31	10	0
Chakpahu	1	4	0	1
Kokopnyama	0	2	0	0
First Mesa				
Sikyatki	0	0	0	6
Off Hopi mesas				
Homolovi II	0	0	1	0
Total	34	40	11	8

sites on the Hopi mesas (TABLE 6). The compositional attribution of these samples is unambiguous and suggests two possibilities, either exchange or the mutual exploitation of clay lenses, especially along Antelope Mesa. There is less evidence of interchange between the mesas. No samples from other mesa sites occur in the primary ceramic reference group for the site of Sikyatki nor do Sikyatki-provenienced samples occur in the primary reference units for the sites on Antelope Mesa. Evidence of exchange from First Mesa to Antelope Mesa might be indicated by the presence of Kawaika-a and Chakpahu-provenienced vessels in a secondary Sikyatki grouping, SIK-3. Evidence of exchange from Antelope Mesa to First Mesa may also be indicated by one vessel from the site of Sikyatki (HPS020) that has a high probability of belonging to KAW-1, the primary compositional reference group for Kawaika-a (TABLE 7). The lack of a strong linkage between mesas is difficult to interpret at present. Distance might negate the mutual exploitation of resources by villages located on separate mesas (FIG. 1; see Arnold 1985: 32–60).

The differentiation of other production locales on the mesas, needed to assess directionality of exchange, is incomplete. Samples included in the primary reference groups also come from sites off the Hopi mesas, however, and there is increasing evidence that exchange with sites off the Hopi mesas may have been directional. Samples compared to the primary reference groups show evidence of exchange linked to specific sites (TABLE 7). For example, the vessels from Homolovi II, located on the Little Colorado River, are related compositionally to the primary reference group for Awatovi. Some of the sherd materials from Pottery Mound on the Puerco River in New Mexico, which can be assigned to a reference group, appear to have been produced from the same clays as those used at Kawaika-a and at Awatovi. The Sikyatki assemblage continues to be relatively isolated as there are no samples from sites off the Hopi mesas relating to the Sikyatki reference groups. The evidence of vessel transport from sites on the mesas and to sites off the mesas is limited because the majority of the vessels cannot yet be assigned to a compositional reference unit.

Thus far, the interaction of the Jeddito alliance group has been predicated on the distributional presence/absence of the yellow wares on sites off the mesas (Upham, Lightfoot, and Feinman 1981; Upham 1982). Exchange involving other dimensions of pottery production has not been considered. For example, raw materials used in pottery production, such as clays or pigments, might have been exchanged in addition to whole vessels (Bishop, Rands, and Holley 1982: 318). Although the evidence is preliminary, there are indications that some of the ceramic pastes from the site of Homolovi II, for example, are processed differently than pastes from the sites of Awatovi, Sikyatki, or Kawaika-a. Stylistic similarities and differences within these yellow wares and between the yellow wares and other late Anasazi styles, which are not apparent at the level of ware groups, may also suggest affinities between widely dispersed households.

Information Exchange: Stylistic Considerations

In Upham's model, the ability to channel and acquire materials from a distance signals the ability to correlate geographically-distant materials with social distance (see Helms 1979). Material exchange models depend upon the differential distribution of raw materials and catchment resource potential. Exchange also includes the exchange of other information associated with the materials, however. The formation of alliance structures and even the obligatory reciprocity of kin groups have been hypothesized to have stylistically reinforced behavioral correlates, regardless of whether the information takes the form of actual material exchange or only the exchange of stylistic information.

If as Huse (1976) suggests, replicate exterior motifs indicate kin relationships, there is little evidence to support the presence of similar kin groupings at other sites on the Hopi mesas or to trace extended networks off the Hopi mesas on the basis of these motifs. At present, redundancy in Hopi exterior design motifs can be seen in some of the simple geometric exterior motifs described by Smith (1971: 151, figs. 98–100) for the early Jeddito yellow wares. Occasional repetitions of these are found on later Sikyatki type bowls. The burial assemblage at Kawaika-a exhibits the highest degree of association between exterior motifs and burial data, although similar associations are found in the same site provenience or, in cases where records exist, the same burial provenience at other sites on the Hopi mesas.

In the present sample of approximately 50 provenienced, whole vessels from off the mesas, only one vessel from Chavez Pass or Nuvakwewtaqa (Upham and Plog 1986: 226, note 27) exhibits an exterior motif that replicates those found at sites on the Hopi mesas. The exterior motif is one of the two most common types found at Kawaika-a (TABLE 5, Type 1; FIG. 4). Interestingly, five of the six Kawaika-a cases were recovered from one adult burial, Burial 51 (Talus F). The vessel from Chavez Pass cannot be assigned to any ceramic compositional reference group at this time.

Because the figural or representative art styles found on the yellow-firing pottery tends to be asymmetric and individualistic in most of the motifs, the similarity in Hopi design styles from within-site and between-site proveniences is not initially obvious. The similarities and differences in design styles are, therefore, more difficult to measure and evaluate. In this situation, the organizing principles underlying the designs, rather than the elements, have to be compared in order to ascertain whether the morphological similarities and differences result from a single decorative system or whether there are significant differences between groups.

Table 7. Material exchange on and off the Hopi mesas.

Provenience	*Compositional reference group* *SIK-1*	*AW-1*	*KAW-1*
Antelope Mesa			
Awatovi	0	1*	0
Kawaika-a	0	0	1*
Chakpahu	0	0	1
First Mesa			
Sikyatki	1*	1	1
Second Mesa			
Shungopovi	0	1	0
Mishongnovi	0	3	0
Third Mesa			
Oraibi	0	1	0
Off Hopi mesas			
Homolovi II	0	25	0
Pottery Mound	0	6†	6†
No site provenience			
Miller Collection (Sikyatki?)	1	0	0
Gila Pueblo Collection (Roosevelt Area)	0	1	0
Total‡	2	39	9

*Although the sample falls within a 90% confidence interval, it has not been included in the site's Primary Compositional Reference Group because it falls at the edge of the probability curve, which is an arbitrary construct.

†The 12 samples from Pottery Mound are inversely related; i.e., the 6 samples that have a high probability of belonging to the Awatovi Compositional Reference Group have a low probability of belonging to the Kawaika-a Compositional Reference Group and vice versa.

‡Because the analysis is ongoing and subject to further refinement as more samples are analyzed, the data presented here reflect comparison of 556 samples in June, 1987, at a 90% confidence interval enclosing the primary compositional reference groups.

A preliminary examination of the designs indicates 1) that basic patterns appear in a Sikyatki design style spanning production locales both on and off the Hopi mesas, and 2) that subtle differences in the execution of these patterns correspond to within-site and between-site differences. For example, Fewkes identified two highly-stylized bird-feather motifs in the Sikyatki assemblage and illustrated their structural underpinnings without further analytical discussion in his 1919 monograph on Hopi designs. One of them, shown here in Figure 8, is an open spiral that terminates in end feathers. This Sikyatki design motif is very distinctive and easily recognized in other design contexts; that is, spirals appearing on kiva murals during this period recall the motifs appearing on the pottery (Smith 1952; Hibben 1975; Brody 1964). This same spiral or rotational structure is also found on locally-made pottery from New Mexico, at the site of Pottery Mound (Brody 1964), and the Zuni site of Hawaikuh (Kintigh 1985; Smith, Woodbury, and Woodbury 1966). The contemporaneity of the Pottery Mound Polychrome pottery and the Matsaki Polychrome pottery of New Mexico with the Sikyatki Polychrome pottery of Arizona is problematical, however.

Despite the chemical diversity, the configurations of the spiral designs on bowls from the site of Sikyatki are highly patterned. As illustrated in Figure 8, the spiral can appear alone (Configuration 1, $n=8$); it can be attached to a second or secondary motif (Configuration 2, $n=6$); or it can occur with a second unattached motif that is positioned across from the midpoint of the spiral (Configuration 3, $n=2$). This basic structure also appears in representational forms other than the bird-feather combination. Mythological beasts are often shown curved around the interior wall of the vessel, sometimes accompanied by an unattached secondary motif.

Similar designs are found on the vessels from Kawaika-a, but the spiral is located higher up on the walls of the vessel or centered and balanced with a second spiral. The spiraled motifs at the sites of Hawaikuh and Pottery Mound exhibit still other variations. A pie-shaped appendage that anchors the spiral to the side of the vessel appears on a large number of vessels from Hawaikuh (Smith, Woodbury, and Woodbury 1966: figs. 53, 58–59 especially). On vessels from Pottery Mound, though the spiral can occur unrestrained in the center of the bowl, when a band is present the centered motif is definitely connected,

Figure 8. Sikyatki spiral configurations: a) Configuration 1, HPS039, D. 25 cm [Cat. No. 155553, Smithsonian Institution]; b) Configuration 2, HPS033, 23.5 cm [Cat. No. 155554, Smithsonian Institution]; and c) Configuration 3, HPS037, 23.5 cm [Cat. No. 155552, Smithsonian Institution].

either physically or by the use of similar motifs in the banding and central design areas (Brody 1964: 79, fig. 12).

New figurative styles, more or less symmetrical, characterize ceramic wares produced in the 14th and 15th centuries throughout northern Arizona and New Mexico. Access to design information or connectivity of design information seems less economically oriented than ritually coordinated, as the design styles cross both compositionally-distinct ware groups and media: for example, kiva murals and rock art. Brody's (1964) study of the entire Pottery Mound assemblage suggests that the Rio Grande and Sikyatki design styles were mutually influential in rendering design elements and layout in the Pottery Mound polychromes. Stylistic similarities are, therefore, more likely to reflect frequency of interaction and learning behavior than transfers of goods and information between elites.

Summary and Conclusions

The ceramic analytical groups that we have formed using compositional, technological, and stylistic data are not homologous to the Hopi potters who produced and exchanged their wares between A.C. 1300 and 1600. The information about the interaction of clays, technology, and design in the manufacturing process, however, does permit us to begin modeling the conditions of production and exchange that influenced their behavior. The present analysis shows us that pottery production was village specific. Compositional differences in pastes between villages and measurable differences in design size between villages suggest that potters/artists groups worked closely together within a village and were not sharing knowledge of resources or techniques to any large extent with nonresidential groups that might be otherwise related, such as extended kin or clan groups.

We do not find evidence of centrally controlled resources within these major Hopi villages. An unspecified number of potters/artists groups in each village apparently exploited several clay sources. From the burial associations at the site of Kawaika-a, we infer that these clay sources were exploited simultaneously, and the decorative evidence suggests preferential but not exclusive use of these clay resources. Certain vessels that are most aesthetically pleasing display unique artistic and chemical signatures, and potters of exceptional ability may, therefore, have guarded information about the location of their clays.

Hypotheses proposed by Upham and others (Upham 1982: 89–100; Upham, Lightfoot, and Feinman 1981; Upham and Plog 1986) about the regulation of ceramic production and exchange within any one of the Western

Pueblo settlement clusters depend, in large part, on the way in which the cluster is scaled, spatially. According to Upham (1982: 90), the regular spacing of settlements, as exemplified by the Hopi settlements, suggests one of two types of models of production: 1) competitive production, with equal access to goods and services; or 2) specialized production, creating an interdependency. Although further consideration of the relevance of these organizational models to Hopi settlement is necessary, the emerging pattern of ceramic production along Antelope Mesa is suggestive.

Each of the spatially separate, reasonably large, and more or less contemporary pueblos located on the eastern edge of Antelope Mesa during the 14th and 15th centuries appears to have been a pottery production center. The pottery groups from Awatovi and Kawaika-a, which are only 8 km apart, are compositionally distinct from each other and from the other sites along Antelope Mesa. Following Hodder and Orton (1976), Upham (1982: 89) believes that 10 km is a reasonable estimate for the spacing of production centers in nonindustrial societies. The evidence of ceramic production on the Hopi mesas between A.C. 1300 and 1600 would appear to support a model of production wherein Hopi villagers at each site had equal access to resources and manufactured ceramics that were used on-site.

Interestingly, each of the production models may apply to different periods of Hopi amalgamation; for example, Stephen's (1936: 1020–1022) reference to the specialized production of pottery on First Mesa and the specialized production of baskets on Third Mesa during the 1800s is more in accord with the second model. Greater settlement clustering beginning in the 15th century noted by Upham (1982: 106) may have contributed to the 19th-century pattern of economic interdependency, although diminished technological skills due to population loss and dispersal during the historic period may have resulted in an interdependency that was not entirely artificial (compare Ford 1972; Peterson 1978).

Evidence that some vessels produced on the Hopi mesas were transported to sites off the mesas is present but not overwhelmingly so. One reason for the small magnitude of exchange is that many of the vessels in the sample cannot yet be associated with production centers. As the analysis is refined the documentation of exchange relationships can be better assessed. In the present analysis, we note that several vessels apparently produced on Antelope Mesa have been recovered at Homolovi II on the Little Colorado River in Arizona and at Pottery Mound on the Puerco River in New Mexico. The Homolovi sites have strong ancestral connotations in the oral traditions of the Hopi, whereas the site of Pottery Mound is adjacent to an area of strong historical Hopi-Zuni interaction.

The yellow wares have been hypothesized to symbolize aspects of an alliance and concomitant power structure (Upham 1982). The hypothesized basis of alliances in the Southwest has been related to the management of risks under highly variable environmental conditions (Dean et al. 1985; also Braun and Plog 1982). Materials are exchanged on the basis of social ties that are invoked to even out the environmental vagaries in subsistence endeavors. According to Upham's model, the intensive agricultural activities that accompanied the aggregation of the western puebloans would seem to have necessitated some cooperative, especially managerial, endeavors. Decisions about the community at large, use of surpluses, organization of labor, or the acquisition of nonlocal materials may have been concentrated in the hands of a relatively few individuals.

In time, Upham (1982: 157) proposes that exchange as security against risk may have changed to exchange as symbols of the power structure, in which the yellow wares served to signal such information. Although Jeddito yellow wares appear to be widely distributed (Adams, Dosh, and Stark 1987; Upham 1982), their frequency within assemblages at large sites such as Chavez Pass is relatively small. Upham suggests that the small number of vessels would preclude an even pattern of distribution in households and that differential representation in the higher status burials in the Chavez Pass settlement area suggests limited access to the yellow wares by a few individuals who may have formed an elite (Upham, Lightfoot, and Feinman 1981; Upham 1982).

We do not yet have information that would enable us to support a model of restricted access to material or information that could be signaling intervillage alliances of producers and/or consumers. The decision to sample vessels with similar designs was made in order to evaluate the degree of rule sharing among individuals or groups relative to the degree of circumscription of motifs found in special contexts of production and use. If, as Huse (1976) hypothesizes, similar exterior motifs should signal kin groups, the evidence does not support their role as a strong predictor of kin networks between villages at this time. Vessels from off the Hopi mesas that have exterior motifs that duplicate those on the mesas are limited to three cases, none of which can be assigned to an analytical paste group at present.

That exchange should necessarily evolve from risk management at the household level to the interconnection of elites at the community level is unclear (see Earle and Brumfiel 1987). Alliance structures in the face of environmental perturbations occurring on the southern Colorado Plateaus are seen to have changed as the population range became more restricted after the 13th century (Dean et al. 1985: 546). If the southern Colorado Plateaus are considered a catchment area, the kind of exchange between off-mesa sites, such as the Homolovis, Chavez Pass, or Pottery Mound, and the Hopi mesas might be modeled as redundant according to O'Shea (1981; Halstead and O'Shea 1982). In this model, most of the exchange would involve goods and not food; these goods would provide the basis for the accumulation of wealth and prestige. Exchange of foodstuffs would be activated only in cases of localized deprivation relative to the larger catchment area.

If the plateau is further subdivided on the basis of differential access to predictable resources, such as water supplies, the inhabitants may have exchanged food resources on a more regular basis. This complementary kind of exchange may have been better managed at the level of the household, however. In the often-cited case of the Hawaiian chiefdoms, households continued to function as one of the primary means of homogenizing food-resource diversity, even as the elites collected food and other commodities for their own consumption rather than redistribution (Earle 1977: 223–225; Earle and Brumfiel 1987).

Although ceramic containers may codify social ties through which resources may be made available, households and kin groups tend to share resources selectively, especially in situations where large regions are experiencing the same general environmental degradation. The argument that the small number of vessels transported into the archaeological district of Chavez Pass enabled a developing elite to monopolize the exchange network begs the question of an elite that is able to organize followers, mobilize resources, and delay repayment in times of environmental stress (Sahlins 1963). Widely-recognized community managers or leading households would have had to be able to activate socioeconomic ties symbolically, as well as materially, in order to legitimize economic obligations that are not easily coerced or transformed from one type of material to another. Otherwise, the yellow wares may only be signaling the regular interaction of formerly mobile groups who share a common, even fictive, ancestry (see Johnson in press).

Given the extent of population movement immediately preceding the 14th century, we might expect *widespread exchange of vessels* between far-flung peoples who are biologically or fictively related. The familiarity of the potters with the figurative design styles manifested in the late prehistoric pottery (that is, the Jeddito Yellow Wares, the White Mountain Red Wares, the Zuni Wares, and Rio Grande Glaze Wares) would argue for *widespread stylistic similarity* as well. Therefore, until the production and distribution of yellow wares can be shown to be contextually circumscribed and/or until conventionally circumscribed design-motifs can be shown to be associated with particular groups, the role of yellow ware as a symbol of an alliance or power structure is largely conjectural.

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