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Late Woodland Period "Waste" Reduction in the Ohio River Valley

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The "good and gray" (Williams 1963:297) cultures of the Late Woodland period in the Eastern Woodlands are so named because they lack the elaboration of the preceding Middle Woodland. Traditional attempts to explain this loss of elaboration as a consequence of social breakdown or climatic change fail empirically or are untestable and do not account for the variety of trajectories observed. The "waste" hypothesis both accounts for this kind of variation and is testable. Here we describe the critical variation in different areas of the Ohio Valley and outline a brief explanation, relying on simple variables drawn from evolutionary theory.
Key Words: evolution; Hopewell "collapse"; Late Woodland period; selection; waste.

INTRODUCTION

The concept of "waste" was originally developed (Dunnell 1989) in the context of attempting to explain the so-called florescence or cultural climax in the eastern United States typified by Middle Woodland Hopewell, especially Ohio Hopewell, cultural units (e.g., Griffin 1952, 1960, 1961, 1997; Seeman 1979). Although the epitome of cultural elaboration in the pre-Columbian Ohio Valley, relatively little effort was expended on explaining Hopewell's occurrence, largely because, one suspects, its causes were not seen as exceptional. Hopewell's origin was simply an expression of cultural progress that dominated archaeological thought throughout most of the nineteenth and twentieth centuries. Ohio Hopewell and the sequence leading to it, in fact, exemplify the power of such covert mechanisms. Until this century, Ohio Hopewell was thought to postdate Fort Ancient because it was more "advanced" (cf. Mills 1907; Moorehead 1899; Putnam 1886). With the clarity born of hindsight we can also see how "facts" grew to meet the interpretive need. Woodland subsistence was thought [although not universally so (e.g., Caldwell 1958; Cleland 1966; Dunnell 1972)] to be agricultural or at least "horticultural" (e.g., Griffin 1960, 1967; Willey 1966; Willey and Phillips 1958; Wray and MacNeish 1961; contra Prufer 1997a), i.e., "food-producing" (Morgan 1877). In this scenario, although it is rarely explicit, it was a *surplus* generated by food production that fueled the Middle Woodland climax of the Ohio Valley.

There are manifold problems with this explanation. Since these have been detailed elsewhere (Dunnell 1989), it is necessary only to enumerate the principal flaws here. First, the existence of a "surplus" does not provide a mechanism for cultural elaboration even in the ad hoc, commonsensical explanatory mode; it is at best a condition, not a cause. Second, the concept of surplus is, itself, indefensible in scientific explanation. It is not well-defined, even when such is attempted, and when it is defined, it is clearly an ethnocentric concept, i.e., it *values* particular uses of energy as better than other uses

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(e.g., Harris 1959; Pearson 1957). Even if these faults were overlooked, the surplus-based explanation leads to empirical expectations manifestly falsified both in time [i.e., Hopewell elaborations are not founded upon or even associated with the appearance of large-scale maize-based agriculture (Bender et al. 1981)] and in space [i.e., the distribution of elaboration is virtually opposite that anticipated by surplus generation (Dunnell 1989)].

If accounting for the origin of the Hopewell phenomenon is difficult, the problem posed by the so-called Hopewell "collapse" (Yerkes 1988:1) or "devolution" (Bender 1985:48; Munson 1988:7) is even more troublesome. Typically, anthropologists and other social scientists are far more comfortable dealing with the rise of traditions than their fall (Yoffee 1988). Like other well-known examples (e.g., the breakdown of the Roman empire, the collapse of the Classic Maya civilization, the fall of the Han dynasty), the end of Hopewell presents a dilemma for the unilinear progress notion underlying both cultural evolution and Western common sense.

Cultural Elaborations of the Middle and Late Woodland Periods

Profound differences in the archaeological records of the Middle and Late Woodland periods mark the "end" of Hopewell at about 400 A.D. Indeed, these differences are so stark that, while the former is referred to as a "high culture" (Griffin 1943:211) and a "flamboyant explosion" (Prufer 1964:63), the latter is a "good and gray" culture (Williams 1963:297) and a "colorless interval" (Phillips 1970:19). The contrast between Hopewell and the succeeding (and to some extent the preceding) cultural manifestations was so dramatic that it was the first "horizon" to be recognized in the East (e.g., Griffin 1946; Setzler 1933) and thus played a critical role in integrating the fledgling chronology of the eastern United States (Dunnell 1996). Prior to considering hypotheses proposed to account for the Hopewell "collapse," it is appropriate to briefly characterize the relevant expressions in the archaeological record.

The Middle Woodland Hopewell phenomenon is known for its large-scale geometric earthworks, hilltop enclosures, and complex burial mounds with elaborate tombs. Materials interred in the mounds are remarkable for their sheer quantity and their "aesthetic" qualities (i.e., amount of labor invested). Most of the burials include finely crafted grave goods, many made of exotic raw materials obtained through interregional trade: marine *Busycon* and *Cassis* shells from the Gulf and southeast Atlantic coasts, mica and quartz crystals from the southern Appalachians, grizzly bear teeth and obsidian from the Rocky Mountains, pottery from the Southeast, galena from northern Illinois, copper and silver from the Upper Great Lakes area, and chalcedony from North Dakota (Griffin 1952, 1967; Prufer 1964; Seeman 1979; Walthall et al. 1979). Even domestic pottery exhibits a degree of elaboration not seen in Ohio Valley archaeological assemblages before or since.

From a cultural evolutionary perspective, the impressiveness of the earthworks and finely made artifacts meant the Hopewell phenomenon *had* to be at the peak of cultural development in the Eastern Woodlands (Griffin 1943:211). Consequently, it wasn't until 1937 (Griffin 1937) that proper chronological placement of the Hopewell tradition, as older than Fort Ancient, was resolved. Compared to the large mounds and earthworks of Hopewell and the dense village deposits of the Late Prehistoric period, the archaeological record of the Late Woodland is nearly invisible. Indeed, it was not until the mid-1950s that Ohio Valley archaeologists even recognized the existence of materials dating to what is now known as the Late Woodland period. At that time, the newly developed radiocarbon dating technique documented a significant temporal discontinuity between the end of Hopewell and the beginning of Fort Ancient, the mid-Ohio Valley expression of the Late Prehistoric. At about the same time, excavations by Allman (1957) at Lichliter and Oehler (1973) at Turpin Farm produced artifact assemblages unlike any previously known.

Late Woodland-aged remains differ significantly from those of the preceding Hopewell (Griffin 1957). There are no grand earthworks and no hilltop enclosures. Mounds, when present, are quite small and lack evidence for elaborate mortuary ceremonies. When there are grave goods, they are much reduced in quantity and aesthetic quality. Exotic materials are a rare occurrence. Utilitarian items (e.g., pottery, lithics) are exceedingly plain. These changes, especially with regard to the mortuary elaborations which dominated early archaeological work, form the basis for the notion that the Late Woodland represents a "collapse" of Hopewell.

EXPLANATORY ATTEMPTS: BASIC ARGUMENTS AND EMPIRICAL IMPLICATIONS

Historically, several reasons [e.g., disease (Prufer 1964; Olsen 1999), social and/or political disruption (e.g., Griffin 1952; Ford 1974; Wray and MacNeish 1961), and climatic change (e.g., Griffin 1960, 1961)] have been forwarded to account for the end of Hopewell. To these, we add a fourth hypothesis—an increase in carrying capacity (or in its reliability) decreased the fitness of "wasteful" Hopewellian populations. These accounts all differ in terms of derivation, testability, and data requirements. Thus, as potential explanations, not all accounts are equal. Some (e.g., social and/or political disruption) are inductively derived *interpretations* of the archaeological record, while others (e.g., climatic change and waste) are deductively reasoned hypotheses; some are empirically testable, while others are not; of those that are potentially testable, the data requirements are imperfectly met.

It is this last point, data requirements, that causes the most concern. Because different theories have different data requirements, each generates its own "facts" (e.g., Dunnell 1971; Fitting 1973; Lewontin 1971). However, most of the data relevant to the Hopewell "collapse" have been generated within the framework of culture history. As a consequence, data necessary to evaluate, e.g., hypotheses generated within an evolutionary perspective, may not have been collected or, if collected, may not be in an appropriate form. Because the end of Hopewell was so abrupt and affected so many parameters, however, some empirical testing is possible, even if conclusive results cannot be achieved here. Below, we offer a brief account of the four principal hypotheses proposed to account for the end of the Hopewell phenomenon, deduce expectations testable with archaeological data, examine the relevant data, and suggest directions for future research necessary to explain the end of the Hopewell phenomenon.

Disease

The disease hypothesis (Prufer 1964; Olsen 1999) presumably arose in analogy to the documented havoc wreaked on Late Prehistoric populations by introduced Old World diseases. According to this scenario, widespread epidemics disrupted the social network and economic base that supported the Hopewell phenomenon. This hypothesis is currently testable to the extent that the diseases involved are ex-

TABLE 1
Social and/or Political Hypotheses Proposed to Account for the End of the Hopewell Phenomenon and Some Empirical Expectations

Reason for "collapse"	Expectations
"Cultural fatigue"[a]	None
Outside "cultural influence"[a]	None
Internal social/political collapse[b]	None
Intergroup competition (warfare)[b,c]	Correlation with defensive situations and violent deaths
Increased local autonomy due to establishment of agricultural economy[d,e]	Correlation with subsistence change
Replacement of atlatl with bow and arrow, leading to increased warfare[b] and/or disruption of trade networks[f]	Correlation of evidence for warfare and/or loss of exotics with bow-and-arrow technology

[a] Griffin (1952).
[b] Wray and MacNeish (1961).
[c] Prufer (1964).
[d] Cleland (1966).
[e] Dragoo (1976).
[f] Ford (1974).

pressed as pathologies in skeletal remains. Even though many burials have been recovered and examined closely, there is no pathological evidence to suggest that epidemic disease played any role in the "collapse" of Hopewell. Furthermore, evidence for significant population decline and/or mass burials (found in some Late Prehistoric contexts and argued to be evidence for epidemic disease) is lacking. While future research may find evidence for disease by isolating human immunoglobulins (e.g., Tuross 1991) or the DNA of relevant organisms (e.g., Braun et al. 1998) from human skeletal remains, this account does not at present merit further consideration.

Social and/or Political Hypotheses

Several versions of the "social breakdown" hypothesis have been suggested and these are summarized in Table 1. Indeed, the initial expositions of these scenarios go little beyond what is presented in the table—the mechanisms by which the end is achieved are not detailed, presumably because they are considered intuitively obvious. Nevertheless, while each rendition proposes a different reason for the disruption of Hopewell social and/or political organization, the outcomes are more or less the same: the social glue that held together the fabric of the Hopewell phenomenon became "unstuck" and the entire system collapsed.

Table 1 also lists some empirical expectations that suggest some aspects of the hypothesized scenarios can be tested with archaeological data. In every case, though, appeal to social or political factors leaves them ultimately untestable. For example, hypothesis 4, seemingly empirically testable as indicated in Table 1, requires an invariant law linking warfare and collapse (e.g., Sabloff and Willey 1967; cf. Binford 1968) or a set of conditions under which a more limited mechanism operates. No such laws exist or can exist (Popper 1963). Similarly, hypothesis 5 assumes a mechanism linking "local autonomy" with agri-

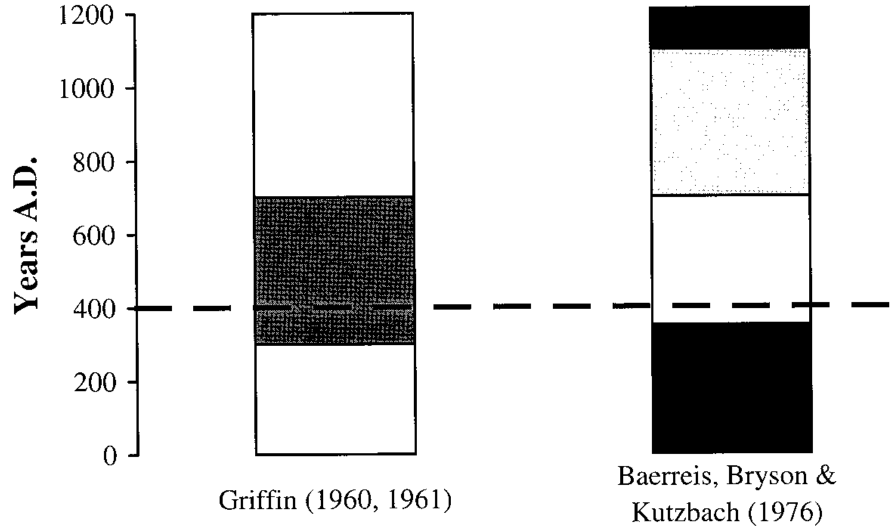

FIG. 1. Climatic models of Griffin (1960, 1961) and Baerreis et al. (1976). The dashed line at about 400 A.D. indicates the end of the Middle Woodland period. White, warm and/or dry conditions; light gray, warm and/or moist; dark gray, cool and/or dry; black, cool and/or moist.

culture or some correlate of agriculture. The point is that none of these accounts can be considered valid hypotheses because they either make use of unstated "theoretical" propositions drawn covertly from Western common sense or they lack empirical referents rendering them untestable or both.

The Climatic/Surplus Hypothesis

Griffin [1960, 1961; see also Vickery (1970)] claimed that the Hopewell "collapse" followed the onset of a colder and drier climatic regime closely (Fig. 1); such a climatic deterioration was hypothesized to decrease significantly the productivity of the agricultural subsistence base that was *assumed* to support the Hopewell phenomenon. In this account, a cooler climate would lead to a shorter growing season, resulting in decreased predictability of agricultural yields (in particular maize, despite limited direct evidence for it from Middle Woodland contexts). Decreases in maize productivity would make acquiring the surpluses believed necessary to support Hopewell's level of cultural complexity more difficult, thereby causing the "collapse."

Empirical expectations. Unlike the ad hoc proposals involving social or political factors to account for the "collapse," this explanation of Hopewell elaboration does generate empirically testable expectations. This hypothesis, as originally proposed, has already been falsified; it assumes that maize agriculture was the subsistence base. It has since been established that Hopewell populations were not dependent upon maize (Bender et al. 1981). Smith's (1992) proposal for a nonmaize but nonetheless agricultural basis for Hopewell could be employed in the same role and is not falsifiable with existing data. Fortunately, these details are not critical here because any climatic change that decreased the net productivity of any key resource or set of resources, could have had a similar impact on populations. Thus, regardless of the subsistence base, climatic deterioration is expected to correlate with the timing of the "collapse" in "surplus" explanations.

The "Waste" Hypothesis

As initially outlined by Dunnell (1989), this hypothesis designates the counterintuitive notion that under some specific selective conditions (e.g., unpredictably variable or "marginal" environments) the diversion of energy into nonreproductive activity (e.g., cultural elaborations termed "waste"), necessarily at the expense of reproduction, might become fixed in some populations at relatively high levels. This is so because such populations at whatever scale waste has become fixed are more likely to survive unpredictable resource crises. A corollary of relevance here is that *increases* in the environmental carrying capacity[1] (or in its predictability) will *decrease* the fitness of those cultural elaborations. Higher rates of reproduction will be at the expense of waste. Lineages that come to dominate the archaeological record are those whose individuals reproduce most rapidly. The Hopewell "collapse" is thus turned on its head. An improvement in subsistence security eliminates all of the markers intuitively signaling "advancement."

Empirical expectations. An increase in carrying capacity would select against high levels of waste. Increases in net productivity might arise in one or both of two broadly distinct ways: climatic change toward warmer and/or wetter conditions or a change in subsistence productivity. Thus, we expect that one or both of these events must correlate with the loss of cultural elaborations.

Second, the particular form that waste takes within a population, in this case earthworks, mounds, mortuary features, grave goods, and so on, is a matter of history and transmission (i.e., homology). While the Woodland expression of waste may have spread in large part by diffusion (here we mean the *form* waste takes when present, not the amount of waste fixed), its disappearance should prove to be highly variable. When waste disappears, only the amount of waste, not its form, is amenable to selection. There are no external forces to mold it in similar directions, nor is there the possibility of diffusion (there is nothing to diffuse) to unify the trajectory of waste reduction. Thus, if we are correct in what caused the Hopewell phenomenon, then we expect that it should end variably in terms of form.

Third, the loss of waste has implications for population size. As carrying capacity increases for whatever reason, time and energy previously invested in cultural elaborations such as mound building and other nonreproductive energy uses will decrease fitness. Thus, we expect an increase in population to correlate with the loss of waste.

Fourth, the elimination of waste has implications for the demographic makeup of the population (see Madsen et al. and Sterling, this issue). When energy is no longer channeled away from reproduction, fertility rates will increase. Increasing fertility rates may be observable in skeletal populations as relatively greater proportions of children to adults [e.g., Hoffmann and Parson 1997:36–37 (biology); Milner et al. 1989 (archaeology)]. Thus, in the absence of significant bias, skeletal populations from the more "efficient" Late Woodland should exhibit higher children/adult ratios than the more "wasteful" Middle Woodland populations.

HYPOTHESIS EVALUATION: THE EMPIRICAL RECORD

It is obvious to anyone familiar with the archaeological record of the region that the data to rigorously evaluate these propositions are largely nonexistent, strongly held beliefs notwithstanding. Even so, simply because of the magnitude of the

*See Notes section at end of article for all footnotes.

changes involved, we expect that patterns in existing data will allow us to identify the principal, if not the only, factors that explain the "collapse" of the Hopewell phenomenon.

Evidence for Warfare

The hypotheses of both Prufer (1964) and Wray and MacNeish (1961) make reference to intergroup competition or warfare. Warfare disrupted the sociopolitical system which, in turn, is expressed as the Hopewell "collapse." In order for these hypotheses to become explanations, evidence for warfare must increase significantly toward the end of the Middle Woodland period. Potential evidence for warfare includes occupations in strategic locations and/or with defensive constructions and occurrences of lethal trauma in skeletal populations. Because the temporal distribution of these traits is important, we use Prufer's (1964) chronological scheme, which establishes the relative age of some Ohio Hopewell assemblages.

Settlement location and construction. Prufer's (1964) hypothesis that warfare was responsible for Hopewell's demise came from trying to determine the function of hilltop enclosures. These large earthworks, essentially earthen and stone walls constructed following the topographic outline of isolated hilltops, have been labeled "forts" because of their eminently defensible situations. At the time, Prufer (1964) believed the construction of these features was chronologically late, when Hopewell populations needed them in defense from the arrival of their enemies, possibly Fort Ancient populations. Recent excavations, however, have revealed more than one episode of wall construction at the enclosures (Connolly 1997; Prufer 1997b) and there is no evidence for the intrusion of a new population into the area (Church 1987; Graybill 1984; Rafferty 1974), making this scenario less likely.

Middle Woodland habitations in the vicinity of these hilltop enclosures are situated *outside* the presumed fortifications (Connolly 1997) and debris inside the walls is more of a ceremonial than occupational nature. While this would render them somewhat less effective, Prufer (1997b) counters that they served as places of refuge for local populations during times of need. The Middle Woodland domestic settlements examined thus far do not suggest their occupants lived under fear of attack. Most are located in easily accessed floodplain and terrace settings (Carskadden and Morton 1997; Dancey and Pacheco 1997). Although excavation of Middle Woodland habitation deposits is limited, there is no evidence for defensive structures (e.g., earthen walls, wood palisades, ditches) like those associated with some Late Woodland- and Late Prehistoric-aged settlements (Dancey 1992).

Lethal trauma. Milner (1995) has reviewed the incidence of lethal trauma to prehistoric skeletal populations in eastern North America. Even given his caveat that his survey was not exhaustive, in the middle Ohio Valley the frequency of injuries consistent with warfare is negligible until the Late Prehistoric period. Of the nine post-Archaic period Ohio Valley references cited, seven (Allman 1960; Hanson 1975; Hooton and Willoughby 1920; Lovejoy and Heiple 1970; Mills 1917; Murphy 1968; Pollack et al. 1987) refer to remains from Late Prehistoric contexts (Blain, Feurt, Erp, Buffalo, Madisonville, Hobson, and Larkin), with the last five from the late Late Prehistoric (post 1400 A.D.). The other two citations refer to occurrences at the Early Woodland Miesse Mound (Shetrone 1925) and the (probably) Late Woodland-aged Continental Construction (Sciulli et al. 1988) locales. While we know of a few other similar examples, none are from Middle Woodland contexts.

Trophy skulls. "Trophy skulls" are isolated human skulls or skull fragments,

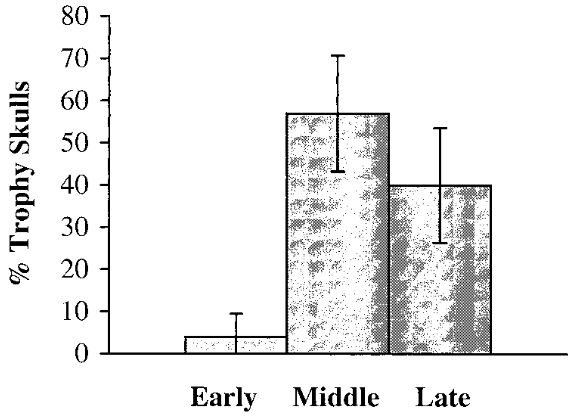

FIG. 2. Frequency of trophy skulls (n = 53) in Hopewell mounds (Seeman 1988) through time. The error bars show 95% confidence intervals (Beals et al. 1945).

modified and deposited in Hopewell mounds in both burial and nonburial contexts. There is some ambiguity in their interpretation; they are viewed by some as cherished ancestors, by others as tokens of defeated enemies. A reanalysis of several trophy skulls by Seeman (1988) noted that the remains are most often young adult males, consistent with the notion that they are remainders of vanquished foes. To the extent that these artifacts are indeed trophies of warfare, we might anticipate that their frequencies will increase near the "collapse" if intergroup conflict grew. This is not the case (Fig. 2). Of the 53 trophy skulls listed by Seeman (1988), 2 (4%) are from early (Tremper and Mound City) Middle Woodland contexts, 30 (57%) are from middle (Harness, Seip, and Hopewell) Middle Woodland contexts, and 21 (40%) are from late (Turner, Ater, and Marriott) Middle Woodland contexts. As Fig. 2 shows, the small sample size results in a large potential error; nevertheless, the late deposits appear to have fewer, and certainly not more, trophy skulls than those from the middle period.

Appearance of Bow-and-Arrow Technology

Both Wray and MacNeish (1961) and Ford (1974) argue that the replacement of the atlatl by bow-and-arrow technology was instrumental in the Hopewellian demise. Wray and MacNeish are concerned with its impact on hunting strategies and warfare, Ford with trade networks. Since only the tips (projectile points) are preserved, identifying how and when this replacement occurred has proved to be contentious (e.g., Hughes 1998). Relying on characteristics of the tips, most researchers (e.g., Hall 1980; Muller 1986; Seeman 1992; Shott 1990) place the introduction of the bow and arrow in the Eastern Woodlands during the Late Woodland. In the lower Ohio Valley, the appearance of this technology takes the form of small triangular points in Late Woodland contexts (Schwartz 1962). Such points do not occur in the slightly earlier (?) burial mounds of the same general area (Hoffman 1969). Indeed, no small triangular points are associated with late Middle Woodland or early Late Woodland contexts. In his analysis of middle Ohio Valley projectile points, Seeman (1992) noted a marked decrease in mean point size (weight, length, and thickness) at about 700 A.D. If projectile point size does reliably reflect the use of bow-and-arrow technology, then a late Late Woodland period introduction into the region is too late to have played a role in the Hopewellian "collapse."

Carrying Capacity Change

Evidence for carrying capacity change is potentially the best way to evaluate the waste explanation of the Hopewell "collapse," inasmuch as the direction of change, not just the magnitude of change, is different from that envisioned in other accounts. Thus, in the face of poor-quality data, there is still a reasonable chance to eliminate some of the competing hypotheses. There are two ways that such change may take place, externally ("naturally") and internally ("culturally") induced. With the more traditional terms used in

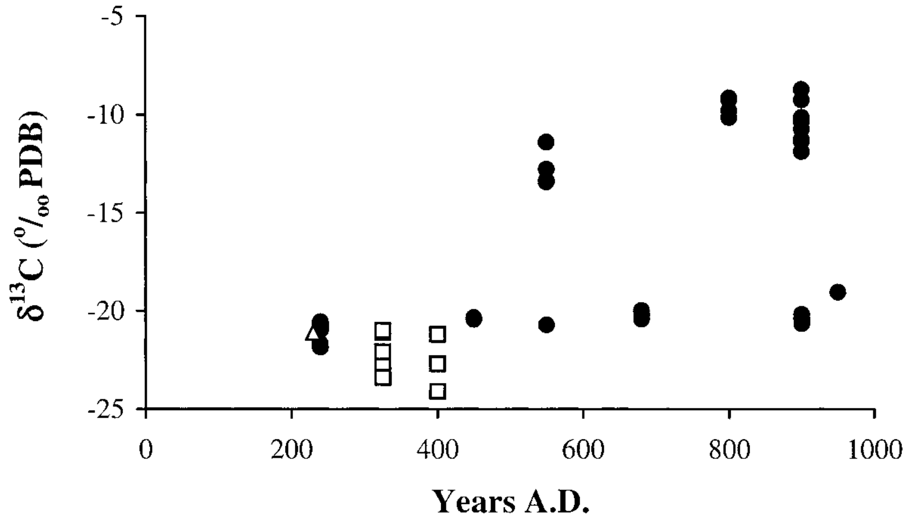

FIG. 3. Temporal variation in stable carbon isotope ratios in human skeletal remains from Ohio Valley locales. □ Bender et al. (1981); △ van der Merwe and Vogel (1978); ● Greenlee (1999).

archaeology, the former is explored under "climatic change" and the latter is treated under "subsistence change."

Subsistence change. Internal changes might arise either as technological change (changes in the human phenotype) or as changes in the exploited organisms (changes in other organisms' phenotypes) through human manipulation of selective conditions. While they leave different kinds of evidence, they are closely interactive (Rindos 1984). Technological change might be as simple as a new tool or technique or as complex as an integrated suite of tools, techniques, and schedules (e.g., agriculture). Change in the properties of plants and animals in response to human predation is usually discussed as "domestication."

The waste hypothesis predicts that, if agriculture is involved at all, the appearance of agriculture and/or maize will correlate with "collapse," not "climax."[2] Stable carbon isotope data from the time period of interest (Bender et al. 1981; Greenlee 1999; van der Merwe and Vogel 1978) in the Ohio Valley indicate that significant maize consumption does not appear until well after the Hopewell "collapse" (Fig. 3). It is of particular interest that not all individuals from those Late Woodland contexts with evidence for early maize consumption had the same diet. Data generated by one of us (DMG) shows that some individuals appear to have been significantly committed to a maize-based diet, while others apparently ate little or no maize. This kind of individual scale data is essential if we wish to determine how the dietary change to a maize-based system occurred (Greenlee 1999). It should also serve to illustrate Neiman's (1998:286) error in characterizing the waste argument as inherently "group selection." The scale at which waste occurs is, as in all other evolutionary processes, an empirical matter and must be determined on a case-by-case basis.

Nonmaize-based agriculture, i.e., one employing starchy seeds (Smith 1992), remains a possibility. If Eastern Agricultural Complex starchy seeds were critical to Middle Woodland subsistence, changes to the subsistence system (e.g., different planting, harvesting, or storage technologies) might have resulted in increased productivity of that resource base. Indeed, short-lived nucleated settlements, like the Late Woodland-period Water Plant occu-

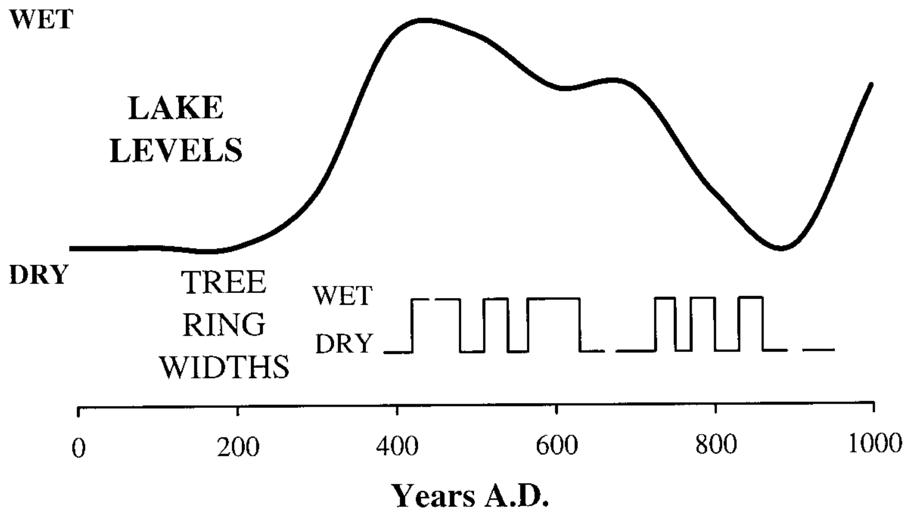

FIG. 4. Evidence for increased wetness at the time of and following the Hopewell "collapse." At top, the frequency of high lake levels recorded in shoreline features of the Upper Great Lakes; at bottom, bald cypress tree-ring widths in North Carolina.

pation (Dancey 1988), may represent unstable responses to the increased yield of those native cultigens. Wymer's (1987, 1992) examination of the composition of archaeobotanical assemblages in Middle and Late Woodland contexts seems to support this notion, where differences between the two periods reflect changes in exploitation intensity more than changes in resources utilized.

Climatic change. The differences between the two hypotheses that posit climatic change as a cause of the "collapse" are dramatic and can be differentiated with poor-quality data. In the surplus case, "collapse" should be associated with a decrease in carrying capacity and in the waste explanation, it will be associated with an increase in carrying capacity. Even in the absence of maize agriculture or any kind of agriculture, a climatic change to colder and/or drier conditions would lower net productivity and, thus, carrying capacity; alternatively, a change to warmer and/or wetter conditions would increase productivity and, thus, carrying capacity.

Recent models of climatic change suggest that climate did not become colder and drier at the end of Hopewell as believed at the time Griffin (1960, 1961) first proposed the climatic/surplus hypothesis. Based largely on pollen records from the midcontinent, Baerreis et al. (1976) instead posit an episode of *warmer and/or drier* conditions associated with the end of Hopewell (Fig. 1). Without more specific information, however, it is impossible to determine the probable impact of that climatic episode on productivity: warmer conditions would increase productivity while drier conditions would decrease it.

To better resolve the climatic conditions at that time, we turn to studies of past lake-level fluctuations conducted using beach ridge and dune features along the shores of the Upper Great Lakes. We have plotted (Fig. 4) for each century the frequency with which evidence for high lake levels has been documented (Anderton and Loope 1995; Delcourt et al. 1996; Dott and Mickelson 1995; Fraser et al. 1990; Johnson et al. 1990; Larsen 1985, 1994; Lichter 1995; Petty et al. 1996; Thompson 1992). Assuming that historically documented relationships between lake-level fluctuations and climatic conditions in the Upper Great Lakes drainage basin extend over the past 2000 years, the peak indicates a time of significantly increased precipitation and perhaps slightly cooler temperatures. That conditions are generally wet during the early Late Woodland period is also supported by tree ring widths in bald cypress (*Taxodium distichum*) trees from North Carolina (Stahle et al. 1988). Thus, the direction of climatic change appears to be toward *warmer and wetter* conditions (and therefore increased net productivity and carrying capacity) at the end of Hopewell.

Population Size and Demography

We anticipate that population size should increase as waste is reduced. Because it is unknown to what degree a burial population is a sample of the living population, archaeologists often turn to settlement attributes (e.g., settlement counts, settlement areas, and roofed areas) to identify ordinal scale changes in population size and density. Unfortunately, archaeologists' preoccupation with Middle Woodland mortuary contexts and the relative invisibility of the Middle and Late Woodland settlement records in the Ohio Valley combine to make such an assessment currently impossible.

The waste hypothesis has direct implications for the demographic structure of "wasteful" and "efficient" populations that can be addressed cautiously with human skeletal assemblages. We stress "cautiously" because of the many biases that can influence the composition of skeletal collections. First, our burial data are only a sample of the actual burial population. Thus they are subject to several sources of error, including n-transforms (i.e., are the chemical and mechanical properties of the deposit such that infants and children are likely to be underrepresented due to postdepositional factors?) and sampling (i.e., is the skeletal assemblage recovered an unbiased sample of the burial population?) and analytic (i.e., are there systematic errors in age or sex estimation?) errors. Second, the burial population is only a sample of the living population and is also subject to bias [i.e., does the burial assemblage include the entire population or were some segments of the population treated differently (not all bodies buried or, if buried, not in the same way and/or place) and, thus, not represented in the sample?]. These potential sources of bias need to be evaluated for skeletal assemblages on a case-by-case basis. Comparing the age structure of archaeological skeletal assemblages with models derived from modern populations can help to determine when assemblages are severely biased (Konigsberg 1985; Milner et al. 1989).

Comparing the ratio of children (<5 years of age) to old adults (>45 years) in age-at-death distributions has been shown to be a reliable indicator of relative fertility rates (Milner et al. 1989). Unfortunately for this analysis, there are few published reports of skeletal assemblages with reasonable sample sizes from Middle and Late Woodland deposits in the Ohio Valley that would lend themselves to that sort of evaluation. A comparison between Middle and Late Woodland populations would be telling. Unfortunately, there are no appropriate data from Late Woodland contexts available.

Figure 5 compares the age-at-death distributions of two Middle Woodland-aged archaeological skeletal assemblages with modeled distributions for the !Kung (low fertility) and Yanomamo (high fertility) (Milner et al. 1989). The age-at-death structure for the population from Fairchance Mound is quite similar to that modeled for the !Kung, with slightly fewer children (<5 years) and correspondingly more young adults (20–35 years). At Turner, the very young appear to be significantly underrepresented and old adults are overrepresented; this pattern *may* reflect very low fertility rates or, more likely, a bias against infants and children.

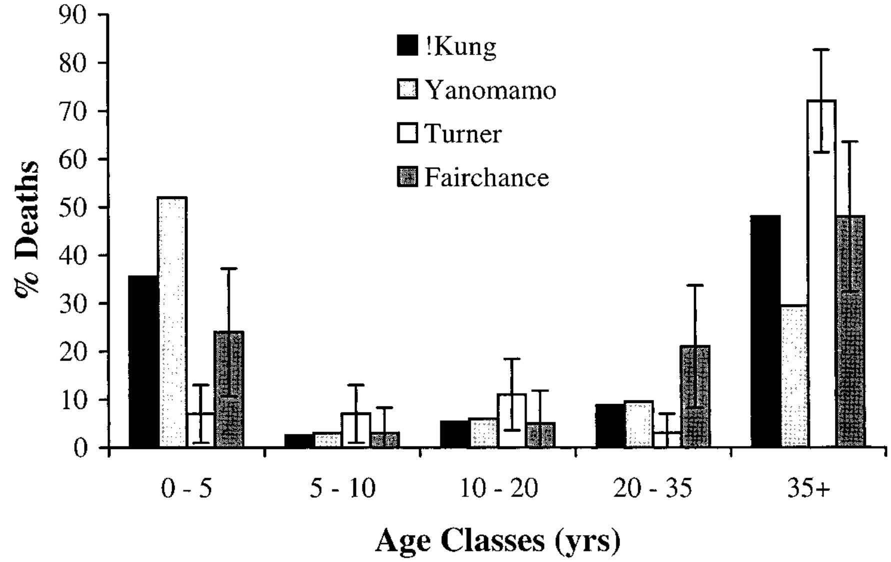

FIG. 5. Age-at-death distributions for comparing fertility among different modern and prehistoric populations. Data for the !Kung and Yanomamo models (Milner et al. 1989) have been retabulated to match the age divisions of archaeological samples. The archaeological skeletal populations are from Middle Woodland contexts: Turner (n = 73) (Hooton 1922); Fairchance (n = 42) (Baby and Langlois 1984). The error bars show 95% confidence intervals (Beals et al. 1945).

Without more information, however, that is impossible to assess.

The Loss of Cultural Elaboration

While most accounts of the Hopewellian "collapse" emphasize the apparently abrupt loss of cultural elaboration, that generalization is not sustained by the empirical record. Indeed, the supposed "collapse" is an artifact of the theory used to describe it[3] and incomplete knowledge of the record (e.g., comparing cemeteries with towns). In reality, different forms of cultural elaboration are maintained for different lengths of time in different areas of the Ohio Valley. In many places, particularly on the eastern and western peripheries, the loss of the mortuary elaboration affects mounds, mortuary features, and grave goods more or less evenly. Mounds get smaller and less elaborate, and grave goods become less numerous and/or elaborate, but often show continued access to at least some exotic materials.

Watson-period mounds in the upper Ohio Valley are usually quite small when compared to earlier works and lack elaborate tombs, but continue to contain small amounts of copper and/or other imported materials (McMichael 1968). In this area, the grave good tradition continues, even as mounds disappear, into early Monongahela, partially overlapping the appearance of nucleated settlements attributed to maize agriculture (Fuller 1981). The Hughes Farm location (Dunnell 1962) has early Monongahela material scattered in a roughly donut-shaped ring around the highest area. One burial produced a pair of copper ear ornaments; analysis of the copper shows it to be native copper identical to that in nearby Middle Woodland mounds, not, as McMichael (1962) once suggested, European copper or brass. The burial also included hundreds of marginella shell beads.

The Isinglass mound further south (Graybill, p.c.) shows the same pattern; a smaller mound with few grave goods, but here including mica. While the material is exotic, aesthetic sophistication does not compare favorably with Middle Woodland examples. The quantity of grave goods, from Late Woodland and later contexts (e.g., lithics from Isinglass) do not begin to approach that recovered from some Hopewell contexts, like the Hopewell site (Moorehead 1922).

In west-central Kentucky the same pattern is encountered. The Ashby mounds (Hoffman 1969) are small versions of classic Woodland mounds; the grave goods include a only a few normal bifaces and a couple of tiny, inch-long copper celts, a great contrast to Hopewellian examples. In other cases, burial mounds persist, sometimes fairly large as at Turpin (Oehler 1973) in southwest Ohio or at Cleek-McCabe (Rafferty 1974) in north-central Kentucky or sometimes small as at Roseberry Farm (Graybill 1981) in West Virginia, but they are of a different character. Here they are part of the domestic site, the grave goods are minimal and most often of local materials, and the structure of the mounds themselves seems more accretionary, an inverted cemetery if you will, than the ritual event markers that preceded them (Clay 1991; Clay and Niquette 1992). Roseberry Farm and Turpin are intriguing cases because not all burials occurred in the mound, suggesting that waste is being eliminated at an individual rather than community scale. In all, Drooker (1997:60) reports that 42% of all early and middle Fort Ancient (1050–1450 A.D.) settlements in the central Ohio Valley are associated with mounds. In the upper Ohio Valley over the same period, burial mounds are completely absent save perhaps as cairns in the extreme eastern part of the region (Mayer-Oakes 1955).

Finally there are even cases where burial goods persist, albeit reduced in quantity and/or elaboration, while mound construction drops out. Sometimes older mounds are used for Late Woodland burials as in Intrusive Mound deposits (Mills 1922) or the use of mounds disappears altogether as in Newtown Firehouse (Genheimer 1981).

Unlike the rise of the Woodland mortuary complex, which follows a similar pattern over a broad area [so much so that it gave the notion of an "interaction sphere" (Caldwell 1964)], the loss of this complex is a mosaic of trajectories of change. The examples cited provide a sense of the variation in waste reduction that constitutes the Hopewell "collapse." It is clear that the loss of Middle Woodland cultural elaboration did not follow a single unilinear path. Different forms of waste persisted differentially. Of course, waste does not disappear completely just as it was not completely absent before the Woodland. What is significant, however, is that once clearly agricultural communities using maize were established in the region, the "climax" that was Hopewell was gone and the number and especially the size of domestic sites increased dramatically.

DISCUSSION

Several of the social and/or political hypotheses can be eliminated from consideration as potential explanations of the Hopewell "collapse" because their empirical implications were not met. There did not appear to be an increase in indicators of warfare toward the end of the Middle Woodland period, and the appearance of bow-and-arrow technology and maize-based agricultural systems both occurred during the Late Woodland period, after the "collapse." Even if the correlations they posited had been documented, however, these social hypotheses would fail as explanations because they provide no causal connections, i.e., there is no mechanism directly tying the "reason" to the outcome. For some scenarios, no empirical implications could be deduced, rendering them completely untestable.

As initially conceived, the climatic/surplus hypothesis assumed that Hopewell populations were dependent upon maize-based agriculture. While that has been shown not to be the case (Bender et al. 1981), there is no reason why a climatic change might not have affected negatively the productivity of other plants that did provide the subsistence base. As climatic data accumulate, however, it appears that climatic conditions became more favorable, not less so, at the end of Hopewell. Thus, the climatic/surplus hypothesis is falsified.

While data are lacking for a rigorous test of the waste hypothesis, it was not falsified with the data at hand. A climatic change that would result in an increase in carrying capacity was documented. Although the appearance of maize farming was apparently later than the "collapse," the composition of archaeobotanical assemblages and the short-term occupation of nucleated villages suggest some corresponding changes in the subsistence system. Finally, the loss of cultural elaboration was shown to be a highly variable process, with multiple pathways toward a common endpoint.

Future Directions

A satisfactory explanation of the Hopewell phenomenon will require considerable data that are currently unavailable. Here we suggest a few directions for future research that will provide the crucial missing data. Perhaps most importantly, all data must be generated so as to represent the variability of the parameters being described. Assemblage-wide, component-level, or even phase-level characterizations are wholly inadequate because evolutionary theory can only explain variability. You can, for example, go only so far knowing that the mean number of rows on maize cobs changes from x to y over period a to b. There is no way to explain that observation unless you know about the distribution of the parameter. For example, do row numbers have a normal, bimodal, multimodal, or Poisson distribution? Or, what is the variance and how it is linked to changes in means? Only with these kinds of data can evolutionary mechanisms for the change be brought into play and alternative hypotheses about selective conditions be evaluated. Some more specific issues can be enumerated.

1. Chronologies of greater precision and accuracy are required. Typological "dating" cannot be used to establish the age of materials when the object is to document change in cultural phenomena. Furthermore, chronometric dating has to be improved by making better associative arguments (Dunnell 1999) and by ensuring the methods selected are appropriate to the materials sampled and the questions being asked.

2. More detailed understanding of environmental change is needed. Such understanding cannot be, as it currently is, biased toward a few environments that preserve pollen well, but account for only a fraction, variable and probably always small, of the exploited habitats. There is room for optimism, as the accuracy and precision of climatic reconstructions are increasing dramatically (e.g., Houghton et al. 1996; Mann et al. 1998, 1995).

3. Much better data are required on subsistence and, most especially, diet. Dietary information, such as that provided by stable carbon isotope ratios in human bone, can (unlike faunal and floral data) be linked to individuals. This is important for revealing how subsistence change spreads in populations (Greenlee 1999) and, when linked to demographic and disease data, the effect of subsistence change

on populations. Research is currently underway to document dietary, subsistence, and settlement changes associated with the appearance and spread of maize farming in the Ohio Valley.

4. Finally, more data on the demographic structure of Middle and Late Woodland populations are necessary to evaluate the impact of subsistence changes on those populations.

CONCLUSIONS

We have shown that many of the so-called explanations for the "collapse" of Hopewell are not testable hypotheses. Even those few with testable implications, however incomplete, have proved to be falsifiable with existing data. The only hypothesis surviving empirical testing is the waste thesis derived from evolutionary theory. While this qualifies it as an explanation of the Hopewell "collapse," it is by no means clear that it survived testing because it is a robust account or because of the poor quality data that exist for testing currently. In looking at general patterns over large areas and focusing on the end of Hopewell (rather than its origin), we have shown that the waste hypothesis is worth pursuing and we have suggested ways in which this might be done.

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NOTES

[1] That one cannot measure "carrying capacity" on a ratio scale does not alter the fact that there must exist some limit on the number of real organisms that can live indefinitely in some real environment, nor does it preclude its use in initial explanatory sketches such as this.

[2] Maize-based agriculture has also been cast as the cause of "collapse" in some social scenarios (Cleland 1966; Dragoo 1976). In this view, maize farming allowed local populations to decrease their dependence on the Hopewell social organization and, thus, the system fell apart. Like the other commonsense accounts, there is no mechanism to link cause and effect, nor is the scenario empirically testable.

[3] One cannot help but be struck by the similar conclusion reached by Erasmus (1968) concerning another famous cultural "collapse," that of the Classic Maya. One can only hope that archaeology is better prepared to understand the impact of theory on the creation of "facts" than was true in 1968.

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