Determining Provenance of Shell-Tempered Pottery from the Central Plains Using Petrography and Oxidation Analysis

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REPORTS

DETERMINING PROVENANCE OF SHELL-TEMPERED POTTERY FROM THE CENTRAL PLAINS USING PETROGRAPHY AND OXIDATION ANALYSIS

Donna C. Roper, Richard L. Josephs, and Margaret E. Beck

Late prehistoric sites on the Central Plains contain both grit/grog- (mineral-) tempered pottery and shell-tempered pottery. This appearance of shell-tempered pottery around cal A.D. 1000 has traditionally been explained as a colonization from the Mississippi River valley with further dispersal via trade. As a result, very little is known about the role of this material in the region. We report the results of a provenance analysis of shell-tempered pottery from seven sites extending from the Missouri River valley to north-central Kansas. We use petrography and oxidation analysis to compare the shell-tempered pottery across these localities and the shell-tempered to the mineral-tempered pottery from each locality, and we compare mineral inclusions and clay characteristics in all pottery with published geological and pedological information for each locality. The results demonstrate that shell-tempered pottery was locally produced throughout at least a portion of the Central Plains. Differences in firing technology are apparent across the study area and may play a role in the distribution of shell-tempered pottery. Two other results are the identification of composite temper in a notable proportion of the sherds studied, and indications of from where on the landscape Central Plains potters were procuring their raw materials.

Sitos prehistóricos tardíos de los Llanos Centrales contienen cerámica templada por minerales ("grit/grog") y también cerámica templada con conchas de aqua dulce. La aparición de cerámica templada con conchas alrededor del año 1000 d.C. se ha explicado tradicionalmente en términos histórico-culturales. Por consiguiente, no se sabe mucho del papel de estos materiales en la región. Reportamos los resultados de un análisis de cerámica templada con conchas encontrada en siete sitios, desde el valle del Río Misuri hasta la región norcéntrica del estado de Kansas. Hacemos el análisis petrográfico y el de oxidación para comparar la cerámica templada con conchas con la templada por minerales en cada uno de los sitios, y comparamos las inclusiones minerales y las características de la arcilla de toda la cerámica con la información geológica y pedológica que se ha publicado para cada sitio. Los resultados demuestran que la cerámica templada con conchas se produjo localmente por lo menos en una parte de los Llanos Centrales. Se notan diferencias en la tecnología de cocer la cerámica a través del área estudiada y es posible que tengan un papel en la distribución de la cerámica templada con conchas otros dos resultados son la identificación del temple compuesto en una proporción significativa de los fragmentos estudiados, y también indicaciones de dónde en los Llanos Centrales los alfareros encontraron la materia prima para su trabajo.

Central Plains tradition (ca. cal A.D. 1000–1300; Roper 1995) sites contain two pottery wares. One of them is tempered with grit, grog, sand, or a composite of these aplastics. It is ubiquitous in assemblages from this period and is diagnostic of the Central Plains tradition as a whole (Lehmer 1954:146) as well as of the phases that compose it (e.g., Wedel 1959). The second ware is shell-tempered. It has a more restricted distribution on the Central Plains, appearing primarily in the southeastern part of the Central Plains cultural subarea (*sensu* Lehmer 1971:29, slightly modified from Wedel 1961:23). It is predominant in assemblages from the Steed-Kisker phase sites in the greater Kansas City area of far western Missouri and extreme eastern Kansas, but also occurs in parts of Kansas and Nebraska to the west and north of the Steed-Kisker phase sites. The Central

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Plains material represents the westernmost occurrence of shell-tempered pottery in eastern North America.

Mid-twentieth-century efforts to understand the appearance and distribution of shell-tempered pottery in eastern North America often involved constructing culture-history narratives that posited expansions and colonizations by what came to be called Middle Mississippi or Mississippian people (e.g., Griffin 1946:89–91; Phillips et al. 1951:109; Strong 1935; Wedel 1943; see also Smith 1984 or Griffin 1985 for reviews of these postulated explanatory models). By the last two decades of the twentieth century and continuing to the present, although issues of timing of the appearance of shell-tempered pottery and the spatial patterning of this material's appearance remain active research topics (e.g., Boszhardt 2008; Cook and Fargher 2008; Feathers 2009; Herbert 2008; Lafferty 2008; Peacock and Feathers 2009; Pollack et al. 2008; Rafferty and Peacock 2008; Sabo and Hill 2008; Weinstein and Dumas 2008), considerable attention also is being directed toward establishing the provenance of shell-tempered pottery using compositional analysis (Galaty 2008; Porter 1984; Riley et al. 1994; Steponaitis et al. 1996; Stoltman 1991; Stoltman et al. 2008; Wells and Weinstein 2007:56–58; see also Neff 2008 for a review) and evaluating performance characteristics of this pottery to explain why it became the predominant ware in many areas where it was used (Bronitsky and Hamer 1986; Dunnell and Feathers 1991; Feathers 1989, 1990, 2006; Herbert 2008; O'Brien et al. 1994; Steponaitis 1983; Steponaitis et al. 1996). To a large extent, however, Central Plains archaeologists working with the late prehistoric horizon have continued to rely on culture-historical explanations for the presence of shell-tempered pottery in this subarea of the Plains and have failed to participate in the broader studies by actually establishing provenance or seriously addressing other questions concerning this material. As a consequence, the role of shell-tempered pottery on the Central Plains remains elusive. Yet, lying at the western edge of this ware's distribution as they do, the Central Plains form a natural laboratory to study some of the factors limiting the continent-wide distribution of this material. Thus, the failure of Central Plains archaeologists to study provenance and performance issues means that the region's potential contribution to the questions surrounding shell-tempered pottery in eastern North America remains unrealized.

Seeking to reverse this trend and recognizing that one of the first questions that must be resolved is whether shell-tempered pottery was locally produced or whether it was indeed physically brought from an external source to sites in the region, our objective in the research reported here is to determine the provenance of shell-tempered pottery in selected Central Plains tradition assemblages. For this, we use petrography and oxidation analysis to examine and compare the composition of both mineral-tempered and shell-tempered pottery from seven sites along a transect extending from the western edge of Missouri, where shell-tempered pottery is predominant, across northeast and north-central Kansas to one of the westernmost shell-tempered-pottery-bearing localities in all of North America. The analysis uses three independent lines of evidence, first comparing the composition of the shell-tempered pottery from the seven localities on the transect, then comparing the composition of the shell-tempered pottery to the locally produced mineral-tempered (grit, grog, or sand) pottery, and finally comparing mineral inclusions and clay characteristics to the local geological and pedological resources. The results reveal that both the mineral-tempered and the shell-tempered pottery were locally produced throughout the Central Plains. They also suggest firing as a factor that may be implicated in limiting the distribution of shell-tempered pottery on the Central Plains and perhaps in eastern North America in general.

Clay procurement and pottery production is very poorly studied on the Central Plains. A second purpose of this study, therefore, is to broadly characterize the clays used in each locality. This should lead to knowledgeable sampling of possible source clays for use in future compositional studies and studies designed to evaluate performance characteristics of local pottery.

Shell-Tempered Pottery on the Central Plains

Figure 1 portrays the distribution of shell-tempered pottery on the Central Plains using data culled from numerous published, grey literature, and manu-

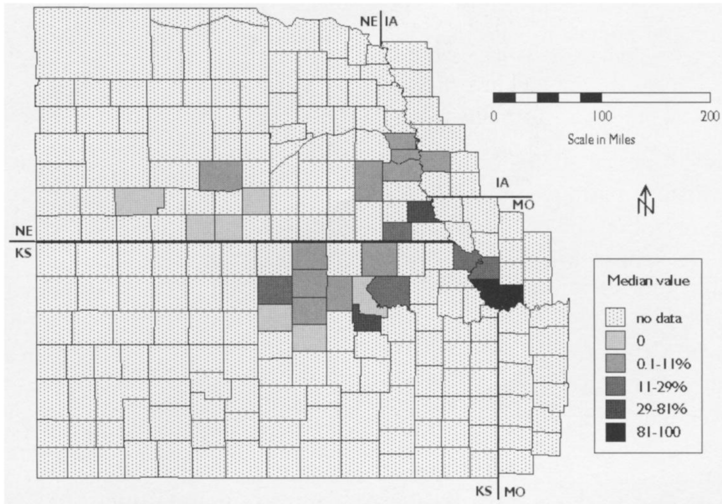

Figure 1. The Distribution of Shell-Tempered Pottery in Central Plains Tradition Sites. The map is based on data from 97 sites, usually individual excavated lodges. The mapped value is the median proportion for sites in the county. See Roper (2009) for further details.

script site reports, and some actual collection counts (see Roper 2009 for further details and all references). The southeasternmost sites are the Steed-Kisker phase sites in Platte and Clay counties, Missouri. Here, shell-tempered pottery is by far the predominant ware, often accounting for more than 90 percent of the sherds in an assemblage. Nowhere else on the Central Plains is shell-tempered pottery this dominant. It does, however, appear in reasonably high proportion in sites associated with the larger river valleys elsewhere on the southeastern part of the Central Plains. These include sites in the Missouri River valley to around the latitude of the Iowa/Missouri state line and its western extension across southeast Nebraska, or the lower reaches of major tributaries of this segment of the river. To the west, shell-tempered pottery may appear in high proportion in sites within or near the Kansas River valley and in the valleys of the lower reaches of its major tributaries, particularly the Blue and Republican rivers. Proportions of shell-tempered pottery are considerably lower over a greater distance north along the Missouri River valley and through the smaller valleys of the lower Kansas River basin. Central Plains tradition sites are well-represented over a large area of Nebraska and the northern half of Kansas, but shell-tempered pottery either is absent or present in only minor proportion in assemblages from west of central Kansas and away from the Missouri River in Nebraska.

Chronology must have a high priority for continuing research. At present, we do not have sufficient or sufficiently reliable chronological data to evaluate whether or not temporal trends are a factor in the abundance of shell-tempered pottery or to more specifically determine when the production of this material was initiated on any part of the Central Plains. The existing chronology, however, would suggest that the earliest sites with shell-tempered pottery are the earliest Steed-Kisker phase sites. These sites probably date to around cal A.D. 1000 or at least sometime in the eleventh century (Roper 1995, drawing on the full set of dates available at the time; see also Hoard and Banks 2006:299–302, 325–326 for a list of relevant radiocarbon dates). The initial use of shell-tempered pottery on the Central Plains thus was coeval with this material's greatly increased use in the Emergent Mississippian period of the American Bottom (Kelly 1990:136). The technology of shell-tempered pottery production probably appeared elsewhere on the Central Plains in a time-transgressive fashion as the lifeway epitomized as the Central Plains tradition expanded throughout the region over the next century or so (Roper 1995, 2007).

The highly uneven spatial distribution of shell-tempered pottery is implicated in the development of the cultural taxonomy for the eastern Central Plains. Early in the twentieth century, Frederick

Sterns (1915:245) noticed shell-tempered pottery in some eastern Nebraska sites of what he called the "culture of the rectangular earth lodges." Shortly thereafter, Robert F. Gilder, who had investigated sites in the greater Omaha area, informally named this the Nebraska culture and mentioned the presence of some pottery that was tempered with shell (Gilder 1926:32). W.D. Strong, who formally defined Gilder's Nebraska culture as the Nebraska aspect (1935:2), also recognized shell-tempered pottery in some of the sites assigned to this taxon, although he was somewhat unsure what to make of it. On the premise that this material represented, as he put it, "northern extensions of common Middle Mississippi ceramic types," he proposed that either the people of the Nebraska aspect engaged in direct trade with people to the south and east (not specifying where to the south and east) or that the sites with the shell-tempered pottery might represent outposts (his term) of these same people (Strong 1935:256). He favored the latter explanation, but did not taxonomically separate the sites with shell-tempered pottery from those without it. Hill and Cooper (1937:323–324), reporting the Majors site (25NH2) in Nemaha County, Nebraska, where shell-tempered pottery accounted for 80.4 percent of the sherds in the assemblage, also did not separate this site and others with high proportions of shell-tempered pottery from other Nebraska aspect sites. To the contrary, they thought that the cultural complex represented at Majors did not differ appreciably from that of other components of the Nebraska aspect and that the Middle Mississippi elements of the assemblage (i.e., the shell-tempered pottery for the most part) were introduced and did not represent what Strong had called outposts of another society.

It was Waldo Wedel who formally set apart sites whose assemblages are dominated by shell-tempered pottery and ensconced the difference in the regional cultural taxonomy. Reporting his 1938 excavation at the Steed-Kisker site (23PL13) in the Missouri River valley in Platte County, Missouri, Wedel aligned it not with the nearby Nebraska aspect, but with the Middle Mississippi phase (in the Midwestern Taxonomic Method sense of the term), largely on the basis of the predominance of shell-tempered pottery at Steed-Kisker. He went on to postulate Steed-Kisker as a "thrust up the Missouri [River] from the readily accessible Cahokia mound region" (Wedel 1943:221) and later referred to Steed-Kisker and similar sites of what came to be called the Steed-Kisker phase (Chapman 1980:156–161) as "settlements of ... Middle Mississippi people" (Wedel 1961:97) and their cultural complex as a "watered-down version of Middle Mississippi culture" (Wedel 2001:181).

Wedel's interpretation of the origin of Steed-Kisker culture for the first time actually engaged the question of shell-tempered pottery on the edge of the Central Plains and proposed a mechanism for its arrival in this region. Many have since accepted and elaborated on his proposal. Thus, in recent decades, the Steed-Kisker phase has been asserted to be a Mississippian culture and an entirely separate cultural entity from the Central Plains tradition (O'Brien 1988:28), and sites with both grit-tempered and shell-tempered pottery have been considered multicomponent sites (e.g., Feagins 1988; Nickels 1971; Shippee 1972:14) or declared to represent a "frontier" between members of these separate cultural entities (Logan 1988). In this same vein, shell-tempered pottery beyond the greater Kansas City area has been thought to represent either a movement of people from the Steed-Kisker sites (Sperry 1965) or tradeware (Scott 1995; Wood 1962:34). Although this view is not universally held (e.g., Henning 1967, 2007; Johnson 1992:134; Roper 2006, 2007), it continues to dominate discourse and direct research agendas toward assessing the nature of the relations between Steed-Kisker Mississippians and the people of the Central Plains tradition.

Underpinning virtually all interpretations and recent research agendas that involve shell-tempered pottery on the Central Plains is the set of intertwined implicit assumptions, also widely held in the Southeast, that a pottery ware is an ethnic marker, that a society produces only one pottery ware, and that the presence of a second ware in a society's assemblages must indicate contact or interaction with a different society. In the Central Plains case, therefore, it is assumed that Central Plains tradition people produced only a grit- and/or grog-tempered pottery, and that the shell-tempered pottery was physically brought to the Central Plains sites, either by immigrant colonizers or through direct exchange with a shell-tempered pottery manufacturing Mississippian society to the east. But Central Plains archaeologists have never really

Table 1. Sites Used in this Analysis.

Site Name	Site Number	River Basin	% Shell-Tempered	Reference	Comments
Minneapolis	14OT5	Solomon River/ Salt Creek	< 2%	Fosha 1994; Witty 1971, 1974	sherds are from House 8
Mugler	14CY1	Republican River	10%	Beck 1995, 2001	
Rush Creek	14GE127	Republican River	53%	Sperry 1965	
Strafuss	14RY301	Kansas River/ McDowell Creek	—	Monger 1960; Kansas state site files	only one vessel represented in this collection
Budenbender	14PO4	Blue River	21%	Johnson 1973	
Cloverdale	23BN2	Missouri River	24%	Greatorex 1998	
Steed-Kisker	23PL13	Missouri River	>90%	Wedel 1943	collection sampled for this study is a private collection donated to ARC-KU

shown that these assumptions are warranted or seemed to grasp that a Mississippian society is defined by its organization and adaptive strategy (Griffin 1985; Muller 1997), not *per se* by its material culture elements, and that it does not represent a specific ethnicity. Since many *a priori* do not consider shell-tempered pottery to be indigenous to Plains ceramic assemblages, they apparently have not thought it necessary to determine actual provenance using compositional analysis, with two limited exceptions (Beck 1995, 2001; Munger 1960). It was to clarify what assumptions could or could not be made that we undertook this provenance analysis of shell-tempered pottery from the Central Plains.

Materials and Methods

Sherds examined in this study were chosen from seven sites in five river valleys extending from the Missouri River valley to the lower Solomon River valley in central Kansas (Table 1). The sites represent both the heart and the margin of the Steed-Kisker phase area in the greater Kansas City area and lie along an east-west transect extending across the lower Kansas River basin (Figure 2), through an area where the Central Plains tradition sites contemporaneous with Steed-Kisker are generally assigned to the Smoky Hill phase. Proportions of shell-tempered pottery in the sampled sites range from very high to very low. Our strategy is to compare mineral inclusions and clay properties among shell-tempered sherds from each locality, and to compare the shell-tempered and grit-tempered sherds from each locality both to each other and to the local geological setting. In so doing, we use all four of Stoltman's (2001:312) independent approaches to demonstrate local production, working from the weakest to the strongest form of demonstration. We do this by sequentially addressing three specific research questions that test each of three postulates. First, do the shell-tempered sherds appear to have been manufactured at a single location, as the standard scenario of vessel movement via migration or trade would imply, or at multiple loci? This is a test of what Stoltman (2001:312) called the *spatial pattern postulate*, where vessel-to-vessel comparisons are made across space but within a single ware. Second, do the shell-tempered and mineral-tempered sherds from each site appear to have been made at the same locus or do they derive from different loci of production? This is a test of the *local-products match postulate*, in which samples of a pottery class of interest—shell-tempered ware in this instance—are compared to those of material that is accepted as locally manufactured—mineral-tempered pottery in this instance. Third, do the vessels represented by either or both wares appear to have been locally produced? This tests the *provenience postulate* (more properly the provenance postulate, i.e., the geologic origin of the material, as opposed to its spatial coordinates), in which sources are tested against a locality's raw materials. Stoltman (2001:312) defined two approaches to testing this postulate, viz., comparing mineral inclusions to local resources, and comparing paste to local sediments. We use both here, and test this postulate using published pedologic and geologic information.

The selected sherds were studied using both petrography and oxidation analysis. For the petro-

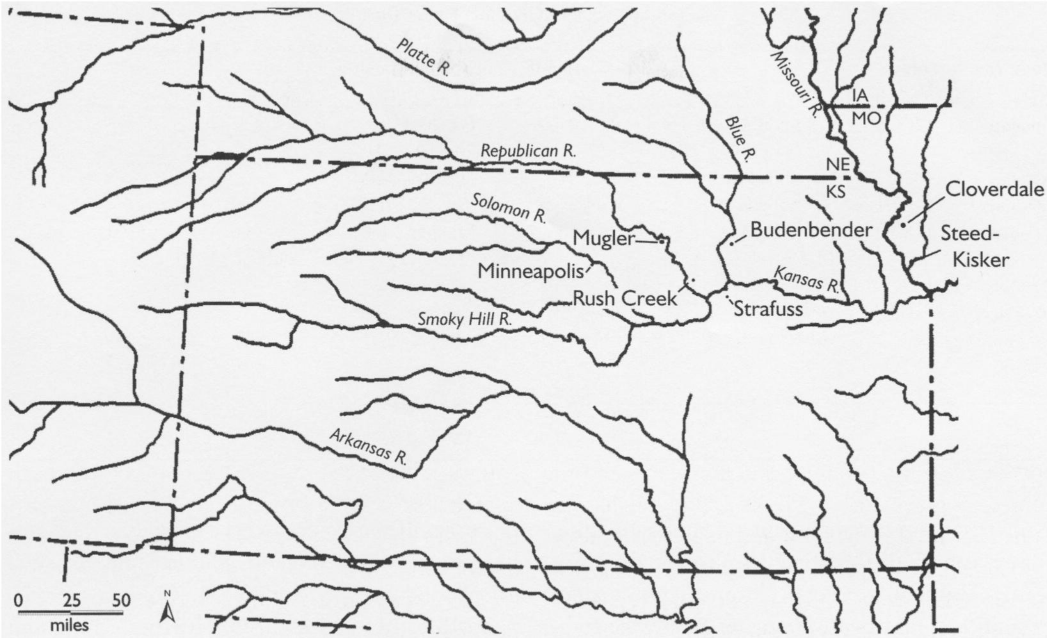

Figure 2. The Distribution of the Sites Used in this Analysis.

graphic analysis, a total of 61 thin sections were prepared from ceramic sherds chosen from the seven study sites. Ten sherds—five grit-tempered and five shell-tempered—were selected from each of Minneapolis site House 8, Budenbender site House 1, Rush Creek site House 1, and the Cloverdale site. Twelve sherds from Mugler site House 1 included seven grit-tempered and five shell-tempered sherds. These included seven thin sections previously studied by Beck (1995, 2001) and five additional sherds selected for this study. Eight sherds from the Steed-Kisker site include five shell-tempered sherds, two of which were previously studied by Beck (1995). Since the Steed-Kisker site collection contains few grit-tempered sherds, only three of these sherds were used in this study. The Strafuss site ceramic assemblage is limited to 65 non-conjoining sherds from one shell-tempered vessel. One sherd from this vessel was examined by Munger in 1960 (Munger 1960) and another sherd was examined as part of this study. Beck's Mugler and Steed–Kisker site thin-sections were prepared by her in 1995 at the University of Kansas. The Strafuss site thin-section was prepared in the Department of Geoscience, University of Iowa. All other thin sections were prepared by National Petrographic Service, Inc., Houston, Texas.

All thin-sections were described by Josephs using a Nikon Optiphot-Pol polarizing microscope. Protocol established by Bullock et al. (1985) and Stoops (2003) for the examination of micromorphological soil/sediment samples was used to describe the ceramic thin sections (Josephs 2005a, 2005b). The descriptions recorded the identification, size, shape, orientation, and degree of sorting of the observable mineral grains (aplastics) as well as an interpretation of the clay matrix (the micromass) based strictly on its optical properties (Josephs 2008). Because individual clay-size particles (< .0039 mm) cannot be distinguished using standard optical methods, the description of the micromass is based on optical characteristics exhibited by small aggregates of oriented clay (clay domains) in cross-polarized light (XPL) (Stoops 2003). The clay domains produce interference colors because of the birefringent properties of the clay particles. The patterns resulting from the orientation and distribution of the interference colors are termed the birefringence fabric or b-fabric (Bullock et al. 1985; Stoops 2003).

There are two major categories of birefringence (b-) fabrics: undifferentiated b-fabrics and crystallitic b-fabrics. Undifferentiated b-fabrics are characterized by an absence of interference colors. They

Table 2. Macroscopic vs Petrographic Temper Identifications.

Site & Macroscopic Temper Identification	Petrographic Temper Identification Grit &/or grog	Shell	Shell & grit or grog
Mn - grit	5		
Mn - shell		5	
Mg - grit	6		
Mg-shell		4	1
RC - grit	5		
RC - shell		5	
Sf - shell			1
Bb - grit	3		1
Bb - shell		5	
Cl - grit	5		
Cl - shell		4	1
SK - grit	1		2
SK - shell		4	1

result from a nontranslucent, virtually opaque, micromass. Undifferentiated b-fabrics are commonly exhibited by clays rich in organic matter. Crystallitic b-fabrics are characterized by the presence of small, birefringent mineral grains. There are three subcategories of crystallitic b-fabrics: speckled, striated, and strial. These patterns result from the spatial arrangement of the clay domains and their resulting interference colors (Bullock et al. 1985; Stoops 2003). The birefringence fabric can be used to infer composition, and therefore provenance, of the matrix material.

A second set of sherds was selected for the oxidation analysis. As with the petrographic analysis, the strategy was to select five grit- and five shell-tempered sherds from each of the Cloverdale, Budenbender, Rush Creek, Mugler, and Minneapolis sites. Five shell-tempered sherds were selected from the Steed-Kisker site collection, and one sherd from the Strafuss site vessel was chosen. Oxidation analysis, most frequently used in the northern U.S. Southwest (Bubemyre and Mills 1993; Fowler 1991; Hays-Gilpin and van Hartesveldt 1998; Mills 1987; Shepard 1939, 1953, 1985; Vivian and Mathews 1965; Windes 1977), relies on the observation that clays with different concentrations of iron oxides fire to different colors in an oxidizing atmosphere. In this technique, sherd samples are refired to completely oxidize the paste. Colors can then be compared to other sherds and to fired clay samples to determine whether ceramics were made from the same or similar clays and which geologic formations or source areas might have been used to produce them. Beck (2006) discusses the basis for this type of analysis and outlines procedures for its use in other regions, such as the southern U.S. Southwest.

Following procedures outlined by Beck (2006:99–100), a small piece was removed from the edge of each sherd using needle-nosed pliers. The piece was then refired in a Fisher Scientific Isotemp® 550 Series Muffle Furnace in the Department of Anthropology, University of Iowa. The kiln took approximately 2 hours to reach a maximum temperature of 950°C. This temperature was held constant for 30 minutes. The kiln then was shut off and the samples were left inside to cool overnight. Under interior fluorescent light, original paste colors and oxidized colors were recorded where the chip conjoined with the original sherd, using the 2000 edition of the Munsell soil color charts.

Results

Table 2 summarizes the temper identifications from the petrographic analysis (Josephs 2008) and compares them with the macroscopic identifications made as each sherd was selected for this analysis. Grit temper in Central Plains tradition pottery is highly varied, depending on locally available materials. Grog may be substituted for grit as a tempering agent or combined with grit to form a composite temper. The thin-section analysis, in fact, identified five examples of composite, grit-and-grog temper. Josephs's (2008) descriptions even note cases where the grog temper was itself grog-tempered. In a few cases, sherds characterized as grit-tempered also contained some shell, and

Table 3. Mineral Inclusions in Shell-Tempered Sherds.

	Mineral Inclusions						
Sherd ID	mQtz	pQtz	mAf	mPl	mMu	pFs	Ls
Mn-6	x	x					
Mn-7	x	x					
Mn-8	x	x					
Mn-9	x	x					
Mn-10	x	x					
Mg-1	x	x	x				
Mg-2	x	x	x				
Mg-3	x	x	x				
Mg-4	x	x	x				
Mg-10	x		x	x			
RC-1	x	x	x	x	x	x	
RC-2	x		x	x	x		
RC-3	x		x				x
RC-4	x		x		x		
RC-5	x		x		x		
Sf-1	x		x		x		
Bb-6	x		x				
Bb-7	x	x	x				
Bb-8	x		x				
Bb-9	x		x		x		
Bb-10	x		x		x		
Cl-1	x		x				
Cl-2	x		x				
Cl-3	x		x				
Cl-4	x		x				
Cl-5	x		x		x		
SK-1	x		x		x		
SK-2	x		x		x		
SK-3	x		x		x		
SK-7							
SK-8							

Key to mineral identifications: mQtz = monomineralic quartz, pQtz = polymineralic quartz, mAf = monomineralic alkali feldspar, mPl = monomineralic plagioclase feldspar, mMu = monomineralic muscovite, pFs = polymineralic feldspar, Ls = limestone

some sherds characterized as shell-tempered also contained grog. Interestingly, the Steed-Kisker site sherds showed the highest incidence of composite tempering.

Identified mineral inclusions within each of the 31 thin-sectioned shell-tempered sherds (Table 3) strongly suggest that the shell-tempered pottery is derived from multiple loci of production and possibly as many loci of production as there are sites in the study. The Minneapolis site shell-tempered sherds, with only mono- and polymineralic quartz grains, [1] resemble no other shell-tempered sherds in this study, and form a distinct subset of the studied shell-tempered sherds (Figure 3). The Mugler site shell-tempered sherds, most of which contain mono- and polymineralic quartz and alkali feldspar grains, also seem to represent a distinct subset. Sherds from all other sites contain monomineralic quartz and monomineralic alkali feldspar inclusions, and usually have other inclusions as well, but rarely include polymineralic quartz. Although sherds from these sites are different from those recovered at the Minneapolis and Mugler sites, they cannot be as clearly sorted into distinct subsets. Nor,

Figure 3. Photomicrograph (PPL @ 40x) of Minneapolis site shell-tempered sherd (Mn-6) with a dark, organic-rich, clay micromass that produces an undifferentiated (virtually opaque) birefringence (b-) fabric. The micromass contains numerous, angular to subangular, very fine sand-size, natural inclusions, predominantly monomineralic quartz grains. Note the wide variety in the size of the shell fragments.

however, do they form a homogeneous group, and their characteristics do not necessarily support the interpretation that this pottery was transported any distance from the point of manufacture to the site where it was found. Two each of the Budenbender (Figure 4) and Rush Creek site sherds (Figure 5), the Strafuss site sherd, and one sherd from the Cloverdale site show the same set of aplastic inclusions as do the Steed-Kisker site sherds. Two of the Budenbender site sherds contain the same set of aplastics as do the majority of the Cloverdale site sherds (Figure 6). Four of these sites, however, including Steed-Kisker but not including Strafuss, contain combinations of aplastics not replicated at any of the other sites (Figures 7 and 8). The data thus strongly suggest that the shell-tempered pottery was made at as many production loci as there are sites in the study, but are not sufficient by themselves to entirely preclude the movement of pottery between the Missouri River valley and at least some locations in the Kansas River basin.

The b-fabrics and pre-refiring color data (Table 4), however, provide a different perspective that strengthens the case for multiple loci of production, even among sites not clearly differentiated by the mineral inclusions data. Sherds from the Steed-Kisker site and the Cloverdale site more consistently exhibit one or more forms of crystallitic b-fabrics, while the other sites, those to the west, have larger proportions of undifferentiated b-fabrics. Undifferentiated b-fabrics are recorded if the micromass (paste) is nontranslucent. This can result from high organic matter content in the clay matrix. The pre-refiring color data are consistent with the petrographic determinations. Lower color value and chroma generally reflect higher organic matter content (Schulze et al. 1993:73–75). They may also reflect the firing of iron-rich clays in a reducing atmosphere, causing the ferrous iron in the clay to appear dark. In either case, oxidation during firing should lighten the color and increase the value (Beck 2006). The shell-tempered pottery data show a predominance of color values in the black to very dark grey to dark grey (2.5, 3, 4) range

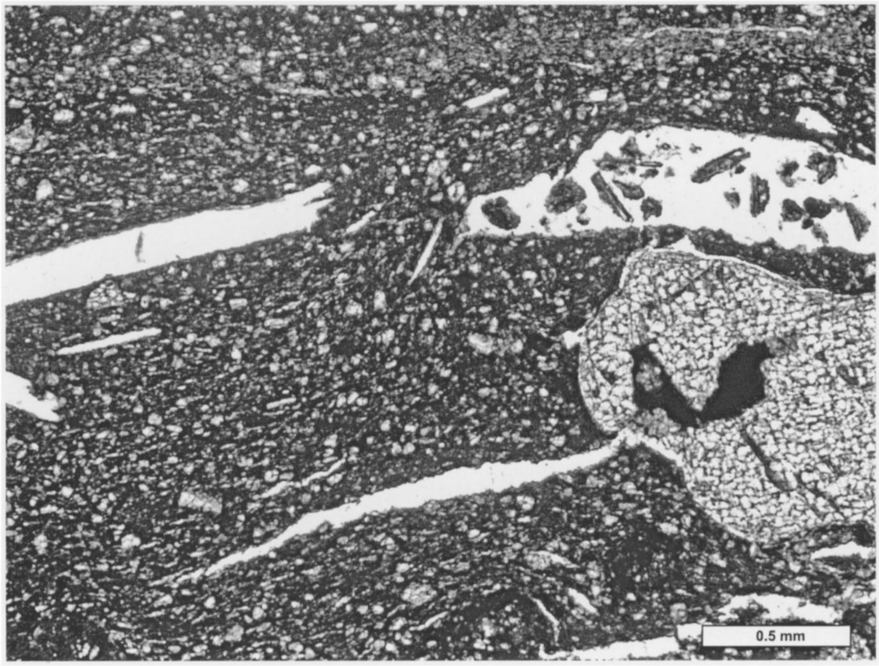

Figure 4. Photomicrograph (PPL @ 40x) of Budenbender site composite tempered (grit and leached shell) sherd (Bb-1) in a dark, organic-rich, clay micromass that produces a predominantly undifferentiated b-fabric. A subrounded, very coarse sand-size, polymineralic (quartz and biotite), grit temper grain straddles the right edge of the photo. Numerous shell fragments can be seen in the pseudomorphic void in the upper-right corner, above the large grit-temper grain. The elongated poroid in the lower center of the image is a planar void and, therefore, not the result of the dissolution (leaching) of a shell fragment. Planar voids are microstructural features that typically result from material shrinkage or slippage (Stoops 2003).

in sherds from the more westerly sites and values in the grey range (5, 6) in the Cloverdale and Steed-Kisker site sherds (Figure 9). This suggests either that the clays used for manufacturing the pots represented on the more westerly sites had a higher organic matter content than did those from the Missouri River valley sites, or that the organic matter in the paste of the Missouri River valley vessels was more completely oxidized during firing. Either way, this represents a difference between the Steed-Kisker phase sites to the east and the Smoky Hill phase sites to the west.

The oxidized or post-refiring colors (Table 4, last column) show too little variation to differentiate the clays from across all sites sampled. Ceramics in the oxidation analysis, regardless of temper type and the site from which they were recovered, have relatively bright reddish colors (hues 2.5YR and 5YR; values 5 and 6) after refiring, indicating the oxidation of organic matter and high levels of iron oxides in the clay. This similarity is present in spite of the fact that high levels of calcium, such as those in the shell-tempered ceramics, might decrease redness (Beck 2006; Gile and Grossman 1979; Shepard 1985:103). These data suggest a similarity in iron content in the clays from throughout the southeastern Central Plains that does not lend itself to even a rough sorting by refiring.

In sum, mineral inclusions clearly separate the Minneapolis and Mugler shell-tempered sherds both from each other and from the other sites studied. Sherds from the other five sites are less clearly separated from one another by their mineral inclusions, but b-fabrics and oxidation data reflect a clay difference between sherds from the Budenbender, Rush Creek, and Strafuss sites on the one hand and the Cloverdale and Steed-Kisker sites on the other. This difference results from either varying organic matter content in the raw clays or differences in firing technology. Within these two subdivisions (the Budenbender, Rush Creek, and Strafuss sites, and the Cloverdale and Steed-Kisker sites) formed by b-fabrics and color data, Budenbender and Rush Creek sherds are distinguished from one another

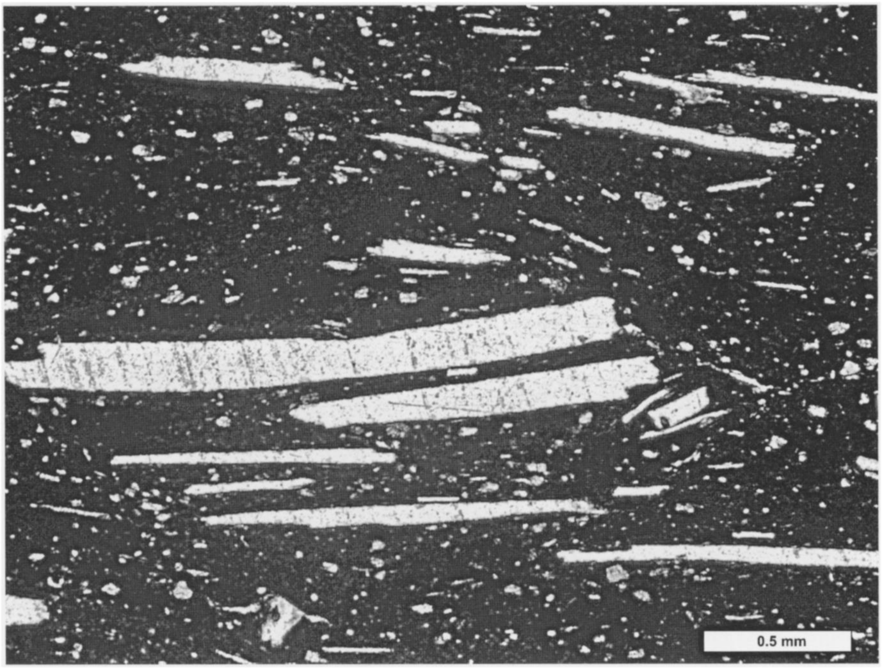

Figure 5. Photomicrograph (PPL @ 40x) of Rush Creek site leached shell-tempered sherd (RC-3) with a dark, organic-rich, clay micromass that produces an undifferentiated b-fabric. The tabular, pseudomorphic voids result from the dissolution of the shell temper fragments. The micromass contains noticeably fewer, angular to subangular, very fine sand-size, natural inclusions, providing a clearer view of the undifferentiated (black [10YR 2/1]) b-fabric.

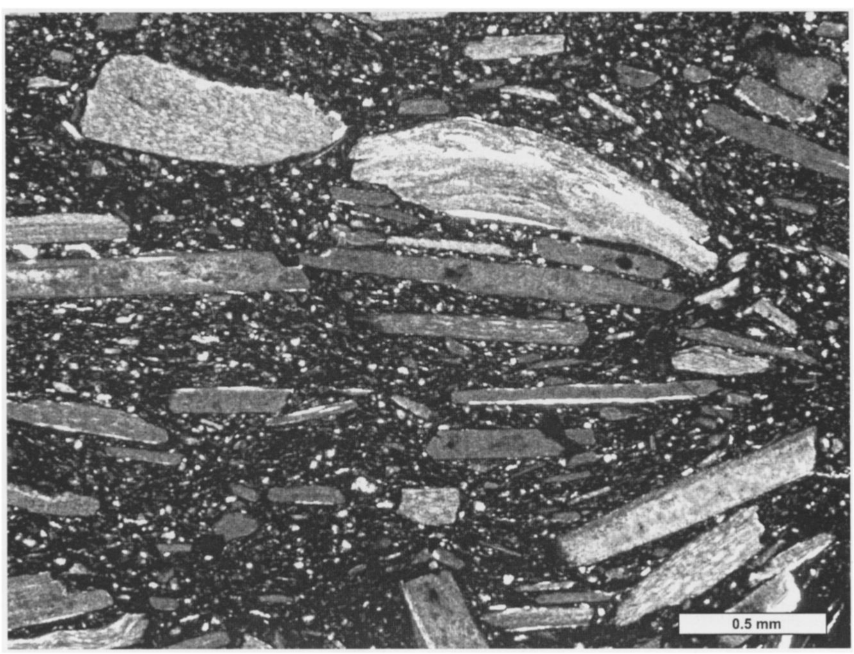

Figure 6. Photomicrograph (PPL @ 40x) of Cloverdale site shell-tempered sherd (Cl-1) with a dark, organic-rich, clay micromass that produces an undifferentiated b-fabric. The matrix (natural inclusions and clay micromass) is similar to that observed in sample Mn-6 (Figure 3); however, the shell fragments are much better sorted in this sample. The natural inclusions are angular to subangular, very fine sand-size, predominantly monomineralic, quartz grains.

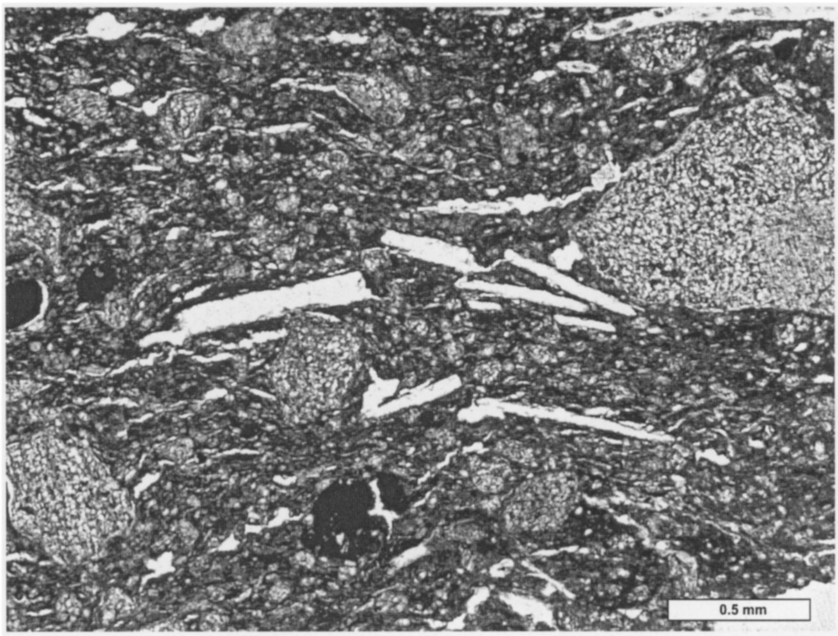

Figure 7. Photomicrograph (PPL @ 40x) of Steed-Kisker site composite tempered (grit and leached shell) sherd (SK-4) with a red (2.5YR 5/8) to dark red (2.5YR 4/8) birefringent clay micromass. The tabular, pseudomorphic voids result from the dissolution of the shell temper fragments. The grit temper grains are subangular to subrounded, medium, coarse, and very coarse sand-size, mono- and polymineralic quartz grains. The red clay observed in this sample is consistent with clays described in the Armster Soil Series, which is mapped in close proximity to the Steed-Kisker site.

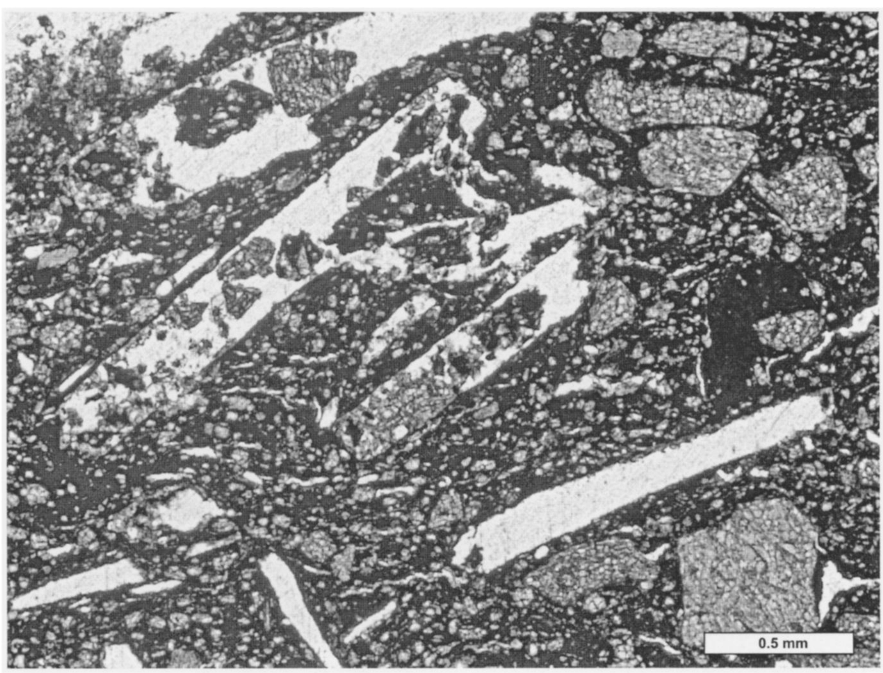

Figure 8. Photomicrograph (PPL @ 40x) of Steed-Kisker site composite tempered (grit and leached shell) sherd (SK-6) with a dark red (2.5YR 3/6 to 4/6) birefringent clay micromass. The tabular, pseudomorphic voids result from the dissolution of the shell temper fragments. Some contain post-dissolutional mineral grains and matrix fragments. The grit temper grains are subangular to subrounded, medium to coarse sand-size, mono- and polymineralic quartz grains. The natural inclusions are predominantly subangular to angular, very fine sand-size, monomineralic quartz grains.

Table 4. Birefringence (b-) Fabrics and Munsell Colors for Shell-Tempered Sherds.

	Predominant birefringence (b-) fabric			Munsell colors	
Sherd ID	undifferentiated	crystallitic	Sherd ID	Before refiring	After refiring
Mn-6	50%	50%	Mn-18	5YR2.5/1	2.5YR6/8
Mn-7		X	Mn-19	2.5/N	2.5YR5/8
Mn-8	X		Mn-20	10R4/1	2.5YR5/8
Mn-9		X	Mn-21	5YR2.5/1	5YR6/8
Mn-10		X	Mn-22	2.5/N	2.5YR5/8
Mg-1		X			
Mg-2	50%	50%			
Mg-3	X		Mg-14	4/N	2.5YR6/8
Mg-4		X	Mg-4	5/N	5YR5/8
Mg-10		X	Mg-10	4/N	5YR6/8
RC-1	X		RC-15	2.5Y3/1	5YR6/8
RC-2		X	RC-16	3/N	2.5YR6/8
RC-3	X		RC-17	4/N	5YR6/8
RC-4	X		RC-18	2.5Y3/1	5YR6/8
RC-5		X	RC-20	5/N	2.5YR6/8
Sf-1	X		Sf-1	3/N	2.5YR6/8
Bb-6		X	Bb-11	2.5Y4/1	5YR6/8
Bb-7		X	Bb-12	2.5Y3/1	2.5YR6/8
Bb-8	X		Bb-13	2.5/N	2.5YR6/8
Bb-9		X	Bb-14	4/N	2.5YR5/8
Bb-10	X		Bb-20	4/N	5YR6/8
Cl-1	X		Cl-12	7.5YR5/3	2.5YR6/6
Cl-2		X	Cl-13	2.5Y5/1	2.5YR6/8
Cl-3		X	Cl-14	5/N	2.5YR6/8
Cl-4		X	Cl-15	4/N	2.5YR7/6
Cl-5		X			
SK-1		X	SK-9	5YR5/6	2.5YR6/8
SK-2		X	SK-10	5/N	2.5YR6/8
SK-3		X	SK-11	2.5Y5/1	2.5YR6/8
SK-7		X	SK-12	10YR6/3	5YR5/8
SK-8		X	SK-13	10YR4/1	5YR5/8
			SK-14	10YR6/3	2.5YR6/8

by their mineral inclusions, and mineral inclusions similarly distinguish the Cloverdale and Steed-Kisker sites sherds from one another. Strafuss, with only one vessel represented, is ambiguous. Thus, combining all data, we arrive at the conclusion that the shell-tempered pottery from the seven sites was made at seven locations. Our next step, then, is to determine if the locations where the shell-tempered pottery was produced are the same as those where the grit/grog-tempered pottery was produced.

Table 5 compares the mineral composition of the grit/grog-tempered pottery with that of the shell-tempered pottery for each site individually. Since it seems likely that few or no mineral aplastics were deliberately added to the paste of the shell-tempered pottery, we might expect the variety of minerals identified in the shell-tempered pottery to be less than in the mineral-tempered pottery. Taking this into account, what emerges from site-by-site comparisons is the high degree of similarity between the two wares at each site individually, and the same dissimilarity among sites as seen in the shell-tempered pottery alone. The mineral composition of the grit/grog-tempered sherds from the Minneapolis site is identical to that observed in the shell-tempered sherds. This again distinctly sepa-

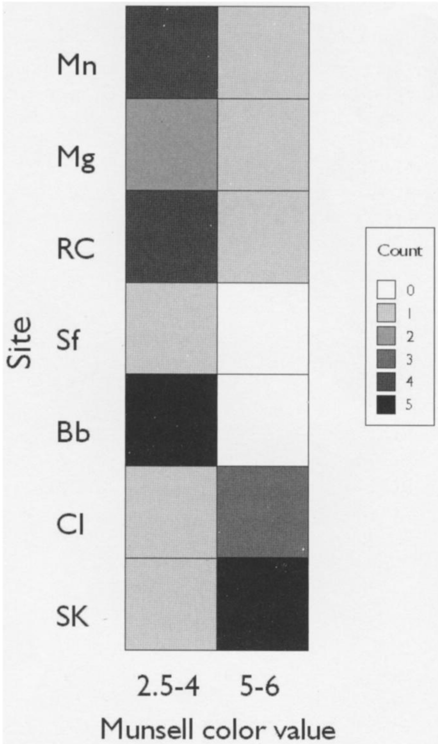

Figure 9. Choropleth Summary of Color Values for Shell-Tempered Sherds, by Site.

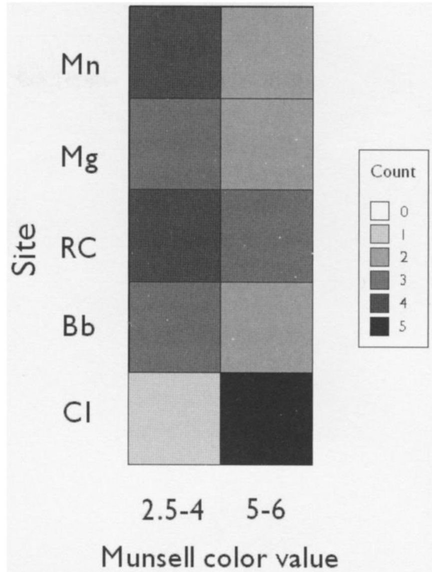

Figure 10. Choropleth Summary of Color Values for Mineral-Tempered Sherds, by Site.

rates this site from all others included in this study. The grit-tempered sherds from the Mugler site contain a greater variety of identifiable mineral grains than do the shell-tempered sherds. The specific suite of identified mineral grains, however, distinguishes the Mugler site sherds of both wares from all other shell-tempered sherds studied here, again distinctly separating this site's sherds from the others studied. In sherds from other sites, the mineral inclusions in the grit/grog-tempered sherds are somewhat more varied than those in the shell-tempered sherds, but in each case, the identifiable mineral grains in the shell-tempered sherds are a subset of those in the grit/grog-tempered sherds. The Rush Creek site might be an exception.

The b-fabrics and oxidation data for all sherds (Table 6) offer some further clarity. As with the shell-tempered sherds, most grit-tempered sherds from the Missouri River Cloverdale site are dominated by crystallitic b-fabrics, and many of these sherds exhibit Munsell color values in the dark grey to grey (4–6) range (Figure 10). Undifferentiated b-fabrics and black to very dark grey (2.5–3) Munsell color values are more common in the sherds from the Smoky Hill phase sites (Figure 10).

In sum, sherds from within individual sites are similar to one another, regardless of temper, in both composition and micromass characteristics and are dissimilar to sherds of the same temper class from all other sites. Thus, the data support the inferences that, like shell-tempered pottery, the mineral-tempered pottery from the six sites (we had no mineral-tempered sherds from Strafuss) was made at six locations and that both wares were made at each of these locations. Assuming, as it commonly is, that the grit/grog-tempered pottery was made locally in each instance, this demonstration of compositional and micromass similarity of shell-tempered pottery to the grit/grog-tempered pottery is strong evidence that the shell-tempered pottery also was made locally. A final step in the analysis, however, is a comparison of the composition of both wares to the local geological setting, using the geological and soils information for the general study area and the area surrounding each site. We consider this evidence for each site individually.

Minneapolis site. The grit temper in Minneapolis site sherds is rounded to subrounded, coarse and very coarse sand-size and granule-size, mono- and polymineralic grains. Quartz is the most common mineral present. The polymineralic grains

Table 5. Mineral Inclusions in All Sherds.

		Mineral inclusions											
Sherd ID	Temper class	mQtz	pQtz	mAf	mPl	mMu	mBi	Gr/MGr	pFs	MSc	Sh	Ls	Ba?
Mn-1	grit & grog	x	x										
Mn-2	grit	x	x										
Mn-3	grit & grog	x	x										
Mn-4	grit	x	x										
Mn-5	grit												
Mn-6	shell	x	x										
Mn-7	shell	x	x										
Mn-8	shell	x	x										
Mn-9	shell	x	x										
Mn-10	shell	x	x										
Mg-5	grit	x	x	x	x						x		
Mg-6	grit	x	x	x	x						x		
Mg-7	grit & grog	x	x	x							x		
Mg-8	grit	x	x	x							x		
Mg-9	none	x		x	x								
Mg-11	grit	x	x	x	x						x		
Mg-12	grog	x	x	x	x						x		
Mg-1	shell	x	x	x									
Mg-2	shell	x	x	x									
Mg-3	shell & grog	x	x	x									
Mg-4	shell	x	x	x									
Mg-10	shell	x		x	x								
RC-6	grit	x	x	x	x			x	x				
RC-7	grit	x	x	x	x			x	x				
RC-8	grit	x		x									
RC-9	grit	x	x	x	x			x	x				x
RC-10	grit	x	x	x	x			x	x				
RC-1	shell	x	x	x	x	x			x				
RC-2	shell	x		x	x	x							
RC-3	shell	x		x								x	
RC-4	shell	x		x		x							
RC-5	shell	x		x		x							
Sf-1	shell&grit	x		x		x							
Bb-1	grit & shell	x	x	x									
Bb-2	none	x		x									
Bb-3	grit	x	x	x		x	x	x	x				
Bb-4	grit	x	x	x		x	x	x	x				
Bb-5	grit	x	x	x								x	
Bb-6	shell	x		x									
Bb-7	shell	x	x	x									
Bb-8	shell	x		x									
Bb-9	shell	x		x		x							
Bb-10	shell	x		x		x							
Cl-6	grit	x	x	x	x	x	x	x	x				
Cl-7	grit & grog	x	x	x	x	x	x		x				
Cl-8	grit & grog?	x	x	x	x	x	x	x	x				
Cl-9	grog	x		x		x							
Cl-10	grit	x		x	x	x	x	x		x			
Cl-1	shell	x		x									
Cl-2	shell	x		x									
Cl-3	shell & grog?	x		x									
Cl-4	shell	x		x									
Cl-5	shell	x		x		x							
SK-4	grit & shell	x	x	x	x	x	x	x	x				
SK-5	grit	x	x	x	x	x	x	x	x				
SK-6	grit & shell	x	x	x	x	x	x	x	x				
SK-1	shell	x		x		x							
SK-2	shell & grog?	x		x		x							
SK-3	shell	x		x		x							
SK-7	shell												
SK-8	shell												

Key to mineral identifications: mQtz = monomineralic quartz, pQtz = polymineralic quartz, mAf = monomineralic alkali feldspar, mPl = monomineralic plagioclase feldspar, mMu = monomineralic muscovite, mBi = monomineralic biotite, Gr/MGr = granitic/gmetagranitic, pFs = polymineralic feldspar, MSc = Mica schist, Sh = shale, Ls = limestone, Ba = basalt

Table 6. Birefringence (b-) Fabrics and Munsell Colors for All Sherds.

	Predominant birefringence (b-) fabric					Munsell colors	
Sherd ID	Temper class	undifferentiated	crystallitic	Sherd ID	Temper class	before refiring	after refiring
Mn-1	grit&grog		X	Mn-12	grit	5YR5/1	2.5YR5/8
Mn-2	grit	X		Mn-13	grit	2.5/N	2.5YR5/8
Mn-3	grit&grog	X		Mn-14	grit	5/N	2.5YR6/8
Mn-4	grit	X		Mn-15	grit	5YR3/1	2.5YR6/8
Mn-5	grit	X		Mn-16	grit	3/N	5YR6/8
				Mn-17	grit	2.5/N	2.5YR5/8
Mn-6	shell	50%	50%	Mn-18	shell	5YR2.5/1	2.5YR6/8
Mn-7	shell		X	Mn-19	shell	2.5/N	2.5YR5/8
Mn-8	shell	X		Mn-20	shell	10R4/1	2.5YR6/8
Mn-9	shell		X	Mn-21	shell	5YR2.5/1	5YR6/6
Mn-10	shell		X	Mn-22	shell	2.5/N	2.5YR5/8
Mg-5	grit	X					
Mg-6	grit	X					
Mg-7	grit&grog	X		Mg-5	grit	3/N	5YR6/8
Mg-8	grit	X		Mg-9	grit	5/N	10R6/8
Mg-9	grit		X	Mg-13	grit	3/N	2.5YR6/8
Mg-11	grit		X	Mg-15	grit	3/N	5YR6/8
Mg-12	grog		X	Mg-16	grit	5/N	2.5YR7/8
Mg-1	shell		X	Mg-14	shell	4/N	2.5YR6/8
Mg-2	shell	50%	50%	Mg-4	shell	5/N	5YR5/8
Mg-3	shell&grog	X		Mg-10	shell	4/N	5YR6/8
Mg-4	shell		X				
Mg-10	shell		X				
RC-6	grit		X	RC-11	grit	2.5Y5/2	5YR6/8
RC-7	grit		X	RC-12	grit	3/N	5YR6/8
RC-8	grit	X		RC-13	grit	4/N	2.5YR6/8
RC-9	grit		X	RC-14	grit	4/N	5YR5/8
RC-10	grit		X	RC-19	grit	2.5Y3/1	5YR5/8
RC-1	shell	X		RC-15	shell	2.5Y3/1	5YR6/8
RC-2	shell		X	RC-16	shell	3/N	2.5YR6/8
RC-3	shell	X		RC-17	shell	4/N	5YR6/8
RC-4	shell	X		RC-18	shell	2.5Y3/1	5YR6/8
RC-5	shell		X	RC-20	shell	5/N	2.5YR6/8
Sf-1	shell&grit	X	X	Sf-1	shell	3/N	2.5YR6/8
Bb-1	grit	X		Bb-15	grit	2.5/N	5YR6/8
Bb-2	grit	X		Bb-16	grit	2.5Y3/1	5YR7/8
Bb-3	grit	X		Bb-17	grit	2.5Y3/1	2.5YR6/8
Bb-4	grit	X		Bb-18	grit	2.5Y5/6	2.5YR6/8
Bb-5	grit		X	Bb-19	grit	2.5Y4/1	2.5YR6/8
Bb-6	shell		X	Bb-11	shell	2.5Y4/1	5YR6/8
Bb-7	shell		X	Bb-12	shell	2.5Y3/1	2.5YR6/8
Bb-8	shell	X		Bb-13	shell	2.5/N	2.5YR6/8
Bb-9	shell		X	Bb-14	shell	4/N	2.5YR5/8
Bb-10	shell	X		Bb-20	shell	4/N	5YR6/8
Cl-6	grit		X	Cl-11	grit	7.5YR5/3	5YR5/8
Cl-7	grit	X		Cl-16	grit	2.5Y4/1	5YR6/8
Cl-8	grit	50%	50%	Cl-17	grit	2.5Y4/1	2.5YR6/8
Cl-9	grit		X	Cl-18	grit	2.5Y3/1	2.5YR5/8
Cl-10	grit		X	Cl-19	grit	2.5Y4/1	5YR6/8
Cl-1	shell	X		Cl-20	grit	7.5YR4/2	2.5YR5/8
Cl-2	shell		X	Cl-12	shell	7.5YR5/3	2.5YR6/6
Cl-3	shell		X	Cl-13	shell	2.5Y5/1	2.5YR6/8
Cl-4	shell		X	Cl-14	shell	5/N	2.5YR6/8
Cl-5	shell		X	Cl-15	shell	4/N	2.5YR7/6
SK-4	grit		X	SK-9	shell	5YR5/6	2.5YR6/8
SK-5	grit		X	SK-10	shell	5/N	2.5YR6/8
SK-6	grit		X	SK-11	shell	2.5Y5/1	2.5YR6/8
SK-1	shell		X	SK-12	shell	10YR6/3	5YR5/8
SK-2	shell		X	SK-13	shell	10YR4/1	5YR5/8
SK-3	shell		X	SK-14	none	10YR6/3	2.5YR6/8
SK-7	shell		X				
SK-8	shell		X	Mn-11	none	2.5YR4/1	2.5YR6/8

were identified as sandstone, some containing minor amounts of biotite. The Cretaceous-age Dakota sandstone crops-out in the Minneapolis area and is the likely source for the highly weathered, polyquartz fragments identified in the thin sections (Franks et al. 1959; Merriam 1963:60). Additionally, a considerable amount of organic matter and plant residue was observed in the ceramic fabric and this also is consistent with characteristics of the Minneapolis site locality. The site lies on a massive alluvial terrace between the Solomon River and its tributary, Salt Creek, just upstream from their junction. Both streams flow within narrow meander belts, and their bottomlands feature a complex mosaic of flat-surfaced terrace exposures interspersed with old meander scars. The abandoned meander scars appear to once have been resource-rich wetlands that produced numerous important resources, organic-rich pottery clay among them.

Mugler site. The predominant minerals identified in the Mugler site samples are highly weathered quartz and alkali feldspar with minor amounts of plagioclase feldspar. Polymineralic grains were identified as fragments of sandstone, shale, and chert. The site, near Clay Center, Kansas, lies at the interface of the Cretaceous and Permian systems. Exposed rocks include the sandstone of the Dakota formation and Permian-age shales and interbedded cherts. The mono- and polymineralic grains identified in these sherds are consistent with the mineralogy and petrology of these bedrock systems and the unconsolidated material blanketing them (Walters and Bayne 1959). Beck (2001) also concluded that minerals in these sherds are consistent with the raw materials available near the site. The site's alluvial setting within a larger river valley, while not presenting as complex a series of swales and wetlands as the Minneapolis site location, would have contained suitable pottery clays with the high organic matter content observed in the micromass and the color exhibited by the sherds from this site.

Rush Creek site. The Rush Creek site samples contain a large variety of minerals. The most common minerals identified are quartz, alkali feldspar, plagioclase feldspar, muscovite and biotite micas, and opaques (iron-oxide minerals). Polymineralic fragments were identified as sandstone (some possibly arkosic), shale, limestone, granitic/metagranitic fragments, and basalt. This site, although in the same river valley as the Mugler site, lies well east of the edge of the Cretaceous formations in an area dominated by Permian-age shales and limestones with interbedded chert. The mono- and polymineralic grains identified in these sherds are consistent with the mineralogy and petrology of the Permian lithologies on the edge of the Flint Hills and the associated alluvial, colluvial, and eolian deposits in this region (Jewett 1941). Pottery clay containing ample organic matter was available in the alluvial sediments.

Strafuss site. All of the mineral inclusions, overwhelmingly monomineralic grains, in the single Strafuss site sample fall into the very fine sand-size category and are thus considered to be natural inclusions. Their small size made it difficult to identify the individual minerals present; however, quartz, undifferentiated feldspar, and muscovite mica grains were observed. Based on the outline of many of the voids, it appears that both shell and grit were used to temper this vessel. Both crystallitic and undifferentiated b-fabrics were observed. The Strafuss site is located in the McDowell Creek valley in southern Riley County, Kansas, just upstream from where that stream enters the Kansas River bottoms. This location is within the Flint Hills and is underlain by Permian-age limestones and shales. Quaternary alluvium and colluvium mantle the river floodplain and terraces (Jewett 1941) and could have been the source of the clay used in vessel manufacture.

Budenbender site. The Budenbender site samples also contain a larger variety of minerals than the sherds from either the Minneapolis or Mugler sites. The most common are quartz, alkali feldspar, and muscovite and biotite micas. The Blue River, which flows overall in a southerly direction, does not drain a region with exposed Dakota formation sandstone, except near its headwaters in central Nebraska, far upstream from the Budenbender site. Hence, the minerals derived from the Dakota formation observed in the Minneapolis and Mugler site sherds are absent from the Budenbender site sherds. Budenbender lies just within the glaciated border in northeast Kansas, near the mouth of a tributary that drains from the glaciated area to the east of the Blue River. The observed polymineralic grains composed of quartz, feldspar, and mica likely represent glacially transported granitic/metagranitic fragments that originated in the Canadian Shield. Overall, the mono- and polymineralic grains identified in the Budenbender site sherds reflect the mineralogy and petrology of the till, outwash, and glaciolacustrine sediments found throughout the till plains of northeast Kansas. Again, the alluvial setting would have been a source for organic-rich clays.

Cloverdale site. The Cloverdale site sherds contain a large variety of minerals. The most common minerals identified are quartz, alkali feldspar, plagioclase feldspar, and muscovite and biotite micas. Polymineralic fragments were identified as sandstone (some possibly arkosic), granitic/metagranitic fragments, and mica schist. The aplastics and micromass identified in the ten thin sections from this site are consistent with geologic raw materials readily available in Buchanan County, Missouri. The mono- and polymineralic grains identified in these sherds are consistent with the mineralogy and petrology of the till, outwash, and glaciolacustrine sediments found throughout the Glaciated Till Plain physiographic region of Missouri (Langer et al. 2002).

Steed-Kisker site. The Steed-Kisker samples contain a large variety of minerals. The most common minerals identified are quartz, alkali feldspar, plagioclase feldspar, and muscovite and biotite micas. Polymineralic fragments were identified as sandstone (some possibly arkosic) and granitic/metagranitic fragments. As with the Cloverdale site sherds, the mono- and polymineralic grains identified in the Steed-Kisker site sherds are consistent with the mineralogy and petrology of the till, outwash, and glaciolacustrine sediments found throughout the till plains of northwest Missouri. The most interesting feature of the Steed-Kisker samples was the highly birefringent, reddish-colored clay used in the manufacture of these vessels. Within Platte County, clays matching this description occur in Armster series soils, a clay-rich alfisol formed on upland slopes in loess or till on the Sangamon paleosol (Preston 1985). This soil series is associated with the Missouri River and is not identified farther west than the Kansas counties in the Dissected Till Plains that border the Missouri River. It is not mapped for the Mississippi River valley in the Cahokia region or elsewhere (WebSoilSurvey 2009).

In sum, the mineral inclusions in the sherds and, to some extent, the clay properties of these sherds reflect each site's specific geologic setting. It is particularly important to note that the characteristics of the shell-tempered pottery not only reflect the specific setting of each site from which they were collected but that they are inconsistent with the specific settings of the other sites. This corroborates the earlier conclusion that the shell-tempered pottery was not transported to the sites where it was found but rather that, like the locally manufactured mineral-tempered pottery, it was locally produced throughout the southeastern Central Plains.

Conclusions

The combined results of the mineral grains identification, characterization of birefringence fabrics, and oxidation analysis of shell-tempered and grit-/grog-tempered sherds from seven Central Plains tradition sites allows definitive answers to the three questions posed for this study. First, the shell-tempered pottery on the Central Plains was produced at multiple loci. Our results suggest that the number of locations where shell-tempered pottery was produced is equal to the number of sites studied. Second, the shell-tempered pottery from each site was manufactured in the same location as the mineral-tempered pottery from that site. Since the mineral-tempered pottery is accepted as locally produced throughout the Central Plains, the shell-tempered pottery also appears to have been locally produced. Third, the consistency in the composition of all sherds with characteristics of the local geological setting confirmed the local manufacture of both shell-tempered and grit/grog-tempered pottery. The people of the Central Plains tradition thus produced and used two ceramic wares, albeit in differing proportions in different parts of the Central Plains cultural subarea.

The demonstration that shell-tempered pottery was locally produced throughout at least a portion of the Central Plains has significant implications for culture-history narratives in the region. No longer will it be possible to regard the shell-tempered pottery as made by people who were socially distinct from the makers of the mineral-tempered pottery. There seems little reason to doubt that the *idea* of shell-tempered pottery was derived from people in the Mississippi River valley and that the idea reached the edge of the Central Plains around cal A.D. 1000. There is no reason, however, to require that shell-tempered pottery was introduced to and spread across the Central Plains by colonizers and/or traders. As we have already noted, and as others have noted, shell-tempered pottery is not an ethnic marker, but rather a technological tradition that is widely shared over the late prehistoric time horizon of the eastern United States. The relevant question concerns not the nature of the relation between distinct peoples, but rather the timing of the spread of this technology onto and across part of the Central Plains, and the circumstances surrounding its adoption in this region.

The study reported here was initiated at the end of 2007. In the months since it began, a considerable body of literature has appeared concerning shell-tempered pottery in the eastern United States. In one of these recent studies, Feathers and Peacock (2008:286) commented that a deficiency in Feathers's (2006) earlier attempt to understand and explain the appearance and distribution of shell-tempered pottery was a lack of knowledge about the spatial and temporal distribution of this pottery in the eastern United States. The series of papers in the recent thematic issue of *Southeastern Archaeology* devoted to shell-tempered pottery in the eastern Woodlands was designed to bring together information about the origins and spread of this technology. Several other recently published studies concerning origins and provenance of shell-tempered pottery provide additional information (Feathers 2009; Stoltman et al. 2008). We suggest that our conclusion that the Central Plains was not simply a passive recipient of imported or traded shell-tempered pottery vessels, but rather a region where shell-tempered pottery was regularly produced, indicates that information from the Central Plains also must be considered in continental studies of the origins and adoption of this material. In fact, since the southeastern Central Plains represents the western limit of the production and use of shell-tempered pottery in the eastern United States, the shell-tempered pottery may be limited in its distribution on the Central Plains for the same reasons that this pottery ware finds its continent-wide western limit here.

To address the reason for these limits, the pertinent questions are why the proportional representation of shell-tempered pottery declines away from the greater Kansas City area, and why shell-tempered pottery is not found throughout the Central Plains tradition. These are complex questions that cannot as yet be adequately answered. Some observations may be relevant and point the way to future research, however. The characteristics of the b-fabrics and results of the oxidation analysis suggest differences in firing technology across space on the Central Plains. Both the shell-tempered pottery and the mineral-tempered pottery from the Missouri River valley sites (Steed-Kisker and Cloverdale) is more highly oxidized than is the pottery of either ware from sites in the Kansas River basin. We suspect these differences are due not to technological preferences *per se*, or what some (e.g., Eckert 2008) might call community of practice or habitus, but rather to differences in fuel availability across the sharp ecological gradient of the Central Plains. Figure 1 and the discussion of the distribution of shell-tempered pottery on the Central Plains (see also Roper 2009) shows the highest incidence of shell-tempered pottery to be in the larger river valleys and the lower reaches of their major tributaries. These larger valleys are lined by timber belts with a diverse set of tree species that yield good fuel wood. Tree species diversity, however, declines relatively rapidly in a northward direction along the Missouri River. Even as close to the greater Kansas City area (the Steed-Kisker site area) as the area around the junction of the Platte River with the Missouri River (ca. 130 miles to the north-northwest), some potentially important fuel-wood species have dropped out of the mix (Great Plains Flora Association 1977). The same is true in a westward direction along the Kansas River and throughout the middle and upper part of the basin that this river drains. The extent of the timber belts also declines rapidly to the west across Kansas and Nebraska, suggesting that fuel use strategies, be it for firing pottery or for day-to-day cooking and other domestic activities, almost certainly would have had to be adjusted. It is possible that animal, particularly bison, dung, and perhaps grass and brush, were used more than wood. These materials, while capable of producing fires that are perfectly adequate for some purposes, also have lower heat values and less energy efficiency than do many woods (Holland 1984; Winterhalder et al. 1974). Their use may have necessitated a firing regime different from that used with woods.

Whether this was a factor and how it might have affected the prospects for successfully firing shell-tempered pottery remain to be explored. The specific properties of the clays available on the Central Plains, including their chemical composition and mineralogy, as well as their reaction to various firing technologies also bear further examination.

An unanticipated, but significant, result of this study was the identification of composite temper in 12 of the 61 sherds examined. Since Central Plains tradition pottery from central Kansas is reported as variably tempered with grit or grog, the composite of grit and grog observed in five sherds may simply indicate that tempering was a matter of what was readily at hand and that the potters were indifferent to any differential effects on vessel production or performance. The identification of a composite of shell and either grit or grog in seven sherds, or just over one-tenth of the studied specimens, is more significant and indicates that temper characterization is oversimplified on the Central Plains. This likely results from the focus on explaining the introduction of shell-tempered pottery to the Central Plains in purely culture-history terms rather than by carefully studying the material and building an explanation that involves vessel function, vessel performance, clay properties, firing properties, and perhaps other variables. Analyzing data that Greatorex (1998:101–118) compiled for the Cloverdale site collection, where the diversity of vessel forms partially reflects that of sites in the Mississippi valley, shows that temper classes correspond reasonably well to form classes represented at that site. Current work with pottery from Smoky Hill phase sites, including all of those sampled for this analysis, is finding that while vessel form diversity is lower than it is in assemblages from the Missouri and Mississippi valleys, shell-tempering is restricted to a few specific forms. Further detailed study, however, might show that the difference is even more nuanced and that composite tempers also show some correspondence to vessel form, as Livingood (2007) found in a sample from the Lower Mississippi Valley. It is clear that much more work needs to be done with compositional analysis of Central Plains tradition pottery as well as with other aspects of vessel variation and performance. This would include detailed studies of vessel function using use-alteration indicators such as carbon deposition and residues (e.g., Skibo 1992).

Finally, in a region where clay procurement is virtually unstudied, it has been impossible to know how to knowledgeably sample potential source clays for use in more direct comparisons with the pottery from archaeological sites. Roper et al. (2007), for example, could do little more than use some clay samples at hand or that could be quickly procured and see how they matched the archaeological materials they studied using neutron activation analysis. The results of this analysis, however, provide some guidance for developing more useful potential source sampling strategies. Specifically, the b-fabrics and pre-refiring color data suggest that Smoky Hill phase potters procured their clay from organic-rich alluvial settings, a conclusion also reached by Beck (2001), whereas Steed-Kisker phase potters may have procured at least some of their raw materials from the uplands. The Steed-Kisker site, while in the bottomlands of the Missouri River valley, is in fact at the base of the river's eastern valley wall, thereby providing ready access to clay sources in both the uplands and the bottomlands. The Smoky Hill phase sites, in contrast, are located on the front edges of terraces in broad river valleys, adjacent to alluvial settings, but sometimes several miles from uplands. Targeting the indicated sources for future sampling and characterizing the clays from them should enhance our understanding of issues surrounding pottery production on the Central Plains.

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Note

1. Monomineralic quartz grains are single, isolated quartz grains. Polymineralic quartz grains are rock fragments. In the case of this study, they are interlocking grains of quartz derived from sandstones or granites/metagranites.

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