FREQUENCY SERIATION, CORRESPONDENCE ANALYSIS, AND WOODLAND PERIOD CERAMIC ASSEMBLAGE VARIATION IN THE DEEP SOUTH

Karen Y. Smith and Fraser D. Neiman

Temporal variation in ceramic-type frequencies often is used to order archaeological assemblages chronologically. Frequency seriation (FS) is one means to do this. If the pottery types used are historical, then frequency seriation is an appropriate method for deriving a chronological order of assemblages. If types measure time and, say, social status, then a frequency-seriation diagram will appear messy, or noisy, and deriving a chronological order will be less straightforward. Correspondence analysis (CA) can, when certain conditions are met, tease apart both temporal and nontemporal sources of variation. We explain why by highlighting the conceptual links between the models that are presupposed by CA and FS. The links imply that these methods are complementary and that, when used together, both can yield a deeper understanding of the causes of type-frequency variation than either can alone. We explore the practical implications for archaeological inference in two case studies of Middle and Late Woodland ceramic assemblages from sites located in the Deep South, primarily along the Gulf Coast and along the lower Chattahoochee and Apalachicola Rivers of Alabama, Georgia, and Florida.

The purpose of this paper is to highlight the analytical power and complementarity of two methods, frequency seriation (FS) and correspondence analysis (CA), for building chronological sequences, exploring rates of change, and recognizing synchronic spatial variation, in the context of the precontact history of southeastern North America.[1] We briefly review the conceptual models behind the FS and CA methods and describe links between them. Those links are not widely recognized in archaeology, yet appreciating them is critical to understanding why the two methods are so useful in combination. However, because our focus is on the utility of the methods to help archaeologists solve the vexing puzzles presented by real archaeological data, the bulk of our exposition is devoted to two case studies from the late prehistory of southeastern North America. We use the practical interpretive problems raised in the case studies to motivate the methodological discussion of FS and CA.

In the first case study, we examine how FS and CA can deepen our understanding of the traditional chronological framework for the Middle and Late Woodland periods in the Deep South. That framework, like those for most of the Southeast and elsewhere in North America, is based on phases. We show how FS and CA of assemblages from sites in central and southwestern Georgia, southeastern Alabama, and northwestern Florida can reveal empirical patterning that is hidden by the phase-based approach (Plog 1973; Plog and Hantman 1990:440–442) and raise new questions about rates of cultural change, regional demography, and temporal bias in archaeological samples.

The second case study examines the utility of the two methods at the intrasite scale. Here we focus on Kolomoki (9ER1), one of the most important sites in the region (Pluckhahn 1998, 2000, 2002, 2003; Sears 1951a, 1951b, 1953a, 1953b, 1956, 1973, 1992; Smith 2005). We show how FS and CA can be used to resolve temporal and synchronic spatial sources of among-assemblage variation and reveal the emergence over time of sacred and secular activity areas at the site.

Woodland Chronology in the Deep South

Our first case study is set in a portion of the northwest Gulf Coast of Florida between Wakulla County on the east and Bay County on the west, and the inland region of Alabama, Georgia, and Florida drained by the lower Chattahoochee and Apalachicola Rivers. Despite the area's physiographic diversity, we consider this region as a unit, in part because qualitative comparisons indicate similarities among material culture in general and ceramic art in particular. This is not surprising since the Chattahoochee/Apalachicola River system likely served as a north-south conduit for the intraregional movement of people and ideas. This waterway also facilitated the intra- and interregional movement of goods from the Gulf of Mexico to the Midwest and points in between (Anderson 1998:279–280). By focusing our efforts on the Middle and Late Woodland periods (roughly 100 B.C. to A.D. 900) (Bense 1994:137, 162), we capture not only the birth and death of certain styles of pottery decoration but also the rise and decline of this region's participation in, if only marginally, the ''Hopewell'' long-distance-exchange network (Brose 1979:141; Smith 1979:181), beginning sometime after A.D. 1, which is marked by increased cultural interaction (Dickens 1980; Dickens and Fraser 1984), population growth (Milanich 1994:134), and incipient social stratification. The last, some argue, may have arisen initially between those who were able to capitalize on the demand for exotic goods and those who were not (Anderson 1998:278–279; Bense 1994:141; Milanich 1994:133–134). It is during this time that we also see the development of habitation areas and, often, mounds anchored to open central spaces, or plazas, a pattern of intrasite spatial organization (Kidder 2004:515) that persisted through Contact period in many parts of southeastern North America. Conical burial mounds with grave goods reflecting differential treatment of the dead and platform mounds, often reflecting differential treatment of the living (Lindauer and Blitz 1997:170–173), further betray the increasing complexities in social relationships witnessed through the Woodland period (Bense 1994:140–162).

Our understanding of these important developments would surely benefit from a single chronology that encompasses sites in the entire region. But none exists. Instead, there is a phase-based chronology for the lower Chattahoochee developed by Knight and Mistovich (1984:211–222; see also Schnell 1975). Gordon Willey developed a similarly conceived chronology for the northwest coast of Florida in the 1940s (1973:Figure 76; see also Willey and Woodbury 1942:Figure 26). These beginnings are useful precisely because they raise a host of unanswered questions. The most basic is how the phases in these two chronologies relate to one another in time. Which phases are contemporary, which overlap? There is also the question of relatedness in a phylogenetic sense. Considered together, do the phases in each chronology comprise a single, evolving historical tradition, or are there two or more traditions represented, with variable amounts social learning among their members over time? More specifically, Knight and Mistovich (1984:219–220) have suggested there is a ''stylistic'' gap between assemblages from two sites in their sequence: Mandeville (9CY1) and Kolomoki (9ER1). Are there similar gaps elsewhere? Do gaps represent punctuated change within a single tradition, or novel interaction with groups that are parts of different traditions?

Archaeologists working in the region have not been unaware of such questions. In fact, the possibility of addressing them is a principal motivation behind the meticulous study of the region's most eye-catching Woodland period ceramic type: Swift Creek Complicated Stamped (SCCS), recognized as a particular kind of paddle-stamped pottery displaying linear and curvilinear elements ''which enter into elaborate composite designs'' of various forms (Kelly 1938:27; see also Jennings and Fairbanks 1939:29; Willey 1939:145–146). Scholars have sought similarities among paddle-stamp designs and even identity among individual paddles as clues to relatedness and interaction among their makers (Broyles 1968; Caldwell 1978; Saunders 1998; Snow 1975, 1992a, 1992b; Snow and Stephenson 1998). But enduring puzzles about the chronological extent of SCCS threaten to impede these efforts. There has been progress, in the form of consensus on the temporal duration of what has been called the Swift Creek period (A.D. 100–800) and a better grasp of the spatial extent of the pottery (Georgia, northwestern and north-central Florida, and eastern Alabama) (Caldwell 1958:36–44; Stephenson et al. 2002:318; Willey 1939:142; Williams and Elliott 1998:1). There is no doubt, however, that Swift Creek stylistic studies would benefit from a single chronology that captures the birth and death of SCCS and places Swift Creek assemblages into a single temporal sequence.

Making further advances requires methods that (1) allow for the construction of a single, continuous chronology for assemblages across the study area, (2) allow us to determine empirically the extent to which the assemblages in the region are parts of a single evolving tradition, or if they represent multiple traditions, and (3) allow detection of the existence and frequency of gaps, punctuations, and other kinds of discontinuities in the sequence. In the following sections, we show how FS and CA are useful tools toward these ends.

Frequency Seriation

The frequency seriation method has a long history in American archaeology, dating back to the 1910s (Lyman et al. 1997:55–59). James A. Ford, one of its leading exponents and practitioners, worked in the Southeast, and some of the earliest chronologies of the region (Ford and Willey 1941; Willey and Woodbury 1942) were based on his work with FS (Ford 1952, 1962) and a related method called interdigitation, or the fitting together of stratified sequences using the similarity in relative frequencies of pottery types (*sensu* Willey 1973:Figure 14). Although there are conspicuous exceptions (e.g., Lipo et al. 1997), there is no doubt that the popularity of FS has declined in the region and the discipline at large with the advent of radiocarbon dating (Gibson 1993:32; Ford 1952:319; Lyman et al. 1997:185; O'Brien and Lyman 1999:225–226). We resurrect this method here because it is capable of delivering a continuous, relative chronological sequence.

FS uses relative frequencies, or percentages, of artifact types within an assemblage to derive an order or sequence among many assemblages (Dunnell 1970:308; Lyman et al. 1997:57; O'Brien and Lyman 1999:121–125). A sequence is produced by attempting to fit *within-assemblage* (the rows) percentages to a model that specifies how *within-type* (the columns) fluctuations should behave over time. This model of change in artifact-type frequencies is often referred to as the popularity principle but can also be thought of as a unimodal or battleship-shaped curve model, placing the emphasis on the shape within types rather than the mechanism driving the change between assemblages. A seriation solution is an ordering of the assemblages in which type frequencies best approximate the battleship-shape curve model of monotonic increase, followed by monotonic decrease.

Success or, more important, failure in a particular application can be judged in two ways. First, there may simply be no order of the assemblages that produces battleship-shape curves. If this happens, then the types may not be historical and progress depends on finding new types that are. However, goodness of fit to the model is no guarantee that the order is chronological. When the battleship-shaped curve model is the sole basis for deriving an order among assemblages, independent evidence (e.g., stratigraphy, radiometric dating) about the chronological relationships among the assemblages can be used to objectively evaluate the seriation solution (Dunnell 1970; see Kosso 2001 on objectivity).

Ceramic Types

FS places a heavy burden on the identification of types that are historical. Fortunately, given the critical role FS played in the culture history of the Southeast, many traditional Southeastern pottery types are (approximately) historical, as are many of attributes on which they are based. As a result, we have been able to mine tables of type counts in assemblages published over the past 60 years for data suitable for our analysis.

However, even under these favorable conditions, mining published data can be a problematic enterprise. The principle issue, of course, is idiosyncratic variation among researchers in the use of ceramic-type names. This problem often manifests as a failure to commit to one type name or another or the creation of one or more new types in spite of existing typologies. This is not a trivial matter, nor is it unique to the Southeast. The only solution, save reexamining tens of thousands of sherds, is to find a least-common denominator among the various classifications that allows meaningful comparisons to be made.

In this study, decoration and surface treatment were chosen as guides in navigating the vagaries of nomenclature because these were the only attributes consistently reported in ceramic inventories. Plain pottery was excluded from the analyses, given that plain-pottery types often are ''less sensitive instruments for measuring … change with the passage of time'' (Phillips et al. 2003:220). This decision is supported by the way in which relative frequencies of plain pottery behave through time. Figure 1 shows the percentage of decorated pottery relative to plain pottery in each assemblage. The assemblages, represented by the solid squares, are ordered from left (late) to right (early) based on the FS and CA analyses described below. Despite a clear, temporal trend, the marked fluctuations among adjacent assemblages indicates that plain pottery, as an all-inclusive group, does not meet the historical standard required of types used to construct chronological sequences. Given this and an apparent precedent for using decorated ceramics to successfully construct and compare chronologies (Ford 1935:7; Ford 1952:322; Phillips et al. 2003:65, 219), we feel justified in our decision to exclude plain pottery.

Figure 1. Relative frequencies of decorated to plain pottery sherds for 80 of the 84 assemblages included in the regional analysis. The solid squares denote assemblages. Their order along the x-axis was derived from FS and CA results. Time moves from right (early) to left (late). Decorated pottery, or at least the extent to which entire vessel surfaces are decorated, decreases over time, from over 60% during the Shorter phase to less than 20% during the Hare's Landing phase (see Figure 6 for phase designations). With the return of check stamping as a surface treatment, decorated-pottery percentages increase again but do not reach the levels seen during the earliest phases.

Using generic decorative types instead of competing traditional typologies also allowed for the inclusion of pottery counts for sherds that are not assignable to specific types, for example, because the sherds are too small even though the decorative mode is apparent. Table 1 presents the gross-scale decorative types used in the analysis and the excavator-reported types that they include. Unless otherwise stated, the generic types used here also include decorated sherds unassigned to a formal type (e.g., cord marked).

A few of exceptions were made to the rule of using gross decorative types instead of reported type names, and these merit explanation. A fair amount of ambiguity surrounds the classification of check-stamped pottery, present in many Middle and Late Woodland period assemblages in the region. The

Table 1. Generic pottery types used in the FS and CA analyses of Deep South assemblages.

Generic Decorative Pottery Types	Excavator-Reported Types
Deptford-Related Check Stamped	Cartersville Check Stamped Deptford Bold Check Stamped Deptford Linear Check Stamped Gulf Check Stamped Linear Check Stamped McLeod Linear Check Stamped ''Check Stamped'' in Lower Sequence
Fabric Impressed	Dunlap Fabric Marked Kellog Fabric Impressed
Simple Stamped	Cartersville Simple Stamped Deptford Simple Stamped Mossy Oak Simple Stamped Swift Creek Simple Stamped Thomas Simple Stamped Thomasville Simple Stamped
Cord Marked	Dunlap Corded Fairchild's Cord Marked West Florida Cord Marked
Santa Rosa Punctated	Santa Rosa Punctated ''Punctated'' in Lower Sequence
Curvilinear Complicated Stamped	Blakely Complicated Stamped Brewton Hill Complicated Stamped Fairchild's Complicated Stamped Hare's Landing Complicated Stamped Kolomoki Complicated Stamped Little Kolomoki Complicated Stamped Mulberry Creek Complicated Stamped Napier Complicated Stamped Pasco Complicated Stamped Swift Creek Complicated Stamped Curvilinear Complicated Stamped Complicated Stamped
Rectilinear Complicated Stamped	Crooked River Complicated Stamped St. Andrews Complicated Stamped Swift Creek Nested Diamond Stamped
Santa Rosa-Related Stamped	Alligator Bayou Stamped Rocker Stamped Santa Rosa Stamped
Crystal River Negative Painted	Crystal River Negative Painted
Curvilinear Check Stamped	New River Complicated Stamped Old Bay Complicated Stamped
Ruskin Dentate	Ruskin Dentate
Red Filmed	Dunn's Creek Red Plain Red Weeden Island Red Weeden Island Zoned Red Weeden Island Red/Zoned Red
Incised	Basin Bayou Incised Carrabelle Incised Crystal River Incised Englewood Incised Indian Pass Incised Keith Incised Lemon Bay Incised Swift Creek Arc Incised St. Petersburg Incised Weeden Island Incised Weeden Island Incised-Punctated Yokene Incised
Weeden Island-Related Punctated	Carrabelle Punctated Linear Punctated Weeden Island Punctated Zone Punctated ''Punctated'' in Upper Sequence
Tucker Ridge Pinched	Tucker Ridge Pinched
Net Marked	Mound Field Net Marked
Cob Marked	Alachua Cobmarked Northwest Florida Cob Marked
Wakulla Check Stamped	St. Johns Check Stamped Wakulla Check Stamped ''Check Stamped'' in Upper Sequence

uncertainty of type assignment stems largely from a lack of temporally sensitive attributes in check stamping at the *body* sherd level (see Brown 1982:11–24 for a succinct discussion of classification issues related to check stamping). Figures 2 and 3, both portions of a larger frequency-seriation diagram, illustrate nicely the region-wide practice for dealing with check-stamped classification. In Figure 2, only the check-stamped types for the lower half of the regional sequence are shown, and the type names used are the ones originally reported. Figure 3 shows only the check-stamped types for the upper part of the regional sequence, again, using the type names reported by the excavators. Clearly researchers prefer to abstain from type assignment with respect to early check stamping (Figure 2); whereas, for late checking stamping the sherds are often classified as Wakulla Check Stamped (Figure 3). Five additional check-stamped types are less often used but nevertheless appear in the literature. These diagrams illustrate that none of the check-stamped type frequency distributions conforms to the model. We think the lack of fit stems primarily from sherd-level ambiguities but may also arise from idiosyncrasies in nomenclature.

Curvilinear complicated stamped pottery types present a similar nomenclature issue and lack of fit to the model, which may, in part, relate to the difficulty of type assignment at the sherd level (Willey 1945:237). Figure 4 represents another segment of the sequence and illustrates the variety of type names in use. Again, none of the types conforms to the battleship-shaped curve model. Kolomoki Complicated Stamped, for example, is one of four types Sears (1956:52–53) created to divide ''the complicated stamped developmental continuum at Kolomoki.'' Although it may well be a sortable type–Sears (1992:66) later doubts many of sherd assignments he made to the type–it, like the others, does not conform to the model of relative-frequency change. Another example is Hare's Landing Complicated Stamped (not shown in Figure 4), created by Caldwell (1978:66–68) based on work at Hare's Landing (9SE33) in southwestern Georgia, which is in the SCCS style but is ''perfectly distinguishable [in] the fact that only one stamped design was used to decorate the vessels.'' Unfortunately, the diagnostic design is not illustrated in the edited manuscript in limited circulation (Caldwell 1978), nor can the design be found in the larger manuscript (Caldwell ca. 1955) from which the edited version was taken. Regardless, while this type may work well for identifying a *very* brief moment in time, as a sort of index fossil (O'Brien and Lyman 1999:212–213), it does little to facilitate the ordering of assemblages by means of FS, since it occurs in only two assemblages in the sequence. Our solution for dealing with check-stamped and SCCS-related types is given below.

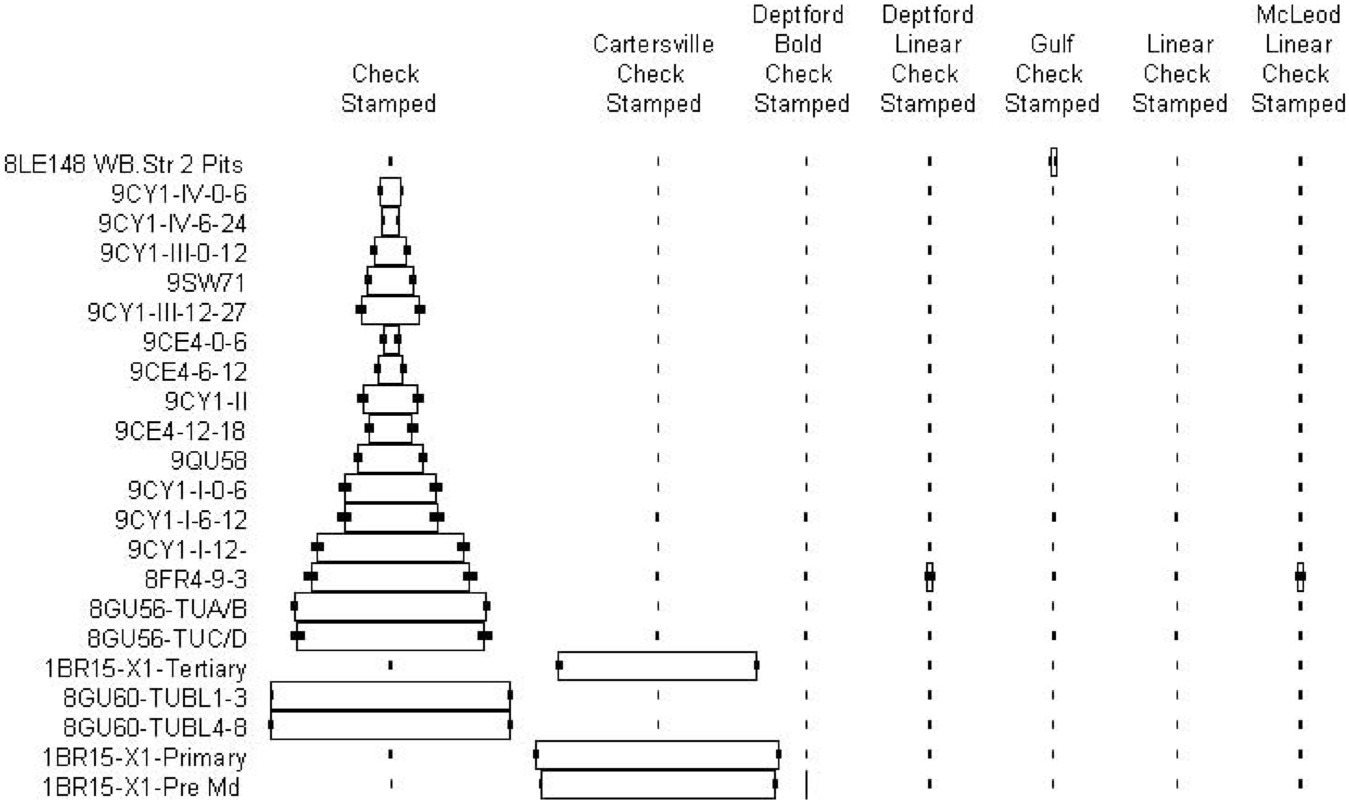


Figure 2. Frequency-seriation diagram showing only the check-stamped types for the lower sequence as they were reported. Other decorated types for these assemblages were included in the generation of the relative frequencies but are excluded from the diagram. Most of the early check-stamped pottery was classified without reference to formally defined types. See Figure 6 for note regarding the creation of the diagram.

Assemblages

Data on type frequencies in the excavator's original provenience units (contexts), from surface collection and excavation, were collected from published sources as well as unpublished site reports and, in a few cases, handwritten drafts. Contexts were included in our sample if the sites from which they came contained Woodland period occupations with *decorated* pottery counts of over 80 sherds. In all, 29 sites from the area had assemblages that met this sample-size requirement (Table 2). The sites are distributed from the Gulf Coast to Columbus, Georgia, a distance of over 300 km (Figure 5). Two sites, Swift Creek (9BI3) in central Georgia and Coahatchee (1CC53) in south-central Alabama, are located outside of the Chattahoochee/Apalachicola/Gulf study area but were included in the seriation because, quite frankly, they fit—that is to say, the frequency-seriation model was not violated by their inclusion.

The question of how to aggregate assemblages from individual contexts at a site into larger analytical units, the assemblages that form the rows of the seriation data table, is important. This is because the FS method comes with requirements about the characteristics of the assemblages used. Even if the types are historical across some assemblages, there is no guarantee that their battleship-shape trajectories will appear in the particular assemblages under study. Traditionally archaeologists have pointed to three additional assumptions about assemblages: they accumulated over similar amounts of time; they come from the same cultural tradition; and they are derived from the same local area (Dunnell 1970). Meeting these assemblage expectations with absolute certainty is difficult (O'Brien and Lyman 1999:125-130).

Our decisions about lumping have been guided by the issues of sample size and time averaging. Excluding samples with fewer than 80 decorated sherds limits the confounding effects of sampling error on the results. This is an arbitrary cutoff, which is ultimately justified by the good fit of our FS solution to the seriation model (see below). In combining contexts we have also been aware of the need for equal duration, or equal time averaging, among assemblages (see Phillips et al. 2003:45, 219). As a result, contexts were lumped to meet the sample-size criterion only when they were stratigraphically or spatially adjacent to one another.

We attempted to reduce further the amount of variation in time averaging among excavation and collection units by eliminating types that are known to be associated with significantly earlier or later periods. Thus the only types considered in this analysis are

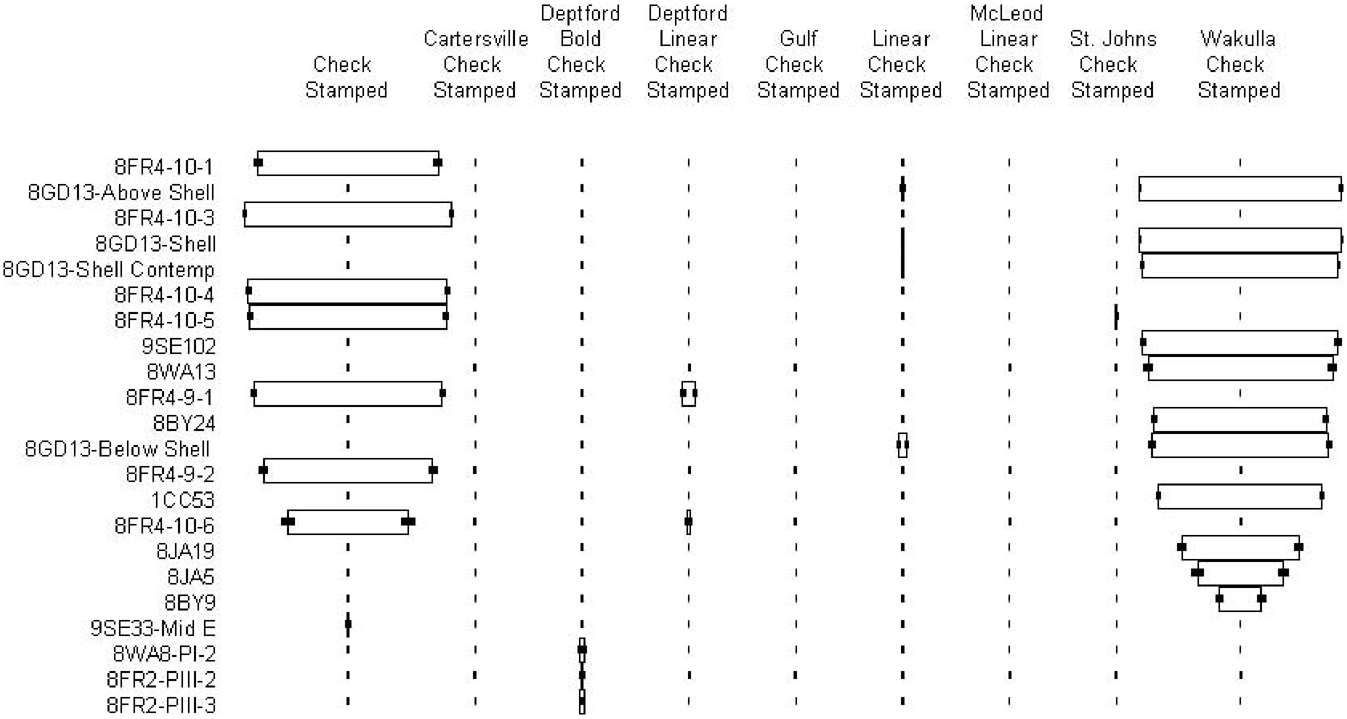


Figure 3. Frequency-seriation diagram showing only the check-stamped types for the upper sequence as they were reported. Other decorated types for these assemblages were included in the generation of the relative frequencies but are excluded from the diagram. Most of the late check-stamped pottery was classified as Wakulla Check Stamped. See Figure 6 for note regarding the creation of the diagram.

those associated with the larger Woodland-era ceramic traditions commonly referred to in the literature as Deptford, Swift Creek, and Weeden Island. This step is necessary in cases where contexts combined Woodland and non–Woodland period occupations. Since a ''tradition'' is ''a (primarily) temporal continuity … of related forms'' (Willey and Phillips 2001:37), removing temporally noncontiguous pottery types from the analysis

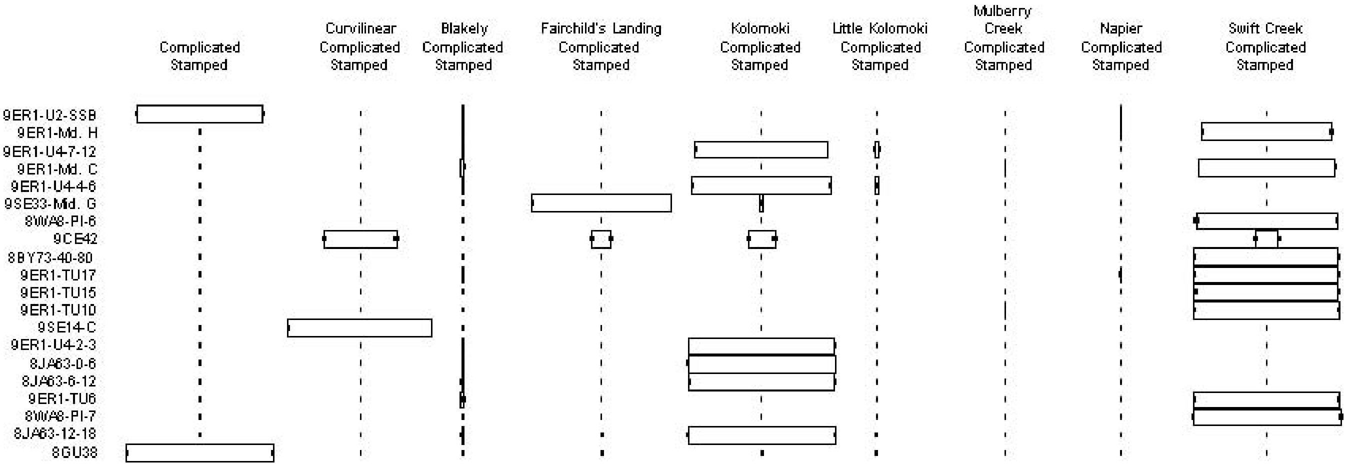


Figure 4. Frequency-seriation diagram showing only the curvilinear complicated stamped types for a portion of the sequence as originally reported. Other decorated types for these assemblages were included in the generation of the relative frequencies but are excluded from the diagram. Several researchers have sought to subdivide SCCS into less inclusive and, presumably, more time-sensitive types. Caldwell (1978:63–65, 66–68), for example, defined Fairchild's Landing Complicated Stamped and Hare's Landing Complicated Stamped (not shown in this figure) based on his work at two Georgia sites that bear these names; however, given the limited circulation of his report, few others have had the opportunity to evaluate or implement his typology. The other types shown here reflect Sears's efforts at Kolomoki (Sears 1951a:9–10; 1956:15–17). See Figure 6 for note regarding the creation of the diagram.

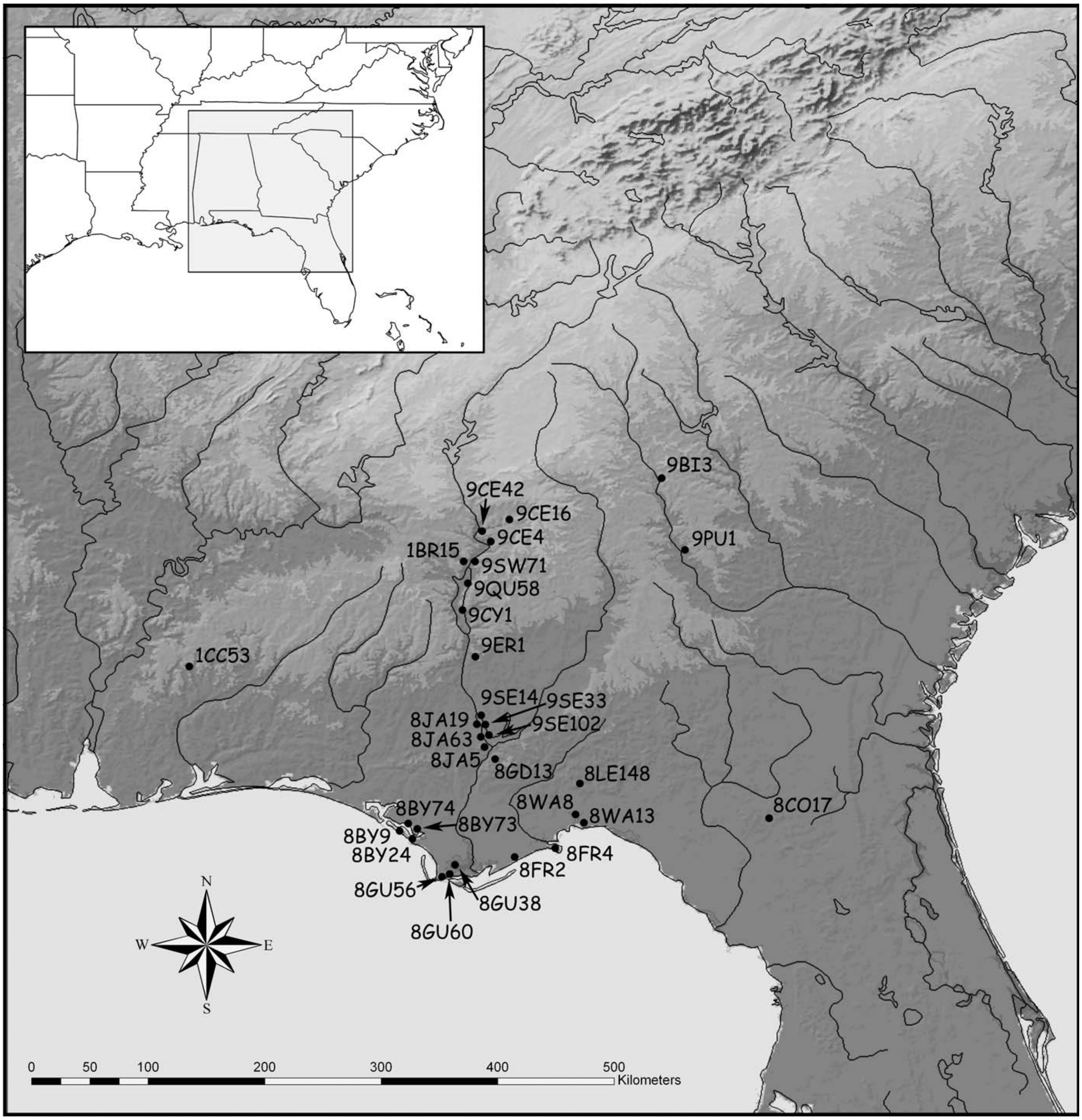


Figure 5. Approximate locations of archaeological sites included in the study. Hartford (9PU1) and McKeithen (8CO17) are discussed in the text but are not included in the analysis.

probably moves us closer to meeting the requirements related to cultural tradition and local area. In the final data set of 84 assemblages from 29 sites, the smallest sample consists of 81 sherds from Overgrown Road (8GU38), the largest sample consists of 1946 sherds from Kolomoki (9ER1), and the median sample size is 172 sherds.[2]

FS is a method that utilizes a model of formal, type-frequency variation through time to construct chronologies, but type-frequency variation can, and does, occur across space. The same-local-area requirement is best viewed as acknowledgment that analytical units should be chosen to minimize synchronic spatial variation, from whatever source. The motivation behind the same-cultural-tradition requirement is similar, only it refers to formal variation at a larger spatial scale. Yet we have no way of knowing a priori over what geographical distances there will be too much synchronic variation

Table 2. References and summary context information for the Deep South assemblages.

Site Number	Site Name	References	Contexts
8LE148	Block-Sterns	Jones and Tesar 1996:405, 406	Western Berm Features Near Str. 2
9CE16	Box Springs		All proveniences
8JA19	Butler	Bullen 1950:Table 1; White 1981:179	Unidentified (J-17)
8FR2	Carrabelle	Willey 1973:49, 52	Excavation Pits I, II and III
8GU60	Clark Creek	White 1994:Table 29	Test Unit B
1CC53	Coahatchee	Lolley 2003:67–69	All excavations
8GU56	Depot Creek	White 1994:Table 1	Test Units A and B
9SE14	Fairchild's Landing	Caldwell 1955:Figure 7A	Stratigraphic Block Excavation
8BY73	Fox's Pond	Bense and Watson 1979:92–93	Excavation Units
9CE4	Halloca Creek	Chase and Kelly 1955:Trait List Table	Main Excavation
9SE33	Hare's Landing	Caldwell 1978:50, 54, 56	Middens E, G and J
9JA5	Jim Woodruff	White 1981:169	Unidentified (J-2)
9ER1	Kolomoki	Pluckhahn 1998, 2002, 2003; Sears 1956	Excavations, Test Units, and Mounds
9CY1	Mandeville	Kellar et al. 1961:Tables	Mound A Excavation
8WA8	Mound Field	Willey 1973:62	Excavation Pit I
8GU38	Overgrown Road	White 1992:Table 2	Test Units and Features
8BY74	Parkers Branch	Willey 1973:237 as 8BY10 (see Stephenson et al. 2002:343)	Surface Collection
8BY24	Pearl Bayou midden	Willey 1973:244	Surface Collection
9CE42	Quartermaster	Beasley 2003:72–75	All proveniences
8WA13	Refuge Headquarters	Willey 1973:297	Surface Collection
1BR15	Shorter	DeJarnette 1975:Table 18	Mound Excavation
9BI3	Swift Creek	Kelly and Smith 1975:Table 1	Mound A Excavation
8GD13	Sycamore	Milanich 1974:21	Area IV (shell midden)
8FR4	Tucker	Sears 1963:17, 19	Tests 9 and 10
8BY9		Willey 1973:236	Surface Collection
8JA63		Bullen 1958:Table 3	Trenches
9QU58		Mistovich and Knight 1986:138–147	All proveniences
9SE102		White 1981:558–559	Surface Collection
9SW71		Mistovich and Knight 1986:109–112	All Provenienc es

within a particular larger regional sequence. A few studies have cleverly approached the problem by empirically identifying, through a process of trial and error, spatially contiguous groups of assemblages which display historical type frequencies and using the resulting groups to defining local areas (e.g., Lipo et al. 1997; see also Ford 1952:322–323, 332; Phillips et al. 2003:224–226).

However, it is unlikely that *any* set of types whose temporal trajectories meet the historical significance criterion will not also be sensitive to synchronic variability expressed in space at one or more scales, only two of which are associated with the phrases ''local area'' and ''cultural tradition.'' It is this realization that motivates our use of CA, in addition to FS. Within the FS framework, the local-area and cultural-tradition requirements are best seen as stipulations that assemblages be chosen ''such that formal variation within the bounded area is minimal and between such areas is maximal'' (O'Brien and Lyman 1999:127).

Frequency Seriation of Deep South Assemblages

In our initial attempt at an FS solution, given the classification issues addressed above, all check-stamped pottery was lumped together. This resulted in *the only type* in the sequence that displayed a bimodal distribution in time, in essence two battleship-shapes within the same type, with a clear absence of check stamping in the intervening assemblages. As an obvious violation of the frequency seriation model, this solution was unacceptable and, given the dominance of check stamping in the earliest and latest assemblages, it was also unacceptable to throw the type out altogether. The only acceptable solution was to split the type. Since the Wakulla Check Stamped type was used most often to denote check-stamped sherds in the latest assemblages, those with minor amounts of Weeden Island series sherds, the type name Wakulla Check Stamped was retained for checked stamped pottery in assemblages that fall in the upper part of the sequence. It was with the earliest assemblages, those with cord-marked and simple stamped type sherds, that a unified terminology seems to be lacking. We reluctantly decided to call the early check stamping Deptford-Related Check Stamped, realizing that some perceive noncoastal (e.g., lower Chattahoochee River) check-stamped pottery as being more related to a Cartersville-Piedmont type adaptation, and therefore more appropriately called Cartersville, than to a Deptford coastal-based way of life (e.g., Milanich 1994:114, 120). For most early assemblages, the decision resulted in assigning a type name to an otherwise unassigned group of check-stamped sherds. For some, it meant lumping Deptford Bold Check Stamped and Deptford Linear Check Stamped or classifying as Deptford the pottery that had been identified as Cartersville Check Stamped. In only five assemblages and for only 13 sherds did this decision result in the lumping of sherds assignable to several, quite likely valid (recognizable), check-stamped types, such as Gulf Check Stamped.

Any curvilinear complicated stamped sherds identified by the excavator as Swift Creek, Early Swift Creek, Late Swift Creek, Kolomoki, Blakely, Fairchild's Landing, Hare's Landing, Little Kolomoki, and Mulberry Creek were lumped under the rubric of Curvilinear Complicated Stamped. There may well be types within this monotype that can be defined so as to have historical utility (see Beasley 2003:80–88 for a recent attempt to tackle this issue), but given that all 84 assemblages were not cataloged with the same suite of types in mind, lumping them seemed to be the only reasonable approach, save reanalyzing tens of thousands of sherds. The fact that the type Curvilinear Complicated Stamped, as defined here, displays a virtually perfect unimodal distribution through the sequence suggests that this approach has merit. The chronology presented below demonstrates the lengthy temporal span of curvilinear complicated stamping and, at the same time, provides a framework by which changes through time in other attributes of complicated stamping, such as land/groove width, can be measured.

From the 29 sites, 84 assemblages and 18 pottery types were selected for inclusion in the regional-scale seriation (Figure 6). Kolomoki (9ER1) assemblages far outnumber assemblages from any other site, although Mandeville (9CY1), Swift Creek (9BI3), and Fairchild's Landing (9SE14) in Georgia and Carrabelle (9FR2) and Tucker (9FR4) on the Florida coast contribute many assemblages to the sequence as well. One rather obvious observation regarding the sequence is the near-total domination of curvilinear complicated stamped pottery in roughly the center, reading from bottom to top, of the chart. Note, too, that the distributions of Deptford and Wakulla Check Stamped do not overlap in this frequency-seriation diagram.[3] Figure 6 also shows the chronological placement of Swift Creek between Mandeville and Kolomoki assemblages[4] and illustrates that the pottery types as defined here are, in large part, historical, meaning that they have unimodal temporal distributions.

FS has delivered a single, continuous chronology. The fact that type frequencies display battleship-shape curves across seriated assemblages suggests that all the assemblages, in some general sense captured by our coarse-grained ceramic types, are parts of a single evolving tradition. However, questions remain. First, there is the possibility of undetected synchronic spatial variation in type frequencies. FS is designed to recover assemblage order when type frequencies assume battleship-shaped curves along a single temporal gradient. But in this case might type frequencies be simultaneously structured by a second dimension? Second, there is question of gaps in the sequence. Inspection of the seriation diagram reveals that many of the Kolomoki assemblages have very similar type frequencies. But how different are they from the other assemblages? Are there other groups of assemblages that are more similar to one another than they are to the others? To what extent is the entire sequence dominated by such clusters of assemblages, separated by unoccupied segments of assemblage space? Answering these questions requires supplementing FS with CA.

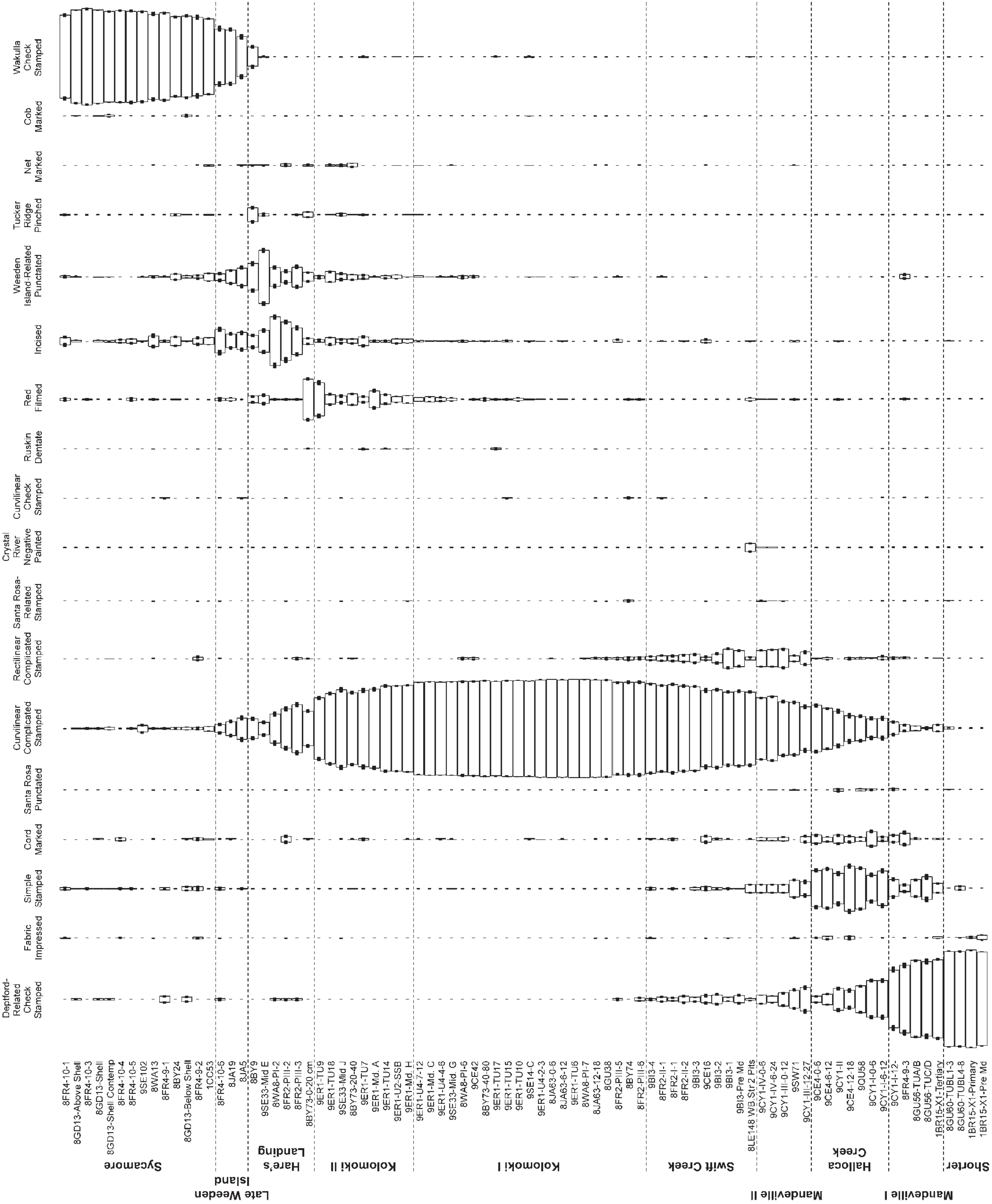
Correspondence Analysis

CA has a long history of use by archaeologists in continental Europe (e.g., Djindjian 1976, 1985; Madsen 1988) but its use by Americanist archaeologists is both more recent and rare (exceptions include Duff 1996; Neiman and Alcock 1995:2–12; Robertson 1999:147–150). The method has been independently invented many times since its first appearance in the 1930s (Hirschfeld 1935), with what in the end have proven to be mathematically equivalent operations derived from very different statistical and disciplinary motivations (e.g., Benzécri 1969; Greenacre and Hastie 1987; Hill 1973, 1974; Nishisato 1980). Only two of these concern us here: CA as an ordination technique and CA as a technique for indirect-gradient analysis. The ordination perspective is the one featured in nearly all presentations of CA to archaeological audiences. However, it is the indirect-gradient analysis perspective that has the deep and methodologically fruitful connections to FS.

Like FS, CA operates on a two-way (row-column) data matrix. The rows comprise individual assemblages, while the columns are type frequencies. As an ordination method, CA provides a way of visualizing as accurately as possible in only a few dimensions, hopefully only two or three, the distances among a set of assemblages whose completely accurate description requires many more dimensions. The measure of distance used in CA is the chi-squared distance:

$$d_{x^2 1,2} = \sqrt{\left[\sum_{j=1}^{c} \frac{\left(\frac{p_{1j}}{p_{1+}} - \frac{p_{2j}}{p_{2+}}\right)^2}{\frac{p_{+j}}{p_{++}}}\right]}$$

where p_{ij} is the frequency of the j'th type in the i'th assemblage, expressed as a proportion of the total number of sherds in all the assemblages. This says that to compute the chi-squared distance between two assemblages, we compute the differences between the relative frequencies for each type, square them, divide each squared difference by the relative frequency of its type in the entire data set, add up the results, and take the square root. The division step gives more weight to rare types. We measure the total amount of variation in the original data set as the sum of chi-squared distances


Wakulla Check Stamped
Cob Marked
Net Marked
Tucker Ridge Pinched
Weeden Island-Related Punctated
Incised
Red Filmed
Ruskin Dentate
Curvilinear Check Stamped
Crystal River Negative Painted
Santa Rosa-Related Stamped
Rectilinear Complicated Stamped
Curvilinear Complicated Stamped
Santa Rosa Punctated
Cord Marked
Simple Stamped
Fabric Impressed
Deptford-Related Check Stamped
8FR4-10-1
8GD13-Above Shell
8FR4-10-3
8GD13-Shell
8GD13-Shell Contemp
8FR4-10-4
8FR4-10-5
9SE102
8WA13
8FR4-9-1
8BY24
8GD13-Below Shell
8FR4-9-2
1CC53
8FR4-10-6
8JA19
8JA5
8BY9
9SE33-Mid E
8WA8-PI-2
8FR2-PIII-2
8FR2-PIII-3
8BY73-0-20 cm
9ER1-TU9
9ER1-TU18
9SE33-Mid J
8BY73-20-40
9ER1-TU7
9ER1-Md. A
9ER1-TU14
9ER1-U2-SSB
9ER1-Md. H
9ER1-U4-7-12
9ER1-Md. C
9ER1-U4-4-6
9SE33-Mid G
8WA8-PI-6
9CE42
8BY73-40-80
9ER1-TU17
9ER1-TU15
9ER1-TU10
9SE14-C
9ER1-U4-2-3
8JA63-0-6
8JA63-6-12
9ER1-TU6
8WA8-PI-7
8JA63-12-18
8GU38
8FR2-PIII-5
8BY74
8FR2-PIII-6
9BI3-4
8FR2-II-1
8FR2-II-2
9BI3-3
9CE16
9BI3-2
9BI3-1
9BI3-Pre Md
8LE148 WB Str 2 Pits
9CY1-IV-0-6
9CY1-IV-6-24
9CY1-III-0-12
9SW71
9CY1-III-12-27
9CE4-0-6
9CY1-II
9CE4-6-12
9CE4-12-18
9QU58
9CY1-I-0-6
9CY1-I-6-12
9CY1-I-12-
8FR4-9-3
8GU56-TUA/B
8GU56-TUC/D
1BR15-X1-Tertiary
8GU60-TUBL1-3
8GU60-TUBL4-8
1BR15-X1-Primary
1BR15-X1-Pre Md
Sycamore
Late Weeden Island
Hare's Landing
Kolomoki II
Kolomoki I
Swift Creek
Mandeville II
Halloca Creek
Mandeville I
Shorter

from each the assemblages to the average assemblage, a measure called ''inertia.''

A completely accurate description of the chi-squared distances among assemblages, and thus the total inertia in the data set, requires 1 less dimensions than the number of types or assemblages, whichever is less. Say we have *r* assemblages and *c* types, and $r > c$. The *r* assemblages are points in a *c-1* dimensional space, whose axes or dimensions correspond to the relative frequencies of the *c* types. CA produces a new set of axes or dimensions. The first of these is placed so that the scores of the assemblages along it account for the most inertia possible. The second CA axis is also placed so that it accounts for the maximum possible inertia, subject to the constraint that the scores of the assemblages on it are not correlated with their scores on the first. The third, fourth, through *c-1* CA dimensions are derived in like fashion. The hope is that because of the inertia-maximizing property, the first two or three CA dimensions will capture most of the inertia in the original data set. The analogy to principal components analysis is obvious: the successive axes of PCA maximize variance, while in CA the axes maximize inertia. PCA is often computed via an eigenanalysis of a cross-products matrix and so is CA. The same analysis can be carried out on the types in the space of assemblages. And with appropriate scaling, the CA scores of the types can be displayed in a space that ''corresponds'' to the CA scores of the assemblages, allowing visual assessment of which types are important in which assemblages (Baxter 1991, 1994:110–123; Clausen 1998; Legendre and Legendre 1998:451–461).

While the ordination perspective on CA is useful, its relevance to FS is opaque. Seeing the connection between FS and CA requires a different derivation of CA, one pioneered by vegetation ecologists as indirect-gradient analysis or reciprocal averaging (Hill 1973, 1974). The starting place is the notion that the abundance of a species in samples taken along some environmental gradient, say elevation, would follow a Gaussian response (i.e., follow a normal curve when plotted against the gradient). The species should be most frequent at some gradient value, the species optimum, and decline in frequency as gradient values departed from the optimum, with the rate of decline a function of the species tolerance. The species optimum and tolerance describe the species response to the gradient, just as the mean and variance describe the location and shape of a Gaussian frequency distribution.

Given this model, ecologists recognized it was possible to produce a naïve estimate of the location of a sample along a particular gradient, as a weighted average of the optima for the species that occurred in it, where the weights were species abundances, a method called ''direct-gradient analysis'' (Whittaker 1956). An analogous estimate of the species optimum was possible from a weighted average of the gradient values for the sample units in which the species occurred. Hill (1973, 1974) realized that one could conduct this kind of analysis using random numbers as initial estimates of species optima, producing weighted-average estimates of sample locations on the gradient from them, using the sample-location estimates to produce new species-optima estimates, and so forth until the values stabilized. Hill showed that the species and sample-location scores derived from this reciprocal-averaging algorithm were equivalent to the scores on the first axis or dimension of correspondence analysis derived from the ordination perspective and executed via eigenanalysis. He also showed how the reciprocal averaging algorithm could be used to derive the subsequent CA dimensions.

The ecologist's Gaussian response model is a parametric gloss of the battleship-shaped curves of the seriation model. While species abundances vary along an environmental gradient, historical-type frequencies vary along a temporal gradient. The naïve location estimates of direct-gradient analysis are analogous to mean-ceramic dates used by historical archaeologists and prehistorians in the North American Southwest (Christenson 1994; South 1972). Like FS, CA requires no initial estimates of historical-type dates or chronological orders. Like FS, the order from CA provides no indication of which way is up.

However, CA offers two results that FS does not. The first is a set of numeric scores on the successive CA dimensions for both the assemblages and the types.

←

Figure 6. Frequency-seriation diagram of all assemblages. Open bars represent the percentages of pottery types in each assemblage. Solid bars represent 95% confidence limits based on a normal distribution and are largely a function of sample size. The assemblage order was derived by hand using trial and error and our own judgment regarding best fit to the frequency-seriation, or battleship-shaped curve, model while maintaining any stratigraphic relationships among assemblages. Dashed lines mark the boundaries between phase groups, which were identified through CA and roughly correspond in terms of pottery content to Knight and Mistovich's phases, though three more phase groups have been added here. The diagram was drawn and the confidence limits were calculated using Seriation Maker 1.0, a Visual Basic front-end to Microsoft Excel© v.5.0 written by Tim Hunt (Lipo 2001; see also Lipo et al. 1997) and available at http://people.virginia.edu/~fn9r/data/SmithandNeiman2007.html.

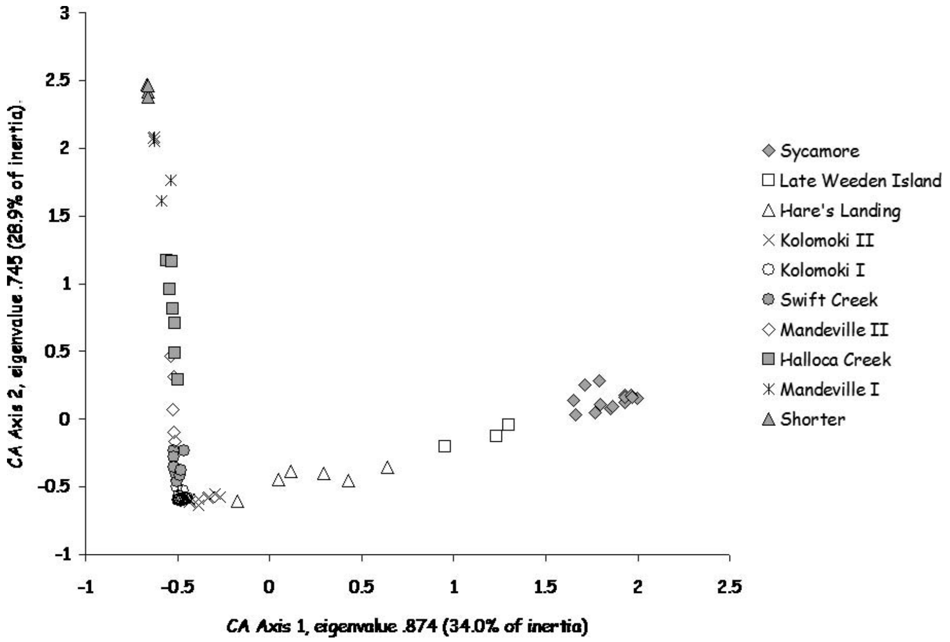


Figure 7. Scatter plot showing Deep South assemblage positions relative to the first two axes of a correspondence analysis performed on all assemblages. Assemblages are sorted along Axis 1 by the amount of Wakulla Check Stamped they contain. Sycamore phase assemblages, shown on the far right, are dominated by this late type; whereas, assemblages on the far left contain no Wakulla Check Stamped.

When scaled properly, the assemblage scores are estimates of the location of the assemblages along a hypothetical underlying gradient, while the type scores are estimates of the type optima, the locations of their points of maximum popularity. The scores thus offer a way to measure clustering among assemblages and types along the gradient. Second, while FS assumes that a single gradient underlies the type frequencies, CA can handle the situation in which the type frequencies in an assemblage arise from its location along *two or more* gradients. In other words, CA generalizes the seriation model to accommodate situations in which type frequencies respond to the simultaneous operation of two or more factors and thus, in principle, allows the identification of those factors, disentangling the roles they play in determining assemblage composition. The proportion of inertia accounted for by each CA axis offers an indication of whether it has identified a meaningful gradient.

The ability to derive accurate estimates of assemblage locations along multiple gradients comes at the price of additional assumptions related to the Gaussian-response model and the distribution of samples along the gradients. Analytical and simulation results show that CA results are likely to be reliable to the extent that four conditions hold (ter Braak 1985): (1) the tolerances or variances of type responses along each gradient are equal or uniformly distributed, (2) type maxima are equal or independent of optima along each gradient, (3) type optima are equally spaced or uniformly distributed along each gradient, and (4) assemblage locations are equally spaced or uniformly distributed along each gradient.

If these conditions are met, and time is the major factor structuring assemblage variability (inertia), then CA Axis-1 scores of the assemblages will be correlated with their temporal positions. Sorting the assemblages on their scores will produce the battleship-shaped curves of the seriation model for types whose frequencies change over time. If a second significant gradient, for example, social status, operates independently of time, and it is also responsible for an additional portion of the variability among the assemblages, then CA Axis-2 scores for the assemblages will be correlated with their positions on it. Sorting the assemblages on their dimension-2 scores should yield battleship-shaped curves for those types that respond to the second gradient. But there is no guarantee that time will correlate with the first-CA dimension. CA is inertia maximizing, so if a nontemporal gradient is responsible for most of the variation in a particular data set, CA Axis 1 will capture it, and temporal variation may emerge on the second axis, or not at all.

CA of Woodland Assemblages from the Deep South

We performed a CA on the on all the assemblages in the original frequency seriation.[5] Figure 7 shows a plot of assemblage positions relative to the first two CA axes. Each assemblage is coded to correspond roughly to Knight and Mistovich's phases (Knight and Mistovich 1984:211–222), primarily for purposes of com-

Table 3. Eigenvalues associated with the successive axes estimated by a CA of all Deep South assemblages. The eigenvalues measure the amount inertia accounted for by each axis and can be re-expressed as percentages of the total inertia in the data set.

Axis	Eigenvalue	Percentage Inertia
1	.87411	34.01
2	.74519	28.99
3	.28037	10.91
4	.22437	8.73
5	.11938	4.64
6	.09762	3.80
7	.06298	2.45
8	.04952	1.93
9	.02493	.97
10	.02397	.93
11	.01751	.68
12	.01150	.45
13	.00955	.37
14	.00889	.35
15	.00845	.33
16	.00747	.29
17	.00448	.17

munication but also to show that assemblages group in a patterned way. Inspection of the proportion of inertia accounted for by each CA dimension suggests that the dataset is essentially two dimensional–note the sudden drop in the inertia accounted for after Axis 2 (Table 3). This assessment is sustained by comparing the inertia values to the broken-stick distribution, which offers a simple null model of the proportion of inertia accounted for in random data (Legendre and Legendre 1998:837).

What do the two dimensions represent? In this case, they both register time, and this warrants some discussion. Axis 1 separates assemblages containing Wakulla Check Stamped–the Sycamore, Late Weeden Island, and Hare's Landing phase groups–from all other assemblages (Figure 7). This variation is temporal in the sense that Wakulla Check Stamped is the latest pottery type used in the analysis. But the Wakulla assemblages are distant from all the others, and the distance is so great, relative to the distances among the other assemblages, that the inertia-maximizing criterion singles it out. This points to violations of one or more of ter Braak's (1985) four requirements. The yawning gap here means either that the period between the Kolomoki II phase group and the Wakulla Check Stamped–bearing assemblages was one of very rapid change or a segment of time is simply not represented in our samples. Once the inertia associated with the Wakulla assemblages distinctiveness has been accounted for, Axis 2 sorts the remaining non-Wakulla assemblages along a temporal gradient (Figure 7).

To evaluate the robustness of Axis 2 and our hypothesis that it also registers time, we performed a second CA, after removing the post-Kolomoki II assemblages, comprising the Hare's Landing, Late Weeden Island, and Sycamore phases. In theory, with elimination of the large chi-squared distances between the Wakulla Check Stamped–bearing assemblages and the others, the first axis should duplicate the second axis in the original analysis. This is precisely what happens (Figure 8). Time moves from right to left along Axis 1, as demonstrated below. On the far right are the Shorter (1BR15) assemblages, and the concentration of

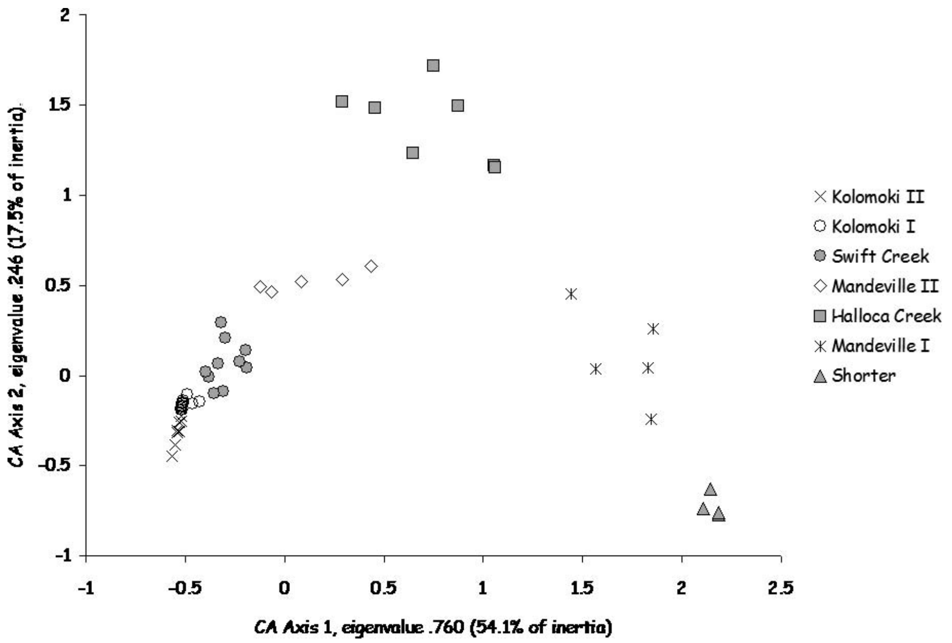


Figure 8. Correspondence-analysis scatter plot of Deep South assemblages with post–Kolomoki II phase assemblages removed from the analysis.

Table 4. Eigenvalues associated with the successive axes estimated by a CA of the Deep South assemblages, excluding Hare's Landing, Late Weeden Island, and Sycamore phase assemblages.

Axis	Eigenvalue	Percentage Inertia
1	.76009	54.10
2	.24693	17.58
3	.12460	8.87
4	.07677	5.46
5	.06348	4.52
6	.03102	2.21
7	.02501	1.78
8	.01757	1.25
9	.01346	.96
10	.00941	.67
11	.00873	.62
12	.00837	.60
13	.00599	.43
14	.00483	.34
15	.00441	.31
16	.00384	.27
17	.0041	.03

assemblages on the far left includes those from Kolomoki (9ER1).

However, there is a puzzle. Inspection of the inertia accounted for by the successive dimensions from the second CA suggests that there is a second significant axis (Table 4). What does it represent? The plot of Axis-2 scores and against Axis-1 scores (Figure 8) reveals that the Axis-2 scores are a quadratic function of the Axis-1 scores. This is ''the arch effect.'' It results whenever CA is used to analyze gradients that are long enough to encompass an increase and decrease of one or more types. Battleship-shaped curves create nonlinear relationships among types, which cannot be fully described on a single CA axis, because the axis is a straight line (see Neiman and Alcock 1995 for an illustration). The nonlinearity therefore appears on higher-order axes, when their scores are polynomial functions of the scores on the lower-order axis that captures most of the gradient. The arch is the most common case, where the scores on the higher-order axis are a quadratic function of the scores on the lower one. But higher-order polynomial dependencies are possible if the battleship curve model fits the data exceedingly well and there are no other sources of variation.

The arch need not emerge only on the second axis. Our first CA offers an example. Here the Axis-3 scores were a quadratic function of the Axis-2 scores (Figure 9). So it makes sense that once the Wakulla assemblages were removed from the analysis, the nonlinear variation that was captured on Axis 2 and 3 now appears on Axis 1 and 2 (Figure 8). The fact that the second CA, without the Wakulla assemblages, duplicates the results of the first CA for the non-Wakulla assemblages supports the reliability of the results.

The arch effect has caused considerable controversy among CA users. Some have seen it as a distortion and have developed an ad hoc procedure, detrended correspondence analysis or DCA, to get rid of it (Hill and Gausch 1980). But DCA introduces new problems, which are arguably worse than the arch (Jackson and Somers 1991). We view the arch as a relatively benign indicator that the underlying data do, in fact, contain battleship-shaped curves (Wartenberg et al. 1987). Thus the appearance of the arch in a CA points to a successful seriation. The quadratic structure in the plot of Axis 1 and 2 scores in Figure 8 and Axis 2 and 3 scores in Figure 9 is the shape one would expect from a good chronological seriation using CA.

To demonstrate that Axis 1 in the second CA (Figure 8) captures the passage of time, its scores were plotted against a handful of available radiocarbon dates. Figure 10 shows the 2-sigma calibrated date ranges for eleven radiocarbon dates associated with assemblages used in the CA represented in Figure 8 (see Table 5 for radiocarbon determinations). Two radiocarbon determinations (DIC-3268 and DIC-3269) from 9QU58 ($x^2 = 1.1$; df = 1) and three (UGA-1B, UGA-3B, and UGA-7B) from Mandeville (9CY1), Mound A, Level 1 ($x^2 = .1$; df = 2) were combined since their differences were not statistically significant.[6] When these date ranges are plotted against their assemblage CA Axis-1 scores, they line up fairly well, meaning that Axis-1 scores decrease as radiocarbon determinations increase. Only the average date for Mound A, Level 1 at Mandeville (9CY1-I) is out of place, appearing too late given its assemblage Axis-1 score.[7] The way assemblages clustered along Axis 1, 2, and 3 guided our grouping of assemblage counts. Figure 11 shows the frequency seriation that results from grouping the assemblages in this way. It is, in fact, a perfect seriation with no violations of the model. We can see here a punctuation between Kolomoki II and the Hare's Landing phases that we could also observe in Figure 7. This punctuation is most noticeable as a dramatic decrease in the relative abundance of Curvilinear Complicated Stamped. We also likely have a jump between Mandeville I and Halloca Creek phases, most noticeable as a sharp decline in Deptford-Related Check Stamped. These punctuations further indicate that either time is not evenly sampled across the assemblages or, alternatively, that change is not continuous.

Discussion of the Regional Analysis

The analysis described above has, on the one hand, specific implications for the way those of us working in the region have traditionally characterized the chronological situation and has, on the other hand, broader implications in terms of the methods used to illicit chronologies. First, the gap described by Knight and Mistovich (1984) between the latest assemblages at

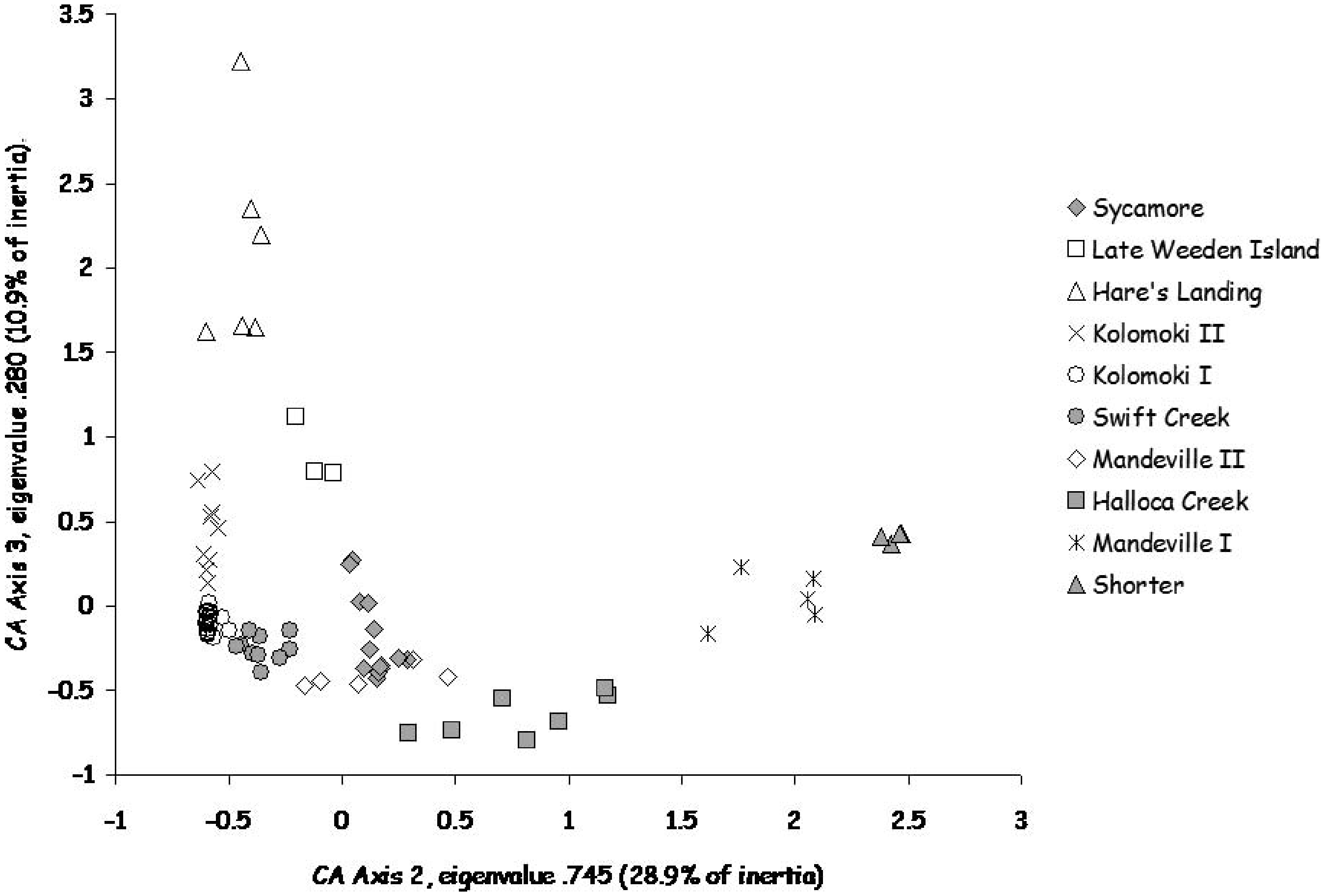


Figure 9. Scatter plot showing Deep South assemblage positions relative to CA Axis 2 and 3. Axis 2 sorts assemblages in terms how much Deptford-Related Check Stamped and Simple Stamped pottery each contains. Shorter phase assemblages, shown on the far right, are dominated by early check-stamped pottery.

Mandeville (9CY1) and the earliest assemblages at Kolomoki (9ER1) is not apparent in either the frequency-seriation diagrams or the CA plots. In short, assemblages from other sites, the most well known being Swift Creek (9BI3), now fill in the gap in ceramic assemblage composition that exists between Mandeville and Kolomoki (see note 3). However, other gaps were detected, such as the one between the Hare's Landing phase assemblages and the other Wakulla Check Stamped–bearing assemblages, but, importantly, these gaps were identified using CA rather than frequency seriation. The advantage CA has, in this case, over frequency seriation is in the way in which relative distances between assemblages are displayed in addition to relative positions among assemblages. This feature of CA allows for the observation of gaps, or segments in CA space within which no assemblages fall. A frequency seriation diagram provides only relative positions among assemblages. This is not to say that gaps are not detectible with frequency seriation only that gaps, even subtle gaps, when they exist are more readily apparent in a CA plot than they are likely to be in a frequency-seriation diagram.

The CA results confirm what the clean seriation solution suggests: there is no significant source of variation in type frequencies other than time. This is important. It means that when new assemblages, classified according to the scheme used here, are added to the seriation and the CA, we can expect them to fall into their correct temporal positions. An alternative procedure, and one currently in vogue, involves assigning new assemblages to phases. But this method potentially can yield far more ambiguous results, as is clear from a comparison of the regional sequence and the phase assignments, some of which are taken from competing schemes (Table 6). Though the terminology may differ somewhat, the earliest phase assignments are more or less consistent in terms of ceramic content and temporal equivalency. But reported phase assignments for the later assemblages, those labeled Kolomoki I and II based on CA groups, appear to be less consistent. Assemblages assigned to the CA-based group Kolomoki I, for example, have been classified by others as Late Swift Creek, Weeden Island, and even Santa Rosa–Swift Creek. These discrepancies may arise from idiosyncrasies in where one draws the line between the late Swift

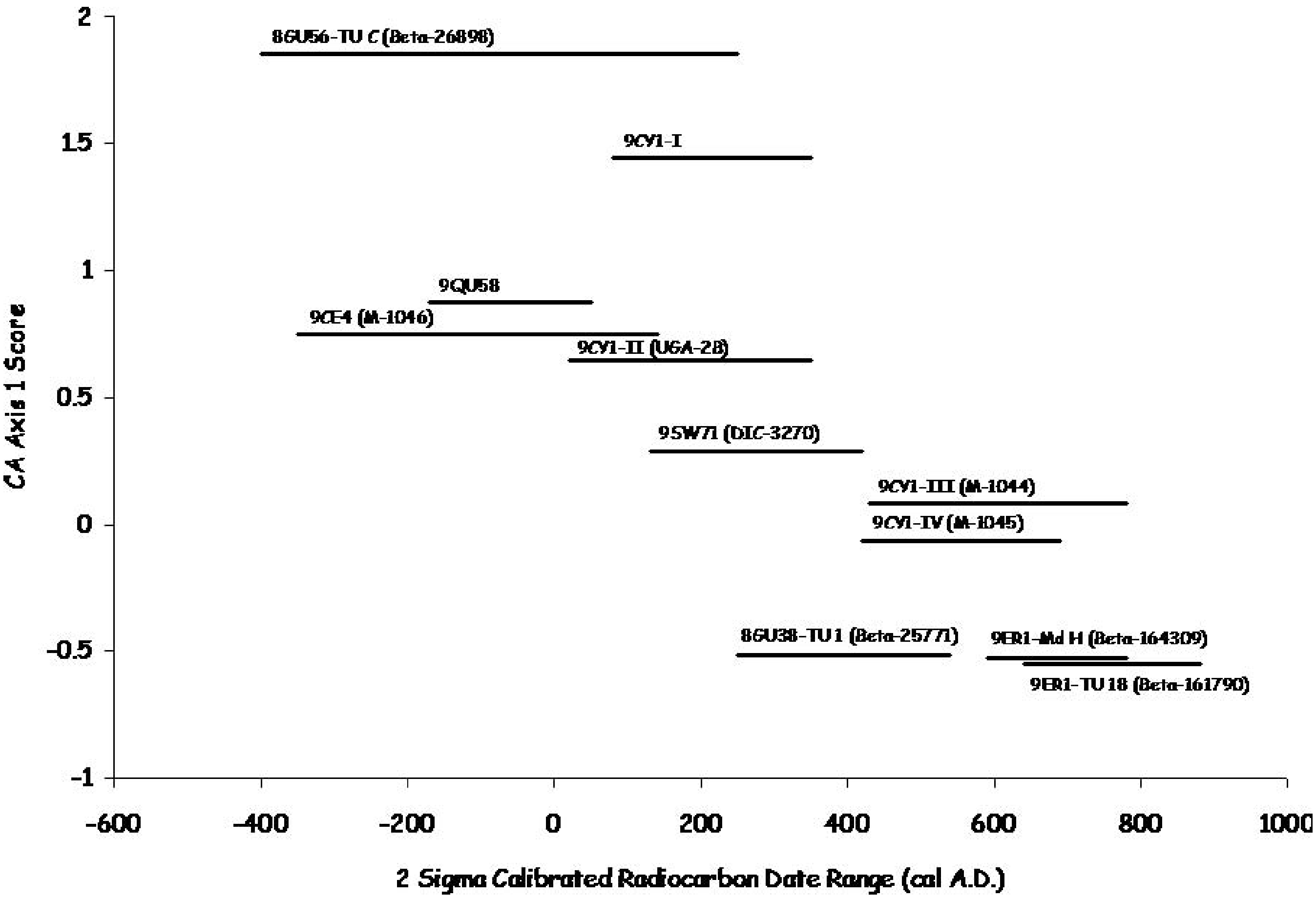


Figure 10. Calibrated radiocarbon dates for assemblages used in the correspondence analysis shown in Figure 9. See Table 5 for references.

Creek and early Weeden Island periods, specifically in terms of how much Weeden Island series pottery denotes the beginning of Weeden Island. With FS *and* CA, one need not draw any lines. In other words, using FS and CA in tandem, we have developed a robust chronology for a thousand years of prehistory. This regional scale, continuous chronology, we believe, is better a better yardstick against which other diachronic changes—say, increases in population size, which may betray other cultural forces at work—can be measured.

The Intrasite Analysis: Kolomoki

Our second case study focuses on spatial variation among assemblages from Kolomoki, a well-researched,

Table 5. Radiocarbon determinations and associated calibrated age ranges for Deep South assemblage contexts.

Site No.	Lab No.	RCY B.P.	Max. cal. age to Min. cal. age (2σ)	Context	Reference
9ER1	Beta-161790	1290 ± 60	A.D. 640–880	Test Unit 18, Feature 34	Pluckhahn 2002:27
9ER1	Beta-164309	1360 ± 50	A.D. 590–780	Mound H, Feature 2	Pluckhahn 2002:27
9ER1	Beta-121909	1660 ± 50	A.D. 250–540	Test Unit 3, a pit	Pluckhahn 2000:150
8GU38	Beta-25771	1650 ± 50	A.D. 250–300, A.D. 310–540	Test Unit 1, Feature 4	White 1992:24
9CY1	M-1045	1460 ± 150	A.D. 420–690	Md A, Layer IV	Kellar et al. 1961:81
9CY1	M-1044	1420 ± 150	A.D. 430–780	Md A, Layer III	Kellar et al. 1961:81
9SW71	DIC-3270	1740 ± 60	A.D. 130–420	Feature 1	Mistovich and Knight 1986:98
9CY1	UGA-2B	1840 ± 70	A.D. 20–350	Layer II	Smith 1975:175
9CE4	M-1046	2020 ± 150	350–310 B.C., 210 B.C.–A.D. 140	Pit 3	Kellar et al. 1961:81
9QU58	DIC-3268	2010 ± 50	170 B.C.–A.D. 90	Feature 1	Mistovich and Knight 1986:137
9QU58	DIC-3269	2090 ± 60	360–290 B.C., 240 B.C.–A.D. 60	Feature 1	Mistovich and Knight 1986:137
9CY1	UGA-7B	1810 ± 70	A.D. 60–390	Feature 3, Layer I, below 12″	Smith 1975:174
9CY1	UGA-1B	1800 ± 65	A.D. 70–390	Postmold, Layer I, below 12″	Smith 1975:174
9CY1	UGA-3B	1775 ± 120	50 B.C.–A.D. 550	Feature 1, Layer I, below 12″	Smith 1975:174
8GU56	Beta-26898	2010 ± 100	400 B.C.–A.D. 250	Test Unit C, Level 3	White 1994:198

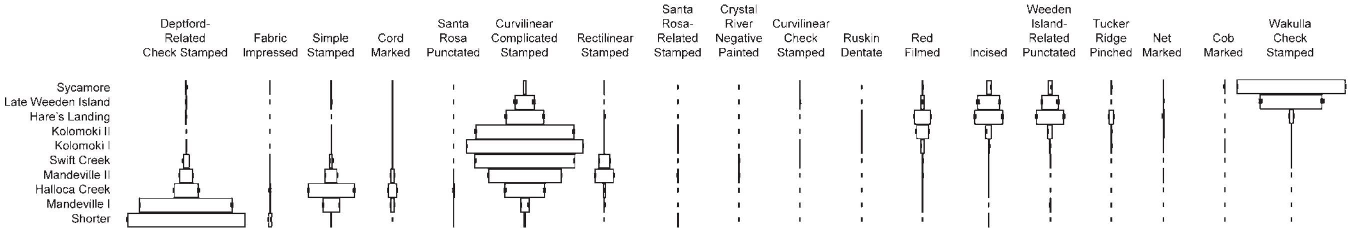


Figure 11. Grouped assemblages frequency-seriation diagram.

multimound site located in southwestern Georgia. It illustrates how CA can resolve type-frequency variation in a single data set with two underlying gradients, both of which simultaneously structure variation among assemblages in type frequencies.

Our work builds on Pluckhahn's recent chronology for Kolomoki, which he derived from a FS of newly excavated assemblages.[8] Type frequencies in Pluckhahn's seriation fit the FS model in a general way. However, they do not display the monotonic increase and decease required for a perfect fit. This leaves ambiguity about the precise order of the assemblages. Smith (2005) has recently proposed an alternative order. Although in large part the independent seriations were in agreement, some differences exist in the later half of the sequence. Specifically, Pluckhahn (2003:Table 2.1) assigned test units 1, 9, and 14 to the Kolomoki III phase and test units 7, 8, and 18 to the Kolomoki IV phase, whereas Smith (2005) placed the assemblages from test units 1 and 9 after (later than) test units 7 and 18.

Resolving the ambiguity depends on exploring the lack of fit to the FS model. On the one hand, lack of fit could simply be the outcome of sampling error or some other random process at work in the formation of the assemblages. On the other hand, it might be due to a second deterministic process operating simultaneously with the passage of time. If, in fact, there are two underlying gradients that determine type frequencies, then CA should uncover them.

Our Kolomoki data set consists of 11 assemblages from Pluckhan's test excavations and additional units from Sears's work at the site in the 1950s (Pluckhahn 2003:Table 5.2, Table 3.2; Sears 1956:34–39).[9] The inertia table indicates the data set is essentially two dimensional (Table 7). However, in this case there is no arch–the second axis scores are *not* a quadratic function of the first axis scores. That is because the temporal gradient being sampled at Kolomoki is not long enough to contain both the increase and decrease within one or more types that creates nonlinearity. However, the Axis-2 scores are significant and meaningful.

Figure 12 illustrates the CA of Kolomoki assemblages. Here, CA reveals an interesting pattern, one not detectable using FS. The earliest assemblages, those grouped on the left, are similar to one another, but as one follows Axis 1 from left to right the single, homogeneous tradition diverges. If Axis 1 does capture variation over time, then the split along Axis 2 signals an increase in ceramic differentiation late in Kolomoki's occupation and may relate to some otherwise nontemporal source. This general interpretation of the variation captured by Axis 2 is completely in line with the Pluckhahn's conclusion that ceramic-assemblage diversity increased in the latest phases of Kolomoki's occupation (Pluckhahn 2003:219). The split along Axis 2 documents the increased differentiation that Pluckhahn described for Kolomoki.

Can we develop a more specific interpretation for Axis 2? There is a spatial component, for example, to the structured variation among Kolomoki's ceramic assemblages. The branching along Axis 2 corresponds to a prominent spatial feature of the site, namely, the central plaza. In Figure 12, the solid symbols indicate assemblages from excavation units that are adjacent to or relatively near the central plaza. The open symbols represent assemblages farther removed from the site center. The units comprising the lower branch are adjacent to or near the central plaza, whereas the units comprising the upper branch are located in other areas of the site. This suggests spatial segregation of people or activities, or both, increased through time.

Figure 13 shows how the pottery types map on Axis 1 and Axis 2. Red Filmed, which includes Weeden Island Red and Weeden Island Zoned Red, and Tucker Ridge Pinched contribute to the split of the lower-branch assemblages, whereas the incised, punctated, and dentate types contribute to the upper-branch split. These types are the ones that structure the atemporal variation in this analysis. Given that the lower-branch assemblages are from excavations close to the plaza area, it is not surprising that the red-filmed types are prominent in the assemblages that make up the lower branch. To test the hypothesis that Axis 1 measures time, the three radiocarbon-date ranges were plotted against assemblage Axis-1 scores, where the radiocarbon sample and the ceramic assemblage used in the CA come from the same test unit (Figure 14). CA scores increase as date ranges increase. The relationship between CA scores and radiocarbon date ranges does lend support to the idea that Axis 1 captures variation among assemblages due to time's passage.

Table 6. Comparison of CA phase groups and reported phases for all assemblages.

Assemblage	CA-Based Phase	Reported Phase
8FR4-10-1	Sycamore	Weeden Island II
8GD13-Above Shell	Sycamore	Weeden Island
8FR4-10-3	Sycamore	Weeden Island II
8GD13-Shell	Sycamore	Weeden Island
8GD13-Shell Contemp	Sycamore	Weeden Island
8FR4-10-4	Sycamore	Weeden Island II
8FR4-10-5	Sycamore	Middle Period
9SE102	Sycamore	
8WA13	Sycamore	Weeden Island II
8FR4-9-1	Sycamore	Deptford
8BY24	Sycamore	Weeden Island II
8GD13-Below Shell	Sycamore	Weeden Island
8FR4-9-2	Sycamore	Deptford
1CC53	Sycamore	Weeden Island II
8FR4-10-6	Late Weeden Island	Middle Period
8JA19	Late Weeden Island	Weeden Island II
8JA5	Late Weeden Island	
8BY9	Hare's Landing	
9SE33-Mid E	Hare's Landing	Cummings
8WA8-PI-2	Hare's Landing	
8FR2-PIII-2	Hare's Landing	Weeden Island I
8FR2-PIII-3	Hare's Landing	Weeden Island I
8BY73-0-20 cm	Hare's Landing	Weeden Island II
9ER1-TU9	Kolomoki II	Kolomoki III
9ER1-TU18	Kolomoki II	Kolomoki IV
9SE33-Mid J	Kolomoki II	Hare's Landing
8BY73-20-40 cm	Kolomoki II	Weeden Island I
9ER1-TU7	Kolomoki II	Kolomoki IV
9ER1-Md. A	Kolomoki II	Kolomoki II
9ER1-TU14	Kolomoki II	Kolomoki III
9ER1-U2-SSB	Kolomoki II	
9ER1-Md. H	Kolomoki II	Kolomoki IV
9ER1-U4-7-12	Kolomoki I	
9ER1-Md. C	Kolomoki I	Kolomoki III
9ER1-U4-4-6	Kolomoki I	
9SE33-Mid. G	Kolomoki I	Weeden Island
8WA8-PI-6	Kolomoki I	
9CE42	Kolomoki I	Quartermaster
8BY73-40-80 cm	Kolomoki I	Late Swift Creek
9ER1-TU17	Kolomoki I	
9ER1-TU15	Kolomoki I	Kolomoki II
9ER1-TU10	Kolomoki I	Kolomoki II
9SE14-C	Kolomoki I	Weeden Island
9ER1-U4-2-3	Kolomoki I	
8JA63-0-6	Kolomoki I	Kolomoki
8JA63-6-12	Kolomoki I	Kolomoki
9ER1-TU6	Kolomoki I	Kolomoki I
8WA8-PI-7	Kolomoki I	
8JA63-12-18	Kolomoki I	Kolomoki
8GU38	Kolomoki I	Late Swift Creek
8FR2-PIII-5	Kolomoki I	Santa Rosa- Swift Creek
8BY74	Kolomoki I	Santa Rosa- Swift Creek
8FR2-PIII-6	Kolomoki I	Santa Rosa- Swift Creek
9BI3-4	Swift Creek	Early Swift Creek
8FR2-II-1	Swift Creek	Santa Rosa- Swift Creek
8FR2-I-1	Swift Creek	
8FR2-II-2	Swift Creek	Santa Rosa- Swift Creek
9BI3-3	Swift Creek	Early Swift Creek
9CE16	Swift Creek	The Gap
9BI3-2	Swift Creek	Early Swift Creek
9BI3-1	Swift Creek	Early Swift Creek
9BI3-Pre Md	Swift Creek	Early Swift Creek
8LE148 WB.Str 2 Pits	Swift Creek	
9CY1-IV-0-6	Mandeville II	Mandeville
9CY1-IV-6-24	Mandeville II	Mandeville
9CY1-III-0-12	Mandeville II	Mandeville
9SW71	Mandeville II	The Gap
9CY1-III-12-27	Mandeville II	Mandeville
9CE4-0-6	Halloca Creek	Mandeville
9CE4-6-12	Halloca Creek	Mandeville
9CY1-II	Halloca Creek	Mandeville
9CE4-12-18	Halloca Creek	Mandeville
9QU58	Halloca Creek	Mandeville
9CY1-I-0-6	Halloca Creek	Mandeville
9CY1-I-6-12	Halloca Creek	Mandeville
9CY1-I-12-	Mandeville I	Mandeville
8FR4-9-3	Mandeville I	Deptford
8GU56-TUA/B	Mandeville I	Deptford
8GU56-TUC/D	Mandeville I	Deptford
1BR15-X1-Tertiary	Mandeville I	
8GU60-TUBL1-3	Shorter	
8GU60-TUBL4-8	Shorter	
1BR15-X1-Primary	Shorter	Shorter
1BR15-X1-Pre Md	Shorter	Shorter

The frequency-seriation diagram shown in Figure 15 contains all the assemblages from the left-hand side of the Kolomoki CA, or those assemblages with similar ceramic inventories, and the assemblages that comprise the upper branch split, or those sorted along Axis 2 by the incised, punctated, and dentate types. The frequency seriation shown in Figure 16 also contains all the assemblages from the left-hand side of the Kolomoki CA but includes the lower-branch assemblages, or those sorted by the Red Filmed and Tucker Ridge Pinched types. In comparing the two figures, one can see how the relative frequencies vary between the upper and lower branch assemblages, especially in terms of red filmed and Tucker Ridge Pinched. By splitting the frequency seriation into two groups, based on the upper and lower branches of the CA, we arrive at not one but two perfectly good seriations.

Discussion of the Intrasite Analysis

In terms of the Kolomoki data set, CA proves to be a more fruitful method for deriving a temporal order among assemblages and, at the same time, sorts out another meaningful dimension of variation, likely of a social or at least atemporal nature. CA works, in this case, because it assumes that multiple underlying dimensions of variation structure the data. Frequency seriation, on the other hand, assumes only one underlying dimension of variation. Hence, frequency-seriation diagrams constructed from pottery types that contain more than one underlying dimension may appear messier or noisier than they otherwise would. It is this ''noise'' in the frequency seriation of all Kolomoki assemblages, which the senior author initially thought might be sampling error, that contributed to

Table 7. Eigenvalues associated with the successive axes estimated by a CA of the Kolomoki assemblages.

Axis	Eigenvalue	Percentage Inertia
1	.13450	62.79
2	.03453	16.12
3	.01911	8.92
4	.01690	7.89
5	.00510	2.38
6	.00236	1.10
7	.00118	.55
8	.00051	.24

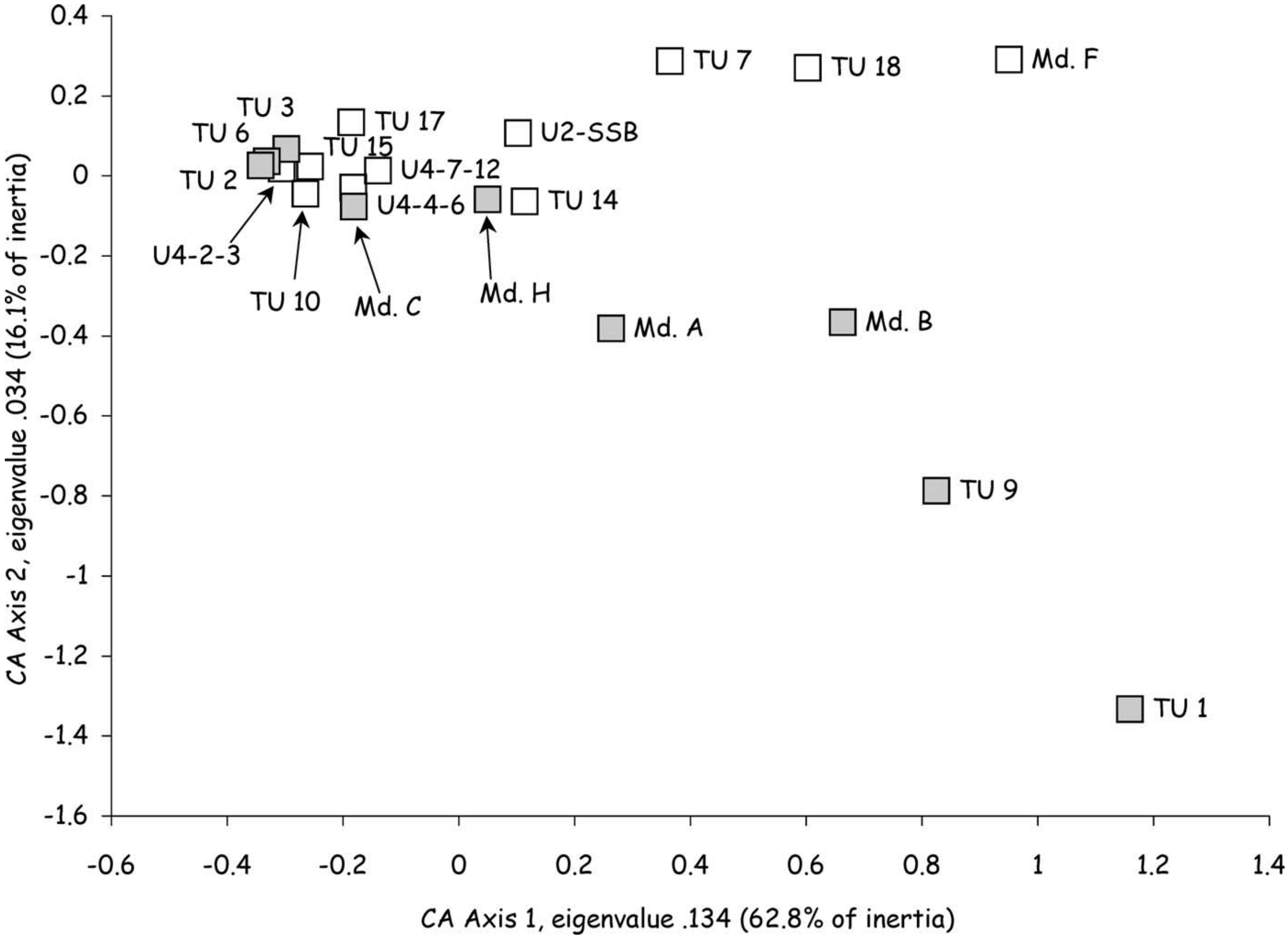


Figure 12. Correspondence-analysis scatter plot of the Kolomoki assemblages. The solid symbols indicate an assemblage's relatively close proximity to the central plaza at Kolomoki. The open symbols mark assemblages farther removed from the plaza area. TU = Pluckhahn test unit, U = Sears excavation unit, Md. = mound assemblage.

the difficulty of independently replicating a single assemblage order using frequency seriation.

The sacred-secular dichotomy, as formalized by Sears (1953b:Figure 83; 1956:22–26, 75, 99; 1962:9; 1973; 1992:Figure 1), is relevant given the pattern just described for Kolomoki, one which shows a divergence through time among assemblage composition that seems to map spatially against plaza, or site-center, and off-plaza assemblages. At Kolomoki, Sears (1956:99, 1973:34) observed several ceramic-assemblage differences between the burial-mound deposits (*sacred* wares) and the village-midden deposits (*utilitarian* wares). Mortuary or sacred ware include effigy and ''compound'' forms, combined decorative styles, and vessels with precut kill holes that occurred only in mound contexts.

Based on work at McKeithen–a multimound site in northern Florida that shares similar Weeden Island series ceramics with Kolomoki–Sears's sacred-secular dichotomy was expanded into a tripartite division among Weeden Island ceramic assemblages from mound-village contexts (Milanich et al. 1997; Rice and Cordell 1985). This new classificatory scheme reinforced a distinction between *cult* and *elite* wares within Sears's sacred or Weeden Island class, a division based on distributional differences among some vessel forms. Put simply, mortuary or cult vessels were defined as exclusively effigy forms, which happened to be found only in mound context, whereas prestige or elite wares included some of the more elaborately decorated types of incised, punctated, and painted pottery whose forms include plates and incurving bowls, and, though found in midden contexts, were more common in mounds at McKeithen.

Unfortunately, the classification scheme used here does not accommodate ceramic variations in vessel form, which likely cross cut the decorative types but also might be correlated with decoration. However, the Kolomoki analysis described above perhaps can contribute something to the interpretation of functional or social distinctions among certain Weeden Island pottery types despite the lack of control over vessel form. The Kolomoki CA sorted assemblages with proportionately more red-filmed pottery, which hap-

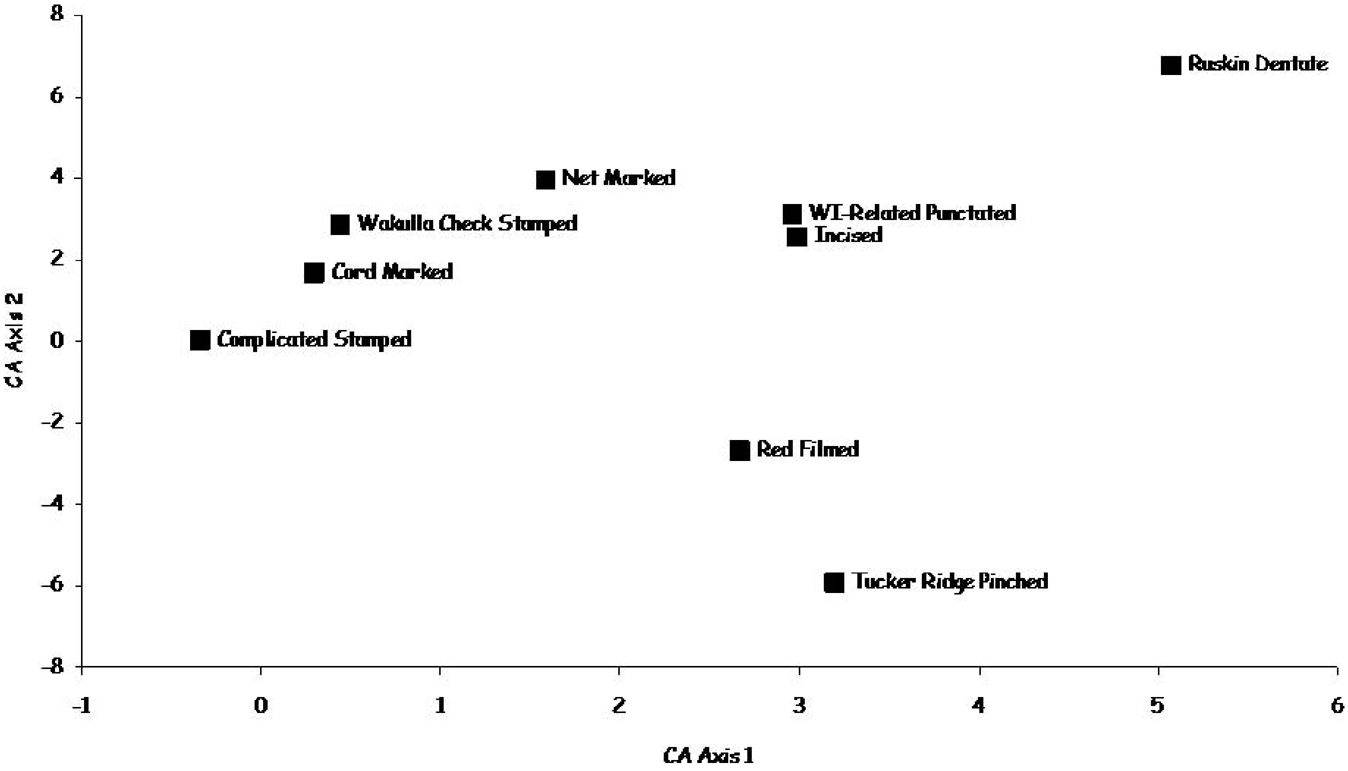


Figure 13. CA scatter plot for types in the Kolomoki assemblages.

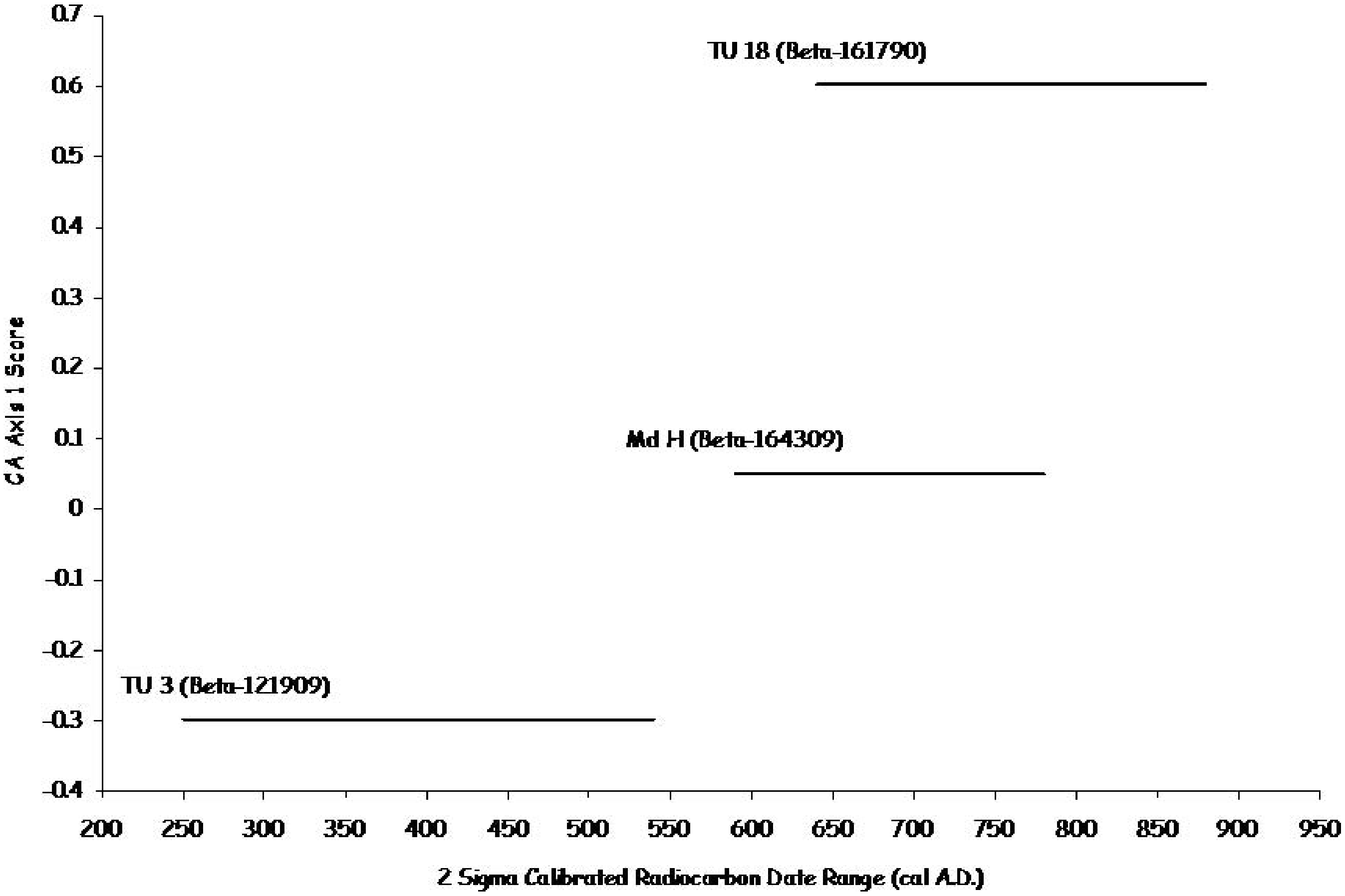


Figure 14. Calibrated radiocarbon dates for assemblages used in the Kolomoki analysis. See Table 5 for references.

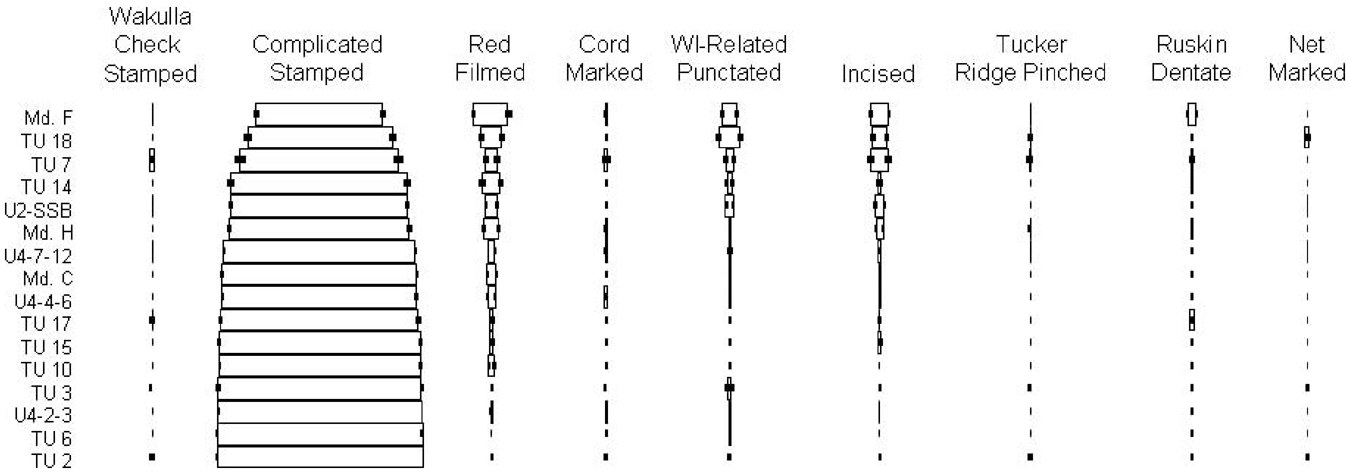


Figure 15. Frequency-seriation diagram of the upper-branch assemblages from the Kolomoki correspondence analysis.

pen to be located near the central plaza, from assemblages with proportionately more incised and punctated pottery, which were not adjacent to the plaza area. Do these CA results indicate another division, in this case *within* the elite wares, between Incised and Punctated, on the one hand, and Red Filmed, on the other hand?[10] We think so. Further, this supposition is not necessarily at odds with the mound-plaza/village distinctions at McKeithen either, depending on how one looks at those data. At McKeithen, red-filmed pottery dominates mound assemblages (Milanich et al. 1997:Table 6.4), being over half of the decorated sherds in mound contexts. Weeden Island Punctated, considered an elite type, does not occur in the mound assemblages (Milanich et al. 1997:127) and is outranked only by Weeden Island Incised, also considered an elite type, in the midden assemblages when a within-elite-types comparison is made (Milanich et al. 1997:Table 6.4). That red-filmed, incised, and punctated wares are not uniformly distributed across either site suggests these wares were not equally consumed by all members of the two societies, a notion championed by Sears and refined by Milanich et al. To this we add our observation that red-filmed types of pottery out rank the other elite wares in terms of deposition and use near mound/plaza space at Kolomoki and likely McKeithen, too.

Final Thoughts

The regional-scale analysis demonstrates that SCCS, defined here to include all curvilinear complicated stamped pottery, is a historically valid type (contra Sears 1992:66) and, at the same time, causes one to question the utility of some other types currently in use. The regional-scale FS provides an astonishingly detailed pictured of ceramic-frequency change, while the regional-scale CA reveals gaps in the sequence that may be caused by inadequate sampling of the area, periods of rapid change in decorative modes, or brief periods of area abandonment. One area requiring further research relates to a better evaluation of small

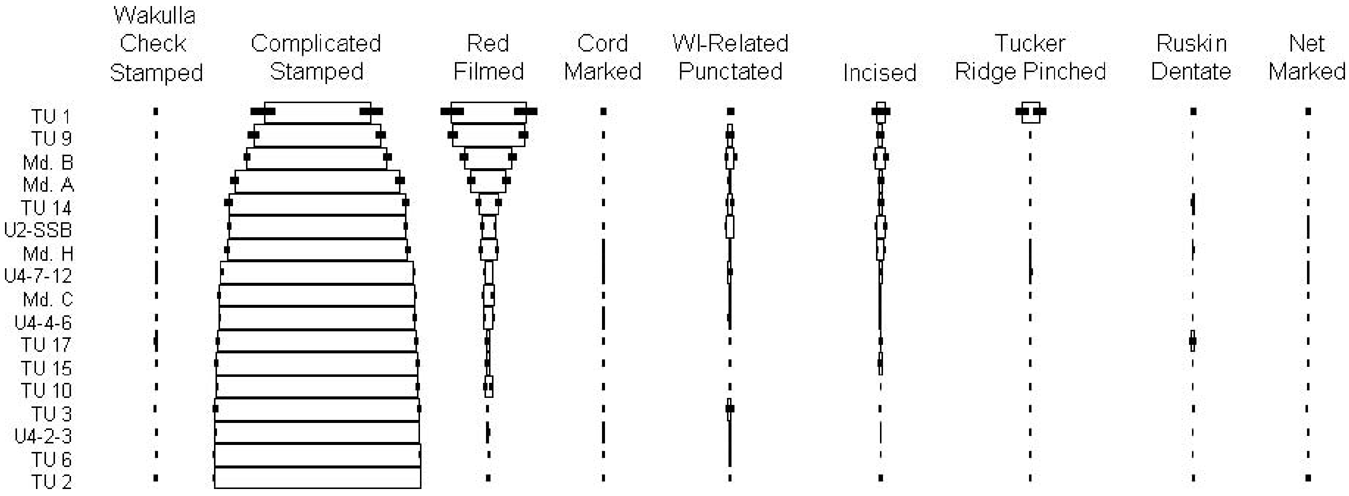


Figure 16. Frequency-seriation diagram of the lower-branch assemblages from the Kolomoki correspondence analysis.

samples. Perhaps smaller sites, those dropped from the analysis because their sample sizes did not reach the arbitrary minimum, fall within the gaps identified through CA. If so, this might implicate fluctuations in population aggregation and density over time. We plan to explore these possibilities in future work using Bayesian methods to mitigate the effects of sampling error in small samples.

At the intrasite scale, the analysis of the Kolomoki assemblages demonstrates that a spatial segregation exists, which appears to make more sense when framed in terms of near-plaza and off-plaza space rather than in terms of mound and nonmound contexts. Put differently, because assemblages comprising the lower branch in the Kolomoki CA are from both mound and nonmound contexts but share a similar spatial relationship to the central plaza.

Finally, we hope this study shows that both frequency seriation and CA are strong analytical tools useful for exploring type-frequency variability at intrasite, local, and regional scales. While much of the variability can be harnessed, using either method, to construct chronologies, the strength of frequency seriation lies principally in the way in which it allows the analyst to (1) evaluate the historical utility of types, that is, whether or not frequency distributions within a type fit the battleship-shaped curve model, and (2) visually assess the degree to which relative frequencies vary across assemblages. CA, on the other hand, allows the analyst to (1) identify gaps in a sequence, (2) tease out time from other sources of variation, and (3) detect divergence within a single tradition. Given these strengths, it should be clear that we are not arguing for the superiority of one method over the other. Rather, we believe the interpretive payoffs are greatest when both methods are used in tandem.

Taken together, frequency seriation and CA along with radiocarbon dating allow one to construct a surprisingly complete picture of artifact change. In this paper, we characterized variation in the relative frequencies of pottery types, defined by decoration, at two scales for the coastal region centered on the Lower Chattahoochee and Apalachicola River valleys during the Middle and Late Woodland periods. We see that the forces that drive change at the regional scale are not necessarily the only forces driving change at the local scale. While regional-scale variation seems most attributable to time, intrasite variation is attributable to time and perhaps some other synchronic, or social, gradient, likely differences in social status.

Notes

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[1] This study comprises part of the senior author's in-progress dissertation at the University of Missouri at Columbia (see also Smith 2002, 2005). The data sets are available at http://people.virginia.edu/~fn9r/data/SmithandNeiman2007.html.

[2] One assemblage, 8WA8-PI-5, was removed from the data set after the initial FS. The sample of 87 decorated sherds, from an intermediate level in a stratigraphic excavation, was only slightly above the sample-size cutoff, and FS positioned it well below the two levels stratigraphically beneath it. One assemblage, 8GU56-TUC/D, was included to gain a radiocarbon date for the early end of the sequence even though the sample size was beneath the arbitrary cutoff by six sherds.

[3] These data directly contradict Sears's observations regarding the archaeological deposits at Tucker (9FR4), where he saw an overlap in Deptford Check Stamped and Wakulla Check Stamped (Sears 1963, 1966:6, 1973). If the occupation at Tucker was not a continuous one, but was interpreted nonetheless as an uninterrupted sequence, then it would appear upon inspection of the percentage distributions of ceramic types, represented either in stratigraphic units or in a frequency-seriation diagram, that check stamping was continuously distributed. Given that a number of other sites (e.g., 8BY74, 8BY73, 8WA8) on the northwest coast of Florida occupy the sequence between the end of Deptford Check Stamped and the beginning of Wakulla Check Stamped, we suspect that the sequence at Tucker, in fact, may be missing more time than previously has been acknowledged. The less likely alternative is that no time is missing from the sequence at Tucker, meaning that the folks at Tucker were doing something completely different during this time than the folks at other sites in the area.

[4] Kelly and Smith (1975:131) arrive at the same conclusion regarding the chronological position of Swift Creek between Mandeville and Kolomoki, and, in a later publication, Smith (1998:118) suggested that Mandeville is ''somewhat earlier than the Swift Creek site[,]'' where the generally accepted terminal date for Mandeville is A.D. 300 (Knight and Mistovich 1984). Price (2003) also advocates this interpretation based on a recent study of the lithic assemblages, proposing a date of A.D. 350–400 for Swift Creek rather than the typically cited date of A.D. 500–750. According to Stephenson et al. (2002:342; see also Snow and Stephenson 1998:108), assemblages from the Hartford mound (9PU1),

located in south-central Georgia on the middle Ocmulgee River, also fill the gap between the latest occupation at Mandeville and the earliest occupation at Kolomoki. Their conclusion is based, in part, on Swift Creek paddle-design matches between the Hartford mound and Mound A at Swift Creek (9BI3).

[5] All CA analyses were carried out in SAS v.9.1, using the PROC CORRESP command and the PROFILE = ROW option. We also have found a readily available and free Microsoft Excel© add-in to be useful for performing CA. The latter, called BIPLOT, is available at http://www.stat.vt.edu/facstaff/epsmith.html. See Lipkovich and Smith (2002), authors of the Visual Basic code, for instructions on using the BIPLOT macro.

[6] Calibrations for radiocarbon determinations used in Figures 10 and 14 were calculated using OxCal v.3.10 (Bronk Ramsey 1995, 2001; atmospheric data from Reimer et al. 2004) with the following analysis options selected: Cubic Interpolation, Use B.C./A.D. (not B.P.), Uniform Prior Span, Probability Method, and Round off Ranges. Standard deviations for the three University of Michigan radiocarbon determinations listed in Table 5 were halved given that early University of Michigan radiocarbon dates were routinely published with doubled standard deviations (Crane and Griffin 1958).

[7] We realize that the event being radiocarbon dated is not equivalent to the time-averaged events being chronologically ordered using CA or frequency seriation. The fact that they line up fairly well is compelling evidence, nevertheless, that the radiocarbon-dated event is contained within the time-averaged assemblage.

[8] Pluckhahn (2002, 2003) established a new four-phase chronology for Kolomoki (9ER1), which he labeled Kolomoki I, II, III, and IV, based initially on the ordering of test units using the relative frequencies of pottery types among those units. Pluckhahn used these phases as a chronological framework for discussing variation in the use of space, including episodes of mound building, at the site.

[9] The typology used in the Kolomoki analysis mirrors the one used in the regional-scale analysis but with a few exceptions. In the Kolomoki analysis, Complicated Stamped includes one sherd with a combination of curvilinear and check-stamped elements in addition to those considered to be Curvilinear Complicated Stamped (see Table 1 for type names). An additional sherd, classified as Alligator Bayou Stamped, was excluded from the analysis as were six sherds classified as Napier/St. Andrews Complicated Stamped.

[10] These results seem to hold whether all incised and punctuated types are lumped into gross decorative categories or not. A CA performed using only Pluckhahn's test-pit data (those units he used to construct phases) and the more specific decorative types still sorted assemblages along Axis 2 primarily by Weeden Island Red and Tucker Ridge Pinched.

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