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Ceramic Dating and Type Associations

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Abstract

This chapter examines a number of issues associated with dating archaeological sites based on the joint occurrence of artifact types. The approach presented permits a quantitative evaluation of the degree of association (or disassociation) of types based on their frequency of co-occurrence in empirical assemblages. Use of this method can aid in the evaluation of ceramic complex or ceramic group models that are so often used in the ceramic dating of sites. Judicious use of the proposed analyses can also help uncover defects in type dating schemes and can help in identifying regional variation in type associations.

The dating of artifact assemblages is, of course, an essential task of archaeologists. In this paper I attack some problems associated with the ceramic dating of assemblages based on the representation of artifact types.

Seriation

Seriation methods based on the presence or absence of artifact classes (often in the context of grave lots) have proved useful (Rowe 1962) as have methods based on the frequencies of artifact classes. Formal methods of frequency seriation began in the early 1900s (Kroeber 1916, Spier 1917) and developed over the last century (Cowgill 1972, Duff 1996, Ford 1962, LeBlanc 1975, Marquardt 1978, Neiman 1995). While seriation is a highly refined and enormously valuable tool in archaeology, its fundamental premises and objectives are not always consistent with our questions.

Seriation's task is to *order* assemblages (usually chronologically). In so doing, it treats assemblages as representing moments in time, not temporal intervals of indeterminate length. When assemblages represent intervals of non-trivial length, as is often the case when surface collections from sites are seriated, the result is not necessarily straightforward to interpret. It is not entirely clear what any particular ordering represents when the temporal intervals of the observations involved overlap. This problem is particularly troublesome when the length of the intervals associated with the different observations varies widely.

Even with a strong seriation, it is frequently the case that it is analytically necessary to divide sites into temporal groups (for example, in order to draw settlement pattern maps). Ideally, of course, these groups would represent contemporaneously occupied sites. Unfortunately, with prehistoric contexts, we almost never have the temporal resolution to do this.

Ceramic Complexes and Ceramic Groups

Despite the fact that they have received much less formal attention, ceramic complexes are widely used (though often not by name, e.g., Fowler & Stein 1992) as a practical alternative to seriation that provides a temporal *grouping* of assemblages. The fundamental idea is that at any given time, a particular suite of ceramic types was in use in a given area. With a knowledge of the overlap of the time spans during which these types are produced (whether or not one has good absolute dates associated with the types), one can chronologically categorize assemblages based on the suite of types present and absent. Based on its representation of ceramic types, an assemblage is dated through an assignment to a ceramic complex.

Some history is worth recounting. Although Harold Colton attributes the use of a similar approach to Gladwin in the early 1930s, Colton gives a clear statement of this method of analysis in his 1946 work on the Sinagua. Colton (1946: 18) defines a ceramic group as "an assemblage of contemporary, usually painted, pottery types recognized at a site of short occupation." Colton goes on to say: "For the purpose of synthesis we consider the pottery complex of a site to be made up of a ceramic group composed of decorated types and the utility pottery wares." He believed that the ceramic groups of decorated types were useful chronological indices, because they were traded over relatively large areas, while the utility ware (index ware) used at a site was indicative of the cultural group, because the cooking and storage vessels were more difficult to transport and thus more likely to be of local manufacture.

In his analysis of the ceramics from Awatovi, Watson Smith (1971: 21-22) adopted the term ‘ceramic group’ from Colton with an additional provision: “It seems semantically legitimate to expand the meaning to include an assemblage representing a brief portion of the total period of occupation at a site of longer duration.”

In its simplest form, the method can be illustrated with a chart of ceramic type spans (Figure 2.1; in this example these have approximate dates of production associated). The vertical strips marked on the figure and labeled with the letters A through L denote temporal intervals—the ceramic complexes. Assemblages dating within a given temporal interval would be expected to have present only those types comprising the complex. To the extent that one can uniquely fit empirical assemblages into those intervals, one has dated them relative to one another, and if the intervals are associated with absolute dates, one can likewise date the assemblages in absolute terms.

Use of Ceramic Complexes

Archaeologists who are unaware of Colton’s treatment of this problem will nonetheless find this method familiar because it encapsulates some basic archaeological logic that is widely applied. Those who have applied this procedure or a similar one will also immediately recognize that things do not always work out so neatly–that assemblages do not always uniquely sort into a single interval. It will be useful to categorize two anomalous situations and discuss what can be done about them:

An assemblage displays a set of types present in more than one interval (ceramic complex) but lacks types that would distinguish among intervals (complexes).

- This is generally a problem of limited samples. If types A and B comprise one ceramic complex and types A, B, and C a second one, then one cannot be sure whether to assign an assemblage containing only A and B to the first or the second complex unless the sample size is sufficient to conclude that the absence of type C in the assemblage is not due to sampling error. Little can be done to refine the dating other than to collect larger samples.

An assemblage displays a set of types inconsistent with any single interval.

- This may be due to the fact that the assemblages (e.g., a surface collection from a site) derives from multiple temporal components, either separated in time or a continuous occupation that spans an interval boundary. Here, there isn’t really a problem–the method has correctly identified a valid empirical pattern.

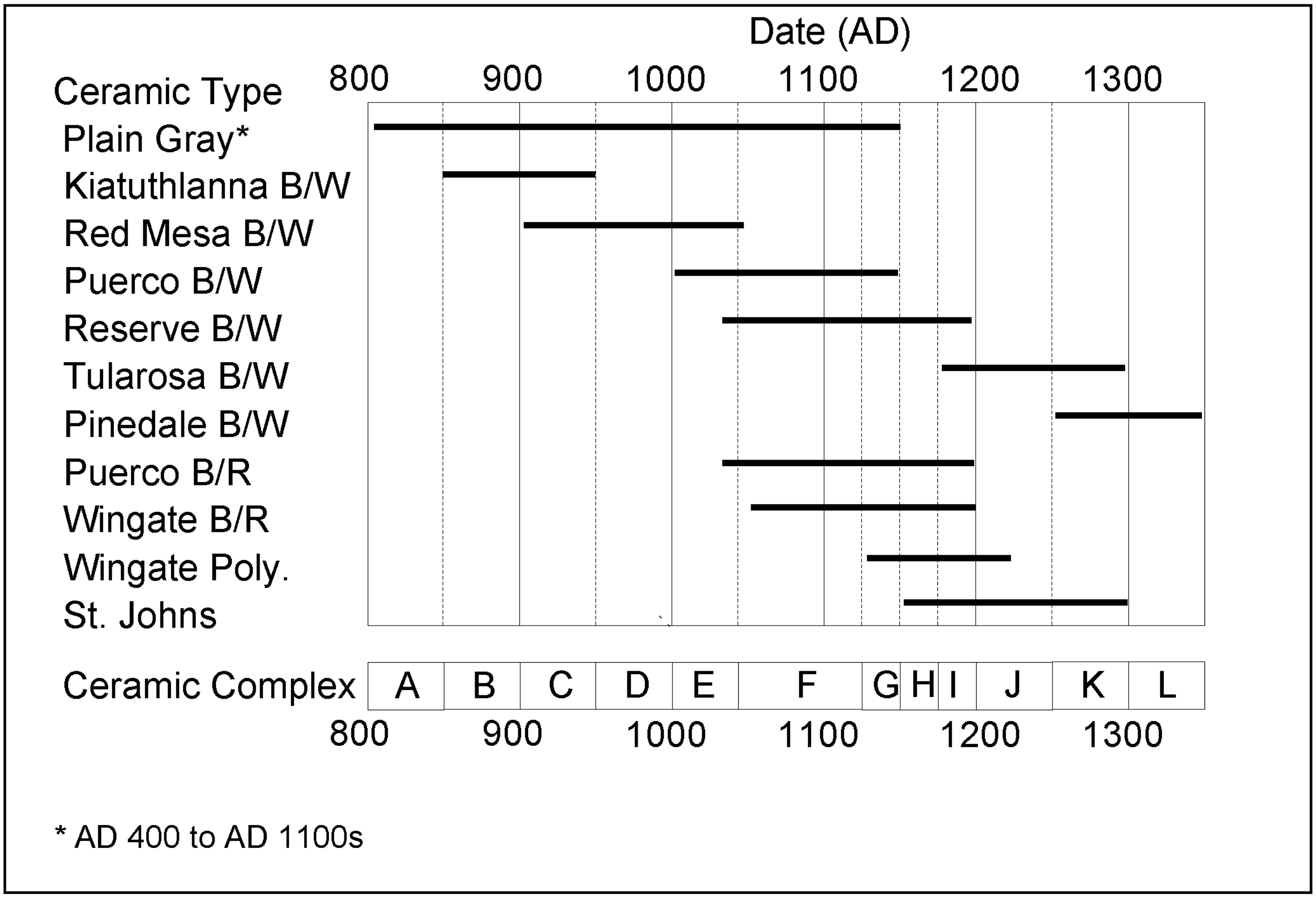

Figure 2.1. Ceramic type date spans (from Hays-Gilpin & van Hartesveldt 1998) and ceramic complexes.

- Because of the heirloom effect earlier types not generally in use at the time (but perhaps taken from earlier contexts or kept as heirlooms) appear in low frequencies in contexts that would otherwise be dated only to a later interval.
- In the opposite case, with low frequencies of later types, it often makes sense to hypothesize the presence of a shrine or some other form of limited reuse that contributes later ceramics not indicative of the main occupational period.
- Finally, inconsistency with a single interval can be due to the fact that the contemporaneous type associations are incompletely or incorrectly known.

While I cannot promise a neat way out of this tangle, it is possible to address the problem of correctly identifying the types composing the ceramic complexes though a quantitative examination of the empirical association of types. That is the principal topic of this paper.

Ceramic Dates

In the Southwestern United States many ceramic types have been assigned absolute temporal intervals in which they are believed to be commonly produced and used. These type date spans are inferred from independently established occupational intervals of sites in which they commonly occur. The absolute date spans assigned to the individual types are then used to derive the sets of types whose date spans overlap, thus comprising the ceramic complexes that are used to date sites lacking chronometric dates.

In the northern Southwest, only tree-ring dated sites are typically used in establishing the type dates (Breternitz [1966] is the most famous example). Ideally, the occupation span of each site used in dating the ceramic types is inferred from a suite of tree-ring dates from that site that can confidently be used to infer its dates of construction and abandonment. There are 4 issues of concern here.

1. Relatively few sites have sufficient suites of tree-ring samples make their occupation spans unambiguous.
2. In sites that have less than clear-cut evidence of their occupational intervals, different analysts may derive different occupational intervals from the same suite of absolute dates.
3. Even given the temporal intervals of sites at which it occurs, there is no agreed upon logic for deducing the type's date span.
4. This procedure is based on the debatable assumption that the type dates, which is to say the temporal intervals in which types are used, are uniform across space and independent of the context (such as site type).

The precision of ceramic dating in the Southwest is the envy of prehistorians across the world. Nonetheless, given the length of the inferential chain that leads to the inference of the type date spans and the inference of ceramic complex dates, we can benefit from an examination of the degree to which the empirical data are consistent with an inference that two types were in use at the same time.

Many type dates (including those used in the examples below) are certainly approximately correct. Nonetheless, I suspect that there exist substantial errors and that even the good dates may not be as good as many archaeologists assume. Indeed the analysts assigning these dates provide frequent cautionary phrases (Breternitz 1966, Carlson 1970).

My point is not that this has been done badly, or that the dates used are wildly wrong. On the whole, I think all this has generally been done well. Nonetheless, I believe that some caution is required when using type dates and ceramic complexes, such as those illustrated in Figure 2.1, to assign dates to sites or assemblages.

Ceramic Associations

One of the key ways in which we can check the accuracy of type dates is to see whether, on the ground, we find associated in the same assemblages, those types that would be predicted by the dates displayed in charts such as Figure 2.1. This paper is directed toward improving our understanding of the association and segregation of ceramic types. By association I mean a relationship in which types tend to be found together and by segregation (or negative association) I mean a relationship in which association is notably uncommon.

I offer no simple remedy. However, I do suggest some systematic procedures by which the association and segregation of types can be assessed. I will illustrate the application of these methods with systematic survey data from projects in the Cibola area of the southwestern United States. While I will draw some conclusions for the specific cases examined, in general, how the results of these procedures are interpreted will vary depending on the situation.

The results may indicate that the ceramic complexes predicted by the type dates are consistent with the empirical type associations. Alternatively, the results may indicate that a set of type dates is not consistent with the empirical record and can suggest the nature of adjustments that would bring them into closer conformity (for example, type X lasts longer or type Y starts earlier). Inconsistencies may be due, in turn, either to errors in the inferential chain that led to the assignment of the type dates, or may suggest that there are regional differences in the inferential chain that led to the assignment of the type dates, or may suggest that there are regional differences in the representation of types over time that had not been previously understood.

Site Survey Data

The data used in this analysis derive from two systematic surveys I have directed. The larger set, presented first and most completely, is from the Ojo Bonito Archaeological Project (OBAP). It includes systematic survey of 58 km^2 on the Hinkson Ranch that spans the Arizona-New Mexico border immediately south and southwest of the Zuni Indian Reservation. The second set of data comes from a 10 km^2 survey completed by the Heshotauthla Archaeological Research Project (HARP) in the central portion of the Zuni Indian Reservation.

For both projects, I use all systematic (not diagnostic) collections with 25 or more potsherds. For OBAP, 247 sites are represented; for HARP, 133 sites are used. Ceramic types for both projects were recorded by a small group of individuals working closely together with a common set of definitions. I think there is little chance that observer bias plays a substantial role in determining the patterning displayed. However, when comparing results of different projects, different operationalizations of the distinctions between types may be quite significant.

In both areas, ceramic period sites date from as early as A.D. 800 until the mid-A.D. 1300s. With the exception of three large, fourteenth-century pueblos (Heshotauthla, Ojo Bonito, and Spier 170) that date to the very end of the sequence, the architectural remains do not suggest long-term occupations of any sites. The surface collections used in these analyses are believed to derive from relatively short periods of site occupation or use.

The same decorated ceramic types are present in both sets of assemblages. The dominant slipped types in both cases are Cibola White Ware (Kiatuthlanna, Red Mesa, Puerco,[1] Reserve, Tularosa, and Pinedale Black-on-whites) or White Mountain Red Ware types (Puerco Black-on-red, Wingate Black-on-red, Wingate Polychrome, St. Johns Black-on-red and Polychrome).[2] The late White Mountain redware types and Zuni Glazeware and Buffware types (Springerville Polychrome, Kwakina Polychrome, Heshotauthla Glaze-on-red and Polychrome, Pinnawa Glaze-on-white and Red-on-white, Kechipawan Polychrome, and Matsaki Brown-on-Buff and Polychrome) are omitted from this analysis because they are present on so few sites (at most six in either project area). While later graywares and brownwares are omitted from the present discussion, Plain Gray sherds (which are unidentifable by type, absent the rim [Hays-Gilpin & van Hartesfeldt 1998: 122]) are included because they date prior to about A.D. 1030 and represent the only ceramics found on the earliest ceramic-period sites.

Figure 2.1, presented earlier, represents Hays-Gilpin & van Hartesveldt's recent assessment of the relevant type dates for the types under consideration. Certainly many archaeologists who have worried over these types would argue with some of the details of their dates. However, there is no widespread agreement about the absolute dating spans (and hence the temporal overlap determining the ceramic complexes) and these dates certainly represent a quite substantial improvement over others available in the literature (Breternitz 1966, Carlson 1970, Reid et al. 1991). Correspondence analysis-based frequency seriations (not presented here) of data sets from both projects order the types in ways that are generally consistent with this dating scheme.

Methods for Examining Ceramic Type Associations

My premise is that if the temporal overlap predicted by the type date spans is approximately correct, overlapping

Table 2.1. OBAP type co-occurrence counts. The number of collections in which each type is found is shown below the bottom row of type labels.

Gray:	.	35	48	65	49	35	5	26	23	5	16
Kiat:	35	.	35	37	27	20	0	14	11	6	4
RedM:	48	35	.	81	61	33	2	36	31	7	13
PuBW:	65	37	81	.	111	84	12	57	69	33	46
Resv:	49	27	61	111	.	57	5	49	59	26	31
Tula:	35	20	33	84	57	.	11	31	55	34	51
PiBW:	5	0	2	12	5	11	.	1	8	5	10
PuBR:	26	14	36	57	49	31	1	.	43	13	13
WinB:	23	11	31	69	59	55	8	43	.	27	29
WinP:	5	6	7	33	26	34	5	13	27	.	24
StJo:	16	4	13	46	31	51	10	13	29	24	.
	Gray	Kiat	RedM	PuBW	Resv	Tula	PiBW	PuBR	WinB	WinP	StJo
	103	51	94	184	127	107	13	68	83	38	61

Type label key: Gray=Plain Gray, Kiat=Kiatuthlanna Black-on-white, RedM=Red Mesa Black-on-white, PuBw=Puerco Black-on-white, Resv=Reserve Blank-on-white, Tula=Tualrosa Black-on-white, PuBR=Puerco Black-on-red, WinB=Wingate Black-on-red, WinP=Wingate Polychrome, StJo=St. Johns Black-on-red and polychrome.

types should be commonly associated in site assemblages, and types whose spans show much temporal separation should be segregated; that is, they should tend not to co-occur. Further, I suggest that an examination of type association and segregation may aid in the construction of more accurate ceramic complexes, and point to instances where the type dates need re-evaluation.

I now turn to a consideration of how we can identify association and segregation of types. The most obvious first step is to count the number of assemblages in which each pair of types co-occurs. Table 2.1 shows, for OBAP, the *number* of collections out of the 247 collections with 25 or more sherds in which each pair of ceramic types co-occur.[3] Thus, Red Mesa Black-on-white and Wingate Black-on-red occur together in 31 collections, despite the fact that these types are non-overlapping according to the dates in Figure 2.1. While these data have some independent utility, the number of co-occurrences is strictly limited by the smaller of the numbers of collections in which either type occurs, making the absolute counts a bit difficult to interpret. (The number of collections with the type present is provided below the row of type labels in the table.) In the example, 94 collections have Red Mesa Black-on-white and 83 have Wingate Black-on-red.

Closely related information is presented in Table 2.2 that gives the Jaccard coefficient between types, the *percentage* of all collections in which one or the other type is present that has both types present. Following the same example, Table 2.2 shows that 21% of the 146 collections that have either type, have both. Of the 94 collections with Red Mesa Black-on-white, 31 also have Wingate Black-on-red while 63 do not. Similarly, of the 83 collections with Wingate Black-on-red, 31 also have Red Mesa Black-on-white while 52 have only the redware type. The total number of collections with either or both types is 31+63+52=146. The coefficient is then 31/146 = 21%.

The Jaccard Coefficient suffers from the opposite problem of the co-occurrence counts. By expressing the co-occurrence as a percentage of the collections with one or the other type present, we lose sight of the how often, in absolute terms, these types really do co-occur. We should have more confidence in a high Jaccard Coefficient that is based on a large number of co-occurrences than one with few co-occurrences. Thus, the Jaccard coefficient is best interpreted in the context of the co-occurrence counts or numbers of collections with each type present.

While the tables of co-occurrence counts and Jaccard coefficients provide some useful information, it seems reasonable to assume that types that occur in more collections are more abundant and are more likely to co-occur with other types, even if they are not strictly overlapping in time (remember the heirloom and shrine effects), thus muddying any strong conclusions that might be drawn. Thus, it would be more useful to have a table similar in form to Table 2.2 that highlights the pairs of types that co-occur that substantially more or less frequently *than would be expected by chance*. The derivation of such a table is discussed below.

Assume for the moment that type A occurs in 40 out of 50 (80%) collections, type B occurs in 25 out of 50 (40%), and type C occurs in only 5 out of 50 (10%). We would expect that types A and B would frequently co-occur, even if had they had no particular relationship (i.e., the presence of one type at a given site is independent of the occurrence of the other). In fact, we can easily create an expectation for the co-occurrence of types assuming that one's presence at a given site is independent of the presence or absence of the other. Under the assumption of independence, types A and B would be expected to co-occur in 80% of 40% (32%) of the

Table 2.2. OBAP type co-occurrence Jaccard coefficients.

Gray:	.	29	32	29	27	20	5	18	14	4	11
Kiat:	29	.	32	19	18	14	0	13	9	7	4
RedM:	32	32	.	41	38	20	2	29	21	6	9
PuBW:	29	19	41	.	56	41	6	29	35	17	23
Resv:	27	18	38	56	.	32	4	34	39	19	20
Tula:	20	14	20	41	32	.	10	22	41	31	44
PiBW:	5	0	2	6	4	10	.	1	9	11	16
PuBR:	18	13	29	29	34	22	1	.	40	14	11
WinB:	14	9	21	35	39	41	9	40	.	29	25
WinP:	4	7	6	17	19	31	11	14	29	.	32
StJo:	11	4	9	23	20	44	16	11	25	32	.
	Gray	Kiat	RedM	PuBW	Resv	Tula	PiBW	PuBR	WinB	WinP	StJo
	103	51	94	184	127	107	13	68	83	38	61

(Type label key: Gray=Plain Gray, Kiat=Kiatuthlanna Black-on-white, RedM=Red Mesa Black-on-white, PuBW=Puerco Black-on-white, Resv=Reserve Black-on-white, Tula= Tularosa Black-on-white, PuBR=Pueco Black-on-red, WinB=Wingate Black-on-red, WinP=Wingate Poly-chrome, StJo=St. Johns Black-on-red and polychrome.)

assemblages (0.8*0.4= 0.32). Types A and C would be expected to co-occur by chance in 8% (0.8*0.1=.08) of the assemblages, and B and C in only 4% of the assemblages. The expected *number* of co-occurrences is simply the expected percentage (the product of their separate proportional likelihoods of occurrence) times the actual number of assemblages. Thus, for 50 assemblages, we would expect A and C to co-occur by chance in 4 (8% of 50).

Positive deviations between the observed and expected counts of co-occurrence (more observed co-occurrences than expected), can be interpreted as evidence of temporal association. Negative deviations (co-occurrences less frequent than expected by chance) suggest temporal segregation, or the tendency to not co-occur. We can standardize the difference between the observed and expected *numbers* of assemblages by dividing it by the standard deviation of the expected count. We end up with a Z-score measure of deviation from the expected. For example, if A and C actually co-occurred in 7 out of 50 assemblages, rather than the expected 4 (see above) the deviation from expected is +3. The standard deviation (discussed below) turns out to be about 1.9, so the observed case of 7 co-occurrences is +3/1.9=1.6, interpreted as being 1.6 standard deviations above the expected value. While the distribution of these values is not strictly Gaussian (Normal), the probability of getting a deviation as large or larger than the observed deviation is low (if it were Gaussian, the probability would be about 0.06, the actual binomial probablility is 0.10).

From a statistical standpoint, the idea is to view each comparison between two types, A and B, first as a two-by-two table, where the rows are "Type A" and "All Other Types" and the columns are "Type B" and "All Other Types" and the cells represent the number of assemblages that have type A and type B, type A and not type B, type B and not type A and neither type A nor type B. Using the two-way model, we derive an expected proportion (probability) p of co-occurrence as the product of the row proportion and the column proportion as described above. Having an expected proportion, we then use a binomial model. The standard deviation of the expected count, from the binomial distribution, turns out to be

$$\sqrt{Np(1-p)}$$

where N is the number of assemblages and p is the expected proportion of co-occurrences. Again, the expected count *(e)* is the expected proportion times the number of assemblages *(e=Np)* and we know the observed number of co-occurrences *(o)*. We calculate the A:C co-occurrence Z score as

$$Z_{AC} = \frac{o-e}{s.d.(e)} \text{ or equivalently,}$$

$$Z_{AC} = \frac{o-Np}{\sqrt{Np(1-p)}}$$

The result of this procedure applied to the OBAP sites with more than 25 sherds is presented in Table 2.3. The strongest associations are shown by large positive numbers, the strongest segregations by large negative numbers. Thus, Tularosa Black-on-white and St. Johns types which, by all account have largely overlapping occupation spans, have a very strong association (Z=5.1). Kiatuthlanna Black-on-white, the earliest whiteware type is, as expected, strongly segregated from the late St. Johns types (Z=-2.5).

Z scores with low absolute values (perhaps between -1.0 and +1.0) are more difficult to interpret. They suggest that the observed association is fairly close to the expectation based on an assumption of independence. This does not mean that the association is due to chance, but it suggests

Table 2.3. OBAP type co-occurrence binomial Z-scores.

Gray:	.	3.1	1.5	-1.6	-0.6	-1.6	-0.2	-0.5	-2.1	-2.8	-2.0
Kiat:	3.1	.	3.7	-0.2	0.2	-0.5	-1.6	0.0	-1.5	-0.7	-2.5
RedM:	1.5	3.7	.	1.5	2.0	-1.3	-1.3	2.1	-0.1	-2.0	-2.2
PuBW:	-1.6	-0.2	1.5	.	2.1	0.6	0.8	1.0	1.1	0.9	0.1
Resv:	-0.6	0.2	2.0	2.1	.	0.3	-0.7	2.6	2.7	1.5	-0.1
Tula:	-1.6	-0.5	-1.3	-0.6	0.3	.	2.3	0.3	3.4	4.5	5.1
PiBW:	-0.2	-1.6	-1.3	0.8	-0.7	2.3	-1.4	1.0	2.1	3.8	3.8
PuBR:	-0.5	0.0	2.1	1.0	2.6	0.3	-1.4	.	4.4	0.8	-1.0
WinB:	-2.1	-1.5	-0.1	1.1	2.7	3.4	1.8	4.4	.	4.1	2.0
WinP:	-2.8	-0.7	-2.0	0.9	1.5	4.5	2.1	0.8	4.1	.	4.9
StJo:	-2.0	-2.5	-2.2	0.1	-0.1	5.1	3.8	-1.0	2.0	4.9	.
	Gray	Kiat	RedM	PuBW	Resv	Tula	PiBW	PuBR	WinB	WinP	StJo
	103	51	94	184	127	107	13	68	83	38	61

(Type label key: Gray=Plain Gray, Kiat=Kiatuthlanna Black-on-white, RedM=Red Mesa Black-on-white, PuBW=Puerco Black-on-white, Resv=Reserve Black-on-white, Tula= Tularosa Black-on-white, PuBR=Pueco Black-on-red, WinB=Wingate Black-on-red, WinP=Wingate Poly-chrome, StJo=St. Johns Black-on-red and polychrome.)

that it might be. Following our earlier example of Red Mesa Black-on-white and Wingate Black-on-red, the Z score is -0.1. The co-occurrence counts (31) and Jaccard Coefficient of 21 might be taken to suggest a stronger association than that implied by the Z-score which suggests at most, a weaker association.

Overall, it appears that substantial temporal overlap between types produces relatively high positive Z-scores, that a temporally distinct temporal spans produce relatively strong negative Z-scores, and partial overlap or temporal adjacency produces scores with low absolute values.

Analysis of Cibola Area Type Associations

The ceramic type associations at the OBAP sites provided in Table 2.3 can be compared with expectations derived from the temporal overlap in types shown in Figure 2.1. I can suggest no quick analytical procedure for making these comparisons. I simply examined each coefficient in the table relative to the interpretive framework of the preceding paragraph and the overlap or separation of date spans as shown in the figure. How this comparison, combined with some archaeological judgment using information not in evidence here, suggests changes in the type spans is illustrated in the following paragraph.

First, a type-by-type comparison shows that the association data are generally consistent with the expectations of the type date spans. In the OBAP area, however, the use of Plain Gray must end much earlier than is shown on the figure (perhaps A.D. 1000 or 1050 rather than some time in the 1100s). This is indicated by negative associations with of Plain Gray with Puerco Black-on-white (-1.6), Reserve Black-on-white (-0.6), and strong negative association with Wingate Black-on-red (-2.1) and later redwares. The strong association between Red Mesa Black-on-white and Reserve Black-on-white (2.0) and between Red Mesa and Puerco Black-on-red (2.1) might be taken to indicate more overlap of these types, but the lack of association with Wingate Black-on-red (-0.1) and especially Wingate Polychrome (-2.0) suggests that the dates for Red Mesa should not be extended past A.D. 1075 or 1100. The strong association of Tularosa Black-on-white with Wingate Black-on-red (3.4) would suggest pushing the start date for Tularosa back to A.D. 1150. Finally, the segregation of St. Johns and Puerco Black-on-red (-1.0) and the weak association of the latter type with Wingate Polychrome (0.8) implies an earlier end date for Puerco Black-on-red (perhaps A.D. 1150).

This is not to say that the dates in Figure 2.1 are incorrect for the Rio Puerco, about 50 km to the northwest of the OBAP survey. Indeed, the differences lead us to wonder if this method might be used to help detect spatial differences in the temporal distribution of types. For that reason, the co-occurrence binomial Z-scores were also calculated for 133 sites in the HARP survey area about 50 km northeast of OBAP and 75 km east of the Rio Puerco work.

Results for the HARP survey are provided in Table 2.4. There are two dramatic differences between the HARP and OBAP areas. First, the association between Plain Gray and Puerco Black-on-white is positive for the HARP sites (1.1) and strongly negative in the OBAP sites (-1.6). Second, the association between Kiatuthlanna Black-on-white and Puerco Black-on-white is much stronger at the HARP sites (1.7) than it is for the OBAP sites (-0.2). This combination suggests that Puerco Black-on-white may be substantially earlier in the HARP area. (This is not entirely unexpected as the design styles seem northern in origin.)

Finally, a more visual comparison can be obtained by multidimensional scaling of the sets of co-occurrence Z-

Table 2.4. HARP type co-occurrence binomial Z-scores.

Gray:	.	3.7	2.2	1.1	0.2	-0.7	0.3	-0.2	-2.1	-2.3	-1.3
Kiat:	3.7	.	2.1	1.7	0.7	-0.7	-1.0	-1.8	-1.6	-2.4	-2.1
RedM:	2.2	2.1	.	2.1	2.7	0.2	-0.8	0.9	-0.4	-0.8	-1.3
PuBW:	1.1	1.7	2.1	.	2.5	0.7	0.4	1.7	0.6	-0.6	-0.8
Resv:	0.2	0.7	2.7	2.5	.	0.5	0.0	1.7	2.2	0.9	-0.6
Tula:	-0.7	-0.7	0.2	0.7	0.5	.	2.1	0.9	1.5	1.8	2.6
PiBW:	0.3	-1.0	-0.8	0.4	0.0	2.1	-0.2	0.7	-0.3	1.5	1.5
PuBR:	-0.2	-1.8	0.9	1.7	1.7	0.9	-0.2	.	2.5	1.4	0.9
WinB:	-2.1	-1.6	-0.4	0.6	2.2	1.5	0.7	2.5	.	4.2	2.0
WinP:	-2.3	-2.4	-0.8	-0.6	0.9	1.8	-0.3	1.4	4.1	.	3.0
StJo:	-1.3	-2.1	-1.3	-0.8	-0.6	2.6	1.5	0.9	2.0	3.0	.
	Gray	Kiat	RedM	PuBW	Resv	Tula	PiBW	PuBR	WinB	WinP	StJo
	19	27	56	86	53	55	5	31	54	35	51

(Type label key: Gray=Plain Gray, Kiat=Kiatuthlanna Black-on-white, RedM=Red Mesa Black-on-white, PuBW=Puerco Black-on-white, Resv=Reserve Black-on-white, Tula= Tularosa Black-on-white, PuBR=Pueco Black-on-red, WinB=Wingate Black-on-red, WinP=Wingate Poly-chrome, StJo=St. Johns Black-on-red and polychrome.)

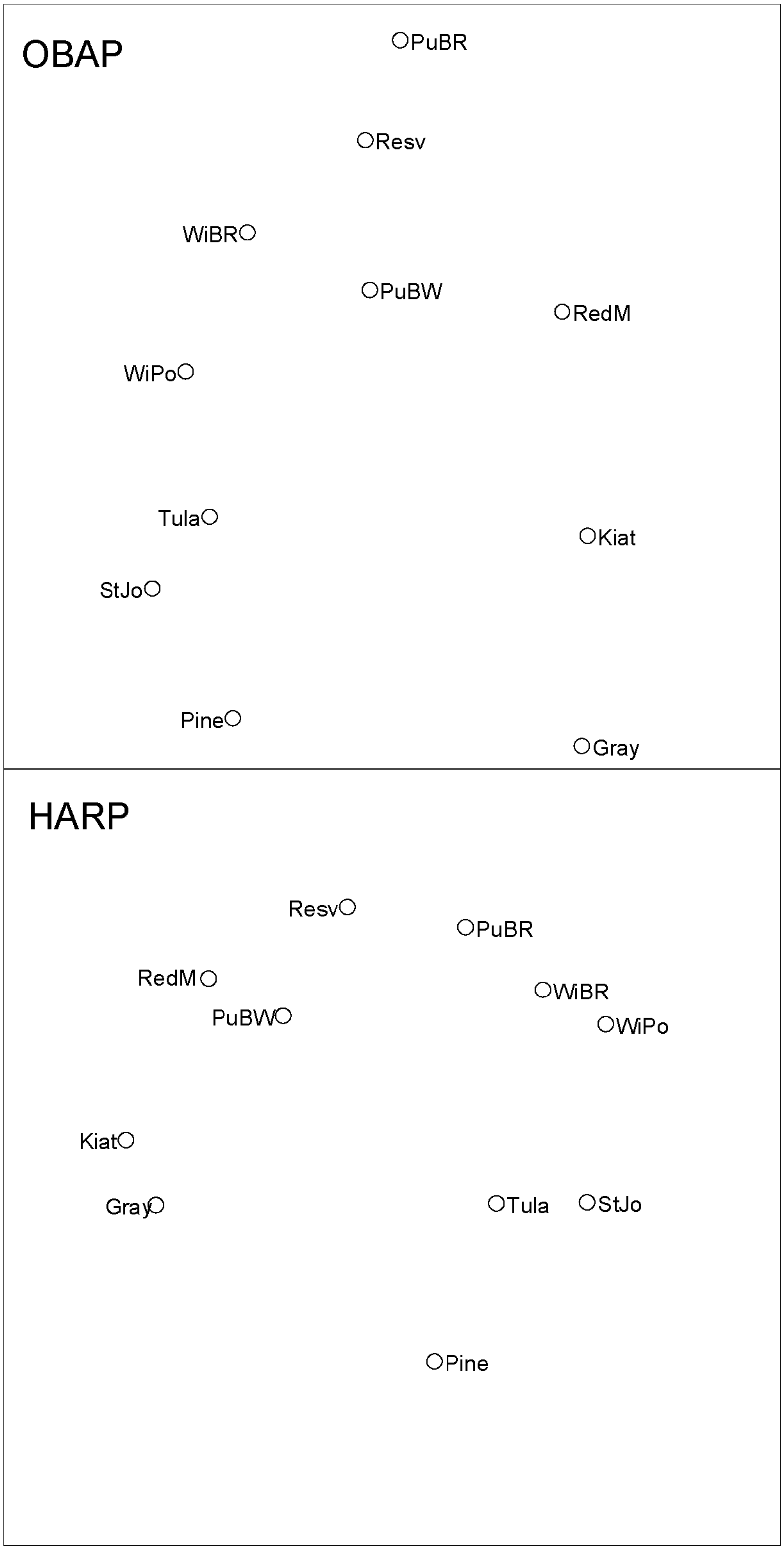

Figure 2.2 Multidimensional scaling in two dimensions of type co-occurrence binomial Z-score coefficient matrices.

scores from each area. The two dimensional solutions that best represent the similarities among the types (as measured by type co-occurrence Z-scores) are displayed in Figure 2.2. In both cases, the types form a temporal arc, in the OBAP case moving counter-clockwise from the point labeled Gray (for Plain Gray) and in the HARP case, moving clockwise from the point with the same label. Because types are represented as points in this analysis, the temporal overlap is not being conveyed, but substantial differences in the relationships among the points would seem to indicate different temporal relationships. (For multidimensional scaling, differences that can be accounted for by a change in scale, by rotation, or with a mirror image are not significant.)

The overall configuration is similar in both plots, with a clear sequence from Plain Gray at the early end, to Kiatuthlanna Black-on-white, to Red Mesa Black on-white, and from Wingate Black-on-red, to Wingate Polychrome, to Tularosa Black-on-white, and St. Johns (plotting close together) and to Pinedale at the late end. Between these two portions of the arc the relationships among Puerco Black-on-white, Reserve Black-on-white, and Puerco Black-on-red differ somewhat between the areas. In the HARP area, Puerco Black-on-white plots close to Red Mesa Black-on-white, followed by Reserve Black-on-white and then Puerco Black-on-red. This is consistent with my earlier suggestion that Puerco Black-on-white may date earlier in the HARP area. In the OBAP area, I would interpret these three types to be approximately contemporary.

Conclusion

The procedures discussed here have both the advantage and the liability of utilizing presence-absence data. That is, these calculations use only the presence or absence of each type at a site; the frequencies are not factored in. The advantage is that one can use these methods when the frequencies are unknown. The disadvantage is that presence-absence data are inherently less robust statistically than frequency data. A single heirloom sherd in a large collection triggers an association in that collection with all other types present. This is why we do not want to take each observed in a collection too seriously. I suspect, however, that the liabilities of this presence-absence approach are mitigated somewhat by the use of systematic (rather than diagnostic) collections and the use of a reasonable sample size cutoff (25 was used here, though higher numbers would be desirable). It should also be possible to develop frequency-based approaches to this problem.

In this chapter, I have illustrated how a systematic analysis of type co-occurrence, with methods proposed here, can aid in the evaluation of ceramic type association models (such as ceramic complexes) that are so often used in the ceramic dating of sites. Judicious use of the proposed sorts of analyses can both help uncover defects in type dating schemes and can help in identifying regional variation in type associations.

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More than 20 years ago, the late Watson Smith induced me to start to think systematically about ceramic dating. I greatly value all I learned from him. Several of the key ideas for this paper were developed while consulting for Pueblo of Zuni and they first appeared in one of the Zuni Archaeology Program's reports prepared for Salt River Project (Kintigh et al. 1993). James Allison is responsible for the main idea of binomial Z-scores as measures of association. Kelley Hays-Gilpin and Gregson Schachner provided many helpful suggestions on an earlier draft of this paper. Finally, I am grateful to Sylvia Gaines for helping build ASU's strength in quantitative and formal approaches to archaeology. It has been a privilege to be her colleague and a part of that program.

Endnotes

1. Puerco Black-on-white here represents the combination of what some analysts would treat as three types, Gallup Black-on-white, Escavada Black-on-white, and Puerco Black-on-white. Because they are approximately contemporary, there is no strong reason to split them for a chronological analysis.

2. St. Johns has both Black-on-red and polychrome types that have similar or identical temporal spans. For present purposes the two St. Johns types are considered together. Wingate Black-on-red and Wingate Polychrome clearly have different temporal distributions so they are tabulated separately.

3. All tables presented here are symmetric, but square rather than triangular matrices are presented to facilitate examination.

4. All analyses reported here, other than the multi-dimensional scaling, were accomplished using programs in Kintigh's *Tools for Quantitative Archaeology* (2002). The multidimensional scaling was accomplished using Systat version 10.

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