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CERAMIC PETROGRAPHY AS A TECHNIQUE FOR DOCUMENTING CULTURAL INTERACTION: AN EXAMPLE FROM THE UPPER MISSISSIPPI VALLEY

James B. Stoltman

The petrographic identification of ceramic tempers has long been known to be a fruitful line of inquiry for investigating intersite and interregional cultural interaction. By applying point-counting procedures to the recording of natural as well as humanly added mineral inclusions in ceramic thin sections, considerable power can be added to this traditionally qualitative technique. The effectiveness of this more quantitative approach in discriminating local from nonlocal vessels is demonstrated through a comparative analysis of two Middle Mississippian-contact sites in the upper Mississippi Valley region—Hartley Fort in northeast Iowa and the Fred Edwards site in southwest Wisconsin.

Desde hace mucho tiempo se ha reconocido la importancia de la identificación petrográfica de los desgrasantes cerámicos en la investigación de las relaciones culturales entre sitios y entre regiones. La técnica de identificación cualitativa tradicional puede mejorarse drasticamente si a ella se añade la técnica de "cuantificación de puntos," aplicable tanto a las inclusiones naturales como a las inclusiones minerales artificialmente incorporadas a la pasta cerámica que se observan en secciones delgadas. La eficacia del método cuantitativo queda demostrada al distinguir entre los recipientes localmente fabricados y los importados mediante el análisis comparativo de dos sitios tipo Mississipiano Medio (período de contacto): Hartley Fort, en el noreste de Iowa, y el sitio Fred Edwards en el suroeste de Wisconsin.

Ever since Shepard's (1936, 1942, 1965) seminal research convincingly challenged the prevailing view of village self-sufficiency in ceramic production in the prehistoric Southwest, petrographic analysis of ceramics has been known to archaeologists as an effective tool for the study of cultural interaction. Yet, despite these auspicious beginnings, subsequent applications of the technique of ceramic petrography have enjoyed relatively little attention or prominence in the English-language archaeological literature (Matson 1960:43; Peacock 1970:382, 1977:viii).

Although generally lacking in fanfare, a number of valuable petrographic analyses of ceramics appeared between 1945 and 1970 in the aftermath of Shepard's initial research. Especially notable during this period was the research of Danson and Wallace (1956) and Warren (1967, 1969) in the Southwest, Porter (1963a, 1963b, 1963c, 1964, 1966) in the midwestern United States, and Peacock (1968, 1969) in Britain. As with Shepard's research, these later analyses focused on the identification of ceramic temper, i.e., humanly added mineral inclusions, as the primary basis for distinguishing local from nonlocal pottery vessels. With but a few exceptions, notably Danson and Wallace (1956), this research essentially was qualitative in character. That is to say, the distinction between local and nonlocal ceramic vessels primarily was made on the basis of the kind rather than the size or amount of temper present.

Since 1970, the number of petrographic analyses of ceramic thin sections employing explicitly quantitative observations of temper has grown considerably (e.g., Dickinson and Shutler 1971, 1974; Garrett 1986 [see also her unreferenced work in Hantman and Plog (1982) and in Plog (1980)]; Ferring and Perttula 1987; Lombard 1987; O'Malley et al. 1983; Rose and Fournier 1981; Rugge and Doyel 1980; Tankersley and Meinhart 1982; and Vince 1977). These most recent efforts constitute a distinct advance in accuracy and precision of estimating temper amounts over most earlier work because they use the highly effective, if laborious, technique of point counting, or modal analysis, derived from geology (e.g., Chayes 1954, 1956; Galehouse 1971; Griffiths 1967). This technique is based on the Delesse relation, which holds that areal proportions of minerals in thin

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sections are equivalent to volumetric proportions of minerals in rocks (Chayes 1956:4–15). Since, as Williams (1983:301) aptly has noted, a sherd can be regarded as a metamorphosed sedimentary rock, the basic principles of point counting are as applicable to ceramic thin sections as they are to those of any other rock.

While the analysis of temper has continued to be the primary focus of ceramic petrography, some notable advances also have occurred in the analysis of the clay-rich matrix. Among the earliest attempts in this regard are those of Porter (1963a, 1963b, 1963c) and Warren (1967). Actually, they did not observe the clays themselves, which are too fine grained to be identified petrographically, but the silt- and sand-sized mineral inclusions that occur naturally in most clay-rich sediments. Their observations were largely subjective in nature, mainly based on unquantified impressions of the amount, distribution, and size of silt- and sand-sized natural inclusions. What was most significant about their work was that they established the precedent that petrographic observations of ceramic thin sections potentially could include the clay-rich matrix as an independent variable from temper that is also relevant to the issue of trade and cultural interaction. One of the main goals of this paper is to explore further the potential of petrography to characterize or discriminate objectively the clay-rich matrices of ceramic vessels.

Since 1985, I have been experimenting with methods to increase the power, precision, and relevance of the technique of ceramic petrography in the service of archaeology under the supposition that its unique strength, the reliable identification of mineral inclusions, is still unequaled by any other easily accessible analytical technique and that such information, expressed quantitatively, can provide accurate and objective bases for addressing a number of archaeological problems, including ceramic production, exchange, technology, and taxonomy. In an earlier paper (Stoltman 1989) a quantitative approach to petrographic thin-section analysis was described and applied to a particular data set in order to demonstrate its relevance to a taxonomic problem, namely, whether or not two ceramic types formerly assigned to a single ware were technologically similar. In this paper the same basic technique is further refined to incorporate more explicit observation of clay-rich matrix as well as temper and then is applied to a different problem, the discrimination of local from nonlocal vessels in ceramic assemblages.

PROBLEM DEFINITION

The main substantive issue addressed in this paper concerns the extent to which petrographic analysis of ceramics can shed light on the topic of culture contact among prehistoric communities. In order to exemplify this issue discussion will focus on two late prehistoric villages located approximately 80 km apart in the Upper Mississippi Valley region.

The first site, Hartley Fort (13AM103), is situated on a terrace of the Upper Iowa River about 11 km upstream from its confluence with the Mississippi River in Allamakee County, Iowa. Early mapping and excavations were conducted at the site in 1882 by the Smithsonian Institution (Thomas 1894). Subsequently, more excavations were conducted in 1964 by Marshall McKusick of the University of Iowa (McKusick 1964). The site takes its name from an earthen embankment that surrounds three sides of a rectangular area of ca. .4 ha, with a stream bank constituting the fourth side. With the exception of later and presumably intrusive Oneota burials and what are now regarded as earlier Late Woodland burial mounds (Tiffany 1982:133–134), the major component at Hartley Fort is a unique expression of the Late Woodland stage that was assigned by McKusick (1964) to a newly defined Hartley focus (phase). A later, detailed analysis of the Hartley Fort ceramics by Tiffany (1982) confirmed the uniqueness of the main Late Woodland component at Hartley Fort, while at the same time noting evidence of both Plains Village, especially Mill Creek, and Middle Mississippian (i.e., Stirling phase Cahokia) cultural contact in the form of apparent trade vessels.

One important anomaly concerning the Hartley Fort site emerged when two radiocarbon dates from the main Late Woodland component were announced: 990 ± 100 B.P., A.D. 960, and 1080 ± 95 B.P., A.D. 870 (McKusick 1973:10). While reasonable for a Late Woodland assemblage in the Upper Mississippi Valley, taken literally, they seem too old to be associated with the marker types of Cahokia's Stirling phase, Powell Plain and Ramey Incised, which have been reliably placed within the interval A.D.1050–1150 in the American Bottom region (e.g., Bareis and Porter 1984). This is especially true of the latter date, the only one directly associated with "Middle Mississippi trade sherds" (McKusick 1973:10), for even at one sigma its range does not overlap with that of the Stirling phase. As will be discussed below, new data from the Fred Edwards excavations have resolved this anomaly.

The second site, Fred Edwards (47GT377), is located on a terrace overlooking the Grant River about 13 km upstream from its confluence with the Mississippi River in Grant County, Wisconsin. Excavations at this site were conducted in 1984, 1985, and 1987 by the University of Wisconsin–Madison under my direction. Like Hartley Fort, the Fred Edwards site was at least a partially stockaded village (though no earthen embankments are visible) occupied by peoples whose cultural assemblage can be characterized as Late Woodland with an obvious admixture of Middle Mississippian influences, including apparent trade vessels of the types Powell Plain and Ramey Incised. Also like Hartley Fort, the Fred Edwards assemblage is unique in its respective locality. Without going into detail, it can be stated categorically that the ceramic assemblages from the two sites, except for being generally Late Woodland (i.e., characterized by grit-tempered, cordmarked, and often cord-impressed jars), are distinctively different from one another. In short the shared presence of apparent trade vessels from the Cahokia cultural province suggests contemporaneity, but the dissimilarities of the prevalent local ceramics require that the sites be assigned to different regional manifestations of the Late Woodland stage.

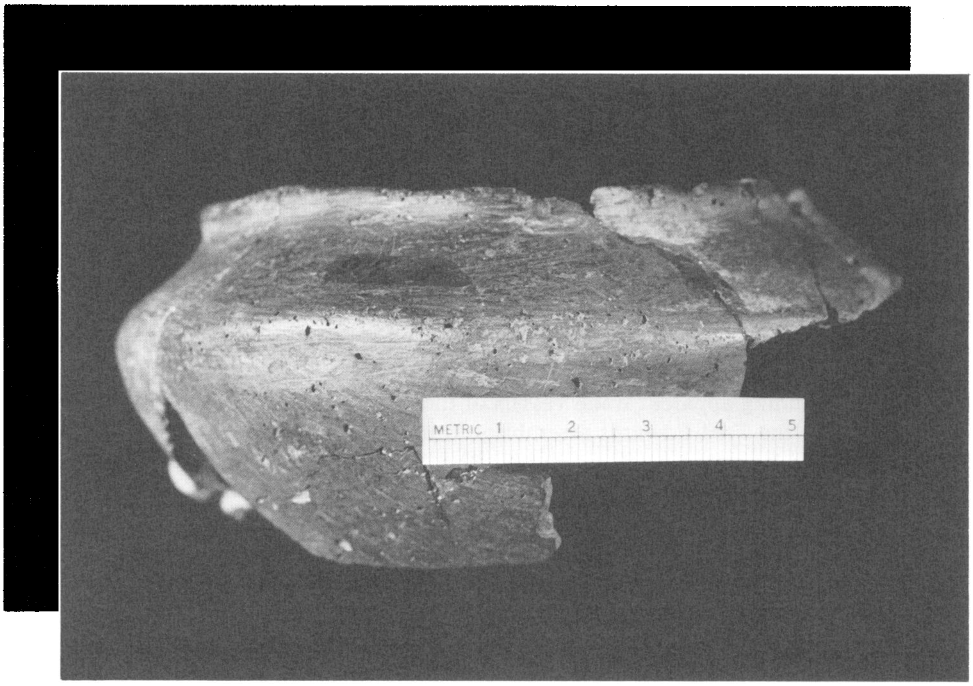
A suite of 18 radiocarbon dates is now available for the Fred Edwards site (Steventon and Kutzbach 1986, 1987, 1988, 1990). The range of these dates spans the interval from A.D. 800 ± 70 to A.D. 1300 ± 70 in radiocarbon years. Five of these dates can be rejected for a variety of site-specific reasons, leaving a cluster of 13 dates that overlap comfortably with the A.D. 1050–1150 interval that is the generally accepted age of the Stirling phase at Cahokia. Clear and consistent archaeological evidence for the single-component character of the Fred Edwards site combined with the presence of the Stirling phase marker types, Powell Plain and Ramey Incised, strongly supports the conclusion that A.D. 1050–1150 is the most reasonable estimate of the site's age in radiocarbon years.

The compatibility of the Fred Edwards evidence with the generally accepted sequence at Cahokia was satisfying, though not unexpected, but, as the ceramic analysis progressed, the recognition of a few stylistically Hartley-like pottery types in the Fred Edwards assemblage came as a surprise. A direct comparison of the Fred Edwards sherds with the type collection of Hartley Fort ceramics in Iowa City revealed the suspected stylistic similarities to be striking indeed, reinforcing the view that direct culture contact may have occurred between the two sites. Since Hartley ceramics had not previously been recognized beyond the type site, this seemed like an ideal situation for the application of petrographic analysis to the problem of culture contact. Moreover, the issue of culture contact was doubly interesting in light of the apparent discrepancy in the radiocarbon assays from the two sites.

SAMPLE SELECTION

In order to address the problem of cultural interaction between Hartley Fort and Fred Edwards through the technique of ceramic petrography, representative sherds from each of the sites were required for thin sectioning. With the cooperation of Joseph Tiffany, then acting state archaeologist of Iowa, I was allowed to select a sample of 10 vessels from the Hartley Fort ceramic assemblage for thin-section analysis. Examples of each of the four main types that make up the Hartley Fort ceramic assemblage were selected as follows: three French Creek Cord Impressed, three Hartley Cross-Hatched, two Hartley Plain, and one Hartley Tool-Impressed (See Tiffany [1982] for descriptions of each of these types). In addition to these nine local vessels a sherd from a classic Powell Plain vessel recovered at the site was included in the analysis (Figure 1). Of the 10 vessels selected, all except three are illustrated in Tiffany (1982). Using figure numbers from Tiffany's article (1982: 138, 141, and 143), the following seven vessels are included in the thin-section analysis: Figure 6A, B, F, G; Figure 8B, G; and Figure 10E.

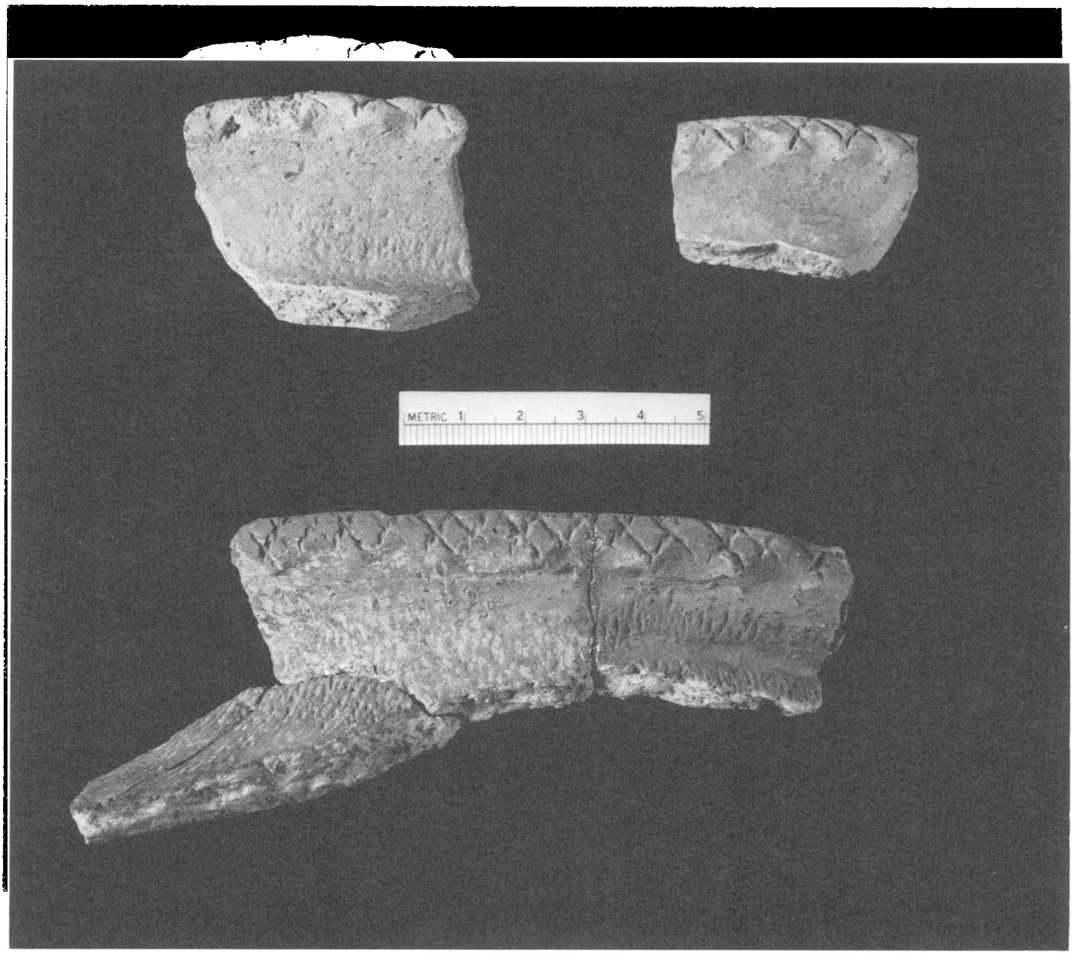
From a total of 331 ceramic vessels currently recorded for the Fred Edwards site, 10 were suspected



of being Hartley types on stylistic grounds. Five of these vessels were thin sectioned. Based on stylistic considerations, these vessels were assigned one each to the following five types: Hartley Cross-Hatched, Hartley Tool-Impressed, Hartley Plain, Mitchell Modified Lip (a minority type at Hartley Fort), and untyped incised-over-cordmarked (see Tiffany 1982:Figure 11R). Figure 2 compares two Hartley Cross-Hatched vessels from the type site with an analogous vessel from Fred Edwards.

For comparative purposes, an additional 27 ceramic vessels from the Fred Edwards site were included in the thin-section analysis. Twelve of these vessels were assigned to a newly defined Grant ceramic series and include the following types: Grant Cord-Impressed (3), Grant Filleted/Collared (2), Grant Cordmarked (5), and Grant Plain (2). These grit-tempered jars are presumed to be of local manufacture. Also presumed to be of local manufacture are undecorated jars with paste properties similar to those of the Grant series but with Powell/Ramey-like vessel forms. These apparently hybrid ("Woodissippian") vessels have been assigned to a new ceramic type, Potosi Plain, 4 of which are included in the thin-section analysis. Finally, 11 shell-tempered vessels complete the inventory of Fred Edwards vessels subjected to thin-section analysis. Representative examples of the main Late Woodland and Mississippian types from Fred Edwards are shown in Figures 3–5.

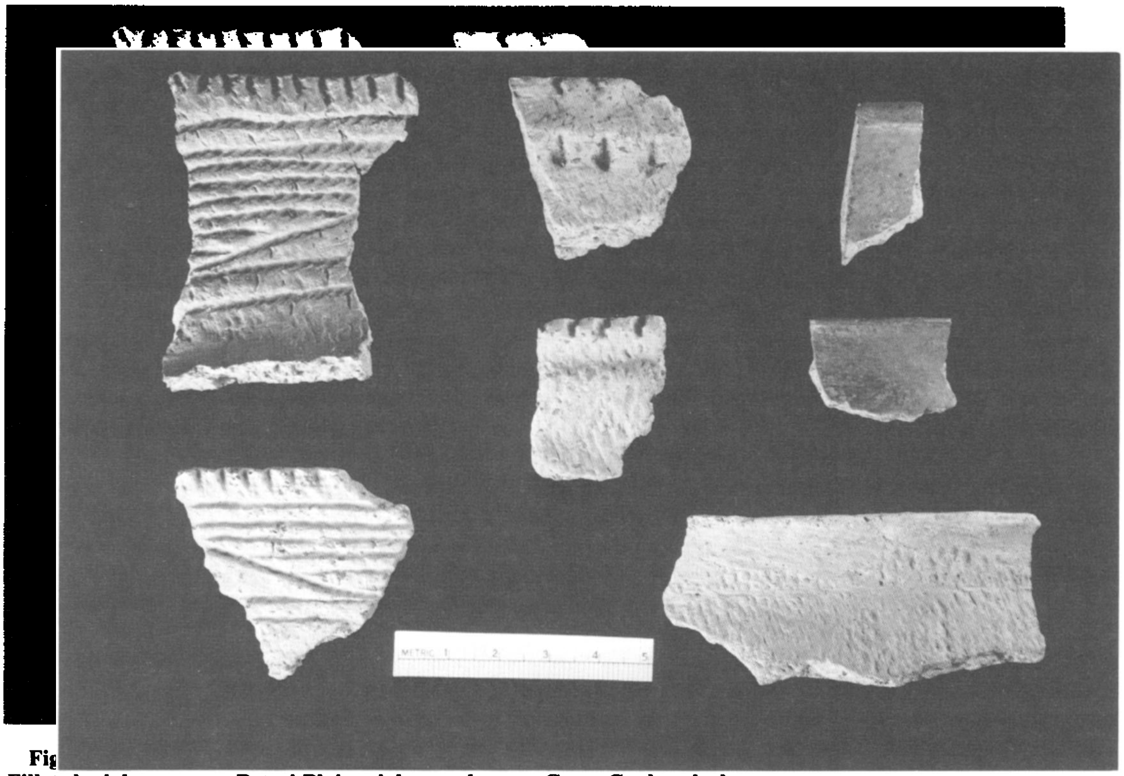
In sum, a total of 42 vessels—10 from Hartley Fort and 32 from Fred Edwards—was included in this analysis. The selection of this sample was guided by two pragmatic considerations. First, because thin-section preparation requires the destruction of a portion and sometimes all of a sherd, only certain vessels in any assemblage are suitable or available for such analysis. Vessels represented only by one or a few small sherds, as well as unique or rare vessel types, typically are placed "off limits" to thin-section analysis by collection custodians. Second, since only a portion of any ceramic assemblage is normally available for thin sectioning, it is unlikely that a formal random-sampling scheme could yield a representative sample of the total assemblage. In light of these realities the sherds used in this analysis were selected on the basis of careful visual inspection of those that were available for thin sectioning, but with special care taken to ensure that the full range of variation in the total assemblage was represented in the sample.



METHODS

Following the same basic procedures described in an earlier paper (Stoltman 1989), each thin section was subjected to a two-step analysis. The first, or qualitative, step involved getting acquainted with the thin section, observing the mineral inclusions, and compiling a list of those that were natural as opposed to those that had been introduced as temper. The second, or quantitative, step consisted of a point-count analysis, which involved the use of a 1-mm counting interval over the entire area of the thin section. If fewer than 100 "good" points (i.e., exclusive of voids) were counted, the thin section was rotated 180° on the microscope stage and was counted a second time. In this way between 100 and 350 nonvoid points were counted for each slide. To ensure maximum objectivity thin sections were point counted in groups of mixed types with the results for individual thin sections tabulated only after the entire group had been completed. In this way the analyst could have no prior knowledge of what results were expected for any thin section, and any inadvertent tendencies to homogenize a data set thereby were prevented.

The use of a 1-mm counting interval appears to be an effective compromise among a number of considerations, including sound sampling procedure, precision of analysis, and labor intensiveness of the analysis (Stoltman 1989:148–150). It has the added virtue of allowing a single procedure to be used simultaneously for counting individual grains as well as for estimating volumes. Because the size distribution of mineral inclusions in a thin section requires the measurement of *individual*



Fi[illegible]
Filleted; ***right two, top***, **Potosi Plain;** ***right one, bottom***, **Grant Cordmarked.**

grains, whereas the proportion of silt, sand, and temper is a volumetric parameter that can be estimated on the basis of the *area* of a thin section occupied by specific minerals (i.e., the Delesse relation), separate sampling procedures normally would be required for each. This problem is alleviated by the simple expedient of using a large enough sampling interval to minimize the incidence of individual grains being counted more than once while at the same time recording all instances of multiple counts on single grains. The 1 mm interval has proved to be especially satisfactory for point counting pottery because it yields a total count in excess of 100 points for most thin sections (large enough to ensure a good chance of representativeness), while at the same time resulting in few enough multicount grains, even in coarse-grained thin sections, to allow one to tabulate them reliably. It is essential to keep track of all multicount grains because all points falling on mineral grains are counted equally for volumetric estimates; whereas, for grain-size estimates, all counts over one on any grain must be excluded. Thus, in this way it is possible to provide reliable estimates of both the grain sizes and volumetric percentages of mineral inclusions in a single point-counting procedure.

At each of the points counted during the quantitative analysis the observations made were assigned to one of the following mutually exclusive categories: clay matrix, silt, sand, temper, or void. The silt and sand categories in this case apply not only to size classes (the boundary between silt and sand is .0625 mm), but also denote natural inclusions in contrast to temper, which is an intentional human additive. Where more than one kind of temper is present, or when particular silt or sand minerals are suspected of being diagnostic, individual minerals or rocks can be tabulated under any of the appropriate categories during this stage of the analysis. Finally, each mineral grain identified as sand or temper is assigned to one of the following size classes in an ordinal scale based on measurement of maximum grain diameter: 1 = fine (.0625–.249 mm); 2 = medium (.25–.499 mm); 3 = coarse (.50–.99 mm); 4 = very coarse (1.0–1.99 mm); 5 = gravel (> 2.0 mm).

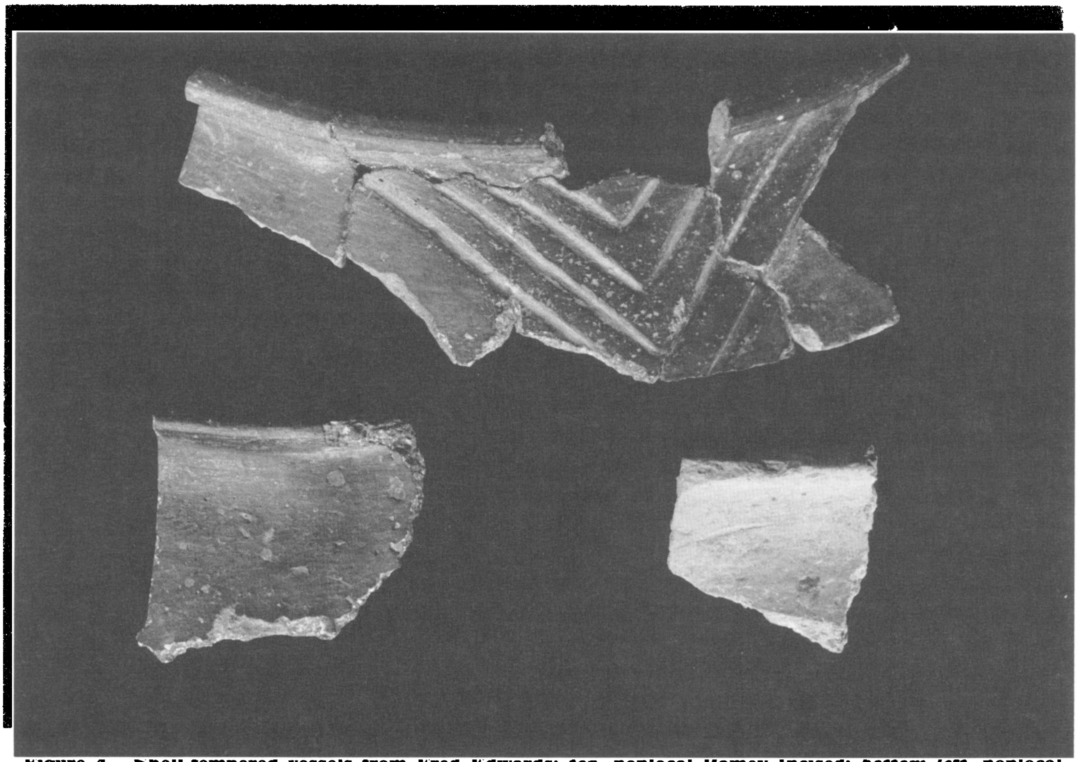
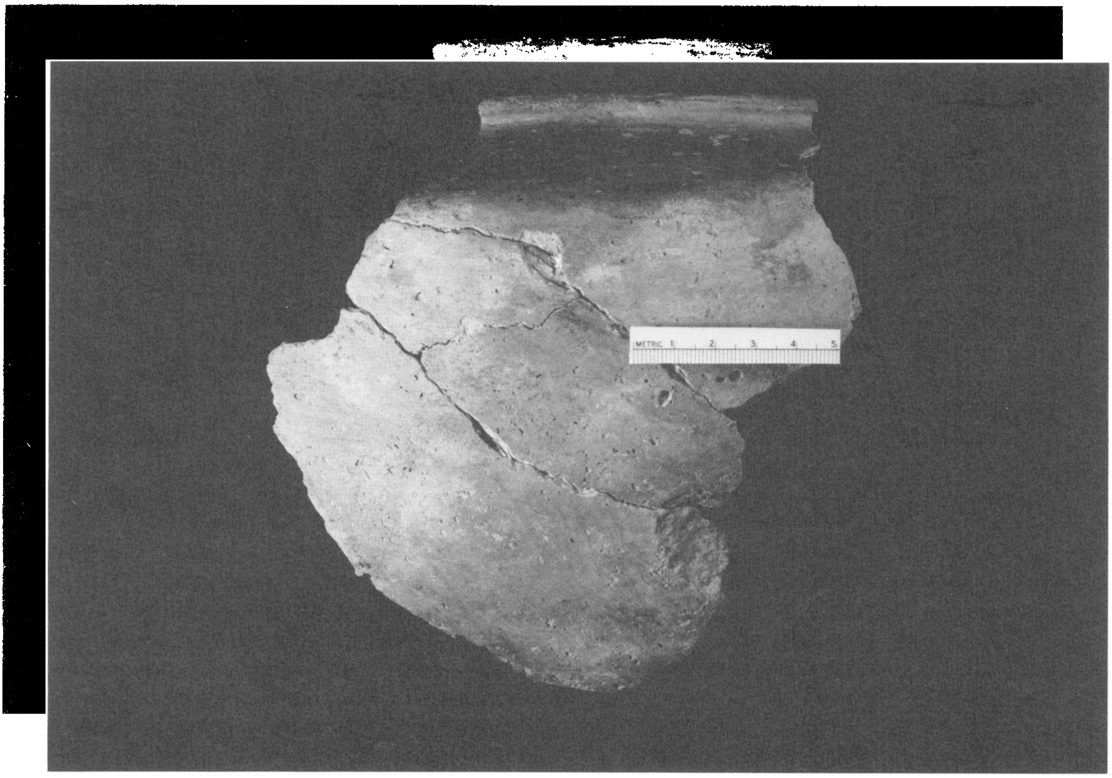


Figure 4. Shell-tempered vessels from Fred Edwards: *top*, nonlocal Ramey Incised; *bottom left*, nonlocal Powell Plain; *bottom right*, local Powell Plain-like.

A grain-size index of from 1 to 5 then can be computed easily for sand and temper for each thin section. Silt is not included in this scale because its small size makes objective discrimination between natural and humanly added inclusions difficult. As a convenient expediency, all silt-size particles are assumed to be natural inclusions and are so tabulated independent of the size scales for sand and temper. It also should be noted, however, that for certain distinctive tempers, for example shell or gabbro, it is sometimes possible to identify reliably some temper grains in the silt size range. In instances where this occurs, the silt grains are recorded as temper and incorporated into the size scale with a value of 1.

The data resulting from these procedures then can be used to characterize each thin section in terms of four basic properties: (1) kind of temper, (2) temper size, (3) temper amount, and (4) paste, i.e., relative proportions of natural inclusions excluding temper. While the first is inherently qualitative in nature, the remaining three are quantitative. The latter thus have the added virtue of being amenable both to objective presentation by the analyst and to critical evaluation by the reader. Once these data have been generated, the manner of their presentation is a matter of choice. However these data are presented, their relevance to a wide range of archaeological problems, including production, distribution, exchange, and classification of pottery, and the fact that they are not easily obtainable by any other single method, should constitute clear confirmation of the vitality and efficacy of ceramic petrography.

In presenting the quantitative data derived from the point- count analyses a basic distinction between body and paste will be used. *Body* is defined here as the bulk composition of a ceramic vessel, including clays, larger natural mineral inclusions in the silt, sand, and gravel size ranges, and temper. Precedents for this usage of the term may be found in Shepard (1936:394, 1954:155) and Rye (1976:109, 1981:18). The term fabric also commonly is used in this way and may be considered a synonym (e.g., Peacock 1968; Whitbread 1989). In contrast, the term *paste* is reserved for the



aggregate of natural materials, i.e., clays and larger mineral inclusions, to which temper was later added to produce the body from which a vessel was made. Since most naturally occurring, clay-rich sediments from which pottery vessels are made almost never are composed purely of clay—variable amounts of silt and sand are usually present as well—the term clay is technically inappropriate for such sediments.

The distinction between body and paste is important because it gives explicit recognition to the fact that temper, the primary discriminator of body, and paste normally have independent origins. For maximum precision and power, provenience studies of ceramics must be conceptualized as a dual problem involving source determination of temper *and* paste. It is in this regard that most elemental analyses fail to live up to their full potential, for they generally attempt to ascertain ceramic provenience through analysis of a mixture of the two, i.e., body, which yields a mixed signal as to source (e.g., Arnold et al. 1978; Bishop et al. 1982; Rice 1978; Wilson 1978).

Because the distinction between temper and natural silt and sand is critical if body is to be distinguished from paste petrographically, some words of explanation concerning how this distinction is to be made are in order. For those unfamiliar with petrographic analysis, it should be emphasized that clay-size minerals cannot be discriminated individually under the petrographic microscope. Indeed, it is because of this important constraint that ceramic petrographers have focused their attention primarily on temper. But, the insensitivity of petrographic analysis to clay-mineral identification does not mean that all pastes are therefore indistinguishable. As already stressed, most clay-rich sediments also contain varying amounts of silt and sand, sometimes even gravel, and these particles *are* identifiable petrographically. In other words it is potentially possible to discriminate different clay-rich sediments used in ceramic manufacture on the basis of the relative proportions of silt and sand that occur as natural inclusions. This, of course, requires the analyst to distinguish these natural inclusions from temper, something rarely encountered in the archaeological literature. Important exceptions are Porter (1963a, 1963b, 1963c, 1984) and Warren (1967), both of whom impressionistically identified different paste types on the basis of proportional differences in natural silt and sand. One of the goals of the present paper is to build on the pioneering efforts of Porter and Warren to distinguish different paste types on petrographic grounds independent of temper by proposing a technique for quantifying, and thus making more explicit, these observations.

A number of authors (e.g., Rye 1981:52; Shepard 1954:161–162) have suggested various criteria for distinguishing natural mineral inclusions from human additives in pottery. Yet these suggestions largely seem to be ignored, for it is commonplace in the archaeological literature to see petrographic analyses that treat as temper either all observed mineral inclusions or all mineral inclusions above a certain size and to ignore the remainder (e.g., Dickinson and Shutler 1974; Ferring and Perttula 1987; Garrett 1986; Lombard 1987; Rugge and Doyle 1980). While admitting that the discrimination of natural inclusions from temper is not always easy, it is, nonetheless, the contention of this paper that such distinctions commonly can be made objectively and that it behooves petrographers to attempt them as often as possible because of the added insights such distinctions can provide.

In order to distinguish objectively natural silt and sand from temper two steps are especially important. First, one must spend time inventorying the minerals that can be identified reliably as temper through their associations. This knowledge then can be used to distinguish those minerals that must be natural inclusions. For certain types of temper, for example, shell, grog, limestone, or volcanic glass, the identification of nontemper among the mineral inclusions is straightforward. In cases where grit temper is present, making this distinction is facilitated by the tendency for temper grains to be larger, polymineralic, and more angular than natural inclusions. Second, samples of various local clay-rich sediments should be collected and mounted on thin-section slides for comparative analysis with a site's ceramics. In this way the expectable range of natural inclusions normally can be ascertained objectively. Obviously judgement and a certain amount of subjectivity come into play in this portion of the analysis, but multiple counts of the same thin section at different times with closely similar results have convinced me that these discriminations can be made reliably most of the time.

In the discussion to follow, the point-count data pertaining to body and paste are presented in tabular form (Tables 1 and 2) as well as in separate ternary diagrams for each (Figures 6–9). The poles of the ternary diagram for body are labeled as follows: matrix (includes silt), temper, and sand (applies to all natural mineral inclusions larger than silt). The primary purpose of the body diagram is to provide a visual representation of the relative volumetric proportions of all mineral inclusions in each vessel, with particular emphasis on temper. Normally, only those vessels with the same kind of temper (e.g., grit, grog, shell, etc.) will be plotted on the same diagram. By contrast, the ternary diagram for paste is labeled as follows: matrix, silt (now separated from matrix), and sand. This diagram is intended to provide a visual representation of the relative volumetric proportions of the silt, sand, and clay in the untempered raw materials from which each vessel was manufactured. It is on this diagram that samples of natural clay-rich sediments most productively may be plotted for comparative purposes in considering paste sources. It should be noted that voids have been excluded from the computation of both the body and paste indices.

Returning now to the Fred Edwards/Hartley Fort comparative analysis, the basic problem is to ascertain whether or not the Hartley-like vessels recovered from the former site are in fact trade vessels from the latter or merely stylistically similar, local products. The assessment of this problem will begin with a discussion of the petrographic data pertaining to both body and paste for the 16 Late Woodland ceramic vessels from the Fred Edwards site that are presumed to be of local manufacture. Confirmation of the local origin for these vessels also will be sought through a paste comparison with local soil samples. Next, the body and paste properties of the nine Late Woodland vessels from Hartley Fort will be contrasted with those of the Fred Edwards sample. Third, the five Hartley-like vessels from Fred Edwards will be evaluated under the supposition that the probabilities of their nonlocal origin are high if they (a) are homogeneous as a group and (b) differ from the remainder of the Fred Edwards vessels in body and paste properties. If, besides being different from the other Fred Edwards vessels, they are simultaneously similar to the Hartley Fort sample, the hypothesis of a Hartley Fort derivation is accepted as the most credible.Finally, in light of these

Table 1. Ranges, Means, and Standard Deviations for Body Values for the 41 Vessels Analyzed.

	% Matrix	% Temper	% Sand	Temper Size Index
Fred Edwards, Late Woodland				
Range (n = 16)	72–91	8–27	0–4	2.5–4.2
Mean (n = 16)	80 ± 4.6	18 ± 4.6	2 ± 1.2	3.2 ± .5
Fred Edwards, local shell tempered				
Range (n = 6)	81–93	5–18	0–4	2.9–4.4
Mean (n = 6)	88 ± 4.5	11 ± 5.0	1 ± 1.4	3.5 ± .5
Fred Edwards, exotic shell tempered				
Range (n = 5)	66–78	22–34	0	1.6–2.5
Mean (n = 5)	72 ± 4.8	28 ± 4.8	0	2.2 ± .4
Fred Edwards, Hartley like				
Range (n = 5)	77–90	4–11	6–16	3.0–4.0
Mean (n = 5)	81 ± 5.4	8 ± 3.5	11 ± 4.6	3.4 ± .5
Hartley Fort, Late Woodland				
Range (n = 9)	75–90	1–13	6–17	2.7–3.9
Mean (n = 9)	82 ± 5.0	7 ± 3.3	11 ± 3.3	3.3 ± .4
Hartley Fort, Powell Plain (n = 1)	69	30	1	2.4

comparisons, the shell-tempered vessels from both sites will be evaluated for evidence of their local as opposed to nonlocal derivation. These latter data raise the interesting possibility that petrographic analysis can distinguish local from nonlocal vessels within what otherwise appears to be a unitary type.

RESULTS

The point-count data strongly suggest that the 16 Late Woodland vessels from the Fred Edwards site are, indeed, all of local manufacture. In the first instance, on the basis of both body and paste properties, they constitute discreet and homogeneous groupings in contrast with the Hartley-like vessels from the same site as well as with the Late Woodland vessels from the Hartley Fort site (Tables 1 and 2 and Figures 6 and 7). Much more convincing than group homogeneity, however, is the observed similarity between the soil sample collected from the B horizon of the loess that blankets the terrace on top of which the Fred Edwards site is situated and the paste values for the 16 vessels (Figure 7). Indeed, as can be seen from Table 2, the mean of the paste values for the 16 Late Woodland vessels from Fred Edwards is identical to the paste of the subsoil sample from the

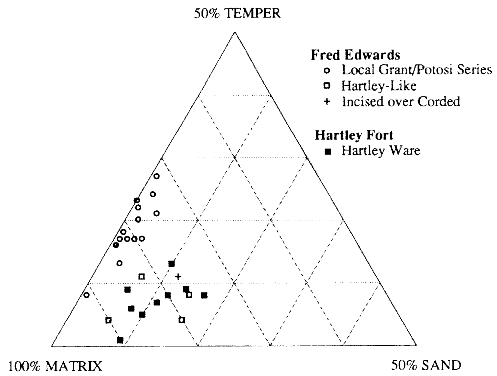


Figure 6. Ternary diagram for body: Late Woodland vessels from Fred Edwards and Hartley Fort.

Table 2. Ranges, Means, and Standard Deviations for Paste Values for the 41 Vessels Plus Two Raw Clays Analyzed.

	% Matrix	% Silt	% Sand	Sand Size Index
Fred Edwards, Late Woodland				
Range (n = 16)	73–86	13–23	0–5	0–2.0
Mean (n = 16)	80 ± 3.7	18 ± 3.2	2 ± 1.3	1.1 ± .5
Fred Edwards, local shell tempered				
Range (n = 6)	76–88	8–23	0–4	0–2.0
Mean (n = 6)	83 ± 4.4	15 ± 5.2	2 ± 1.4	1.1 ± .6
Fred Edwards, exotic shell tempered				
Range (n = 5)	95–98	2–5	0	0
Mean (n = 5)	97 ± 1.3	3 ± 1.3	0	0
Fred Edwards, Hartley like				
Range (n = 5)	66–81	13–18	6–17	1.2–2.6
Mean (n = 5)	73 ± 7.5	15 ± 2.3	12 ± 4.9	2.0 ± .6
Hartley Fort, Late Woodland				
Range (n = 9)	69–85	4–15	7–19	1.4–2.3
Mean (n = 9)	77 ± 5.4	11 ± 4.1	12 ± 3.8	2.0 ± .3
Hartley Fort, Powell Plain (n = 1)	92	7	1	1.0
Fred Edwards subsoil (n = 1)	80	18	2	1.2
Grant River alluvium (n = 1)	57	29	14	1.6

site—80 percent matrix, 18 percent silt, and 2 percent sand. There is thus every reason to believe that these vessels were manufactured locally at the Fred Edwards site.

The primary temper added to these vessels was hematite, which occurs as a natural concretion in the local sandstone bedrock. Substantial numbers of these concretions were recovered at the site during excavation. Fourteen of the 16 vessels have hematite temper, while the remaining two were tempered with granite. There is no patterned covariation between ceramic types and temper properties to suggest that functional differences contributed to the observed variation within the local Fred Edwards Late Woodland ceramics. As can be seen from Table 1 and Figure 6, the amount of temper added ranges from 8 to 27 percent, with 14 of the vessels having from 16 to 27 percent temper. None of the Hartley Fort vessels, or the Hartley-like vessels from Fred Edwards, overlap with these values. This combined with the low percentage of sand (an average of 2 percent), which is generally fine in texture (a mean size index of 1.1), appear to be the salient properties of the local Fred Edwards vessels.

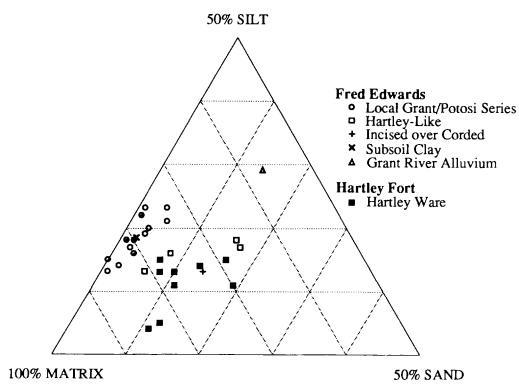


Figure 7. Ternary diagram for paste: Late Woodland vessels from Fred Edwards and Hartley Fort.

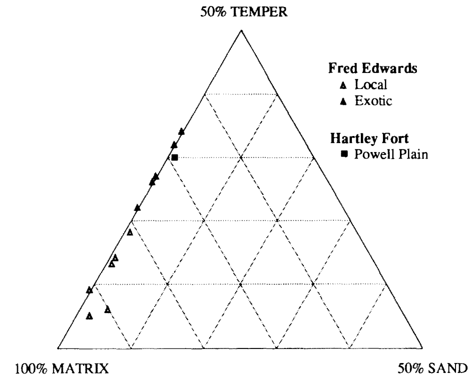


Figure 8. Ternary diagram for body: Shell-tempered (Mississippian) vessels from Fred Edwards and Hartley Fort.

As can be seen from Tables 1 and 2 and the mutually exclusive distributions on Figures 6 and 7, the 9 Late Woodland vessels from Hartley Fort are distinctly different from the 16 Late Woodland vessels from Fred Edwards. The main differences between the 2 site samples involve the sandier pastes at Hartley Fort (a mean of 12 percent vs. only 2 percent for Fred Edwards) and the greater incidence of temper at Fred Edwards (a mean of 18 percent vs. 7 percent for Hartley Fort). Unfortunately, soil samples from Hartley Fort are not available to confirm the local origin of these vessels as was done for Fred Edwards. Lacking these data, the relative homogeneity of the Hartley Fort vessels in contrast to those from Fred Edwards will be accepted tentatively as confirming their local manufacture.

Two temper types are present in the Hartley Fort sample. Interestingly, as at Fred Edwards the preponderant temper used in five of the nine vessels was hematite. This is perhaps significant in that I have not witnessed the use of an opaque mineral for temper at any other sites in the Upper Mississippi Valley region except these two. The temper used in the remaining four vessels is a distinctive hornblende-rich metamorphic rock, an amphibolite of unknown derivation. As with the Late Woodland ceramics from Fred Edwards, no patterned covariation between ceramic types and any temper properties suggestive of differences in vessel function were observed within the Late Woodland sample at Hartley Fort.

Having identified the main petrographic criteria that distinguish the Late Woodland vessels at the two sites from one another, we are now in a position to evaluate the status of the five stylistically Hartley-like vessels recovered at the Fred Edwards site. (The unique incised-over-cordmarked vessel is identified separately on Figures 6 and 7 from the other four Hartley-like vessels because it is grog tempered.) Reference to Tables 1 and 2 and Figures 6 and 7 indicates clearly that in both paste and body these vessels are unlike the local Late Woodland vessels from the same site, while at the same time they closely resemble the Late Woodland vessels from Hartley Fort some 80 km away. Beside the unique grog-tempered, incised-over-cordmarked vessel, two of the Hartley-like vessels from Fred Edwards contained the same, distinctive amphibolite temper observed in the Hartley Fort sample, while one each has hematite and granite as temper. It is concluded from these data that the five Hartley-like vessels recovered at the Fred Edwards site are actual imports from Hartley Fort.

It will be recalled that the sample of 10 vessels from Hartley Fort selected for thin-section analysis contained one Mississippian vessel. This vessel, one of four Powell Plain jars recovered from the site (Tiffany 1982:Figure 10E; Figure 1), was selected in order to confirm its suspected nonlocal derivation insofar as this was possible through a comparative petrographic analysis with the local vessels from the site. Since shell-tempered vessels, including classic Powell Plain and Ramey Incised jars, also were present at the Fred Edwards site, it was decided to expand this portion of the analysis by including 11 of the Mississippian vessels from Fred Edwards. The results proved to be most interesting.

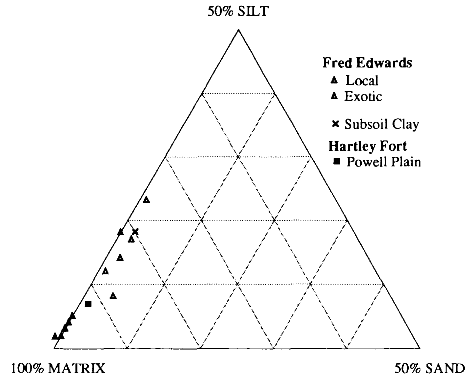


Figure 9. Ternary diagram for paste: Shell-tempered (Mississippian) vessels from Fred Edwards and Hartley Fort.

As expected, both the paste and body properties of the Powell Plain vessel are different from the local Late Woodland vessels from Hartley Fort, suggesting that this vessel is, indeed, of nonlocal origin (Figures 6–9). More significant, perhaps, is the evidence that in both paste and body properties, the Powell Plain vessel from Hartley Fort closely resembles a grouping of six of the 11 shell-tempered vessels from Fred Edwards (Figures 8 and 9). From this evidence, two plausible alternatives present themselves: (1) either this vessel was manufactured at Fred Edwards and transported somehow to Hartley Fort or (2) the six vessels from the two sites owe their origins to a common external source. Of these two alternatives, the latter is the most plausible.

Evidence for this latter conclusion is summarized in Figures 8 and 9. On these diagrams the 11 shell-tempered vessels from Fred Edwards have been identified as either local or exotic. This distinction was not immediately evident on stylistic grounds. Of these 11 vessels 9 were Powell/Ramey-like jars (selected to represent a wide range of macroscopic variation), one was a plain bowl, and one was a cordmarked jar. It was only after the petrographic analysis of these vessels had been concluded, however, that the observed variability in the sample became interpretable.

In both Figures 8 and 9 it can be seen that the two categories, local and exotic, have mutually exclusive distributions. On the one hand it can be seen from the body diagram (Figure 8) that all five Fred Edwards vessels identified as exotic have 22 percent or more shell temper, whereas the six local vessels (including both the bowl and the cordmarked jar) all have 18 percent or less shell temper. Taken alone, this evidence lacks force, but in conjunction with the paste evidence, it carries more weight. For, as can be seen on Figure 9, the same five "exotic" vessels cluster tightly in the lower left corner of the diagram. All have no sand and five percent or less silt in contrast to the "local" vessels, which possess only slightly more sand but significantly more silt—8–18 percent.

What is deemed most significant about these data is the close resemblance of the pastes of the six local vessels to the local subsoil sample that previously has been associated with Late Woodland pottery production at the site (Table 2; Figure 9). In other words the petrographic data suggest that some of the shell-tempered vessels recovered at the Fred Edwards site were manufactured locally, while others were made from different pastes, i.e., are potentially of nonlocal origin. Significantly, it is these "exotic" vessels from Fred Edwards that most closely resemble the Powell Plain vessel from Hartley Fort. Finally, further evidence for the nonlocal origin of the Powell Plain vessel from Hartley Fort and the five "exotic" vessels from Fred Edwards can be seen in the presence of exterior slips discernible in thin section only on these six vessels among the 42 vessels included in the analysis. From all of these data combined, then, it is postulated that (a) there was direct cultural interaction between the Fred Edwards and Hartley Fort sites *and* (b) the two sites were interacting with a common external source. All factors considered, this external source was most probably Cahokia or one of its satellites during the Stirling phase, but this, of course, remains to be confirmed.

We now may return to an issue raised earlier, namely, the anomalously early radiocarbon dates from Hartley Fort. The battery of 18 radiocarbon dates from Fred Edwards assigns the main period of site occupancy to the interval A.D. 1050–1150, precisely the estimated duration of the Stirling phase in the American Bottom. In light of the petrographic evidence that suggests direct cultural interaction between Fred Edwards and Hartley Fort, and between both sites and a common external source of Stirling phase affiliation, one can only conclude that the main periods of occupation at Fred Edwards and Hartley Fort were contemporary with each other and with the Stirling phase in the American Bottom. Accordingly, the central values of the two radiocarbon dates (or their mean) from Hartley Fort cannot be accepted at face value. A plausible explanation for the anomalously early mean ages of the two Hartley Fort dates is that the dated charcoal came from inner rather than outer rings of tree fragments, which would result in an overestimation of the actual age of occupation.

CONCLUSIONS

The main goals of this paper are twofold, one methodological and the other substantive. Methodologically, the paper amplifies and refines an approach to petrographic analysis of ceramics that had been introduced previously (Stoltman 1989). The utility of this method is then demonstrated by applying it to a substantive issue, a suspected case of cultural interaction among sites in the Upper Mississippi Valley region.

Contrary to most traditional petrographic analyses of ceramics, the method introduced in 1989 and refined herein attempts not only to generate quantitative data concerning size and amount of temper, but also to give quantitative expression to the clay-rich matrix that constitutes the major portion of any ceramic vessel. In order to accomplish this objective one must distinguish temper from nontemper among the mineral inclusions observable in most ceramic thin sections. It is then possible to characterize ceramics in terms of two independent properties—temper and natural inclusions—that are potentially sensitive indicators of such important cultural variables as technology, function, source, production, and exchange.

Although the distinction between temper and nontemper may not always be simple, it nonetheless is a distinction that must be made if the term temper is to have any analytical value (i.e., be more than a synonym for mineral inclusion). In this regard it is interesting to observe how this problem has been handled in the past. Basically, there are two approaches to the problem of temper/nontemper discrimination evident in the archaeological literature. The first involves making no distinction at all, at least not explicitly. In the majority of the literature where "temper" is identified confidently the topic is simply not discussed. This leaves the reader to his or her own devices to chose between two mutually exclusive alternatives: (a) either all visible mineral inclusions were considered temper or (b) the distinction between natural and artificial inclusions was made but not explained. The second approach involves the application of an arbitrary but consistent rule to distinguish the two. For example, in an analysis of southwestern ceramics Garrett (1986:124) considered all silt and very fine sand to be natural and analyzed only the larger mineral inclusions as temper.

In contrast, a third approach is advocated here. Rather than distinguishing temper from nontemper either tacitly or arbitrarily, the goal of this approach is to make the distinction as explicitly and objectively as possible. As discussed previously, this involves a two-step analysis of each thin section, the first qualitative and the second quantitative. Through this procedure the sizes and volumetric percentages of both the natural and artificial inclusions can be estimated with reasonable reliability for most ceramics. On this basis two important parameters of a ceramic vessel can be defined: body (bulk composition including temper) and paste (all natural inclusions excluding temper). The former reflects best the nature of the finished product that the manufacturers created and in this capacity should be a reliable gauge of technology, production, and function. Insofar as body properties are restricted in time and space, this parameter can be useful for investigating problems of production and exchange. The latter, by contrast, has its primary application in the domain of materials acquisition. As an index of raw materials used in ceramic manufacture, paste has the potential (along with, but independent of, temper) to discriminate local from nonlocal products and even, when combined with raw-materials analysis, to identify specific production sources.

The main value of the body/paste distinction is to encourage the independent investigation of what are patently independent properties of most ceramic artifacts while at the same time facilitating the expression of these properties in quantified and easily intelligible terms. In some instances true temper may not be present (e.g., self-tempered clays or clays that have been subjected to various refining methods to remove coarser inclusions—see Rye [1981:36–37]) or the temper may not be identifiable as such (some sand tempers). In such cases body cannot be identified reliably. These instances do not vitiate the method, but simply constitute inappropriate circumstances for its full application. The total mineral content of such artifacts still can be reported in a paste-like diagram indicating percentages of matrix, silt, and sand. Along with a sand size index, these bulk-composition data are still potentially of considerable relevance to a variety of archaeological issues.

In sum the method proposed here involves the observation and reporting of multiple variables for each ceramic thin section. Some of these variables are qualitative, for example temper type and types of natural inclusions. Other variables, for example, size and percentage of natural inclusions and size and percentage of temper, are quantitative. From these variables a number of indices can be constructed, for example, paste and body, to be employed for the graphic presentation and comparative analysis of the data in order to address a range of problems from taxonomy to cultural interaction. The utility of any observation or index is likely to vary with the specific data set and with the specific problem under investigation, but the variety of data generated and the explicitly quantitative character of many of them are strengths of this approach that hopefully will inspire further experimentation and refinement.

As a demonstration of the potential of this method, it was used to address the issue of suspected cultural interaction between two sites in the Upper Mississippi Valley region, Hartley Fort and Fred Edwards. This problem was formulated for investigation when a number of ceramic vessels stylistically similar to types previously known only from Hartley Fort were uncovered at Fred Edwards. Petrographic analysis of a series of Late Woodland vessels from Fred Edwards revealed group homogeneity in both body and paste, suggesting local manufacture. When the pastes of this group were compared to local subsoil sediments and shown to be virtually identical, it was accepted as confirmed that these vessels were indeed of local manufacture.

The next step was to compare the local Fred Edwards vessels with a sample of Late Woodland vessels from Hartley Fort. While some qualitative similarities were observed (notably hematite temper), the quantitative data revealed the two site samples to be discernibly different. These two data sets, then, comprised the context for a comparative analysis of five of the Hartley-like vessels from Fred Edwards. In both paste and body the Hartley-like vessels from Fred Edwards were shown to be not only distinctly different from the local vessels from the same site, but to resemble more closely the Hartley Fort sample over 80 km away. From these data, it was concluded that these Hartley-like vessels represent actual trade vessels from Hartley Fort.

A fortuitous decision—the inclusion of a Powell Plain vessel in the sample of sherds obtained from Hartley Fort for thin sectioning—led to an unanticipated expansion of the analysis. As expected, its paste and body properties were distinctively different from the remainder of the Hartley Fort sample, suggesting that it was of nonlocal derivation. Eleven shell-tempered vessels from the Fred Edwards site were then added to the analysis. The surprising results indicated that Mississippian vessels from Fred Edwards do not comprise a homogeneous grouping, but can be subdivided into two distinctly different classes based on their petrographic properties. The first class, despite its distinctive shell-tempered body, can be seen to have been manufactured from the same paste as the local Late Woodland vessels. By contrast, the second class not only differed from all other vessels from Fred Edwards in both paste and body, but closely resembled the Powell Plain vessel from Hartley Fort. All factors considered, it is unlikely that these latter vessels could have been manufactured at either site. It would appear, then, that not only were the two sites in direct contact with one another, but that they were also in interaction with a common third source affiliated with the Stirling phase at Cahokia. These data, in combination with the new radiocarbon evidence from Fred Edwards, have the further import of forcing a reconsideration of the extant radiocarbon dates from Hartley Fort, which, taken literally, clearly overestimate the site's primary period of occupancy.

Petrography is a venerable geological technique that is virtually unrivaled in its ability to provide reliable qualitative identification of mineral tempers in ceramics. It is hoped that this paper has demonstrated, along with Stoltman (1989), that the technique, far from having achieved its full potential, is still capable of further growth and refinement in the service of archaeology. In particular a major goal of this research is to demonstrate that ceramic petrography is capable of generating quantitative as well as qualitative data concerning not just tempers, but also ceramic pastes, that are valuable for addressing a wide range of archaeological problems.

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