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PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION
Cover Page

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NAME OF SUBMITTING ORGANIZATION TO WHICH AWARD SHOULD BE MADE (INCLUDE BRANCH/CAMPUS/OTHER COMPONENTS)

University of Arkansas--Fayetteville

ADDRESS OF ORGANIZATION (INCLUDE ZIP CODE)

Fayetteville, AR 72701

TITLE OF PROPOSED PROJECT Radiographic Analysis of Ceramic Technological Variation for the Absolute Dating of Archaeological Assemblages: Woodland Southern Ohio

REQUESTED AMOUNT	PROPOSED DURATION	DESIRED STARTING DATE
$37,384	13 months	July 1, 1985

PI/PD DEPARTMENT	PI/PD ORGANIZATION	PI/PD PHONE NO.
Anthropology	University of Arkansas--Fayetteville	501-575-2508

PI/PD NAME	SOCIAL SECURITY NO.*	SIGNATURE	MALE*	FEMALE*
Christopher Carr	342-40-2933	[redacted]	x	
ADDITIONAL PI/PD				
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PRINCIPAL INVESTIGATOR/ PROJECT DIRECTOR		AUTHORIZED ORGANIZATIONAL REP.		OTHER ENDORSEMENT (optional)	
NAME Christopher Carr		NAME		NAME	
SIGNATURE		SIGNATURE		SIGNATURE	
TITLE Assistant Professor		TITLE		TITLE	
DATE 12/20/84	TELEPHONE NO. Area Code: 501-442-3658	DATE	TELEPHONE NO. Area Code:	DATE	TELEPHONE NO. Area Code:

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Gender (M/F)	M				
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White, not of Hispanic origin	x				
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APPENDIX II

NOTICE OF RESEARCH PROJECT

SCIENCE INFORMATION EXCHANGE

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PROJECT SUMMARY

SIE PROJECT NO.
NSF AWARD NO.

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DIRECTORATE/DIVISION	PROGRAM OR SECTION	PROPOSAL NO.	F.Y.

NAME OF INSTITUTION (INCLUDE BRANCH/CAMPUS AND SCHOOL OR DIVISION)

University of Arkansas--Fayetteville

ADDRESS (INCLUDE DEPARTMENT)

Department of Anthropology
University of Arkansas
Fayetteville, AR 72701

PRINCIPAL INVESTIGATOR(S)

Christopher Carr

TITLE OF PROJECT Radiographic Analysis of Ceramic Technological Variation for the Absolute Dating of Archaeological Assemblages: Woodland Southern Ohio.

TECHNICAL ABSTRACT (LIMIT TO 22 PICA OR 18 ELITE TYPEWRITTEN LINES)

The Woodland archaeological record of southern Ohio (1000 B.C - A.D. 1200), including the Hopewell formative cultural development, has great potential for providing insight into a variety of theoretically important topics. This potential can not be exploited for lack of fine chronometric control over the archaeological record. To amend this situation, a means for dating the relevant archaeological assemblages (or proveniences within them) on an absolute, continuous time scale is proposed. The method involves developing regression models that predict date from several technological attributes of cooking vessels found in the assemblages (wall thickness, quantity and size distribution of temper particles). These attributes were altered systematically by potters over time in response to changing subsistence practices and changing performance requirements of the vessels. Building the models will require using industrial radiographic methods to document temper characteristics of select vessels and sherds, dating of select carbon material associated with them, and thermoluminescence dating of vessels. Once built, the models will provide a way to date proveniences/assemblages in southern Ohio that is much less expensive and more accurate on the average than C-14 methods, and also is applicable to the great store of archaeological materials excavated prior to the C-14 era and without associated carbon. Preliminary analyses show much promise for the approach. Requested NSF support will be augmented by minimally 64% matching funding.

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NSF FORM 4 (8-80)

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PROJECT DESCRIPTION

GENERAL BACKGROUND

Chronometric Requirements for the Development of Theory in Archaeology

Since the 1950s, many American archaeologists have aimed their research beyond the goal of reconstructing past lifeways (e.g., Taylor 1948; Chang 1967:231-232), toward the building and testing of anthropological or broader systems-evolutionary theory about the nature of human behavior, culture, or ecosystems (Binford 1962; Clark 1968; Flannery 1972; Jochim 1981). A variety of paradigms have structured this research: cultural ecology (Steward 1955; Sanders 1956, 1962), behavioral ecology (Rappaport 1979; Ford 1977; Braun and Plog 1982), emic and etic microeconomic approaches (Jochim 1976; Keene 1981; Reidhead 1981; Winterhalder and Smith 1981; Limp and Carr 1985), actor-based cognitive approaches (Quinn 1975; McC Netting 1972; Strong 1984), Marxist anthropology (Meillassoux 1972; Bloch 1978; Keene 1983; Root 1983), and symbolic structural approaches (Hodder 1982a, 1982b, Kus 1979). These frameworks differ in their units of study. They also view different phenomena along the structure/process-content/meaning continuum as relevant for study and as sources of unit stability, change, or explanation. Integration of many of these approaches is possible within a larger etic framework concerned with a hierarchy of processes, organizations, and contents/events, and the relationships among them at different hierarchical levels (e.g., Rapport and Turner 1977; Orlove 1980; Boulding 1981; McC Netting 1972; Bronitzky 1983), providing a more wholistic framework for explanation.

Explanation in these different frameworks involves one or more of four kinds of phenomena that span the structure/process-content/meaning continuum: (1) <u>regulatory structures</u> (whether they be, e.g., ecosystemic regulators or grammars for conveying meaning); (2) detailed <u>processes</u> by which structures are maintained or changed over time; (3) <u>adaptive milieu</u> that define, promote, or discourage processes by the constraints they set, and (4) sets of alternative <u>unique events</u> that can trigger processes (modified from Flannery 1972).

Archaeological study of any of these four classes of phenomena, in requiring their reconstruction from artifacts, ecofacts, and relationships among them, presupposes the adequate dating of materials (Dean 1978:223). The adequacy of a temporal framework for a set of materials can vary with the <u>nature</u> and <u>scale</u> of the phenomena being studied and issues being addressed (Chang 1967; Michaels 1973:10) and the <u>rate of change</u> of the components of the cultural-environmental system of which the phenomena are a part (e.g., compare Thomas 1973 or Kvamme 1985 to Plog 1978, Deetz and Dethlefsen 1965, or Goldstein 1981).

Whereas studies of static structural relations can sometimes be accomplished with imprecise temporal control, studies of dynamics concerned with processes, triggering events, and adaptive milieu by definition require as fine-staged or continuous a temporal framework as possible to track changes over time. This position has been argued and demonstrated by F. Plog (1973, 1977, 1979) and Braun (1977) in regard to investigating evolutionary processes for cultural-environmental systems, and implied by Greber (1976, 1979) in regard to studying maintenance processes. When adequate chronometric control is lacking in studies of this kind, archaeological inference and explanation may be severely restricted or biased. (1) At best, inadequate dating limits the archaeologist to describing and analyzing the results of cultural system maintenance or change rather than the detailed processes of maintenance or change and triggering events. (2) It also can constrain the scope of research and explanation to simple <u>correlations</u> between average social or natural environmental conditions and generalized system structure within broad time periods. This can encourage teleological, functionalist "explanations" of change (Orlove 1980) rather than more wholistic constructs concerned with the relations between structure, process, triggering event, and adaptive milieu. (3) It focuses attention on long-term, global, average environmental conditions as opposed to short term, local environmental variations and unpredictable risks, whereas both average and variable conditions determine system maintenance and change (Winterhalder 1980; Slobodkin and Rapoport 1974; Keene 1983, 1985; Pianka 1978; Ashby 1956). (4) At worst, inadequate dating encourages the anxious archaeologist to make unjustifiable simplifying assumptions in order to proceed with processual analysis. This has been combatted by Greber (1976, 1979), for example, in regard to several Middle Woodland studies (e.g., Struever and Houart 1972; Seeman 1977, his global factor analysis particularly). The simplifying assumptions can include: the precise contemporaneity of assemblages, the similar lengths of occupation of sites, and the stability of cultural structure, organization, and content within large blocks of time. These assumptions, if wrong, bias processual analysis, unfortunately in ways that are not easy to assess without a fine-scale temporal framework.

In sum, fine chronometric control is essential for archaeological research within a diversity of theoretical frameworks, and to the sound development of anthropological and broader systems theory.

The Potential of Ohio Woodland Archaeology and Its Dating Problem

One region and time period in the prehistory of North America that is particularly attractive for formulating and testing anthropological and systems theory is southern Ohio during the Woodland period (ca. 1000 B.C. - A.D. 1200; Fig. 1). The area is environmentally dynamic. It includes the eastern-most reaches of the Prairie Peninsula, which has fluctuated in expanse and with sensitivity to relatively minor climatic variations (Brown 1965; McMillan and Klippel 1977). It also includes the ecotone between the glacial Till Plain physiographic province and the Appalacian Plateau. Culturally, Woodland southern Ohio encompasses the Scioto-Hopewell--one of several early "formative florescences" in the eastern U.S. (others include the Poverty Point and Weeden Island complexes). The evolution, structure, and terminal transformation of these suggest many problem domains.

Some topics of theoretical importance that currently are being investigated or that have analytic potential for Woodland southern Ohio include the following:

(1) the regulatory structure of regional exchange systems in relation to local supply, demand, and population density factors (Greber 1976, 1982);

(2) the nature and social implications of valuables exchange (Flannery 1974; Luedke 1976; Griffin 1973; Walthal 1979, 1980; Goad 1978, 1979; Spence in Brose and Greber 1979:252-253; Reichs 1975);

(3) the economic and social regulatory roles of multicentric economic organization (Bohannan 1955; Vayda 1958; Ford 1974);

(4) social boundary maintenance, networks of cooperation, and their artifactual symbolization (Hodder 1982a; Carr and Hinkle 1983, 1984; current studies by Carr, King, Greber, and Ruhl);

(5) the role of ritual and belief in the formation and maintenance of regional networks of cooperation and alliance (McC Netting 1974; Carr 1982; Brown 1982; Hinkle 1984; Fischer 1974:54-56);

(6) the role of ritual and belief in the development of multigenerational offices of leadership (McC Netting 1974; Carr 1982; Strong 1984);

(7) microlocal variability in social structure (Greber 1979, 1984; Smart 1984; Konigsberg 1984) and its determinants;

(8) the structural instability of formative social hierarchies (Sahlins 1968:86-95; Leach 1954; Carr 1984); and

(9) symbolic and cosmological systems of meaning (Hall 1979; Greber 1984), their structure, transformation, and role in social function and ritual.

In addition, the environmental diversity of southern Ohio offers a ripe opportunity for studying local variation in subsistence, settlement, and demographic changes (Fischer 1974; Black 1979; Prufer 1975; Shane and Murphy 1975) in response to agricultural and technological (bow and arrow) innovations and climatic variation (Griffin 1960; Brown 1977:171; Ford 1974; Baerris et al 1976), though these topics remain inadequately investigated.

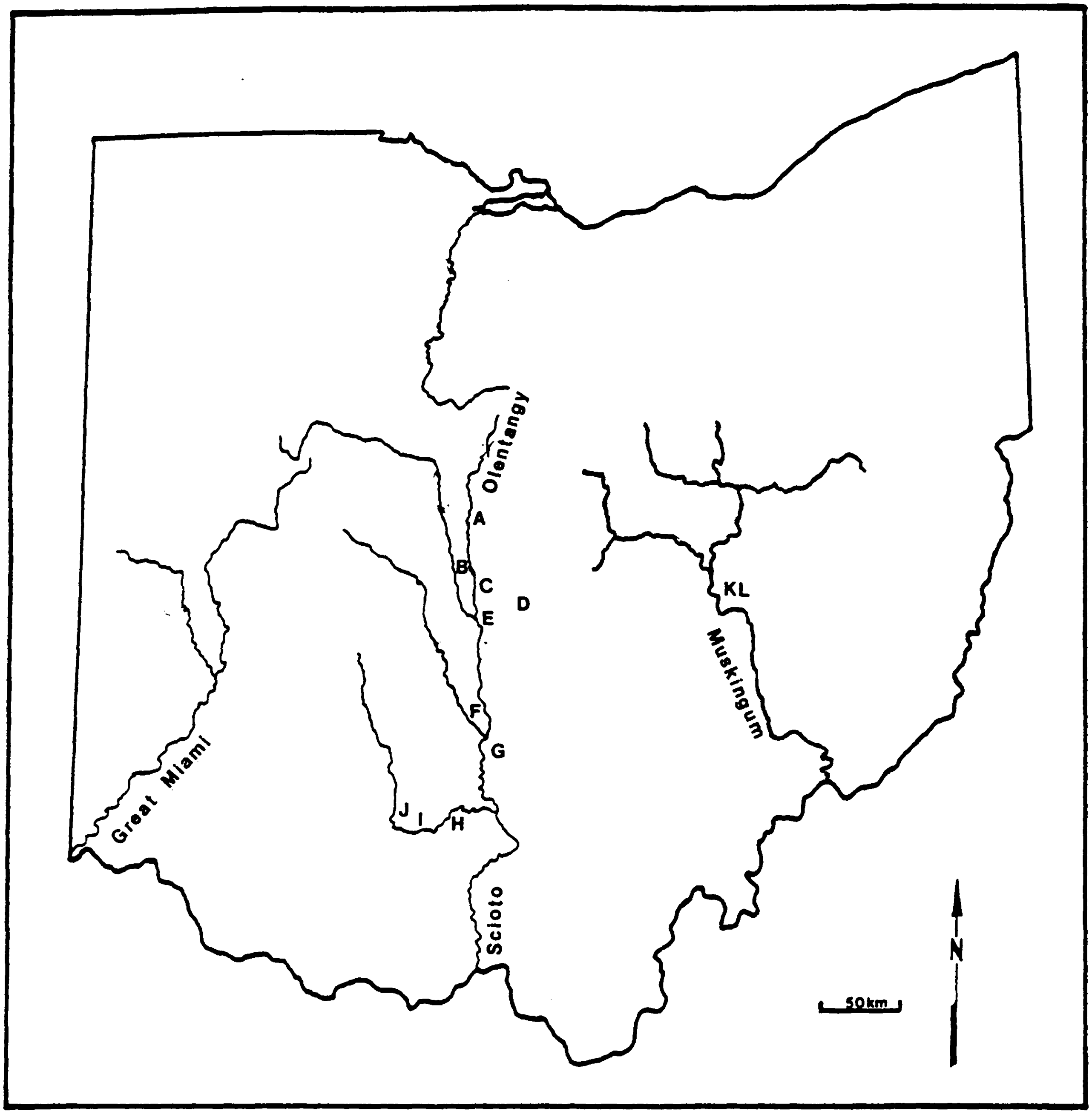

Fig. 1. The research area--southern Ohio--with selected sites mentioned in this proposal. (A) W. S. Cole. (B) Decco. (C) Dominion Land Company. (D) Davis mound. (E) Zencor. (F) Water Plant (G) Florence mound. (H) Baum. (I) Seip. (J) Holmes mound. (K) Philo I. (L) Philo II.

Dating Problem. Despite the rich opportunity that the southern Ohio Woodland offers for investigating regulatory structures, processes, events, and adaptive milieu, such studies have been discouraged or stymied, have had to involve gross simplifying assumptions (see references above), and/or are potentially biased by the lack of a fine chronological framework for this area. The general chronological placement of Ohio Woodland artifact types and assemblages has been established through a number of studies over the past forty years (Griffin 1943, 1945, 1958; Webb and Baby 1957; Dragoo 1963; Potter 1966; Ford 1969; Prufer and McKenzie 1975; Murphy 1975; Clay 1980; 1984; Morton 1984), although there is still disagreement over the position of some Late Woodland time-space units at even this gross level (see Baby and Potter 1965 vs. Seeman 1980 and Barkes 1981; Murphy 1975:231-238). Using this framework, it is impossible to assign most Woodland components of archaeological sites in southern Ohio to periods more specific than 300 to 600 year blocks of time (Seeman 1980:14). Much improvement is required to reach the level of specificity necessary to successfully investigate anthropological problem domains of the kind cited above (cf. Greber 1977:152).

The lack of a fine chronological framework for analyzing Ohio Woodland cultural-environmental systems derives from three circumstances. (1) Most archaeological reconnaissance in this area was undertaken prior to carbon-14 dating, during the late 19th and early 20th centuries (e.g., Putnam 1885; Thomas 1889; Mills 1907, 1909, 1916, 1922; Moorehead 1922). In most such cases, carbonized remains useful for radiocarbon dating assemblages were not saved, or have not been stored adequately. Thus, it is not possible to assign absolute dates to the great majority of excavated assemblages. (2) Few geomorphologically stratified sites, which provide the opportunity to develop a fine relative scale of temporally diagnostic artifacts, have been excavated (Maslowski 1973:1). Exceptions are the Late Woodland rock shelters (A.D. 600-1200) in southeastern Ohio (Prufer 1967; Murphy 1975:231-252, 309-332). (3) Woodland ceramics, which in other areas of the eastern U.S. have provided a major rule for estimating temporal variation (e.g., Griffin 1952b) are both sparce and plain in their decoration (see p. 9 for reasons). This has discouraged attempts at detailed seriation. Thus, it is not possible to define detailed relative dates for most assemblages.

Recent work on seriations of artifacts and/or proveniences using Middle Woodland pipes from the Midwest (Seeman 1976), chemically relative-dated Early Woodland skeletal material from the upper Scioto drainage (Piotrowski, pers. comm. 1984), and Late Woodland and Ft. Ancient ceramics from the Miami drainage (Riggs, Cowan, pers. comm. 1984) are helpful in correcting this circumstance or hold promise to be so. However, the range of applicability of these frameworks over geography and depostional context is restricted, or their level of detail is limited (Seeman 1977; Michaels 1973; Zurer 1983; Riggs, Cowan, pers. comm. 1984). None of these frameworks provide the continuous time-rules that are desirable for studies of dynamics.

In sum, neither the absolute C-14 nor relative dating methods normally employed by archaeologists to develop fine local chronologies are currently feasible for temporally placing most extant Woodland remains in southern Ohio. Given the current rate of archaeological excavation in the region, this unfortunate condition can be expected to continue for a number of decades, unless alternative approaches to chronometry are undertaken.

OBJECTIVE

The purpose of the research proposed here is to develop a chronological framework for the Woodland period of southern Ohio that both: (1) meets the requirements of research on cultural and environmental dynamics, and (2) allows the incorporation of the wealth of extant archaeological collections that can not be temporally sequenced by C-14 or relative dating methods.

Some attributes of a chronological framework meeting these two criteria are: (1) The framework should provide as fine and continuous a temporal scale as possible, the ideal circumstance allowing dating of material within a generation or less.

(2) The framework should be based on a kind of datable material that is widespread in the archaeological record, allowing the ordering of many assemblages.

(3) The framework should be based on a kind of datable material that allows the wealth of archaeological items excavated in Ohio before the C-14 era to be incorporated in that framework; that is, the chosen material should be of a class that was systematically saved in early excavations.

(4) The framework should be based on a methodology that is inexpensive.

(5) The framework should be based on a kind of datable material that is responsive to but one cultural process, if any. This is necessary to avoid blurring and distortion of chronological relationships by multiprocess interactions (Braun 1983). It also is necessary to avoid the possibility of tautological reasoning in explaining cultural change: a cultural evolutionary process cannot be defined on the basis of the same evidence assumed to have chronological meaning.

Each of these criteria for a successful chronological framework would be met completely or to a considerable degree if it were possible to accurately date small integral collections of pottery sherds from sites on the basis of easily observed, ratio-scale technological attributes of them. Pottery occurs at least in small numbers (n >10 sherds) in most Ohio Woodland village and homestead sites and in many Woodland mortuary sites now known (see p. 9 and Appendix 3). [Some Early Woodland mortuary sites are an exception (Piotrowski, pers. comm. 1983).] Pottery also is one of the kinds of artifacts that was systematically collected in early archaeological projects in Ohio. Tracking ceramic technological variation rather than functional or stylistic variation for dating purposes would allow these other forms of information to be used for a variety of processual or structural studies (e.g., reconstruction of patterns of economic exchange or social organization) without circular reasoning. Tracking ratio-scale variation would allow a continuous time scale to be developed.

PROPOSED RESEARCH AND PROCEDURES

Research funds are sought to complete the major work of developing and testing a chronological framework of the nature just discussed. This work as been preceded by several feasibility studies completed over the past four years (see pp. 8-14). Requested funds will be augmented by minimally $15,688 equivalent support provided by Battelle Research Laboratories of Columbus, the Ohio Historical Center, the University of Arkansas, and personal contributions.

General Methodology

The means for establishing a chronological framework of the proposed nature is an extension of methods that have been successfully used by Braun (1977, 1982, 1983, 1985) for the Middle and early Late Woodland in west-central Illinois. There, the resulting framework allows the dating of integral collections of sherds ca. 25 in number to within +/-70 years for a 1 confidence interval during most times within the geographic area and time range studied (Braun 1985 only).

In essence, the methodology used by Braun involves the construction and calibration of a statistical regression model: a time series of the thickness of sherds from domestic cooking pots (Havana, Pike, and later wares) monitored over a carbon-14 time scale. The procedure takes advantage of the fact that in west-central Illinois, during the Middle and early Late Woodland, the wall thickness of domestic cooking vessels decreased steadily over time. Braun tracked this change using ceramic samples from well-dated archaeological contexts. A time-series model predicting thickness from time was constructed (importantly using methods that accomodate error in both the predictor and response variables) and then inverted to allow prediction of time from thickness.

Several theoretical frameworks can be posited, which would explain the observed reduction in wall thickness and which suggest the possibility of applying similar calibration procedures elsewhere in the Midwest U.S.

Interpretive Framework 1. Braun (1983) and Hargrave and Braun (1981) argue that decreases in the wall thickness of vessels were technological adjustments required by by their use in heating foods to higher temperatures and in sustaining the boiling of foods for longer cooking times. These changes in culinary practices, in turn, are seen as a response to changes in subsistence and diet.

In particular, Braun and Hargrave follow recent interpretations of the archaeological record in west-central Illinois and argue that there, over the course of the Late Archaic and the Woodland periods, the importance of several starchy seed foods incresed relative to nuts and game (Ford 1974; Asch et al 1972, 1979; Asch and Asch 1985b; Yarnell 1978; Struever and Vickery 1973; Munson 1971; Johannessen 1983:144, 1984:209, 213-214; Fortier et al 1984:102). This slow subsistence change is proposed to have been required by increases in population density in the area (Asch 1976; Buikstra 1972, 1976, 1977; DeRousseau 1973; Farnsworth 1973; Struever 1968; Asch et al 1979; Kuttruff 1974; Kelley et al 1984:126) and reduced collection teritory sizes (Ford 1974; Styles 1981; Whatley and Asch 1975; Kelley et al 1984:125; but see Asch et al 1978). These factors would have caused both increased competition for the first-line, more easily obtained and processed nut and deer resources and increased fluctuation in their availability (risk) in any given collecting territory (Ford 1974; Cook 1976). These latter stresses would have led to a broadening of the subsistence base so as to include higher percentages of second-line, more labor-intensive resources, such as starchy seeds, as alternative foods, despite their relatively higher net production costs (Asch et al 1972; Brown 1977:168).

Braun (1983:125) proposes that a continuous shift in diet toward greater proportional use of starchy seeds during the Woodland encouraged continuous alteration of cooking methods--specifically, the longer and more intensive application of heat to ceramic vessels used for boiling foods. It is argued that starchy seeds are rendered more palitable and digestable (greater caloric value) when gelatinized by boiling over an extended period of time, as opposed to being chewed raw or roasted. The duration and stability of the boiling temperatures required to efficiently gelatinize the starches in them are greater than those needed to denature proteins in meat in preparation for eating, or to separate oils within meats or nuts for subsistence and other uses (Peckman 1974:208).

Several parameters involved in the manufacture of cooking vessels are known to have changed during the Woodland in west-central Illinois, and, in this framework, are interpreted to have been adjusted to accomodate the higher cooking temperatures and longer cooking periods (see pp. 7-8). One of these is the thickness of vessel walls, which was decreased over time. This would have had the primary effect of increasing wall thermal conductance (van Vlack 1964:117-165). It secondarily would have decreased a vessel's susceptibility to thermal shock and spalling/delamination by decreasing temperature gradients and expansion/contraction differentials between a wall's interior and exterior during heating or cooling (Steponaitis 1983:38; Rado 1968:198-199; Lawrence 1972:174-183).

Braun's interpretation of Illinois Woodland ceramic change is parsimonious but not yet fully secured, for at least two reasons. (a) Evidence for continuously increasing proportional use of starchy seeds over the terminal Late Archaic and Woodland (cited aboved) pertains to the Midwest-riverine region as a whole (Ford 1974, 1977), rather than local west-central Illinois or specific areas within it. Asch and Asch (1985a, 1985c, 1985d, 1983, pers. comm) summarize current paleoethnobotanical evidence from the lower Illinois valley as showing very sporadic use of starchy seeds over space and time until the Middle Woodland, a rapid increase in use during this period, and a questionable and spotty trend for greater use between the Middle and Late Woodland. A continuous Archaic-Woodland trajectory in starchy seed use, which is accepted at the global Midwest scale, is not yet found at the local scale. Thus, local ceramic change monitored by Braun and presumed to be a response to local dietary trends (Braun 1983:125) does not strongly correlate with currently available evidence for local starchy seed use, though it may with more research.

(b) It is questionable whether starchy seeds could have been processed and exploited effectively (calorie yield and palatability) without a long-time boiling ceramic technology. Thus, increasing use of starchy seeds may not have been the sole or primary drive behind ceramic change. Coprolitic and paleoethnobotanical evidence (Yarnell 1969, 1977; Watson 1974; Cowan 1978:275; Asch and Asch 1978:331-334) show that starchy seeds were consumed ungelatinized yet provided a significant portion of the seasonal diets of some terminal Archaic and Early Woodland peoples. Alternative processing methods (e.g., roasting; simple soaking, drying, and winnowing; soaking with depolymerizing organic and mineral compounds) may have been known and allowed increasing starchy seed use during the Woodland. For example, Iva seeds can be roasted to remove their objectionable oder and taste (Asch and Asch 1978:302). Some specimens found in paleofeces at Salts Cave had been roasted (Yarnell 1977). At the same time, an increase in the frequency of juvenile dental caries between the Middle and late Late Woodland periods (Buikstra 1977; Cook 1979) may suggest the preparation of starchy seeds by some depolymerizing method, such as boiling, during the Late Woodland.

Interpretive Framework 2. In this framework, changes in vessel wall thickness and other technological characteristics observed by Braun do not necessarily reflect adjustments to increasing use of starchy seeds, alone. Nor do they necessarily reflect diet and cooking practices at the local level. (a) The performance of ceramic vessels in all cooking and boiling tasks in which they were used generally may have been a significant and continuous selective factor that encouraged ceramic change from the Early Woodland onward. These tasks potentially include cooking meats and vegetable materials, separating nut oils, processing hides and plant fibers, etc. Increasing reliance upon starchy seeds in various locales and times in the Midwest may have only intensified selection for better heating vessels, or perhaps was not a significant contributing factor. It is unclear the degree to which this factor may have been significant over baseline concerns for the performance of vessels in all other cooking and boiling tasks. (b) If concern for vessel performance in any cooking/boiling task was a selective force behind ceramic change, then the geographic scale of the selective process would have encompassed all intercommunicating locales which used ceramics and within which technological innovations might have taken place and had reason to diffuse--e.g., the greater midwest or northeast U.S. The selective milieu would not have been limited to each local area, such as west-central Illinois. Changing ceramic technology at the local level would thus potentially reflect extralocal as well as local developments, which were made in response to extralocal as well as local selection factors but were advantageous to each ceramic-using locale. Evidence for this kind of regional adaptive process and system can perhaps be seen in pan-regional, similarly dated shifts from Marion, Fayette, and other "Thick" ceramic types to thinner wares in the Early Woodland over the northeast, and in the spread of shell tempering in the late prehistoric over the eastern U.S. Thus, in this framework, one would not expect local ceramic technological change to necessarily correlate with local changes in boiling activities, in general, let alone the use and boiling of starchy seeds.

Interpretive Framework 3 . It is possible that changing vessel wall thickness in west-central Illinois does not reflect soley a selective process focused on the performance characteristics of vessels. It could also reflect adjustments made by potters to compensate for continuous modification in the raw materials available for use or chosen, and/or the manufacturing methods used (Rye 1981:21-31, 66-87). These could have included materials and methods controlling the plasticity and workability of the clays: clay type (pp. 12-13, Appendix 4); the content and identity of organics adsorbed to clays; exchangeable ions present or added to clays; the size, shape, and identity of temper materials, which did change over the Illinois Woodland; whether plasticizers such as acorn tannic acid were added to clays; and whether the clay was allowed to sour. Alterations in required drying time and/or season(s) of manufacture (also affecting drying time), as a function of task or mobility reorganization, could have required adjustments in vessel wall thickness. Changes in primary forming methods (coiling vs. slab-building) and intensification of secondary forming and thinning also might account for the observed thickness trend. However, the cited variables that are categorical in nature are less likely to account for the continuous changes in wall thickness than are the continuous variables. Also, the cultural or ecological factors that would have led to directional continuous alterations in materials or methods are not known. Thus, at present, this framework is less parsimonious than arguments stressing vessel performance. Consideration of additional performance characteristics (Braun 1982, 1983) augment this circumstance.

Regardless of which interpretive framework is correct or prefered, the ceramic changes measured by Braun served well for defining an accurate chronometric scale.

Extension of the Method and Expectations

The method devised by Braun for constructing a continuous chronometric framework that is sufficient for processual research seems applicable to southern Ohio. Preliminary analysis of Ohio ceramics indicate systematic, measurable changes in their wall thickness and other parameters over time (see pp. 13-14) analogous to those found by Braun in Illinois. Also, though not necessarily required, the ecological context of ceramic change in Ohio appears to parallel that in Illinois and the midwest generally (Appendix I).

However, it would be desirable if the precision of the predictive regression could be improved, while at the same time keeping low the number/area of sherds necessary to build and apply it. Woodland assemblages with large amounts of sherds are not as common in southern Ohio as in Illinois (see p. 9). Toward achieving this, it is possible to track over time the variation of additional inexpensively determined ceramic attributes that were altered by prehistoric potters, possibly to improve the performance of cooking vessels. The several sources of variation, intercorrelated, might then be used together to construct a more precise time regression requiring small sample sizes. Success would depend on the rates of change of the additional variables and the magnitude of components of nontemporal variability that cannot be isolated and removed from analysis.

Two additional attributes holding promise in this regard are the size distribution of temper particles within vessels and the volumetric percentage of temper particles. These have been preliminarily examined by Braun (1982, 1983) for Illinois and myself (see pp. 10-14) for Ohio. Both of these variables partially govern three ceramic properties that Woodland potters would have had to have adjusted to improve the overall performance of ceramic cooking vessels, assuming interpretive frameworks 1 or 2. These properties are: (1) wall thermal conductance; (2) wall resistance to thermal shock; and (3) wall resistance to mechanical failure. The latter, mechanical property would have had to have been adjusted as vessel walls were thinned (reduced potential for strength) in response to thermal needs. All three of these properties are governed partially by the size distribution and volumetric percentage of temper particles.

The thermal conductance of a ceramic pot's walls can be increased not only by thinning it, but also by increasing the volumetric percentage and size of temper particles in it that have greater thermal conductivity than clay. Table 1 shows that sand quartz and igneous rock, which are typical tempering materials in Ohio or Illinois Woodland ceramics, have thermal conductivities several times greater than low-temperature fired clay. All else being equal, the conductivity and conductance of a wall of a ceramic pot tempered with any of these materials can be increased by including more and larger-sized temper particles in it.

Resistance to thermal shock is the ability of a vessel to endure repeated cycles of sudden heating and cooling without developing cracks or spalling (Rye 1981:113). It is a function of two factors: resistance to crack initiation and resistance to crack propogation. When the tempering materials used to manufacture

TABLE 1

THERMAL CONDUCTIVITY

Material	Thermal Conductivity*
Estimates for clay component of vessels:	
Fire clay brick**	.005 - .008
Porcelain***	.014 - .018
Stoneware***	.012 - .022
Estimates for temper component of vessels:***	
Quartz/Sandstone	.021 - .029
Igneous rocks or their components	
Granite	.022 - .024
Diorite	.023
Gabbro	.018 - .030
Serpentine	.020 - .030
Rhyolite	.015
Andesite	.013
Horneblend	.018
Metamorphic rocks:	
Gneiss	.021 - .034

*Thermal conductivity in joules cm^{-2} $sec^{-1}$$({}^{o}C, cm^{-1})^{-1}$, as given by the National Research Council (1927).

**At 100°C

***At room temperature.

a vessel have different (larger) thermal expansion coefficients than the clays, resistance to crack initiation can be augmented by decreasing the amount and size of temper particles (Shepard 1956:26-27; Chu 1968; Rado 1969:194; Kirchner 1979:1-12; Hasselman 1969), and thus the disruptive stresses that they generate when heated. Resistance to crack propogation, on the other hand, can be augmented (within limits set by a vessel's wall thickness) by increasing the amount and size of temper particles. These conditions increase the probability that an initiated crack will be stopped from spreading by converging with a temper particle (Shephard 1965; Steponaitis 1983; Hasselman 1969; Rado 1969; Lawrence 1972:181-182).

Mechanical failure, like thermal shock, is a function of both crack initiation and crack propogation. The sizes and volumetric densities of temper particles useful for reducing these problems are the same as those necessary for reducing thermal shock, but the <u>optima</u> are different. Attaining thermal as opposed to mechanical stability requires greater attention to crack initiation through reduction in the size and quanitity of temper particles, when temper thermal expansion coefficients differ moderately to greatly from that of their clay matrix.

The optimal balance in the amount and size of tempering particles for a ceramic cooking vessel thus represents several compromises between desirable but opposing performance characteristics (Fig. 2). These are: (1) the relative importance to the potter of thermal conductivity vs. resistance to thermal stress, (2) the relative importance of prohibiting crack initiation vs. crack propogation as a function of the degree of concern over thermal vs. mechanical stress, and (3) compromises between performance characteristics and labor, time, and material costs of production (van der Leeuw 1976; Matson 1965). The particular amount and sizes of temper used by a potter represents choices in regard to these opposing goals--if not to achieve an optimal vessel, then at least a satisfactory one (Braun 1983:10). These manufacturing choices and others typically are made by potters with great awareness of the performance consequences of their choices where potting is a domestic craft, as documented ethnographically (Thompson 1958; Arnold 1971; Rye 1976; Rye and Evans 1976). In this context, potters are exposed continuously to their successes and failures and adjust their technique accordingly (Braun 1983; DeBoer and Lathrap 1979:128).

The compromises required for achieving a balance of ceramic performace properties and production costs must be placed within the context of the nature of the raw materials available to the potter to understand the specific amount and sizes of tempering materials that are chosen. This can be seen as follows.

For the Woodland period, when concern for improving the performance of cooking vessels probably was a continuous selective factor favoring increases in vessel thermal conductance and damping of thermal stress (particularly crack initiation) <u>two different technological trends</u> are expectable. The pertinence of one trend or the other depends in part on the thermal expansion coefficients of the tempering materials that were readily available and used relative to those of the clays. This material condition determines whether or not the factors on the right in Fig 2 are highly constraining to the trajectory of changing technology. The two trends are shown in Table 2. [The trends also depend on potters over time having used clays with similar physico-chemistries (see p. 12 and Appendix 4 for examples) and similar manufacturing methods that govern plasticity (see pp. 6-7)].

The occurrence of either of these technological trends in Ohio ceramics would provide <u>multiple</u> kinds of intercorrelated material changes that can be tracked in addition to wall thickness and that potentially are useful for constructing a very precise time series regression. The occurrence of one of the trends is documented below (pp. 13-14).

<u>Preliminary Feasibility Studies</u>

Over the past four years, I have completed a number of preliminary studies directed toward assessing the feasibility of the proposed project and collecting data ultimately needed for it. These were achieved with personal funds and additional

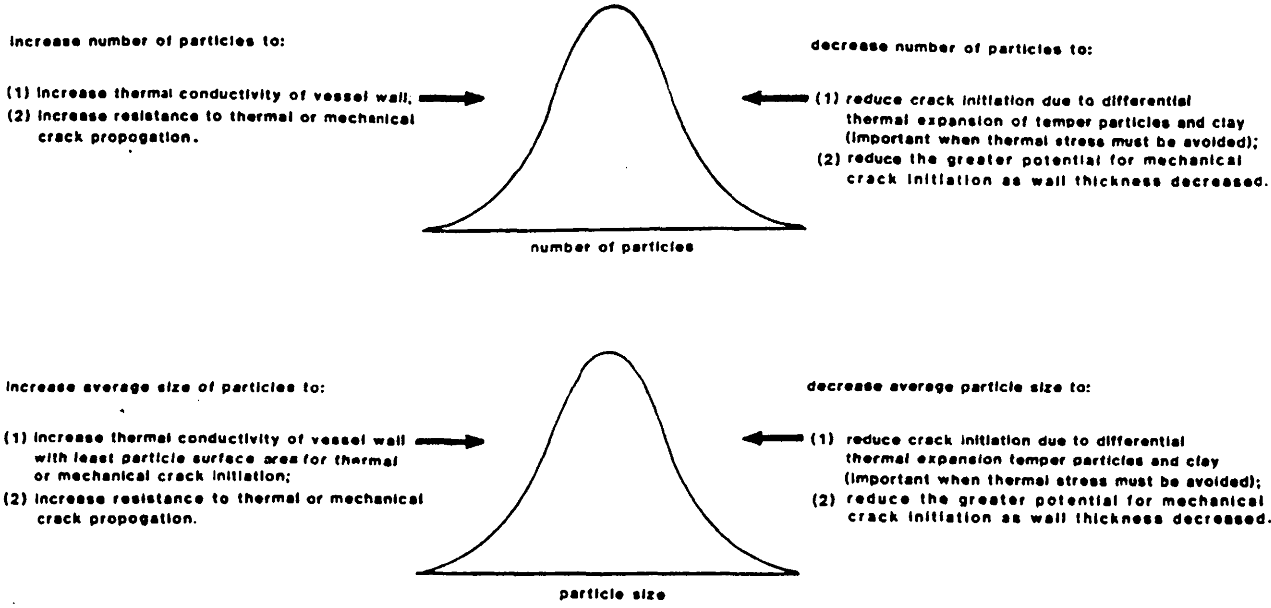

Fig. 2. The number and size of tempering particles that are optimal for a ceramic cooking vessel represent several compromises among opposing relationships.

TABLE 2

TWO CERAMIC TECHNOLOGICAL TRENDS OVER TIME
EXPECTABLE AS VESSELS MUST BE HEATED TO HIGHER TEMPERATURES FOR LONGER PERIODS
AND CONCERN OVER THERMAL STRESS INCREASES RELATIVE TO CONCERN OVER MECHANICAL STRESS

Ceramic Variable	Case I: Tempering materials have thermal expansion coefficients greater than that of fired clay (e.g., quartz temper)	Case II: Tempering materials have thermal expansion coefficients similar to that of fired clay (e.g., igneous rock temper)
amount of temper	Decrease in amount of temper necessary to: (1) primarily reduce thermal crack initiation; (2) secondarily reduce higher potential for mechanical crack initiation as wall thickness is decreased.	Indeterminant: Increase amount of temper to increase wall conductivity and resistance to thermal and mechanical crack propogation. Decrease amount of temper to reduce higher potential for mechanical crack initiation as wall thickness is decreased.
average size of temper	Decrease in average size of temper necessary to: (1) primarily reduce thermal crack initiation; (2) secondarily reduce higher potential for mechanical crack initiation as wall thickness is decreased.	Increase size of temper to: (1) increase wall thermal conductivity; (2) resistance to thermal or mechanical crack propogation, within limits of wall thickness. Thermal crack initiation not a dominant problem.
wall thickness	Decrease wall thickness as only means for increasing wall conductance without increasing the probability of thermal failure.	Decrease wall thickness to increase wall conductance. Thickness reduction need not be as great as in Case I, given alternative means to increase wall conductivity.
variance in size of temper	Decrease in variance of temper particle sizes as a function of their decrease in average size.	Decrease in variance of temper particle sizes as a function of opposing factors 2 and 3, above.

support from Battelle Research Laboratories (Columbus), the Ohio Historical Center, Eastman Kodak (Rochester Laboratories), the University of Arkansas, and Washington Regional Medical Center (Fayetteville). Each study has been successful.

Phase I. Development of Procedures for Measuring Temper Characteristics. To measure the size distribution and volumetric percentage of temper particles within a sherd, x-ray techniques may be used (Rye 1981). Previous work along these lines (Braun 1982) has involved the use of an ordinary high-speed medical grade film (Kodak RPX-1). The approach, however, has not provided the clarity and contrast necessary to count and measure smaller particles with accuracy (Braun 1982:191; 1985), as a result of coarse film grain and low subject contrast.

Experimentation by myself, a professional medical radiologist (Dr. Earl Riddick, Northwest Arkansas Radiology Associates), and an industrial radiographer (William Bowles, Eastman Kodak Company, Rochester) has shown that certain fine-grained medical films (mammography films, Kodak XTL) and especially industrial grade films (e.g., Kodak Industrex M, R, or SR) can be used to produce particle images of the desired clarity and contrast. Fig. 3 illustrates the improvements with a Fort Ancient sherd. Appendix 2 details the particular equipment and laboratory procedures necessary to obtain such results with these films. Xeroradiographic procedures were considered for use but are not as helpful (Appendix 2).

Phase II. Assessing the sufficiency of ceramic and carbon specimens and carbon dates for building regression models. The Ohio Woodland archaeological sequence is poorly dated compared to other sequences in the Midwest--such as the well-known Illinois sequence. This is partly a result of the relative paucity of ceramics that would be useful for dating purposes (see p. 3). A number of factors are responsible for this condition. (a) Ohio ceramics are more poorly made, less coherent, and have preserved less well than Illinois ceramics, particularly for the late Early Woodland through Middle Woodland periods (pers. observ.). (b) The dispersed and mobile settlement system of Ohio Middle Woodlanders, which involved single dwelling "farmsteads" occupied only part of the year (Prufer 1975a; Seeman 1981; Braun 1982) compared to the nearly year-round occupation of sites by multiple households in Illinois, has caused the surface visibility and discovery of Ohio Middle Woodland sites and ceramics to be very low compared to that in Illinois. (c) For the Early and Middle Woodland, archaeological attention has focused more so on mortuary contexts, where ceramics are sparce, than on settlement loci. (d) Until recently (Prufer 1975b; Oplinger 1981; Omerod 1983; Seeman, Dancy, and Otto, pers. comm.), there has been little excavation of early Late Woodland sites.

To determine whether the number of extant large ceramic collections from all time-space units of interest are sufficient for building the proposed regression model, an inventory of Ohio Woodland cermaic collections was made. In 1981, 11 museums and universities in Ohio and elsewhere were visited. Counts of sherds of 2 cm size or better and numbers of partially to fully reconstructable vessels were determined for the collections. Archaeologists (22) were interviewed about potential study collections. These data were supplemented by an inventory of Ohio Middle Woodland ceramics by Prufer (1968) and one of Woodland assemblages in the Scioto drainage by Aument (n.d.). The sherd count tabulations given in Appendix 3 document the generous sufficiency of the ceramic collections for the proposed research.

The number and spatial-temporal distribution of carbon dates that (a) are acceptable in their precision and agreement with known culture history, and (b) have potentially relevant associations with ceramics (criteria in Appendix 5). along with carbon materials available for assay, are sufficient (Table 3). To the degree it is necessary, it will be possible to build separate regression models for several different geomorphological-ecological provinces that may have different ceramic trajectories (p. 12). There is, however, a lack of carbon dates and materials for the Early Woodland in the Miami drainages. This will limit the time depth of any model to be built for this province.

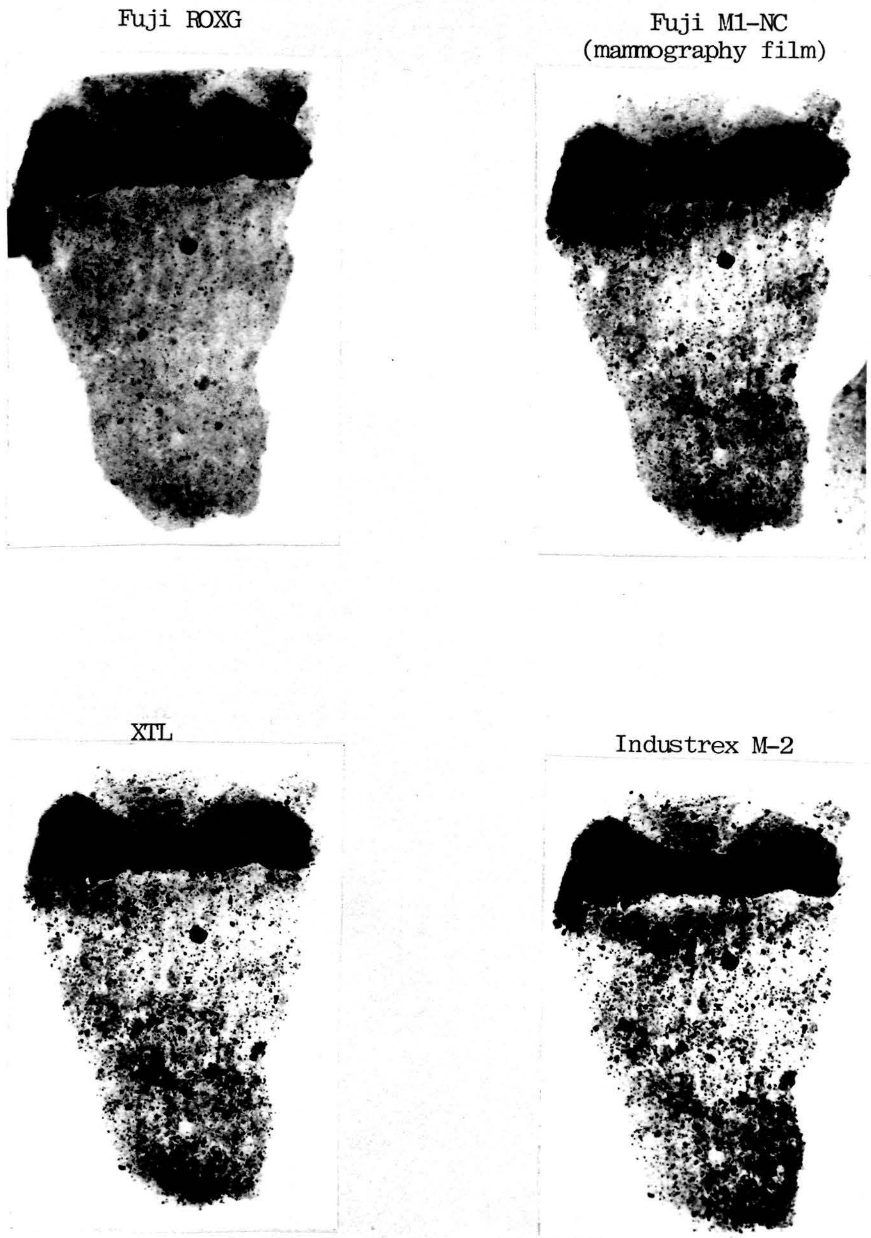

Fig. 3. Comparison of four radiographic films for the contrast they offer between temper particles and their clay matrix. The photographic positive reproductions of the radiograph negatives only partially render the different effects of the films.

TABLE 3

NUMBER OF SITES WITH ACCEPTABLE DATES AND MORE THAN 20 SHERDS*

	Time Period				
River Drainage	Early Woodland	Middle Woodland	Early Late Woodland	Late Late Woodland	Fort Ancient
Scioto	3	3	2	3	5
Muskingham	1 - 3**	2 - 3	1 - 2	1	1
Hocking	0 - 1	0 - 1	0	0	1
Miami	0	3	3 - 4	0	0

*Excludes: (a) sites having C-14 dates that do not correspond with accepted chronology, (b) sites having small numbers of sherds, and (c) earthworks or mounds associated with them, which likely were used over considerable periods of time.

**Range indicates uncertainty in the number of sherds in the site.

TABLE 4

SITES WITH CARBON MATERIAL AVAILABLE FOR DATING

Time Period	Site	Number of Proveniences with > 5 g of Carbon	Total Number of Sherds in Site
SCIOTO DRAINAGE			
Early Woodland	Dominion Land Co.	1	~1300, 4 partial vessels
Early Woodland	Florence	1	100s, partial vessel
Early Woodland	Phillips	1	100s
Early Woodland	Davis	3	~100, partial vessel
Early Woodland	Schottenstein	6	>100
Early Woodland	Edgar Bagley	2	29
Early Woodland	Arthur Jones	1	~25
Early Woodland	La Moreaux-Wright	2	~20
Middle Woodland	Murphy	2 (soil for TL date)	2 partial vessels
Early Late Woodland	Zencor/Scioto Trails	2	many, whole and partial vessels
Late Late Woodland	Ufferman	8	150+
MUSKINGHAM DRAINAGE			
Early Woodland	Nashport	1 (pooled sample?)	<100, partial vessel
Early Woodland	Deeds	1	7
Early Woodland	Cordray	1 (poor storage)	100
Early Late Woodland	Chili	1?	100s
HOCKING DRAINAGE			
Early Woodland	Rock Riffle Run	1	200
Early Woodland	Chapman	1	14
MIAMI DRAINAGES			
Early Woodland	Cowan Creek	1	60
Early Late Woodland	Turpin	2	100s, partial vessel

The available dates/materials also come from a diversity of sites (Table 4), providing sherd-date observations with more independence from each other. This is a requirement of the regression procedures to be used.

Further carbon dating of extant materials, using standard and accelerator mass spectroscopy methods, will be necessary to ensure the adequacy of the spatial-temporal distribution, the relevance of association, and the precision of the carbon dates to be used in building the regression model (see p. 18, Task 7, for details).

Phase III. Documentation of ceramic variation within vessels and over space, time, and specimens of different function. To further assess the feasibility of the proposed project and to gather information necessary for developing a sampling design, 33 whole or partially reconstructed granitic tempered vessels from 19 sites in the Scioto and Muskingham drainages (Fig. 1) were examined radiographically and morphologically in 1983 and 1984 using the improved radiographic techniques discussed above. The work was designed to answer the following questions:

(1) Does the quantity and size distribution of temper material within individual vessels vary in any systematic way over their form, requiring that the position of a sherd on a vessel be controlled when building the regression?

(2) How variable is the magnitude of intravessel variation in temper particle quantity and size from vessel to vessel? Can estimates of typical intravessel variation be made, allowing determination of whether a collection of sherds likely comes from one vs. several vessels?

(3) Do vessels of the same time-space unit but used for purposes other than cooking differ in their tempering charcteristics from those used for cooking, requiring that vessel function be controlled when building the regression?

(4) Do vessels of the same function and time period vary in their tempering and thickness characteristics over space, requiring that separate regression models be built for ceramics from separate river drainages or geomorphological regions?

(5) Do vessels of the same function and river drainage vary over time in their wall thickness and tempering characteristics as predicted by the interpretive frameworks stressing vessel performance (pp. 5-6)?

Results and Discussion:

(1) Variation in temper over form. It is possible that the size distribution and quantity of temper material within an individual Woodland pot would vary in a systematic way over its form. Prehistoric potters could have decreased the amounts and size of tempering material within their clays as they built up a pot, in order to achieve the different optima necessary for the mechanical and thermal durability of the vessels at various load points and heating points along their profiles. The possibility that prehistoric pots were formed using a multistage approach is suggested by experimental work by Holstein (1973:78) on replicating Woodland ceramics and by ethnographic observations of potter decision making (Rye 1981:21-23). This kind of systematic variation of temper size and quantity over a pot's form would require that the approximate position of a sherd on a pot be controlled when building the proposed regression models between temper parameters and time.

The upper positions of four vessels of different time periods were compared radiographically to those of the central to lower portions of the same vessels for their temper size distributions. The results are shown in Table 5 and Fig. 4. Average particle size and variance in particle size both are very similar, statistically, for the upper and lower sections of each vessel. Two vessels have particle size frequency distributions showing a slight tendancy for coarser particles to occur in greater frequency in their bottoms than tops (Fig. 4, b), in accordance with the technological optimum. However, one vessel (Fig. 4c) shows no directional difference between its upper and lower portions, and another (Fig. 4d) shows a slight difference opposite that of the technological optimum (courser particles near the top).

In sum, intravessel variability in temper size distribution probably does not

TABLE 5

VARIATION IN PARTICLE SIZE DISTRIBUTION
OVER VESSEL HEIGHT

Specimen and Time Period	Particle Sizes Near Rim[1] (mm)	Particle Sizes Far From Rim[2] (mm)
Dominion Land Co. Early Woodland	3.02 ± 1.04	* 3.15 ± 1.05
Zencor Site Early Late Woodland	$2.24 \pm .856$	* $2.29 \pm .830$
Cole Site Late Late Woodland	$2.21 \pm .76$	$2.07 \pm .770$
Baum Site Baum Phase Ft. Ancient	$2.24 \pm .810$	* $2.36 \pm .841$

[1]Distance from rim ranges from 1 to 9 cm.

[2]Distance from rim ranges from 20 to 30 cm.

*Indicates specimens having slightly larger particles toward their bottoms compared to particle sizes at their rims. The differences are not statistically significant.

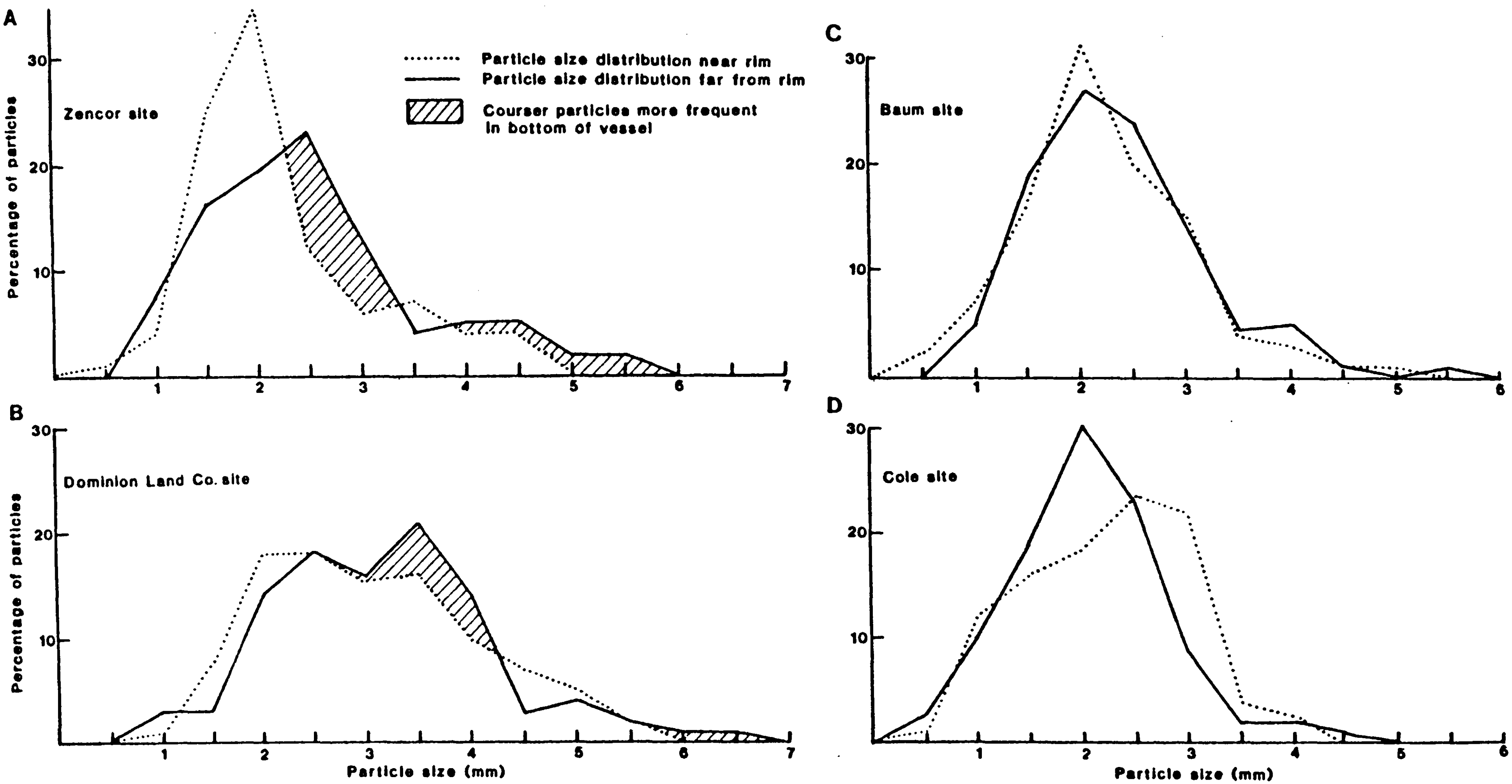

Fig. 4. Comparison of the temper particle size distributions with upper and lower wall sections of large jars. Upper wall sections are 2 to 9 cm below the rim; lower wall sections are 18 to 32 cm below the rim.

<u>require that the approximate positions of sherds on the walls of their source vessels be controlled when building the proposed regression model</u>. A group of sherds from a vessel probably can be taken to represent the vessel at large, regardless of their former position on the vessel's walls. (Elimination of rim and basal sherds, however, is necessary. See Appendix 5).

(2) <u>Magnitude of intravessel temper variation</u>. Ideally, each data point used in building the regression should represent the technological parameters of an <u>individual</u> vessel. A data point should not be a mixed characterization of a group of sherds from multiple vessels having different attribute values and possibly dating to different times. This additional source of variation could reduce the accuracy of the model.

The ideal form of data would be ensured if all data points pertained to assays made on whole or reconstructed integral vessels. However, this is not feasible, given the limited number of such vessels that exist for the Ohio Woodland and the even smaller number that are well dated. It is necessary, instead, to work primarily with collections of sherds from individual archaeological proveniences that hopefully come from one vessel but that are not reconstructable as such.

To assess whether such a group of sherds probably come from one vessel, several kinds of data can be used. These include the depositional context of the sherds; and the uniformity of the sherds in paste color, surface cordmarking (where present), and smoothing over of cordmarking (where present). These kinds of information, however, often are inconclusive (personal observation).

As an alternative, it is possible to compare the variance of the temper size distribution of a group of sherds to those known from individual whole vessels of approximately the same time and location. A sherd lot that pertains to one vessel should not have a temper size distribution with a variance significantly larger than those documented for individual whole vessels of comparable time and location. <u>The temper size distributions documented to date for the whole vessels can be used for this purpose of assessing sherd group integrety</u>.

(3) <u>Variation in temper with vessel function</u>. Ceramics from southern Ohio fall into two broad functional classes that are distinguishable continuously from later Early Woodland times through the late Late Woodland period, at least. These are: (a) small, sometimes finely decorated wares; and (b) large, open-mouthed jars. Both are found in village middens and in burial contexts (Griffin 1983:42). The former were apparently used for serving, the latter for cooking, storage, or both. The cooking function of some large vessels is evidenced by carbonized remains on their interiors [see Prufer's (1965:19-23) description of McGraw ware] and their subconoidal rather than flat bottoms. The continously rounded subconoidal bottom profile characterizing most large vessels is optimal for cooking, relative to a flat-bottomed, angled-wall profile. The former allows thermal expansion stresses to be distributed equally and in an offsetting manner over a vessel's profile and the probability of thermal fatigue to be reduced (Rye 1976:114; Amberg and Hartsook 1946; Braun 1983). Storage functions, on the other hand, are evident by the flat bottoms of some specimens, which allow them to be free-standing (see Prufer 1965:37,55,80,101,117; 1968:44 for examples in McGraw ware). It is possible, however, that some subconoidal-based large vessels served storage functions, given the extremely small proportion of flat-bottomed vessels found at some Ohio Woodland sites (Prufer 1965; Griffin, pers. comm.)

Radiographic data suggest that <u>it is necessary to control for functional variation in temper particle size and quantity among vessels when modeling the temporal variation of these attributes</u>. Minimally, modeling must be restricted to large vessels, and perhaps to those that were used for cooking, specifically. Two Middle Woodland vessels from neighboring sites in the Muskingham drainage were examined radiographically for the size and quantity of their temper particles (Fig. 5). One of the vessels is a small, tetrapodal, finely decorated pot. The second

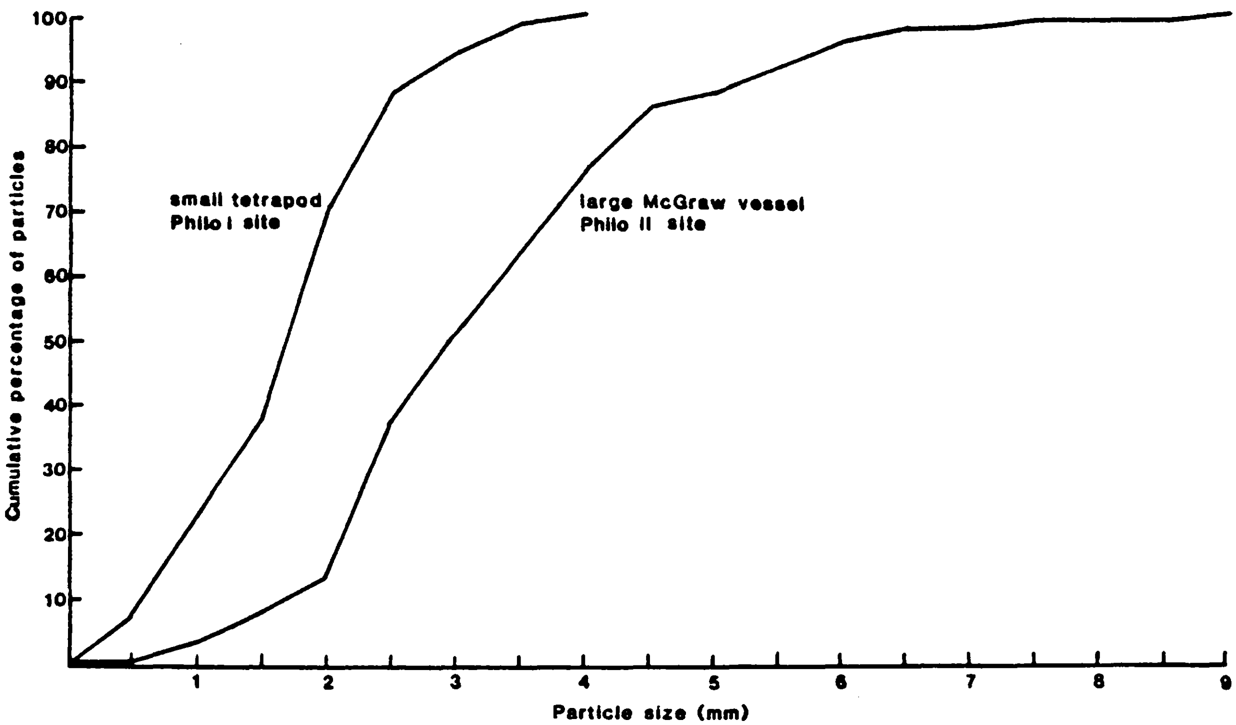

Fig. 5. Comparison of the cumulative temper particle size distributions of two Middle Woodland vessels from neighboring sites in the Muskingham valley: a small, finely decorated, tetrapodal (serving?) vessel; and a large, open-mouthed cooking or storage jar.

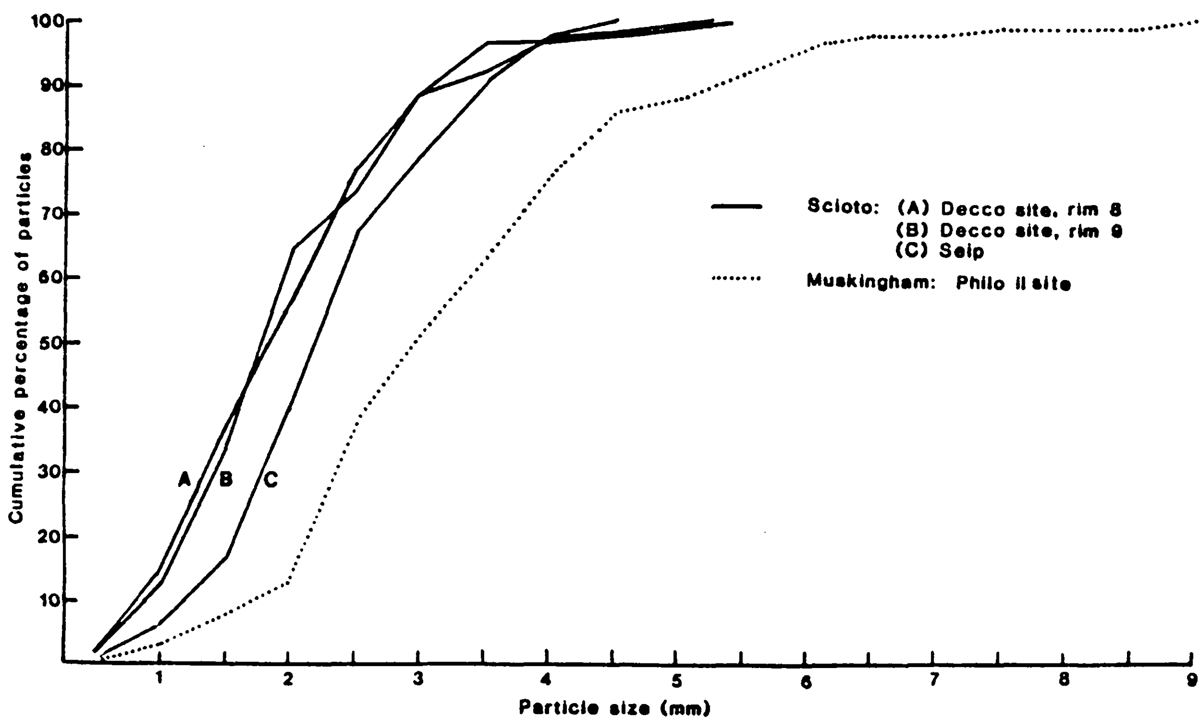

Fig. 6. Comparison of the cumulative temper particle size distribution of vessels from sites in the Scioto drainage vs. Muskingham drainage.

is a large, open-mouthed jar. The small vessel has temper particles of much smaller average diameter and in much lower density than the large, open-mouthed vessel.

It will be possible to segregate sherds of larger cooking and/or storage vessels from those of smaller serving and mortuary vessels using several criteria: (a) vessel circumference estimated roughly (Braun 1985) from minimum sherd radius of curvature; (b) the greater wall thickness/circumference ratio (though similar or thinner wall thickness) of finer wares manufactured for mechanical rather than mechanical and thermal durability (pers. observ.); (c) the lower mean particle size/wall thickness ratio of finer wares manufactured for aesthetic and mechanical durability rather than mechanical and thermal durability (Fig. 2, Table 2), applicable at least to Middle Woodland specimens (pers. observ.); and (d) weakly, the diameter of cord markings and tightness of cord twist, at least during the Middle Woodland (Brown 1984).

At present, it is unclear whether large jars used for storage need to be segregated from those used for cooking when developing the regression models. It is possible that jars for both storage and cooking were manufactured similarly, as a generalized functional class, and were used interchangeably (as may have been the case for Illinois Woodland ceramics; Braun 1983), except for occasional flat-based vessels used only for storage. On the other hand, optimal design of a jar for storage vs. cooking functions would have required adjustments in wall thickness and temper quantity and size distribution (Table 2).

Sorting sherds of storage jars from cooking jars may prove difficult. The presence or absence of carbonized food remains on some jar interiors can be used occasionally to identify cooking jars. Finer categorization may be possible using several statistics: vessel wall thickness/circumference (smaller for cooking vessels); % temper $\geq$2 mm (larger for cooking vessels); the standard deviation of the temper size distribution (smaller for cooking vessels); percentage of medium-sized particles 1.5 - 3 mm in diameter (larger for cooking vessels) and quantity of temper (larger for cooking vessels). Each of these discriminator statistics is applicable to vessels of only the same general time period; care will have to be taken to not confuse temporal and functional sources of variation.

(4) Variation in temper over space. Southern Ohio encompasses minimally four geomorphologically and ecologically different provinces: (a) the Appalachian Plateau, including the Muskingham, Hocking, Raccoon, and other drainages; (b) the Miami drainages within the glacial Till Plain; (c) the upper Scioto-Olentangy drainage of the Till Plain; and (d) the ecotone between the Appalachian Plateau and the Till Plain, including the central Scioto-Paint Creek region. These probably differed in the pattern and rates with which demographic conditions and subsistence practices changed over the Woodland (Seeman 1977; Fischer 1974; Jochim 1976), which may have encouraged different local patterns of adjustment in ceramic cooking technology (interpretive framework 1). The provinces also differ somewhat in their relative availabilities of different clay and tempering resources (Lamborn et al 1938), which could have encouraged different patterns of change in ceramic cooking technology (interpretive frameworks 1, 2, or 3). These conditions would require that different regression models be built for different regions to obtain the most accurate predictive equations possible.

River valleys in the unglaciated Appalachian plateau and those in the glacial Till Plain offer a generally similar range of clays, but in different abundances, as a function of their parent materials and their duration of weathering (Lamborn et al 1938). If there is systematic variation in the amount of montmorillonite present in the clays that were used prehistorically by potters in the two provinces, there may also be nontemporally significant differences in the volumetric density of temper used by them at contemporaneous times. Montmorillonite holds more water than other clays and poses a shrinkage and cracking problem when dried and fired. The problem can be reduced by adding more temper than would otherwise be added, or by tempering with burnt calcium carbonate (e.g., burnt limestone), which absorbs water from the paste during the plastic stage (Stimmell and Heimann 1980). It may be significant that limestone-tempered domestic ceramics, though not frequent in most time periods and regions of southern Ohio, are more common in the Appalachian Plateau than the glacial Till Plain. This may reflect that different clay types or mixtures were used in the two areas, although it also has reasonably been attributed to the relative availability of granitic rock and limestone (Griffin 1945:223).

It is probable that separate regressions will have to be constructed for different geomorphological-ecological provinces. Fig. 6 shows the cumulative temper size distribution for four Middle Woodland large-mouthed, granitic-tempered jars: two from the upper Scioto, one from the central Scioto-Paint Creek area, and one from the Muskingham. All of the Scioto vessels have similar temper particle size distributions, but are distingushed from the Muskingham vessel in particle size distribution.

It is not currently known whether the documented difference between Scioto and Muskingham ceramics reflects a difference in subsistence trends in the two valleys, a difference in the raw materials used, or other factors. The kinds of clays that occur in vessels from different geomorphological-ecological provinces in southern Ohio is now being investigated (see p. 15).

(5) When the function, size, and river drainage of Woodland vessels are held constant, systematic temporal trends in the wall thickness and temper size distributions of vessels are evident.

Thickness. Reductions in vessel wall thickness from the Early Woodland through late Late Woodland are strongly evident, even when vessel size and geographic location are only grossly controlled. This is shown in Table 6, which lists the range of wall thicknesses for a number of reconstructed medium to large sized vessels that come from both the Scioto and Muskingham drainages and that are dated to cultural period. The thicknesses are not corrected for vessel circumference or height (thickness increases with circumference and with wall load as a function of height, p. 16). Also documenting the trend, but over a shorter time span, are unpublished data on the mean thickness of sherds of large vessels from stratified deposits within Mary's Cave--an Early through Middle Woodland site in the Muskingham drainage (Table 7, Carskadden, pers. comm.). For the Miami drainage, Riggs (pers. comm) has found reductions in vessel wall thickness from the Middle Woodland to early Late Woodland (Table 8). These data illustrate similar trends in vessel wall construction from multiple areas over the entire southern Ohio region during the Woodland--a circumstance generally thought true by Ohio archaeologists on the basis of unquantified observations (e.g., Murphy 1975). The data agree with theoretical expectation (Table 2).

From the late Late Woodland through early Ft. Ancient times, there are clear and rapid changes in the technology of large jars, including the thickening of walls (Table 6) and a shift in basal shape from subconoidal to round. The latter would indicate a continued concern over the thermal fatigue of vessels, whereas the reasons for the former are unclear. Wall thickening is not related to alterations in particle size distribution during this time (see next section).

Temper particle size distribution. Holding vessel size, form, and geographic location constant, six large granitic-tempered jars from the upper Scioto drainage were examined for temporal changes in their particle size distribution. The results are presented in Fig. 7 and Table 9.

Two temporal trends are apparent: (a) an initial reduction in the percentage of coarser temper particles ($\geq$2 mm diameter) from the Early to Middle Woodland, followed by a steady but gradual increase from the Middle Woodland through Baum phase Ft. ancient; and (b) a decrease in the variance of particle sizes from the Early Woodland through at least the late Late Woodland, corresponding to greater concentrations of medium-sized particles of a restricted range (1.5 - 3 mm).

TABLE 6

RANGE OF THICKNESS OF BODY SECTIONS OF PARTIALLY RECONSTRUCTED VESSELS (LARGE JARS) FROM WOODLAND SITES IN SOUTHERN OHIO (FIG 1)

Time Period	Site and Specimen Number	Range in Thickness (cm.)
Early Woodland	Dominion Land Company, #1	1.55 - 2.05
	Dominion Land Company, #2	1.00 - 1.30
	Davis Mound	1.20 - 1.55
	Florence Mound	.90 - 1.20
Middle Woodland	Decco, #8	.50 - .75
	Decco, #9	.60 - .85
	Seip, #1	.60 - .90
	Philo II, #1	.50 - .90
Early Late Woodland (Newtown)	Zencor, #1	.50 - .70
	Zencor, #2	.50 - .90
	Weidner	.60 - .80
Late Late Woodland (Cole complex)	W. S. Cole	.40 - .65
	Decco	.40 - .75
	trend in thickness reverses after the Woodland period	
Fort Ancient (Baum phase)	Baum, #1	.65 - ..90
	Baum, #2	.90 - 1.20

TABLE 7

MEAN THICKNESS OF AND RANGE OF THICKNESS OF BODY SHERDS FROM THE ARCHAEOLOGICAL STRATA OF MARY'S CAVE, MUSKINGUM VALLEY

Archaeological Stratum	Surface Finish/ Temper of Sherds	Mean Thickness (cm.)	Range in Thickness (cm.)	Sample Size
A - B	smooth, grit	.66	.6 - .7	5
	cordmarked, grit	.55	.5 - .6	2
B	smooth, grit	.83	.5 - 1.0	3
	cordmarked, grit	.53	.4 - .6	3
C-1	smooth, grit	.80	.5 - 1.0	10
	cordmarked, grit	.63	.4 - .8	4
	cordmarked, limestone	.60	.5 - .7	2
C	smooth, grit	.84	.7 - 1.1	14
	smooth, limestone	.81	.7 - .9	7
C-1-2	smooth, grit	.90	.8 - 1.0	2
C-2	smooth, grit	.92	.8 - 1.0	13
C-2-3	smooth, grit	.95	.8 - 1.0	8
C-3	smooth, grit	.93	.6 - 1.3	6
	Carbon 14 date of 400 B. C.			
D	smooth, grit	.78	.7 - .9	4
D-1	smooth, grit	.98	.9 - 1.0	8
D-1-2	smooth, grit	.98	.7 - 1.5	47
D-2	smooth, grit	1.03	.8 - 1.4	6
D-2-3	smooth, grit	.93	.8 - 1.2	6
D-3	smooth, grit	1.04	.8 - 1.5	5
	cordmarked, grit	1.30	1.0 - 1.5	12
E	smooth, grit	1.2	1.2	1

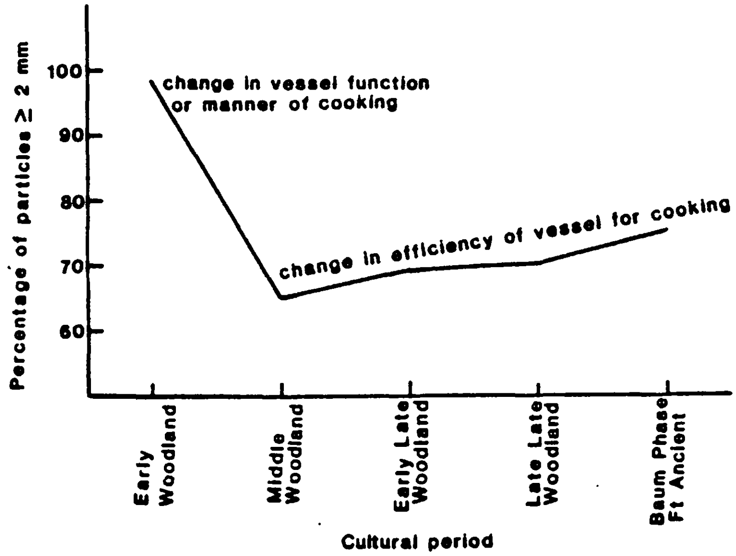

Fig. 7. Temporal trend in the percentage of coarser particles (≥ 2 mm diameter) within large, open-mouthed jars from the upper Scioto. The site proveniences of the vessels are (earliest to latest): Dominion Land Company, Decco (rims 8, 9), Zencor, Cole, Baum.

TABLE 8

CHANGES IN THE VARIANCE OF THE PARTICLE SIZE DISTRIBUTION OF LARGE JARS OVER TIME IN THE UPPER SCIOTO DRAINAGE

Time Period	Standard Deviation (mm)	% of Particles of Medium Size (1.5 - 3 mm) as a Measure of Central Tendancy
Early Woodland (Dominion Land Co. site)	1.04	59.
Middle Woodland (Decco site, rims 8, 9)	.910	74.
Early Late Woodland (Zencor site)	.856	78.6
Late Late Woodland (Cole site)	.76	80.
Baum phase Ft. Ancient (Baum site)	.81	82.

TABLE 9

COEFFICIENTS OF THERMAL, VOLUMETRIC EXPANSION*

Material	% Volume Expansion over State at 20°C for:					
	100°C	200°C	400°C	600°C	800°C	1000°C
Most clays**	.04 - .25	.38 - .50	.75 - 1.0	1.1 - 1.5	1.5 - 2.0	
Quartz***	.36	.78	1.9	4.5	4.4	4.2
Components of Igneous Rocks Other Than Quartz:***						
Olivines	.19 - .20	.46 - .52	1.1 - 1.2	1.8 - 2.1	2.5 - 2.9	3.3 - 3.8
Pyroxenes	.13 - .19	.35 - .42	.83 - .93	1.4 - 1.6	2.0 - 2.3	2.6 - 3.0
Orthoclase Feldspar	.05 -	.16	.59	1.2	1.9	2.6
Plagioclase Feldspars	.09 - .14	.23 - .36	.55 - .85	.78 - 1.4	1.1 - 2.1	1.4 - 2.8
Hornblende	.16	.42	.97	1.6	2.2	2.8

*Total volumetric expansion, considering a, b, and c crystallographic axes for noncubic compounds.

**Rye (1976:116)

***Clark (1966)

The trends from the Middle Woodland onward are consistent with the expectations presented in Fig. 2 and Table 2 for the manufacture of vessels when there is concern for cooking performance and when the tempering materials used have thermal expansion coefficients similar to clay. In these circumstances, temper particle size is increased primarily to increase the thermal conductance of the vessel wall and resistance to wall spalling/delamination as a function of thermal conductance. The increase in particle size does not cause a great problem in thermal crack initiation, given the similar expansion rates of the particles and their matrix. Moreover, it affords resistance to thermal and mechanical crack propogation. Hence, the rising trend of percentages of coarser particles ($\geq$2 mm). At the same time, reductions in wall thickness over time (also to increase wall conductance) provide an opposing constraint on the maximum permissible particle size. Hence, the variance of the particle size distribution decreases over time and the percentage of particles in medium size grades of restricted range (1.5 - 3 mm) increases. The crushed granitic rock that was used to temper the specimens studied here, and that predominates in most Ohio Woodland cooking vessels, has the postulated thermal expansion characteristic (Table 10).

The temporal trend for increasing percentages of coarser particles $\geq$2 mm is opposite that documented indirectly in data of Braun's (1982:190, Fig. 4) for ceramics from west-central Illinois for the Middle Woodland through the early Late Woodland (AD 240-800). Over this duration in Illinois, the percentage of coarser paticles decreases from approximately 50 to 5% (reconverting his data to a percentage particle basis). The total volume of temper also decreases. These trends are consistent with the expectations presented in Fig. 2 and Table 2 for the manufacture of vessels when there is concern for improving cooking performance and when the tempering materials used have thermal expansion coefficients greater than clay. Illinois Middle Woodland and early Late Woodland cooking vessels are tempered predominantly with quartz, which has this thermal characteristic (Table 10).

It is most probable that the opposing temporal trends in particle size distribution for Illinois and Ohio ceramics do not reflect directional differences in local subsistence changes (interpretive framework 1) or different concerns for improving the thermal vs. mechanical performance of cooking vessels (interpretive frameworks 1 or 2) in the two areas. Rather, the different trends are most parsimoniously explained as the result of similar subsistence trends or performance concerns in the two regions, but with ceramic change preceding under different constraints on design imposed by differences in the available raw materials. These include differences in: (a) the composition of the temper particles, as mentioned above; and probably (b) temper particle shape and (c) the water adsorptive and drying properties of the clays used. The effects of all of these physico-chemical differences, as well as details on the tempers and clays of relevant Illinois and Ohio Woodland ceramics, are given in Appendix 4.

All the above factors and trends pertain to the Middle Woodland period forward. From the Early to Middle Woodland in southern Ohio, temper size decreased rather than increased in large jars (Fig. 8). This trend could represent: (a) a shift in the function of large jars from storage to cooking, with a consequent shift in performance goals from mechanical durability to thermal and mechanical durability; (b) a shift in the manner of cooking with large jars from stone boiling to direct heating (Munson, pers. comm., Ozker 1982) again involving a change in performance goals; or (c) a change in the kind of clays used or other raw material or forming factors that affect clay plasticity and that might require temper adjustments (see pp. 6-7).

Amount of temper. It is not clear whether the volumetric percentage of temper in Ohio Woodland ceramic jars increases, decreases, or defines any trend over time. This parameter cannot be estimated directly from radiographs when the percentage of temper particles is great (as in Ohio) or the amount of overlap of particles as a function of sherd thickness is great (Braun 1982). Correlations between radiographic data and petrographic information are required (see pp. 17-18).

Specific Research Proposed and Research Design

The following research tasks will be completed during the proposed period of National Science Foundation and other support. Each task is necessary to build and/or test regression models that predict absolute time dates from the technological characteristics of small, integral sherd collections--one model for each of possibly four different geomorphological-ecological provinces. Most of the tasks involve procedures for isolating and removing potentially undesirable sources of variability when selecting samples for building the models.

Common to many of the tasks is the radiographic and morphological examination of ceramic specimens. Radiographic work will be done in the Nondestructive Testing Section of Battelle Columbus Laboratories with the support of their staff, using the improved techniques applied successfully to date (p. 9). Counts of temper particles of size classes, each .5 mm in range, will be made using methods and precautions similar to those outlined by Braun (1982; also Daniels et al 1968). However, the grid to be used in counting particles will have a mesh greater than the expectable largest-sized particle. This procedure is necessary to ensure the independence of particle size observations so that a specimen's particle size distribution can be calculated on a particle count basis in addition to its total quantity of temper on a volumetric basis. Wall thickness, areal, and curvature measures for sherds and/or reconstructed vessels will be made with common procedures involving curved-arm calipers, planimeter, radius gauge, and formagauge. Maximal cord diameter for cordmarks will be measured by Emery's (1966) standard.

Funds are not sought to examine the clay composition of vessels from different geomorphological-ecological provinces. This work is currently being done by Ms. Arleyn Simon and me at Arizona State University using x-ray diffraction methods. We will document, prior to the grant period, any provinces that may frequently bear ceramics with significantly distinct clays. The number of regression models to be built will be based partially on these results.

Task 1. Estimating intravessel variability in technology. Radiographs and morphological measurements for the 33 whole or partially reconstructed, granitic-tempered vessels examined to date will be coupled with similar data for up to 42 additional partial or whole vessels (Appendix 3) from a greater range of time-space units. The combined data will provide examples of large jars and small containers from as many periods as possible in each of the four geomorphological-ecological areas (p. 12) for which a different model will possibly have to be built.

The data will be used in two ways. (a) For each time-space unit, estimates will be made of the range of variation, within a vessel, of several technological variables that are potentially useful for developing the regression models. The variables include: mean temper particle size, percentage of coarse particles ≥ 2 mm in diameter on a particle count basis, the standard deviation of the temper size distribution, percentage of medium sized particles 1.5 - 3 mm in diameter on a particle count basis, volumetric percentage of particles of all sizes [corrected for wall thickness (p. 17) and particle size], and wall thickness. Diameter of cordmarking also will be assessed. These estimates of intravessel variability will be used (in later steps) to assess whether sherd collections from particular proveniences do likely pertain to single vessels, as is preferable in building the regression models. (b) A more detailed examination of variation in the quantity and size distribution of temper particles in the tops and bottoms of vessels will be made, supplementing the preliminary study presented above. This is necessary to evaluate with greater certainty whether the approximate wall position of sherds on their vessels of origin need not be controlled when building the regressions.

Task 2. Calibrating discriminators of vessel function. Univariate and multivariate clustering and discrimination procedures will be used to segregate populations of large cooking/storage jars from smaller serving containers and to define their characteristic attribute states for each time period. Whole vessels augmented by large rim sherds from site collections listed in Appendix 3 will be used, along with four variables potentially diagnostic and estimable for sherds examined in later analytic steps: circumference, wall thickness/circumference ratio, mean particle size/wall thickness ratio; and cord marking diameter/circumference ratio (see p. 12). This step is necessary to provide means (in later steps) for sorting integral sherd collections by function, so that regression analysis can be focused on cooking/storage jars that exhibit the documented technological trends.

Similarly, it must be evaluated whether jars used for cooking differ in their technology from those used for storage and must be discriminated. Whole and partial vessels of the same time period and probably being cooking vs. storage containers will be divided into these two classes. This will be done on the basis of whether they have carbonized food remains in their interiors (cooking vessels) or flat bases (probable storage vessels) Members of the two classes for each time period will then be examined for expectable differences in several technological variables (see p. 14): wall thickness/circumference; mean temper particle size; % temper particles ≥ 2 mm; standard deviation of the temper size distribution; percentage of medium sized particles 1.5 - 3 mm in diameter; and volumetric percentage of temper. If two populations are definable with any of these variables for any time period, the variable states characterizing them will be noted.

It would be preferable in Step 2 if discrimination could be made for each time-space unit, rather than only time units. Such fine-grained segregation is not possible, given the limited number of whole or partial vessels and large rim sections extant in southern Ohio.

Task 3. Determining the minimal sherd area necessary to characterize a vessel's temper distribution. The minimal sherd area required to obtain a stable estimate of the proportion of temper particles of a given size class will vary inversely with the frequency of particles of that class. To determine such areas for particles of the size classes pertinent here (≥ 2 mm; 1.5 - 3 mm), a dimensional analysis of particle size variability will be made on whole and partially reconstructed vessels representing each time-space unit for which specimens are extant. This can be done by making particle counts in increasingly expanded areas and then plotting size class proportions against area. The resulting curves will break or flatten at the necessary minimum areas. Large-area radiographs for this purpose have already been made for the whole and partial vessels investigated thus far.

The minimum area defined in this manner will be used to determine whether a group of sherds, tightly associated and presumably belonging to one vessel, is large enough in its composite area to be useful in building the model.

Task 4. Determining empirical correction factors for adjusting vessel wall thickness for vessel girth. The trend for decreasing vessel wall thickness that is expected and documented over time for large cooking and/or storage jars is likely to be most clearly defined when holding the girth of vessels as constant as possible. This is so because the wall thickness of a vessel is adjusted by a potter not simply to control its thermal conductance and fatigue, but also its mechanical durability and flexural strength (as a function of moduli of rupture and elaticity) and their variation with vessel size. Larger, taller vessels require thicker walls to maintain a desirable breakage loading strength (Rado 1969:194, 199; Jones and Berarb 1972:147-148; Braun 1983, 1985).

To compensate for variation in jar size when documenting time trends in wall thickness, two approaches might be used. The first, modified from Braun (1983), involves constructing regressions that predict body wall thickness from true vessel girth for each cultural time period, using the whole and partial vessels. The regression can then be applied to an individual whole or partial vessel or a sherd in order to estimate its residual or "corrected thickness"--that aspect of thickness which is not explained by the girth of the vessel and the concern of the potter for mechanical durability, but rather, the potter's concern for thermal conductance and fatigue (plus unaccountable error). When a sherd rather than a whole or partial vessel is analyzed, an "apparent girth" of its source vessel, which is estimated with the sherd's minimum radius of curvature (Braun 1983, 1985), must be used rather than a true girth value.

This strategy may not lead to fruition, however. Braun did not find a well-defined relationship between wall thickness and girth for Illinois late Woodland ceramics. This occurred in part because individual subconoidal-shaped vessels can each yield sherds with a great variety of apparent girths (Smith 1981, pers. comm.), and perhaps because during this time, thermal performance considerations predominated greatly over mechanical performance considerations (Braun 1985). Should these factors be problematic for Ohio Woodland ceramics, an alternative approach (Braun 1985) will be used. Analysis will be restricted to jars of a limited girth range and sherds of a limited apparent girth range. This approach worked adequately in Braun's study.

Task 5. Determining empirical correction factors to aid in estimating quantity of temper from radiographs. Estimates of quantity of temper must be made on a volume basis rather than the areal basis recorded directly on radiographs. It is the volumetric percentage of temper which determines the drying, firing, and performance characteristics of a vessel and which potters control (Braun 1982; Rye 1976). In contrast, a radiograph records the density of particles over the total thickness of a sherd projected onto a single plane--a density which varies with sherd thickness as well as volumetric particle density.

Conversion of a radiographically determined areal proportion of temper to a minimum volumetric proportion can be achieved with simple mathematics (Braun 1982:188). The procedure assumes, however, that sherd thickness and particle density are not great, so that superpositioning and masking of particles behind each other are not great.

Ohio Woodland ceramics have high particle densities that pose a particle superposition problem and do not allow reliable estimates of temper volume percent to be made by radiographic measurement and mathematical correction, alone. It is necessary to determine empirically the effects of superpositioning on estimates of temper volume percent and to correct for this systematic bias. Correction factors can be determined by: (a) obtaining accurate estimates of temper volume percent on a small selection of sherds using petrographic methods (Bishop et al 1982; Shepard 1956; Chayes 1956; Griffiths 1967) and principles of sterology (Weibel and Elias 1967a, 1967b; Schuleter 1972); (b) having radiographed the same sherds and determined the apparent temper volume percent with superpositioning bias, and (c) defining several regression correction equations between the true temper quantity and apparent temper quantity of sherds--one equation for each of several different classes of sherds that vary in their thickness and particle size distribution. A small sample of sherds from each time-space unit will be used for this purpose. Once determined, and tested, the correction equations can be applied routinely to the radiographic data for the time-technology regression models, without further petrographic work.

The petrographic work will also provide information on the particular minerals used to temper ceramics of different time-space units and their sizes. These data will be useful for assessing the relative magnitude of thermal stresses to which vessels were susceptible and for checking whether the clays chosen for manufacturing vessels contained "natural temper" particles in any substantial quantity at the forming stage (Bishop et al 1982). The latter condition is not expected on the basis of the temper size distributions and particle shapes documented to date.

Task 6. Selection of sherd-date associations for building the time-technology regression models. Sites having sherds in large enough numbers to be potentially useful for building the time-technology regression models are listed in Appendix 3. Sherds include those falling broadly within the following traditional types: Fayette Thick, Adena Plain, McGraw Cordmarked, McGraw Plain; Newtown, Peters

Cormarked, Peters Plain, "Cole," and Baum phase Ft. Ancient (Griffin 1945; Dragoo 1963; Clay 1980; Prufer 1965, 1968; Griffin 1952; Prufer and McKenzie 1966; Baby and Potter 1965; Potter 1966; Barkes 1981; Griffin 1943). From this universe, sherds and associated carbon samples/dates will be selected for analysis and for building a given model on the basis of many criteria, some outlined by Braun (1985). These criteria pertain to two areas of potential problems: the nature of the ceramics and the relevance of the dating material to the ceramics. They include: (a) the homogeneity of the sherds used in any model relative to ecological context and subsistence trends; (b) ceramic sample homogeneity relative to materials, especially temper and clay types; (c) vessel function--the use of cooking and/or storage vessels only; (d) the relevance of body sherds rather than basal or rim sherds; (e) adequate areal (size) representation of vessels; (f) the integrity of each group of sherds considered to be one observation relative to their vessel of origin; (g) use of burnt food residues on vessel interiors and hearth carbonized nuts or annual plants as carbon sample sources, when possible, to eliminate the dating of old heartwood, old deadwood, recycled wood, and depositional mixing; (h) the brief formation and sealing of deposits that provide associations; (i) avoidance of curated ceramics; (j) acceptable levels of precision of carbon dates; and (k) the length of occupation of sites from which samples are drawn. These criteria are discussed and justified in Appendix 5 and/or Tasks 1 - 4, above.

Task 7. Determining additional dates. The radiocarbon samples to be selected according to the criteria of relevance will be assayed for several purposes. (a) Improve the time-space distribution of dates. Extant dates are sparce in some time-space units (Fig 4, Tables 3, 4) but these can be filled in with additional carbon assays (Appendix 3, Table 2). (b)Cross-check sherd-date associations and improve model accuracy. Extant carbon dates, being based largely on hearth charcoal and also wood rather than nut or annual plant charcoal, may reflect a list of associational errors between between vessel manufacture/use date and carbon date (Appendix 5; Dean 1978). Even when integral rather than composite samples are used and undisturbed contexts are sampled, old heartwood, deadwood, or recycled wood can result in irrelevant sherd-date associations. These problems can be eliminated by dating carbonized food residues on vessel interiors (Bill 1984; Tamers, pers. comm.), which provide very tight associations. Such specimens occur occasionally among Ohio ceramic collections (Prufer 1965:19-23; Table 11) and will be assayed for as great a range of time-space units as possible. Sherd-date associations derived from them can be used both to increase the number of relevant sherd-date associations and to cross-check the probable relevance of extant and new hearth charcoal sherd-date associations to be used in building the time-technology models. This will improve model accuracy. Dating the food residues will require the use of accelerator mass spectroscopy methods. (c) Improve model accuracy. Similarly, ceramic-associated samples of hearth charcoal that are derived from nuts or annual plants and that minimize old wood problems, will be selected to increase the number of probably relevant sherd-date asociations and improve model accuracy. (d) Improve model precision. Extended counting of hearth charcoal samples, and selection of samples with an eye for sources of contamination and so as to avoid depositionally dispersed specimens, should increase the number of dates with high precision. This will improve the precision of the regression models. Table 11 lists some sites known to have carbon materials that have been adequately curated and that are of enough mass to meet these four purposes.

All carbon samples will be assayed for their C-13 as well as C-14 values to allow correction for isotopic fractionation, in line with modern standards (Browman 1981). The work will be done by the Institute for the Study of Earth and Man, Southern Methodist University (Dr. Herbert Haas) with accelerator mass spectroscopy support by ETH, Zürich, Switzerland (Prof. W. Oelfli).

Task 8. Correction of date and dating error. To reduce dating discrepancies that result from formation processes in the physical-physiological domain (Dean 1978), the radiocarbon age and measurement error for each sherd-date association will be corrected to dendrochronological age. This will be done using the recent calibration of Klein et al. (1982) rather than that of Damon et al. (1974). Isotopic fractionation correction will be applied for those specimens for which C-13 values are available. It will not be possible, however, to adjust for between-laboratory measurement differences (Klein et al 1982).

Task 9. Adjusting estimates of vessel wall thickness for approximate vessel girth. The regression equations for determining corrected thickness values, constructed in Task 4, will be applied to each group of sherds if appropriate. Alternatively, analysis will be restricted to jars of a limited girth range and sherds of a limited apparent girth range.

Task 10. Correcting estimates of temper quantity for particle image superpositioning. The calibration regressions constructed in Task 5 will be applied to each group of sherds when estimating percent volume of temper.

Task 11. Formulating the time-technology regression models. For each geomorphological-ecological unit, a polynomial multiple regression model will be built predicting corrected date from (corrected) vessel wall thickness, percentage of temper particles >2 mm, the standard deviation of the temper size distribution or the percentage of particles 1.5 - 3 mm in diameter as a measure of constraint, and corrected temper quantity. Nonstandard time series/filtering procedures (Braun 1985) will be used to accomodate several methodological constraints defined by the structure of the data. The statistical details are presented in Appendix 6.

Task 12. Validating and testing the regression models. The models will be both cross-validated and tested. Cross-validation procedures will involve generating with partial data reduced models that approximate the full models, and then comparing prediction against observation using the residual data (Draper and Smith 1981:418). Testing will involve predicting the dates of multiple sherd groups that have not been used to build the models and that come from vertically or horizontally stratified deposits. Predicted sequences of sherd groups will be compared to their stratigraphic sequences. Some sites having potential for the stratigraphic tests include: Davis, Maybell Hall, Kettle Hill Cave, Rais Rockshelter, Harness-28, McGraw, Caldwell's Bluff (in the Scioto valley); Whitaker, Haag, Twin Mounds village, Miami Fort, Sand Ridge, and Turpin (in the Miami drainage area); and Mary's Cave and Philo II (in the Muskingham valley).

Task 13. Publication and presentation of results. During the period of NSF support, I will write several articles on the methodological innovations and substantive results of the proposed research, to be submitted to scholarly journals and regional journals. I also will organize one symposium on ceramic technology, to be given at a national archaeological meeting in 1987-1988.

SCHEDULE OF RESEARCH AND COORDINATED FUNDING AND FACILITY SUPPORT

Research will begin May 15, 1986. All data collection and preliminary quantitative analysis (Tasks 1-7) will be completed by January 15, 1987. This includes morphological and radiographic measurement of the ceramics, radiocarbon sampling and assay, and initial quantitative analyses that are necessary to control irrelevant variability and determine specific sampling parameters. This work will be accomplished in Columbus, Ohio, where re-examination of specimens in light of ongoing results is possible. Refinement of regressions and discriminating procedures (Tasks 2,4,5,9,10), correction of date (Task 8), and building and testing the time-technology models (Tasks 11-12), will be completed at my home institution, Arizona State University, by August 15, 1987. A final report will be submitted by May 15, 1988.

Partially matching funding ($15,688), facility support, or personnel support additional to that sought here will be provided by: Battelle Laboratories (Columbus), the Ohio Historical Center (Columbus), and the University of Arkansas (Fayetteville). Appendix 7 details their contributions and the research facilities available through them. Letters documenting permission to work with ceramic collections and field notes at 10 institutions also are provided.

BUDGET JUSTIFICATIONS

A. Senior Personnel Requested: $13,250

1. Principle Investigator, Dr. Christopher Carr. One-half year's salary covering the period of Aug 15 - Dec 31, 1986 is requested from NSF. The requested salary rate is my current one; it does not include a salary raise (estimated at 4%) for academic year 1986-1987. I will personally encumber this potential salary loss, equivalent to $550 for 6 months.

   I will provide my own support during May 15 - Aug 15, 1986 and May 15 - Aug 15, 1987 by distributing my nine-month salary over a twelve month period. ASU will pay may salary between Jan 1 and May 15, 1987.

   During the periods of May 15, 1986 - Jan 15, 1987 and May 15 - Aug 15, 1987, I will have no teaching or administrative duties. Research will be done in Columbus, Ohio during the former and an off-campus research overhead charge rate has been used for the salary requested for this period. I will carry out most phases of the work myself, from obtaining loan collections to synthetic quantification, with the exception of radiographic, dating, and vessel reconstruction work. I will be directly involved in the latter activities. I will make all temper particle radiographic measures myself, to eliminate between-observer variability. I will have normal teaching and administrative duties (50% time commitment) during the period of Jan 1 - May 15, 1987, when I will be on ASU payroll.

B. Other Personnel Requested: $ 403.

5. Secretarial support. Funds will cover expenses of secretarial services and drafting work through Arizona State University and the Ohio Historical Center to help prepare progress and final reports on a word processor. No direct-cost funds for internal bookkeeping are requested.

E. Domestic Travel Requested: $3,770

   Funds will support automobile expenses involved in transporting ceramic collections from 8 institutions to the Ohio Historical Center and back. It also will cover room/meal expenses at the locations of those institutions while I examine collections and unpublished field notes and select samples for transport to and analysis in Columbus. The locations include: Cincinnati, Kent, Akron, Chillicothe, and Zanesville, OH; Ann Arbor, MI; and Bloomington, IN. Total mileage is 3,524 miles @ 20.5 c/mi; total days spent away from Columbus is 39 @ $55/day, of which I will provide $23/day (total $897) personally and request only $32/day.

   During my stay in Columbus, my family will remain in Tempe. I will have to maintain both my family home in Tempe (rented) and a small apartment for myself in Columbus (rented). I estimate that the latter will cost $2800 total ($350/mo x 8 mo). I will encumber a part of this cost personally ($1000) and will limit my NSF request to $1800 for my housing away from Tempe.

   I will provide the costs of airfare, meals, and lodging (est. $550) for my reporting project results at a symposium that I will organize and chair at a national archaeological meeting.

G. Other Direct Costs Requested: $23,461.

1. Materials and supplies. Funds will cover the costs of purchase of 1 pair of curved-arm 600 mm calipers, 1 pair of straight-armed dial metric calipers, materials for a project-tailored light box, office supplies, Xerox copies of selected field notes, film to document whole vessels and selected sherd

samples, and other miscellaneous supplies.

4. Computer services. Funds will support the costs of computerized data file management and statistical analysis at Ohio State University and Arizona State University. For OSU, expenses include: 1 hr. of CPU @$738/hr; 2 cylinders of disk storage for 6 months @ $11.25/cyl/mo, and 120 hrs of connect time @ $1.80/hr. For ASU, expenses include: 1 hr of CPU @$143/hr; 120 hrs of connect time @$1.68/hr; $50 for I/O; and no storage costs.

6. Other
All laborator work (6a-d) will be done while I am in Columbus, Ohio, and are subject to the off-campus research overhead charge rate.

6a. Radiocarbon assays (Total $14,260). Funds will support 32 radiocarbon assays of hearth charcoal and 14 accelerator mass spectroscopy assays of food residues carbonized on ceramic vessel interiors, including C-13 values for isotopic fractionation correction, for samples in sites listed in Table 11. The assays will supplement extant sherd-date associations for building the time-technology regression models. They will provide tight associations between sherd samples and dating material. If vessels with carbonized food residues additional to those listed are discovered during the course of examining ceramic collections, they will be assayed in lieu of some hearth charcoal samples, given the tighter sherd-date associations they would provide. The standard assays will be made by the Institute for the Study of Earth and Man, Southern Methodist University at a cost of $185 to $225/sample, depending on the Institute's level of NSF funding in 1986 ($205 assumed here). The AMS assays will be prepared by the Institute at the cost of $50/sample and analyzed at ETH, Zurich, Switzerland at an estimated cost of $500/sample.

6b. Radiographic analyses (Total $4625).
Funds will support the radiographic examination of 42 whole or partially reconstructable vessels and sherds from 172 provenience units to document the size distribution and quantity of temper particles of the ceramics. The examinations will require a total of 18.5 8-hr days of radiographic work @ $250/day, based on the following parameters: 6+ exposures per vessel to accomodate vessel curvature, exposure adjustments for vertical variation in wall thickness, and required areal coverage; mean of 9.5 minutes lab time/setup and exposure for whole vessels; 6 exposures per sherd provenience unit to accomodate areal coverage and exposure adjustments for thickness variation; and mean of 6.3 minutes lab time/set up and exposure for sherds. The charge of $250/day includes lab time and film/chemical expenses (proportional to lab time) using Kodak M381 70 mm x 200 ft Ready Pack rolls and Kodak M2 8 X 10" Ready Pack sheets (both Industrex M2). Radiographic work will be done at Battelle Columbus Laboratories, Non destructive Testing Section, by a certified Level II radiographer and myself under the supervision of Dr. Roger Hyatt, Section Manager. Battelle is effectively contributing 200-300% matching funding for this phase of the project by charging no labor overhead costs.

6c. Petrographic analyses (Total $850).
Funds will support the petrographic examination of 200 radiographed sherds for the quantity and size distribution of their temper particles. This will allow calibration of radiographicaly determined estimates of these parameters for sherd thickness/particle superpositioning error. The sample represents 5 Woodland time periods x 4 geomorphological-ecological provinces (defining 20 time-space units differing in average particle density and size distribution) x 10 observations (average) of varying thickness per time-space unit (a minimal number of observations for developing a calibration curve for each time-space unit). The unit cost is $4.25/sherd ($3.00 to thin section, $1.25 for quantitative assay). The University of Arkansas Department of Anthropology Petrographic Laboratory will contribute approximately 1.5 days

of supervision time (@ $100/day) gratis.

6d. Ceramic vessel reconstruction (Total $1097).
The Archaeological Collections Manager for the Ohio Historical Center, will spend 5 weeks locating the parts of and reconstructing between 10 and 15 vessels from the Center's collections that are to be examined morphologically and radiographically, locating field note descriptions of carbon-sherd associations, and examining collections for additional vessels bearing carbonized food remains. These activities are beyond the Collection Manager's normal range of responsibilities. The Manager's help, specifically, is required to complete these tasks efficiently, given his familiarity with the collections. Funds are requested for only 3 weeks of the Manager's time (@$365.50/wk); the OHC will provide an additional 2 weeks of his time gratis.

6e. Phone (Total $350).
Funds will support long distance phone charges for arranging collections and loans and discussing collections housed at 8 institutions and involving 19 archaeologists and personnel at 3 labs outside of Columbus. The Ohio Historical Society will support basic phone charges (@$20/month) for 8 months.

6f. Artifact Collection Loan Insurance (Total $0).
The Ohio Historical Center will provide insurance fees (ca. $250) involved in bringing collections from other institutions to the Center for study as part of the Research Associate position for which they have invited me to apply (should this position be granted).

6g. Ohio Historical Center Overhead Costs (Total $0).
The Ohio Historical Center will not request reimbersement for space and facility usage costs (ca. $2200) during my 8 month stay there.

APPENDIX I.

CULTURAL HISTORIC AND ECOLOGICAL CONTEXT OF WOODLAND CERAMIC CHANGE IN OHIO

Subsistence-settlement data for Woodland southern Ohio is sparce. Available data, however, suggest an ecological context for ceramic change that parallels that in Illinois and the Midwest generally. Increases in population density over time are indicated by: (1) greater densities of sites and/or counts of total surface debris found by survey in the central Scioto valley from PaleoIndian through Ft. Ancient times (Prufer 1975); (2) substantial decreases in the expanse of settlement systems and collection territories from the Late Archaic to Early Woodland (Seeman 1982:15); (3) increases in the mean number of burials per mound from the Early Woodland (13.9) to the Middle Woodland (22.6) (Fischer 1974:55), although this does not control for length of use of mounds; (4) apparent decreases in residential mobility that possibly indicate territorial packing from the Early Woodland to Middle Woodland, evidenced by a change in house shape from circular to subrectangular (Fischer 1974:Appendices D.2, D.3; Whiting and Ayres 1968); and (5) an apparent areal expansion of Scioto Hopewell populations from the middle to late Middle Woodland, marked by a peripheral distribution of ridge-top enclosures or "forts" Fischer (1974:269). Data provided by Fischer (1974:101-105) on the increasing floor areas of "houses" from the Early through Middle Woodland are debatable in relevance, given current interpretations of the use of at least the Middle Woodland structures (Brown 1979) and perhaps the Early Woodland ones (Seeman 1982) as mortuary rather than domestic facilities. Broad-spectrum gathering and use of starchy seeds during the Early and Middle Woodland is indicated for the greater southern Ohio/Kentucky area by paleoethnobotanical records from a number of sites (Watson 1974; Ford 1979; Yarnell 1983; for many references see Struever and Vickery 1973 and Yarnell 1976). The increased use of starchy seeds over time and/or perhaps their preparation by boiling may be indicated by a five-fold increase in the frequency of carious teeth for persons from the Late Archaic to the Middle Woodland in southwest Ohio (Perzigian et al 1984), with similar trends documented for other groups in southern Ohio and western Pennsylvania (Addington 1973; Sciulli and Carlisle 1977; Sciulli et al 1982).

APPENDIX II:

SPECIFIC RADIOGRAPHIC LABORATORY PROCEDURES AND XERORADIOGRAPHY

Certain fine-grained medical films (mammography films, Kodak XTL), and industrial grade films (e.g., Kodak Industrex M, S, or SR) are pable of producing the particle image clarity and contrast required in this project. These films are designed specifically to offer great image resolution and contrast under conditions of low subject contrast (Eastman Kodak 1980: Zmeskal 1943) such as those typifying Woodland ceramics. In particular, the average gradient of their characteristic curves is greater than that of standard medical films (4:1 density:log relative exposure for Industrex M; 2-3:1 for mammography film), providing the necessary radiographic contrast. Also, their grain is fine.

A comparison of the images produced by an ordinary, fast medical grade film (Fuji ROXG), mammography film, XTL, and industrex M2 is shown in Fig. 3 for an early Ft. Ancient sherd. The preferability of industrex M2 and XTL is clear. XTL has the additional advantage of simplified film processing with 90 to 150 second Kodak XOMAT processors available in most hospitals.

To obtain the desired radiographic contrast using mammography film, XTL, or Industrex M2, it is necessary to use kilovoltages as low as possible (50 - 70 kv at 28" ffd). Also, the x-ray equipment must have a beryllium window which allows most soft as well as hard radiation to be emitted, rather than a glass window which is normally used in medical applications and which absorbs some soft radiation for patient protection. Radiography with soft as well as hard radiation is necessary to improve radiographic contrast under low subject contrast conditions. Use of a front lead foil intensifying screen is unnecessary with any of these films; it will provide little exposure advantage. A fluorescent intensifying screen should not be used because it will decrease image clarity. Filters also are unnecessary. However, a lead backdrop should be used to reduce background scatter.

The recently developed method of Xeroradiography (Wagner 1974; Alexander and Johnston 1982), which has been applied to study the temper characteristics and construction of shell tempered ceramics (Adler 1983), was considered for this project. Xeroradiography uses a selenium electrostatically charged plate rather than an ordinary silver halide photographic emulsion, thereby providing images with edge enhancement. Although useful for problems involving the <u>definition of boundaries</u> between different <u>compositionally uniform</u> media (e.g., defining wall outlines of hollow closed vessels, seams between coils of coiled ceramics, or the outlines of compositionally uniform shell temper or voids leached of shell temper), it is not well suited to studies requiring <u>continuous image representation of a subject</u>. In particular, it is not suited for defining multicomponent igneous temper inclusions occurring in high densities in ceramics. There are two reasons. (1) Where temper particle density is high and particle image overlap is great, continuous imaging of the particles allows one to distinguish intersection areas of overlapping particles from cases of simple particle adjacency more easily than does edge enhancement imagery. This is essential to studies of temper particle size distribution, such as this one. (2) Where temper particles are multicrystal igneous rock, continuous imaging renders the facets and multiple crystals comprising the particles and the integrity of the particles more clearly than does edge-enhancement imagery. This allows one to distinguish singular, multicrystal temper inclusions from multiple, overlapping temper inclusions--again essential to studies of particle size distribution such as this one. Thus, more standard radiographic procedures, rather than Xerogradiographic methods, will be used.

APPENDIX III.

WOODLAND AND EARLY FT. ANCIENT SITES HAVING MANY SHERDSAND/OR RECONSTRUCTABLE VESSELS USEFUL FOR THE PROPOSED PROJECT

TABLE 1

SITES HAVING POTENTIAL FOR STUDY

Site	County, Site#	Storage Location	Type of Site	Ceramic Series	Number of Sherds	Dates? C-14 Material?
				SCIOTO DRAINAGE		
Early Woodland Sites						
*Melvin Phillips Mounds 1, 2	Franklin	OHS	mound	Fayette Thick	100s body, 4 rim, 1-2 partial vessels	1 date for each mound; material
*Dominion Land Co.	FR 12	OHS	mounds and enclosure	Adena plain	~1300, 4 partial vessels	material
*Stanhope Cave, EW component	Jackson	Kent	rock shelter	Fayette Thick	800, complete vessel in total collection	1 date on component
*Maybell Hall	Lawrence	OHS	habitation		some	3 dates
*Rais Rockshelter, EW component	Jackson	Kent	rock shelter		some	4 dates on component
*Clough	Pike	Cincinnati Museum			many; partial vessels	1 date
*Schottenstein	Franklin	OHS	mound		>100	material
Davis Mound	Franklin?	OHS	mound	Fayette Thick	~100, partial vessel	material
Florence Mound	Pickaway	OHS	mound	Adena plain	100s, partial vessels	1 date (bad); material
Edgar Bagley Mound	DL 17	OHS	mound	Adena plain	29	material
Arthur James	Delaware	OHS	mound	Fayette Thick	~25	material
La Moreaux-Wright	Delaware	OHS	mound	Adena plain	~20	material
Darby Dan	Franklin	OSU			<20	2 dates
Toephner Mound	Franklin	OHS	mound	Adena plain	a few	6 dates
Spruce Run	DL 22	Peabody	mound and earthwork		whole and partial vessels	
Adena Hillworks, Mds. 34-37, 39	RO 25	OHS	mounds		several 100 from several vessels	
Barger Mounds	Pickaway	OHS	mound		~100	
Adena Mound	RO 1	OHS	mound		1 broken jar	
Phillip Dunlap Mound	RO 57	OHS	mound		31	
John Galbreath	FR 58	OSU	mound		sherds	
McMurray Mounds 1, 2, 3	FR 61	Private	mound		sherds	
James Mound	Delaware		mound			1 date
James Starr Mound 1	Ross		mound			1 date
Thurman DeLong Md	Ross		mound			1 date
James Chase Hambleton	Ma 4					1 date
Schultz	HI 11	OHS				1 date
Kettle Hill Cave EW component	FA 2	OHS	rockshelter			
Middle Woodland Sites						
*McGraw	Ross	U. Michigan	habitation	McGraw	8968 body, 367 rim partial vessel	8 dates

*Sites that appear most useful for study, on basis of current information. Order of sites in list indicates their approximate potential, on the basis of a hierarchy of criteria: (1) availability of dates or datable material plus sherds; (2) habitation rather than burial sites; (3) short-term rather than long-term occupation, or internal provenience information on sherd-date associations.

*Decco, MW component	Franklin	OHS	habitation		2 partial vessels	4 dates
*Murphy		OSU	habitation		2 partial vessels	thermoluminescence
*Rais Rockshelter, MW component	Jackson	Kent?	rockshelter			3 dates on component
*Harness-28, MW component	Ross	Kent	camp	McGraw	2500	
Browns Bottom, 2	RO 40	Kent	habitation	McGraw	276 body, 3 rim	
Russell Brown, Middle Terrace, 2	RO 36	OHS	habitation	McGraw	63 body, 2 rim	
Lynch 4, MW component	RO 130 (RO 46)	Kent	habitation	McGraw, Seip	40 body	
Alum Creek	Franklin	private	habitation	McGraw	35 body, 1 rim	
Raymond Alter	RO 63	OHS	mound		500+	
Ater	Ross	OHS	mound	McGraw	497 body, 8 rim	
Ginther Mound	Ross	OHS	mound	McGraw	250 body, 11 rim	
Porter Mounds 17, 38	RO 38	OHS	mounds		100s	
Walnriter	Ross	OHS			100s body, 47 rims	
Rockhold Mound 2	RO 39	OHS	mound	McGraw	89 body, 1 rim	
Russell Brown Mound 1	Ross	Kent	earthwork, mound	McGraw	40 body	2 dates
Russell Brown Mound 2	Ross	Kent	earthwork, mound	McGraw	71 body	1 date
Russell Brown Mound 3	Ross	Kent	earthwork, mound	McGraw	21 body	3 dates
Hopeton Square	Ross	Cleveland Museum?	earthwork		several dozen	
Edwin Harness	Ross	Peabody, OHS	earthwork, mound	McGraw	81 body, 14 rim	4 dates
Seip 1	Ross	OHS	earthwork, mound	McGraw	203 body, 14 rim	1 date
Harness cluster 13	RO 9	Kent	habitation	McGraw	24 body	
Infirmery Lane, MW component	RO 315	ODOT	habitation		10s	
State Route 104	Ross	ODOT	camp		40	
McGraw 2	RO 111 (RO 20)	Kent	habitation	McGraw	17 body	
Morrison Farm, MW component	RO 120 (RO 2)	Kent	habitation	McGraw	17 body	
Russell Brown, Middle Terrace, 3	RO 36	OHS	habitation	McGraw	16 body	
Rightfoot	PI 52	OSU	habitation	McGraw	11 body	
Harness-3	Ross	Peabody, OHS	earthwork, mound	McGraw	45 body, 2 rim	
Harness-4	Ross	Peabody, OHS	earthwork, mound	McGraw	113 body, 10 rim	
Mound City, general	Ross	NPS	earthwork, mounds	McGraw	247 body, 28 rim, 5 whole or partial vessels	
Hopewell, general	Ross	OHS, Field Mus., U. Mich.	earthwork, mounds	McGraw	416 body, 26 rim	4 dates
Tremper	Scioto	OHS	earthwork, mounds	McGraw	397 body, 23 rim, 1 partial vessel	1 date
Seip General	Ross	OHS	earthwork, mounds	McGraw	2154 body, 68 rim	
Seip 2	Ross	OHS	earthwork, mound	McGraw	12 body, 1 rim	
Seip Enclosure	Ross	OHS	earthwork	McGraw	2 body, 2 rim	
West Mound	Highland					2 dates

Early Late Woodland Sites						
*Harness 28	Ross	Kent	habitation	Newtown cordmarked	8000	1 date
*Zencor/Scioto Trails	Franklin	OHS	habitation		many, whole and partial vessels	material
*Stanhope Cave, ELW component	Jackson	Kent	rockshelter	Peters	800, 1 whole vessel, in complete collection	1 date on component
Caldwell's Bottom	RO 129 (RO 8)	Kent	habitation	Peters	321 body, 2 rim	
Caldwell's Bluff, ELW component	RO 117 (RO 7)	Kent	habitation	Peters	117 body	
Water Plant	FR 155	OSU	habitation		92 body, 2 rim, partial vessel	
Harness cluster 8	RO 9	Kent	habitation	Peters	86 body	
Harness cluster 3	RO 9	Kent	habitation	Peters	82 body	
Wise Rockshelter	JA 8	Kent	rockshelter	Peters	50 body	
Voss-McKenzie	RO 47		habitation	Peters	25 body	
Written Rock	FA 18/2	OHS	rockshelter	Peters	20 body	
Swinehart Village	FA 7	OHS	habitation			
Morrison Farm, ELW component	RO 120	Kent	habitation	Peters	13 body	
Kettle Hill Cave, LW component	FA 2	OHS	rockshelter			
Hudson		OHS, display			whole vessel	
Late Late Woodland Sites						
*Decco	Franklin	OHS	habitation	"Cole"	partial vessel	2 dates
*Ufferman	DL 12	OHS	habitation, cemetery	"Cole"	150+	1 date; material
*Cole	DL 11	OHS	habitation, cemetery	"Cole"	partial vessel	1 date
	RO 145	OHS	habitation	"Cole"	600+	
Greencamp	Delaware?	OHS		"Cole"	many	
Fort Ancient, Baum Phase						
*Island Creek	AD 25	Huntington Army Corps	habitation	Baum	1232 body, 61 rim	6 dates
*Paint Creek Lake 7	HI 123	Huntington	habitation	Baum	115 body, 6 rim	3 dates
*Blain	RO 128	Kent	habitation	Baum	1000s, 2 partial, 1 whole vessel	5 dates
*Voss	FR 52	OHS	habitation and mound	Baum	100s	18 dates; material
*Howard Baum		OHS	habitation	Baum	1084	1 date
*Holmes	Highland	OHS	habitation	Baum	4 whole vessels	1 date
Cramer Mound and Village	Ross	Kent, ODOT	habitation	Baum	10,000	
Baum	RO 4	OHS	habitation	Baum	100s, partial vessel	
Caldwell's Bluff, FA component	RO 117 (RO 7)	Kent	habitation	Baum	83 body, 15 rim	

Lenington	FR 127	OSU	habitation?	Baum?	10 body	
Henderson Road	FR 55	OHS	habitation	Baum	sherds	

Woodland, General

30 additional sites with 15 or more undiagnostic, grit-tempered sherds; no dates or C-14 material.

MUSKINGHAM DRAINAGE

Early Woodland Sites

*Buckmeyer	Perry	Muskingham College	Adena plain and Montgomery Incis.			2 dates
*Nashport	Muskingham	OHS		Adena plain	<100, partial vessel	1 date, material
*Mary's Cave		J. Carskadden			10s	1 date
Gerlack Mound	Morgan		mound		sherds	2 dates
Kline Mound	Tuscarawas		mound		sherds	1 date
Riker	Tuscarawas				sherds	1 date
Cordray	Licking		mound		~100	material
Deeds	Licking		mound	Fayette Thick	7	material
Peters Cave A		Kent	rockshelter		<20	
J. H. Colville	LI 32	OHS	mound		75 body, 1 rim	
Larimore Mound	KN 6	OHS	earthwork, mound	EW?	2 whole vessels	
Duncan Falls	Coshocton	J. Carskadden			sherds	
Miskimens Mound	Cs 6	J. Mortine			sherds	
Woorley Collection	Licking	OHS		Adena plain	1 whole vessel	

Middle Woodland Sites

*Philo II, MW component	Muskingham	J. Carskadden			100s, partial vessel	1 date
*Martin Mound	Coshocton	J. Carskadden	mound	"McGraw"	350, 1 partial vessel	1 date
Kohl	Tuscarawas					1 date
*Mary's Cave, MW component		J. Carskadden	rockshelter		168	
Dresden, MW component	Muskingham	J. Carskadden	habitation	"McGraw"	~200	
DeGiondomenico	Licking	OHS	earthwork		~100 from 1-2 vessels	
Philo I	Muskingham	J. Carskadden			partial vessel	

Early Late Woodland, Late Late Woodland

*White Rock	MO 8	Kent	rockshelter	Peters cord-marked	2013 body, 78 rim	1 date
*Chesser	Athens	Kent	rockshelter	Peters	819 body, 44 rim	1 date
*Philo II, LW component	Muskingham	J. Carskadden			sherds	1 date
Chili	Coshocton		rockshelter	Peters	100s body, 10s rim	material
Peters Cave B		Kent	rockshelter	Peters	120	
Dresden, LW component	Muskingham	J. Carskadden	habitation		sherds	
Eden Church	LI 1	OHS	village		many sherds	
Granville village	LI 2	OHS	village		many sherds	

Speckman Mound	Cs 55	J. Carskadden			whole vessel	

Fort Ancient, Baum Phase

*Locust	Mu 160	Huntington	habitation	"Baum"	sherds	5 dates

Woodland, General

7 additional sites with poor information on time period, number of sherds: Eden Church, Granville Village, Butcher Mound, Cordray Mound, Kirpatrick Mound, Mu 73, and Athens 50.

HOCKING DRAINAGE

Early Woodland Sites

*Rock Riffle Run					~200	material
Bob Evans, EW component	Gallia		rockshelter		sherds	1 dates
Chapman Mound	Athens		mound		14	material
Connett Mounds	Athens		mound		10	2 dates
Daines Mound 2	Athens		mound		a few	1 date

Middle Woodland Sites

Earl Delong	Hocking				sherds	2 dates

Late Woodland Sites

Dumond	HO 52	OHS			159	
Ash Cave	Hocking				sherds	1 date
Bob Evans, LW component	Gallia		rockshelter		sherds	2 dates

Fort Ancient, Baum Phase

*Graham Village	HO 1	Kent	habitation	Baum	4012 body, 424 rim	2 dates

MIAMI DRAINAGES

Early Woodland Sites

*Miami Fort	Hamilton	U. Cincinnati	fortification, habitation	Marion Thick	100s body, 30-40 rims, all components	1 date
Cowan Creek Mound	Clinton		mound	Fayette Thick	60	1 date
Haag, EW component	12 D 9	Glenn Black	habitation	Adena plain	some body, 4 rims	

Middle Woodland Sites

*Twin Mounds Village	Hamilton	U. Cincinnati	habitation		100s body, 30-40 rim	1 date
*Miami Fort, MW component	Hamilton	U. Cincinnati	fortification, habitation		100s body, 30-40 rim, all components	1 date
*Todd Mound	Butler	U. Cincinnati	mound		27 body, 3 rim	5 dates
*Headquarter	Ha 65	U. Cincinnati			some	1 date
Fort Ancient, MW component	Warren	OHS	fortification, habitation		243 body, 9 rim	
Fort Hill	Highland			McGraw	127 body, 14 rim	
Cove 2	Hi 44			McGraw?	24 body, 2 rim	
Denneman Village	Hamilton	Peabody	habitation	McGraw	sherds	
Turner 1	Hamilton	Peabody	mound	McGraw	365 body, 82 rim	
Turner 3	Hamilton	Peabody	mound	McGraw	490 body, 32 rim	
Turner 4	Hamilton	Peabody	mound	McGraw	363 body, 45 rim	
Turner 6	Hamilton	Peabody	mound	McGraw	34 body, 3 rim	
Turner 7	Hamilton	Peabody	mound	McGraw	32 body	

Turner 9	Hamilton	Peabody	mound	McGraw	28 body, 2 rim	
Turner 12	Hamilton	Peabody	mound	McGraw	3 body	
Turner embankment	Hamilton	Peabody	earthwork	McGraw	809 body	
Turner cemetery	Hamilton	Peabody	cemetery	McGraw	32 body	
Mariott 1	Hamilton	Peabody	mound	McGraw	351 body, 26 rim	
Early Late Woodland Sites						
*Sand Ridge	HA 19	Cincinnati Museum	habitation	Newtown	100s body, 100s rim, partial vessel	1 date
*Turpin	HA 28	Cincinnati Museum	habitation	Newtown	100s body, shoulders, 1 whole vessel	1 date
*Lichliter	MO 423	Indiana U, Pa	habitation	Newtown cordmarked	100s	1 date
Haag, ELW component	12 D 9	Glenn Black	habitation	Newtown	17,500	perhaps
Firehouse	HA 419		habitation	Newtown	237 body, 13 rims	
Late Late Woodland Sites						
State Line	Hamilton?	U. Cincinnati Cincinnati Mus.	habitation		100s	
Woodland, General						

4 additional sites with poor information on time period, number of sherds: Shawnee Lookout, Schultz, Sayler Park Mound, GR 101.

APPENDIX IV.

PHYSICO-CHEMICAL DIFFERENCES BETWEEN OHIO AND ILLINOIS WOODLAND CERAMICS AND THEIR EFFECTS ON CERAMIC CHANGE

Temper particle composition. Middle and early Late Woodland cooking jars in west-central Illinois were tempered primarily with crushed rock consisting mainly of quartz crystals with occasional admixture of feldspar, horneblend, and limestone, or with quartz sand (Braun 1983; Griffin 1952; Fowler 1955; Struever 1968:140-173). In contrast, Woodland ceramics in Ohio usually were tempered with crushed granitic rock (see citations p. 22; personal observation; Barkes 1981). Quartz and granitic rocks (and their nonquartz consistuents) differ in their thermal expansion coefficients (Table 10). At temperatures within the range of low fired ceramics (900 oC), granitic rocks and many of their constituents expand at rates approximately similar to most clays. In contrast, quartz expands at 2 to 4 times the rate of most clays. Moreover, at 572 +/- 5 oC, it undergoes a change in crystalline structure (alpha to beta quartz), which results in a rapid 2% expansion (Shephard 1956:23, 29; Rye 1976:34, 114). These differences in the composition and physical properties of the tempering materials used in Ohio and Illinois cooking vessels, and the different potentials they offer for causing thermal fatigue of a vessel's wall, are in line with the general interpretation that the different temporal trends in temper particle size in Ohio and Illinois over time reflect differences in temper thermal expansion coefficients (p. 17).

Temper particle shape. Ohio and west-central Illinois ceramic temper may differ significantly in their shape. The quartz sand which comprises the temper in many Illinois Middle through early Late Woodland ceramics presumably is waterwashed. Minimally, it is fairly equidimensional, if not smoothed in outline. In contrast, the crushed granitic rock comprising Ohio Woodland tempering materials is very irregular and angular in outline. These shape differences have implications on the mechanical strength of a vessel's paste--in particular, its tensile strength and Young's modulus of elasticity, E (Steponaitis 1983). Although in general an increase in the quantity of temper particles in a fired paste will decrease its strength (Shepard 1956:131-132), reducing both its tensile strength and modulus of elasticity (e.g., Steponaitis 1983), the addition of smoother, equidimensional particles will produce a greater decrease in strength than the addition of rough, irregular particles (Shepard 1956:27,132). As a consequence, the strategy of improving a vessel's thermal performance by increasing its wall thermal conductance with more and larger additions of high-conductive temper within it would have been more sharply constrained for the Illinois Woodland potters who employed more equidimensional and possibly smoother temper materials than for Ohio Woodland potters who employed rough granitic rock. This circumstance, too, is in line with the different temporal trends in temper particle size distribution noted for Illinois and Ohio (p. 17).

Clay physical chemistry. Finally, it should be noted that west-central Illinois Middle through early Late Woodland cermics and Ohio Woodland ceramics in general differ considerably in the quantity of temper they include: between 1.2 and 5.6% for Illinois ceramics (Braun 1982:Fig. 3) and approximately 25 and 40% for Ohio ceramics (pers. observ.). This difference suggests gross differences in the water adsorptive properties and drying characteristics of the clays used to make pots in the two areas (clay texture and/or structure). Temper is addded to clay when potting, in part to: (a) reduce the amount of water necessary to make the clay plastic--water which is lost in the vessel drying process and which can potentially cause cracks to form; and (b) to open the clay's texture to allow water transport from the interior to the exterior of a vessel when drying (Shepard 1956:26, 53). It is possible that the trend for increasing percentages of larger sized temper particles in Ohio ceramics relates partly to the advantages in vessel drying (particularly water transport) offered by larger particles in the context of more water-adsorptive clays, as well as advantages afforded in increasing vessel wall thermal conductivity. In contrast, the reverse trend in Illinois would reflect the lack of importance of this factor in the context of less adsorptive clays and the overriding importance of circumventing thermal fatigue.

APPENDIX V.

OPERATIONALIZED CRITERIA FOR SELECTING SHERD AND CARBON SAMPLES AND JUSTIFICATIONS FOR THEM

Criteria about the ceramics:

(1) Ecological context. The sherd-date associations used to build any single time-technology model will probably have to be restricted to those from one of the four geomorphological-ecological provinces discussed earlier (p. 16). This will probably be necessary to ensure that the observations are relevant to a single technological trend, should technological change be a response to localized demographic, subsistence, and culinary changes (interpretive framework 1).

(2) Ceramic chemico-physical system. The sherd-date associations used in any single model will be restricted to those from a geomorphological zone that offers predominantly a family of similar clays and that includes vessels which have been documented by X-ray diffraction to be similar in paste composition (p. 20). Minimally, these zones will probably be the four geomorphological-ecological provinces discussed previously. This is necessary to increase the chance that ceramic variation in the quantity of temper particles reflects temporal changes in performance demands rather than atemporal differences in clay plasticity that might occur (p. 16).

Also, the ceramics to be analyzed should be tempered with primarily crushed igneous or metamorphic rocks or chert, not limestone or quartz sand. Limestone tempered ceramics represent a technological system that is chemically and physically different from igneous/metamorphic/chert tempered ceramics and similar to shell tempered ceramics (Steponaitis 1983; Rye 1976). They cannot be expected to exhibit the technological trends described above.

This criterion will be most important in the selection of Middle Woodland ceramics of the lower Miami drainages, for which limestone tempering is frequent. The same is true for sporadic time-space units in the Appalachian Plateau: e.g., the Chessar phase Late Woodland in Raccoon Creek (Prufer 1967:12); isolated sectors of the Muskingham, where limestone outcrops predominate; and some assemblages in the Hocking valley (Murphy 1975:228).

(3) Ceramic vessel functions. Each group of sherds should pertain to vessels of the large cooking jar (or possible storage jar) variety expected and documented to exhibit the proposed technological trends over time. The ceramic variables and means for segregating such sherds and focusing analysis on them have been described above (p. 20, Task 2).

(4) Intravessel variation in sensitivity to the tracked subsistence processes. Each group of sherds should come from the body, rather than base or rim sections, of a vessel. Basal sections must be eliminated from analysis because vertical loading and thermal stresses concentrate there (Amberg and Hartsook 1946; Rye 1976:114; Braun 1985). This condition requires the potter to strike a different balance of mechanical strength vs. thermal durability than that characterizing a vessel's wall. In particular, the base must be thickened for mechanical strength, which is not pertinent to the regressions to be built. Rims must be excluded from analysis because they commonly exhibit decorative thinning or thickening rather than functional constraints. The position of a body sherd on the wall of its source vessel probably will not have to be controlled (p. 11).

(5) Single origin of sherds. Each group of sherds should have technological, morphological, and surface attributes indicating that they likely come from one vessel--or at least several very similar vessels manufactured within a short time span by one potter or a few having similar technique--and that the dating material is relevant to all the sherds. The variables to be used in assessing homogeneity and the means for estimating intravessel ranges of variation are described above (p. 19, Task 1).

In addition, the sherds should be as large as possible, reducing the possibility that they were moved about (e.g., by sweeping, foot traffic) during the formation of deposits and come from multiple vessels of origin. Braun (1985) used a 1/2" minimum sherd diameter. This threshold seems appropriate for the analysis of the Ohio Woodland collections, based on personal observations of the availability of sherds of various size classes.

Criteria about the relevance of the dating material to the ceramics and vice versa:

A great variety of formation processes can lead to temporal discrepancies between a target event which the archaeologist wishes to date (here, the manufacture of a ceramic vessel) and an associated reference event which is represented archaeologically and datable (e.g., the death of a tree, the charcoal of which is deposited with the vessel). These include processes in the physical, physiological, behavioral, archaeological, and analytic contexts (Dean 1978). To control for these possible associational and measurement errors, the following selection criteria will be used.

(6) Close relationship between date of ceramic manufacture/use and date of death of the assayed plant tissue. When ceramics from archeological deposits are dated using associated firewood charcoal, numerous formation processes, may weaken any given sherd-date association. Some examples include: the possibility that the charcoal to be dated represents the incompletely oxidized heartwood of a tree rather than outer rings reflecting the time of its death; the use of firewood that has long been dead, perhaps mined/salvaged from some other archaeological context; mixture of older and younger charcoal with the ceramic sample through pit intrusion, burrowing mammal activity, or improper excavation and feature definition; and in the case of site-wide associations, the possible lateral displacement of the site over the course of multiple sporadic, short-term reoccupations spanning decades or long-term differential site abandoment.

To help eliminate these errors, seven steps will be taken.

(a) Use of carbonized food residues. Where possible, carbon samples comprised of carbonized food residues on the interiors of vessels will be submitted for dating. This approach, which eliminates essentially all of the above-named sources of association error, has previously proven highly successful (Bill et al 1984; Tamers, pers. comm.). Carbon from fire smudging on the exterior of vessels will not be used, as it can reintroduce many of the association errors listed above. Carbonized plant fibers inside the vessels, which would provide another source of tightly associated carbon (Johnson et al 1985), do not occur and cannot be used. Dating food carbon will require the use of accelerator mass spectroscopy.

(b) Use of nuts or annuals. When hearth charcoal associated with a vessel must be used, preference will be given to carbonized nuts (sometimes used in making fires) or annuals over wood. This will eliminate the problems of possibly dating old heartwood, old deadwood, or recycled wood (Richard Ford, pers. comm.).

(c) Tight, undisturbed contexts of deposition. When hearth charcoal (wood, nuts, or annuals) must be used, each sherd-carbon date association should come from a provenience indicating that the pottery was made or used with the fire that produced the carbon. Such tight depositional contexts, however, are likely to be rare, or not adequately documented. Short of this, each sherd-dating material association should come from a deposit of likely brief formation and sealed context. Pit features with documented stratigraphy ruling out slow accumulation or the possibility of fill disturbance will be preferred.

(d) Sample integrity. Each submitted carbon sample will be required to be an integral whole rather than a composite sample from dispersed contexts.

(e) Level of precision. Each sherd-date association will be required to have a dating precision of no less than +/-250 radiocarbon years. This will lessen the possibility that carbon for a sherd-date association pertains to a mixed archaeological context, when hearth charcoal (wood, nuts, or annuals) is used. This criterion also is of practical importance: any greater imprecision will result in regression models that predict dates with associated standard errors approaching those of traditional seriations.

(f) Correspondence of date to time-technology relations known to be accurate and accepted culture history. Some geographic provinces and cultural time periods may offer few depositional contexts ensuring strong associations between hearth charcoal and ceramics, such as sealed pits. In these cases, site-wide associations in small, short-occupation habitations will be examined for their potential relevance in building the regression models, with an eye for their possibly anomalous time-technology relations. In particular, each used sherd-date association will be required to be approximately similar in its time-technology relationship to those of associations known to be very tight--especially those derived using food residues on vessel interiors and accelerator mass spectroscopy methods. Also, each sherd-date association will be required to correspond approximately with traditional seriations for the region (cited previously). This second criterion will allow apparent association discrepancies on the order of hundreds of years to be eliminated from analysis, but not fine segregation.

(g) Length of occupation. Sherd-date associations on a site-wide basis will not be sought for earthworks or mounds, which were likely used over extended periods of time, or large, extended-occupation habitation sites.

(7) Lack of evidence for sample contamination. Submitted carbon samples will be required to have little visible contamination by roots; no contamination by organic, museum-used, curatorial chemicals; and to have been stored in adequate containers.

(8) Expediency of ceramic deposition. Groups of sherds and associated dating material will be drawn from habitation contexts rather than from burials or mound features. Vessels contained in graves or mortuary features have a greater potential for having been curated and/or served as heirlooms rather than broken and deposited soon after their manufacture (David 1972; DeBoer 1974; DeBorer and Lathrop 1979).

Additionally, the vessels should not be extraordinarily large--a feature that encourages their having been curated and that correlates with vessel use-life (Longacre 1981:64; DeBoer 1981). Likewise, they should not be anomalously small, increasing their potential for having been traded and curated as valued items (Roe 1980; DeBoer 1981; Lathrop 1976).

APPENDIX VI.

DETAILS OF THE STATISTICAL METHODS TO BE USED AND THEIR JUSTIFICATION:

It will not be possible to use standard regression approaches to predict corrected date from the ceramic variables, for two reasons. (a) The data define a statistical _process_ and will have been collected in a _design_ in which date is the predictor variable and sherd group characteristics are response variables--the opposite (inverted) form of the model that is needed. (b) Variables on _both_ sides of the equation encompass errors that need to be accomodated by the modeling procedure. In particular, the values of the predictor variable--corrected date--should not be analyzed as absolute point dates (Dean 1978:230). To do so would be to overlook the several kinds of associational and measurement errors in the biological, behavioral, archaeological, and analytic contexts (Dean 1978) that can characterize a carbon sample (only some of which will have been controlled by selection criteria given in Appendix 5) and to allow these errors to affect the modeling outcome in an uncontrolled manner.

To derive a model in a manner concordant with the nature of the data, a multivariate version of Braun's (1985) time series approach can be used. This involves the following steps. (a) The PROBNORM filtering procedure is used to define a smoothed time series of each technological variable against time. This procedure simultaneously calculates smoothed values of the technological variable at the midpoints of equispaced interpolated time intervals and filters noise arising from dating error. This characteristic and the fact that time is treated as the predictor variable accomodates problems a and b, above. (b) The smoothed sherd characteristics from each time series and the interpolated dates are described by a polynomial multiple regression of the uninverted form--with time as a response to multiple sherd characteristics. This equation allows the prediction of the date of a group of sherds from its technological characteristics. It also is possible to predict date from technology using an inverted _graphic_ representation of the smoothed time series constructed in step _a_. In either case, estimation of the error of prediction of date is not directly possible. In the polynomial regression description approach, this is so because the final regression is defined from the smoothed technological and time data rather than the original data. (c) It is possible to estimate the error of prediction of a date within a given interpolation interval using procedures described by Braun (1985) after Long and Rippeteau (1974:208).

APPENDIX VII.

SUPPORT BY OTHER INSTITUTIONS
AND LETTERS OF INVITATION AND PERMISSION

Arizona State University will allow me 100% release from teaching and administrative duties during the period of May 15, 1986 - January 15, 1987.

The Department of Anthropology at ASU has a number of facilities and staff services that will be useful in the final analytic and report writing stages of the proposed research. These include a 7500 sq. foot laboratory/storage building providing work space; 2 fully equipped dark rooms; a half-time photographer; a full-time archaeological laboratory technician; one full-time professional word processor; a full-time administrative accountant; PCs and Laserjet printer; a microcomputer graphics and statistics laboratory including an AT, 2 XTs, digitizer, publishable-quality plotter, printer, emulated Tektronix graphics terminal, and software for statistics, data base management, file management, plotting, and programming. At ASU, I will also have access to an IBM 3081 mainframe operating under MVS/WYLBUR and CMS; mainframe SAS, BMDP, and other statistical packages; and mainframe graphics facilities including DI-3000, Calcomp, Zeta, and Versatec plotters, and interactive CMS graphics terminals; and x-ray diffraction equipment. The ASU library has 1.9 million volumes and 21,000 serial subscriptions. I will be able to bring a portable PC and printer owned by the Department of Anthropology to Ohio.

Battelle Columbus Laboratories, Nondestructive Testing Section, will continue to provide technical and financial support of the radiographic aspects of this project (see letter of support, below). Battelle has contributed a minimum of $1500 to the preliminary research stages of the project since 1983. Their confidence and interest in the project is indicated by their willingness to do all radiographic work without labor overhead charges, equivalent to 200 - 300% matching funds totalling to a minimum of $9,250.

The Battelle system is the largest independent, nonprofit research firm in the United States. In the last two years, the Battelle Columbus Laboratory branch drew 183 million and 208 million dollars of government and industrial contracts in a diversity of engineering and biological fields. Battelle Columbus Laboratories has over 1500 employees. The Nondestructive Testing Section's radiography lab is equipped with all the research facilities necessary for this project. These include: three industrial x-ray machines with beryllium windows (General Electric 250 kv; Norelco 150 kv; Picker 50 kv high resolution unit); attachments; complete dark room and viewing area; and optical scanning and image enhancement equipment (VAC 750; Gould 8400).

The Ohio Historical Center (Columbus) will serve as my home base for resarch during my stay in Columbus. The Ohio Historical Center has agreed to provide me work space and basic office facilities. In addition, they have invited me to apply for a Research Associateship position (see letter, below). This would provide me with staff privileges, including the subsidizing of mailing fees and museum collection insurance fees of other institutions and access to various helpful research facilities (e.g., photographic, drafting, and measurement equipment). The Center has word processing equipment and staff, which will facilitate my research there.

The Center is the best institutional choice for a home base for research because: (1) it houses the majority of the archaeological collections with which I will work over the course of the project, and comprises the main repository of archaeological materials from Ohio; (2) it houses a large library on Ohio archaeology and is the main repository of unpublished archaeological site reports and field notes in Ohio; (3) Columbus is central to (ca. 1 - 2 hrs away from) each of the other institutions having collections to be studied. It also is the location of Battelle Laboratories, which will do all radiographic work, and Ohio State University, which will provide computer facilities and which has a large Department of Ceramic Engineering, providing consultation potential.

The University of Arkansas Department of Anthroplogy's physical anthropology and petrographic laboratory will do all petrographic analysis (Task 5) for this project. Pertinent to the needs of the project, the laboratory is equipped with: 1 Blue Blazer 10" slab saw, 1 Buehler low spped Isomet diamond saw, 1 Buehler polisher/grinder, 2 Buehler low speed polishers, 2 Whirlimet automatic polishing attachments, pressure and vacuum embedding equipment, fume hood, sonic cleaner, electric balance, 1 Zeiss Standard 18 transmitted light microscope with Halogen illuminator; Zeiss optics for fluorescence microscopy and Nomarski reflected light differential-interference attachments, 2 Olympus KHC transmitted light microscopes; 2 SZ-III steromicroscopes, 1 Projectina Micro Projector, 1 Polaroid MP-4 copy camera system, 1 Olympus PM-10A automatic 35 mm and large format microscope camera.

Letters of Permission

Letters documenting that I have permission to work with the archaeological ceramic collections and field notes housed in each of 10 institutions or foundations are provided next.

APPENDIX VIII:

VITAE AND OVERVIEW OF CREDENTIALS OF RESEARCH PERSONNEL

Primary responsibility for this project will be with the principal investigator. My curriculum vita is provided here. Please note that my credentials include preparation for each of the facets of this project. Among these are: (a) 16 years of archaeological research in the Midwest U.S., with 9 seasons of field work there; (b) 4 years of work with museum collections from the Ohio Woodland, 3 with ceramics specifically; (c) 13 years of research and major publications on quantitative analysis; and (d) 10 years of research and major publications on the physics, chemistry, and physical chemistry of soils and clays, serving as a background to my studies of ceramic physics, chemistry, and manufacture.

Mr. Floyd Brown, a certified Level II radiographer at Battelle Columbus Laboratories, Nondestructive Testing Section, under the supervision of Dr. Roger Hyatt, manager of the section, will provide technical support for all radiographic work. Petrographic analysis will be done by a University of Arkansas graduate student under the direction of Professor Jerome C. Rose, Director of the Anthropology Department's physical anthropology and petrographic laboratory. The laboratory has done 7 major petrographic projects in the last 5 years. Mr. Brad Baker, Collections Manager, Ohio Historical Center, will provide assistance in reconstructing between 10 and 15 vessels to be examined as part of this project.

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