THE RINGLER ARCHAIC DUGOUT FROM
SAVANNAH LAKE, ASHLAND COUNTY, OHIO:
WITH SPECULATIONS ON TRADE AND
TRANSMISSION IN THE PREHISTORY
OF THE EASTERN UNITED STATES

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ABSTRACT

In late November, 1976, a dugout canoe was accidentally recovered by commercial
dredging of Savannah Lake, Ashland County, Ohio. The dugout lay 1 m below the
peat bottom of this kettle lake, which heads the Vermilion River. Its significance
recognized, the dugout was transferred to the Cleveland Museum of Natural
History for analyses and preservation.

By considering the dugout's performance and the context of the find, the likely
uses of the dugout can be surmised, perhaps giving insight into prehistoric water
trades in the area. This paper describes the dugout, discusses the techniques of its
preservation for museum use, gives estimates of the boat's load carrying capability
and stability, and describes the context of the find. Finally, the paper speculates on
some of the implications of this find on an understanding of prehistoric trade
patterns in this area.

Provenience of the Ringler Dugout

In late November 1976 a dugout canoe was recovered from the Ringler
property at Savannah Lake, a small peat-filled bog in Ashland County,
Ohio (Brose 1978). This portion of Ohio is crossed by late Wisconsinan
morain systems which form a 15 to 35-mile wide zone of kame and kettle
topography which separates the flat Lake plains of the north from the more
dissected glacial outwash till plains of the southwest and the deeply
dissected glaciated Allegheny plateau of the southeast (Banks and Feldman
1970; Bier 1967; Goldthwait, White, and Forsyth 1967). In this zone
numerous small lakes and streams represent the divide between the Great
Lakes-St. Lawrence and the Ohio-Mississippi-Gulf of Mexico watersheds.
Specific drainage patterns have fluctuated over the past three to four
millenia in response to the fluctuating water levels of Lake Erie (Fig. 1). At
present the Savannah Lakes system heads the Vermilion River flowing north to Lake Erie. To the south of Spring Lake lies a wet meadow and a 250-\text{m}-wide outwash kame 2 m high. Beyond these a small creek heads Jerome Fork, a tributary of the Mohican-Muskingum River system (Figs. 2, 3). Savannah Lake thus represents the southern Great Lakes terminus prior to portage to the Mississippi-Ohio drainage system. The Vermilion River is navigable in the late spring and early fall in shallow draft craft as far south as Savannah Lake. Ice occurs throughout the winter and early spring, and low water with rock and gravel shoals occurs in mid-to-late summer.

Early nineteenth-century settlements within this zone (Celina, Wapakoneta, Upper Sandusky, Akron, and Warren) were established as transhipment or portage towns, and most appear to have been built upon or adjacent to historic Amerindian villages of considerable size (Evans 1775; Downs 1932). This zone represents the least investigated archaeological area within Ohio. Nonetheless, a number of Middle and Late Archaic sites are recorded within or immediately adjacent to this region (Shepherd 1887; Mills 1914), prominent among which are the multiple internments of the Glacial Kame "Culture" (Fowke 1901; Cunningham 1948; Morgan 1952; Whittlesey n.d.a, n.d.b, n.d.c; Baby 1961; Fitting and Brose 1972). Although known from limited mortuary aspects of their cultural system, Griffin (in Cunningham 1948) suggested that these were not particularly complex societies. Rather, burial represented individuals whose status within the society was marked by burial goods, usually of nonfunctional character. The sources of these goods ranged from the central Midwest to the Atlantic Coast, and from the Great Lakes to the Gulf of Mexico. Items such as copper, mica, shell, steatite, and varieties of nonlocal cherts were standard grave goods for what appear to have been a limited number of individuals (see Winters 1968).

Few nonceremonial Late Archaic sites are known in this portion of Ohio, and questions relating the ceremonial and mortuary aspects of once-living societies to those other, more mundane concerns which undoubtedly occupied most of the participants' energy and thought, remain unanswered. In spite of the resultant focus upon the mortuary complex with its exotic materials, questions concerning actual mechanisms of their transmission also remained unanswered. Although considerable interest focused on the nature of transportation in this period, little substantive data actually existed. The recovery of the Ringler dugout (Fig. 4) may offer an opportunity to address these questions.

**Temporal and Cultural Relationships**

A sample of wood, taken from a cut 12 cm below the surface in the center of
the rear (?) deck or end platform of the dugout, was submitted to the DICARB Radio Isotopes Laboratory and yielded a radiocarbon determination of 3550 ± 70 B.P. (DIC-612).

The dugout canoe itself had been recovered by drag line from the peat, some 3-1/2 to 4 feet below lake bottom. An earlier pollen profile taken from the same bog some 100 m further south demonstrated 27 feet of peat within the bog (Potter 1946). The 3-1/2- to 5-foot levels below lake bed postdated the transition from a beech maxima to the oak-hickory maxima (Potter 1946:45, Table 9, Plate VII). Potter (1946:67–73) assigned this transition to the 2/3 zone of earlier pollen studies from this region (Sears 1930, 1931, 1942a, 1942b; Smith 1940). Sears's transition from zone 2/3 was the same as the transition from C1/C2 pollen zones subsequently recognized by other palynologists throughout this region of the United States. This C2 zone, dated about 4000 B.P. (Cushing 1965; Whitehead 1965; Williams 1974; Shane 1975), appears to have been warmer and relatively more moist than present. Cox and Lewis (1965) dated the C1/C2 transition at 3200 ± 100 B.P. (I-219) at Crusoe Lake in Central New York State, where it was stratigraphically associated with a Late Archaic occupation. A related cultural manifestation appears to have existed at Savannah Lake.

During the past 20 years, two other dugout canoes had been recovered from Savannah Lake, in 1957 (Fig. 2b) and again in 1962 (Fig. 2c). From verbal descriptions and from a photograph in the Ashland [Ohio] Times Gazette files, these appear to have been identical to the present dugout canoe. All of these craft appear to have been deliberately abandoned. Lithic artifacts, recovered by the property owners from shore lines adjacent to the locations of these dugout canoes, represent a chronological range from the Middle Archaic through the Transitional Archaic/Early Woodland periods. Most of the typologically earlier materials appear to have been scattered away from the lake, along the outwash terraces to the northeast. Several aboriginal hearths had been previously exposed on the southwest shoreline adjacent to the Ringler dugout canoe. Materials collected at those loci and those collected from the shoreline adjoining the 1957 dugout include notched and stemmed projectile points which can be assigned to such named types as Brewerton side-notched; Brewerton corner-notched; Ashtabula; Lamoka; Orient Fishetail; Bare Island/Poplar Island/Rossville; Robbins; and Fulton Turkey-Tail (Ritchie, 1961; Converse 1964). Several Meadowood-like cache blades have also been recovered along with a number of ground stone celts, a small 3/4-grooved axe, an unfinished winged bannerstone, and finished humped birdstone. A flat rim fragment of a steatite bowl (CMNH #76–69:9126), and a large Oliva shell have recently been recovered (personal communication, David Morse). This appears similar to Transitional Archaic assemblages from New York (Ritchie 1961), Pennsylvania (Witthoft 1953) and southeastern Ohio (Murphy 1975) dated to the second millenium B.C. Witthoft suggested
that the economic adaptation of these Transitional Archaic cultures was essentially riparian and depended upon canoe communications, while Murphy (1975:118) has noted that Transitional Archaic sites in southeastern Ohio appear confined to major streams. In the Late Archaic cultures of New York and the upper Great Lakes a strong lacustrine economic adaptation has been posited (Griffin 1961; Papworth 1967; Ritchie 1969) while both riparian and lacustrine adaptation have been suggested for the Late Archaic complexes occupying the glaciated portions of Ohio (Blank 1970; Brose and Morse 1977; Geistweit 1970; Moffett 1949; Pickenpaugh 1971, 1974). The implicit significance of watercraft in such economic adaptations lends justification to the following analyses of the Ringler dugout canoe.

Physical Features

A photograph of the Ringler dugout as first encountered on the shore of Savannah Lake is shown in Fig. 3. Overall, the boat is 690 cm long, 110 cm at maximum beam, and approximately 60 cm from keel to gunwhale. The average inside depth from the edge of the gunwhale to the floor is 36 cm. Detailed measurements show a shape sketched in Fig. 4. The boat is composed of a single log of white oak (*Quercus alba*) as identified visually by James Bissell, and from a small sample submitted to the University of Michigan Institute for Wood Technology. In its waterlogged state as found it weighed approximately 500 kg. Extending about 100 cm midships from either end of the craft are two flush deck or end platform areas. Between these two end platforms are two definite areas of polished and worn bottom, as well as one possible area. These areas, 85 to 100 cm apart and 30 to 40 cm in diameter, may represent the locations in which the people paddling the boat sat or knelted. This suggests a crew of two to three people, and a probable crew weight between 150 and 225 kg. With a crew of three the bottom area available for additional passengers or cargo is restricted to two end zones of approximately 50 cm diameter each, and two more focal zones of approximately 120 x 50 cm. If we assume that the crew in fact took up somewhat more space than those areas polished by the knee (or other anatomical portion), the cargo space is restricted to two irregular zones each averaging just over 100 x 50 cm. With the removal of the third or central crew member a central cargo space is about 300 x 50 cm.

Construction

The Ringler dugout canoe reveals some of the details of its construction by charring and scraping. Several early historic accounts (e.g., Harriot 1590; Winthrop 1636) describe the manufacturing of such dugout canoes by the American Indians. Winthrop (1636) described the Indians as going into the
woods and stripping a large, suitable tree of its bark so that it would die slowly over the following year. Winthrop (1636) reports that the base of the tree might then be burned and/or cut with stone and metal axes until the tree fell over. After stripping the limbs, the tree would again be burned into a 15- or 20-foot log. A groove would be cut on the upper surface of the tree and a series of fires lit. The Narragansett would return periodically to scrape the charred wood from the upper burned surface and to rekindle a fire. The entire process would take about two weeks, although during a single day no more than two to four hours were actually involved in physical labor.

The final shaping of the dugout canoes, which Winthrop observed, took about two days of firing, scraping, and cutting with metal adzes or axes. Similar manufacturing methods prior to the use of trade axes are described for the Indians of Virginia. Harriot (1590:55) states that,

The manner of makinge their boates in Virginia is verye wonderfull. For whereas they want instruments of yron, or other like vnto ours, yet they knowe howe to make them as handsomelye. . . . First they choose some longe and thicke tree accordinge to the bignes of the boate which they would frame, and make a fyre on the grownd abowt the Roote thereof, kindling the dame by little, and little with drie mosse of trees, and chipps of woode that the flame should not mounte opp to highe, and burne to muche of the lengte of the tree. When it is almost burnt thorough, and readye to fall they make a new fyre, which they suffer to burne vntil the tree fall of it owne accord. Then burninge of the topp, and bowghs of the tree in such wise that the bodie of the same may Retayne his just lengthe, they raise it uppon po[s]tes laid over cross wise uppon forked posts, at such a reasonable heighte as r[t] hey may handsomelye worke uppon it. Then they take of the barke with certayne shells: they reserve the innermost parte of the lenkke, for the neather most parte of the boate. On the other side they make a fyre accordinge to the lengthe of the bodye of the tree, saving at both the endes. That which they thinke is sufficiente burned they quenche and scrape away with shells, and makinge a new fyre they burne it agayne, and soe they continne somtymes burninge and sometymes scrapinge, until the boate have sufficient bothowmes. This [Thus] god indueth this savage people with sufficient reason to make thinges necessarie to serve their turnes.

The accompanying de Bry engraving, after the John White drawing, clearly illustrates the processes (Fig. 5). The Ringler dugout shows a few indented marks approximately the same size as the stone axes recovered from the Ringler farm surface collections, as well as charred areas (Fig. 6a, b). The preservation of the Ringler dugout canoe, intact (in places) from keel to gunwhale and from stem to stern, suggests that a reconstruction of the capacity and behavior of the craft is possible. This "worst case" model assumes that the deeper, more rounded basal sections were typical.

**Load Characteristics**

A simplified representation of the dugout as it may have appeared in its intact condition was adopted. A scale drawing of the dugout as it was found
is shown in Fig. 7. It was assumed that the dugout's gunwhale originally was at the level of the dotted line in Fig. 7 as reconstructed from the few remaining intact portions. In order to describe the boat's shape mathematically, measurements were made at the deepest stations; A, B, C, D, E and parabolas were fitted to both the inner and the outer wood surfaces at the particular cross-section. A typical cross-section, defining the nomenclature, is shown in Fig. 8. In the parabolic approximation adopted, the wood surfaces at a cross-section are described by

\[
y_{outer} = y_1 \left( \frac{x}{x_1} \right)^2 \quad (1)
\]

\[
y_{inner} = a + (y_1-a) \left( \frac{x}{x_1} \right)^2 \quad (2)
\]

To describe the geometry of the ends of the boat in a suitable approximate way, parabolas were fitted to the cross-sectional shape, the planform, and the longitudinal bottom curve. A sketch defining the nomenclature for the planform and the longitudinal shape of the ends is shown in Fig. 9. Observe that the ends are essentially solid wood, whereas the center is hollowed out. The outer shape at any lateral cross-section in the end regions is described by equation (1), similarly to the central region. The planform shape is described by:

\[
\frac{z}{L} = 1 - \left( \frac{x}{x_{10}} \right)^2 \quad (3)
\]

where \(x_{10}\) is the value of \(x_1\) at the beginning of the end region, \(z = 0\). The longitudinal bottom curve is described by:

\[
h = y_{10} \left( \frac{z}{L} \right)^2 \quad (4)
\]

where \(y_{10}\) is the value of \(y_1\) at \(z = 0\).

Using this smoothed description of the craft's geometry, the displaced volume was calculated as a function of freeboard, that is, the distance of the assumed straight gunwhale above the waterline. To perform this calculation, the displaced area, \(A\), at any cross-section is expressed as the following integral:

\[
A = 2 \int_0^{x_F} (y_1 - F - y)dx \quad (5)
\]

where \(x_F\) is the value of \(x\) at the waterline. In the end regions, observe that the total height \(y_1\) is given by \(y_{10} - h\). Using the parabolic shape given by equation (1) and performing the integration indicated in equation (5), the displaced area is found to be:
\[ A = \frac{4}{3} X y^1 \left( 1 - \frac{F}{y^1} \right)^{3/2} \tag{6} \]

Again, in the end regions \( y^1 \) is replaced by \( y^10 - h \).

The area of wood at any cross-section of the dugout along the hollowed-out region is obtained from:

\[ A_{\text{wood}} = A F=0 - A_{\text{inside}}, \quad F = 0 \tag{7} \]

The area \( A \) inside is obtained from equation (6) by observing that \( y^1 \) inside = \( y^1 - a \). One finally obtains

\[ A_{\text{wood}} = \frac{4}{3} x^1 a \tag{8} \]

In the end regions the area of wood at any cross-section is the total displaced area corresponding to zero freeboard \( (F = 0) \). The volume is found by integrating the area:

\[ V = \int A dz \tag{9} \]

Calculations of volume were obtained by numerical integration of (9) using trapezoidal rule.

The mass of the boat was calculated from the total wood volume obtained using the smoothed geometry, assuming a typical specific gravity of white oak of .897. This gives a total boat mass of 320 kg. The load at any freeboard is the difference between the mass of the displaced water and the mass of the boat.

The results of load-freeboard calculations are shown in Fig. 10. It is seen that the maximum load is 1074 kg, corresponding to zero freeboard, and that the displacement to support the empty weight of the craft corresponds to a freeboard of approximately 31 cm.

**Stability Calculations**

To obtain a measure of the stability of the dugout, a crude estimate was made of the location of the mass center of the boat plus its load for neutral static stability. Because of the uncertainties in this calculation in the absence of accurate information about the original geometry near the boat’s waterline, a complicated accurate calculation was not considered justifiable. Therefore, a weaker approximation of the boat's geometry than in the load-freeboard calculations was used, the boat being approximated...
as a cylinder whose inner and outer cross-sections have the smoothed shapes of station C. The measure of stability was taken to the theoretical metacentric heights, calculated in accordance with standard methods (e.g., Eskinazi 1962). The defining sketch is shown in Fig. 11. The metacentric height, \( MG \), is given by:

\[
MG = \frac{I}{A} \cdot GP
\]  

(10)

where \( I \) is the area moment of inertia per unit length of the planform at the waterline and \( A \) is the cross-sectional area exclusive of the wood, which was denoted by \( A \) inside. Using the parabolic fit to the cross-sectional shape we obtain:

\[
I = 2 \int_0^x y^2 \, dy = \frac{2}{3} x^3 F = \frac{2}{3} \left[ 1 - \frac{F}{y_1} \right]^{3/2} x^3
\]

(11)

\[
A = \frac{4}{3} x_1 (y_1 - a)
\]

(12)

The location of the center of pressure is obtained from the defining equation:

\[
Ay_p = 2 \int_a y_1 - F \int_a x_s y_s \, dy
\]

(13)

where \( x_s, y_s \) denote values of \( x \) and \( y \) on the surface, and \( y_p \) is the \( y \) location of the center of pressure. Using the parabolic surface shape and performing the indicated integration, one obtains from equation (13):

\[
y_p = \frac{3}{5} \left[ \frac{y_1 - F - a}{y_1 - a} \right]^{3/2} \left( y_1 - F - \frac{2}{3}a \right)
\]

(14)

Observing that \( GP = y_G - y_p \) and combining equations (10), (11), (12), (14) results in:

\[
MG + y_G = \frac{1}{2} \frac{x_1^2}{y_1 - a} \left[ 1 - \frac{F}{y_1} \right]^{3/2} + \frac{3}{5} \left( \frac{y_1 - F - a}{y_1 - a} \right)^{3/2} \left( y_1 - F - \frac{2}{3}a \right)
\]

(15)

The craft is neutrally stable to small disturbances; that is, upon a small disturbance it will tend neither to right itself nor to overturn, when the metacentric height, \( MG \), is zero. This occurs when the mass center, \( y_G \), of the boat plus its load is at some critical value, herein regarded as the maximum allowable height location of the mass center.

The maximum height location of the mass center, as a function of load, is shown in Fig. 12. It is seen that the unloaded boat is estimated to be unstable, and that a minimum load of approximated 75 kg is required for neutral stability. As the load is increased, the mass center location also can
be raised. Because of the low center of mass height for light loads, it appears that this may be a poor boat for carrying people only. Considering that its geometry limits it to carrying no more than four people, whose total mass would be about 300 kg, the mass center height for people alone would be no more than 10 cm! It appears the boat must always carry cargo or ballast if the deep rounded sections were typical of the craft.

Although the maximum load is 1074 kg, the practical maximum is considerably less because of the requirement of reasonable freeboard. Taking 10 cm as the minimum acceptable freeboard, the maximum practical load appears to be about 680 kg, including the crew. In considering the possibility of using the dugout under lightly laden conditions, one must recognize that people do in fact operate unstable watercraft. After all, it is not unusual for an experienced canoeist to stand in a canoe in order to examine the water ahead.

The stability calculations presented herein indicate when the boat tends to roll over; they do not consider how rapidly it rolls over. If it rolls slowly enough, then even an unstable craft can be successfully handled by experienced boaters. The dynamic behavior can be significantly improved by proper use of outriggers, leadboards, and similar devices.

This possibility appears quite unlikely. Those reports—archaeological, ethnographic, or historical—which refer to aboriginal dugout canoes in eastern or central North America (see Cushing 1896; Mason 1896, 1907; Harnell 1946; Driver and Massey 1957:275-294; Waugh 1919; Brewington 1963; Chansler 1921; Chapelle 1960, 1961: Neill 1953; Kidd 1959; Gregory 1964; Willis n.d.; Bullen and Brooks 1967; Stowe 1974), have no mention of outriggers. Had outriggers been used they could have significantly improved the dugout's stability. This in turn would have also improved the vessel's cargo capacity. It does not appear that the fore and aft decks offer sufficient area for polling.

Speculations on Trade Patterns

The minimal performance of the boat under these assumptions, the connecting waterways, and the surrounding archeological record can be used to make at least plausible speculations about water-based trade.

In considering the shipment of goods by boats such as the Ringler dugout, we observe that the wear-polished areas of the floor of the boat suggest a crew of two or three people, and a crew weight of 150 to 225 kg. The mass center height for any cargo depends upon the mass and the density of that cargo. The more dense the cargo is, the lower the mass center height will be for any given load. The further the mass center height exceeds the gunwhale height above the bottom of the craft, the greater the degree of negative stability the dugout will exhibit; that is, if the cargo is of low density, a heavy load that must be restricted to the available floor area will have to be piled so high that the dugout will tend to roll over once
equilibrium is disturbed. Given the maximum practical load of 680 kg and the available floor area of the Ringler dugout, with a crew of two the maximum practical cargo mass is 530 kg to be stowed in an area of 1.5 m$^2$; with a crew of three the maximum practical cargo mass is 455 kg to be stowed in an area of 1.0 m$^2$. Accepting a 10-cm minimal freeboard, and assuming a crew whose posture (either sitting back on one heel or kneeling) places their center of mass at a height between 40 and 100 cm above the bottom of the dugout, the relationships between the density of a number of potential cargoes, crew size, and the total load (cargo mass plus crew mass) under conditions of neutral stability is illustrated in Fig. 13.

The limiting factors are the maximum load (beyond which point the 10-cm minimum freeboard is passed and eventually the dugout with crew and cargo sinks) and the minimum load (which represents a point below which the dugout with its crew rides so high in the water that it loses neutral stability). As illustrated in Fig. 13, to maintain or exceed neutral stability requires maintaining a ratio between cargo mass and cargo density which varies with the size of the crew. For a crew of three, a “neutrally stable” cargo weighing 455 kg (the maximum load), would require a minimum cargo specific gravity of 1.9. A stable cargo mass of 350 kg would require a minimum cargo specific gravity of 3.1, and a cargo mass of about 45 kg would require a specific gravity about 9.0 just to maintain neutral stability. With a crew of two, the minimum specific gravity of cargo required to maintain neutral stability is about 1.2 with a maximum mass of 530 kg. Even a cargo with a specific gravity as high as 9.0 would require a minimum mass of about 120 kg with a crew of two and 10-cm freeboard.

By determining the density of a number of potentially relevant cargoes (Table 1) it is possible to estimate how each may have affected vessel stability. A comparison of Table 1 with Fig. 13 suggests that two classes of cargo existed: cargoes that were dense enough to contribute to positive stability when loaded into the available space (to a large extent these are items with a mean specific gravity above 1.2), and less dense cargoes that could not be loaded into available space without being placed so high that they created negative stability. The “stable” materials appear to represent those whose role in long distance exchange within the Eastern Woodlands has been demonstrated archaeologically (i.e., copper, hematite, mica, flint, steatite, pottery, fresh conch shell, and salt), while those “unstable” commodities appear to represent subsistence resources, presumably locally extracted and consumed. The estimates of neutrally stable minimal density for all of these materials assume that the load represents a solid matrix, one without significant pockets of lower density. Thus, unless conch shells and pots are either containers for something with a minimal specific gravity of 1.2, or are reduced to fragments and potsherds, it is unlikely that they alone can be packed within the available cargo space in the Ringler dugout to comprise a stable load any more than can nuts, skins, or meat. One
implication drawn from this “worst case” analysis is that such craft as the Ringler dugout were only minimally efficient in local subsistence resource procurement in spite of the apparent aquatic economic adaptations of the Transitional Archaic populations. At best such craft are less than ideal for the trade and/or transmission of subsistence resources only. And it appears that such craft would be unlikely to have been effective for human transport or communications alone. If we assume that this or other coeval dugout canoes reported (Bullen and Brooks 1967), were typical of Late Archaic watercraft and, in the absence of other functionally specialized watercraft, that such dugouts were in fact used for a wide variety of functions, then we may well draw the conclusion that mixed loads, composed of differing materials, were desirable to maintain stability.

As illustrated in Table 2, remarkably little of any material as dense as copper would be required to provide a sufficient mass with minimal height to meet or exceed the requirements of neutral stability. With a crew of three, a single layer of copper less than 1 cm deep could provide stability for nearly 1 m$^3$ of a low density cargo such as nuts or seeds, or for over 400 kg of meat. Clearly, in any inferred trade or transmission involving subsistence resources, a little heavy metal would go a long way toward insuring stability (hydrodynamic and social). Certainly the rank order of materials presented in Table 1 deserves comparison with rank orderings of similar materials proposed as indices of social status in later prehistoric periods (see Winters 1968; Struver and Houart 1972; Greber 1976; Peebles 1978; Brose and Greber 1979). Although perhaps not chronologically appropriate, the Hopewellian copper celts from the Seip M2 and the Edwin Harness mounds average 66 cc to 170 cc with a mass which varies from 581 to 1500 g (personal communication, Eloise Gadus), with a mean volume of 118 cc and a mean mass of 1040 g. For additional passengers beyond a crew of three, each would require 12.6 such copper celts to maintain neutral stability. Thus presumably lacking our recent mathematical analyses, Late Archaic populations may have had more than mythic justification for assigning to items such as copper celts or hematite cones a significant role in structuring exchange and/or ranking.

To continue this hypothetical attribution of Middle Woodland exotic cargo to Late Archaic watercraft, not only does it appear that Griffin was correct in his argument that “the total amount of obsidian from Hopewell sites might have been obtained on one trip to Yellowstone” (Griffin 1966:146), but also that the mass of the obsidian recovered from Hopewell Mounds 9 and 25 combined may well represent the minimum mass stable cargo for the round-bottomed Ringler dugout.

It would appear (in terms of stable transmission of potential cargoes in this type of watercraft), obsidian, shell, or copper axes could not have represented simple equivalents. That is, a stable cargo of copper or of subsistence resources ballasted with some copper, could not have been
replaced by a stable load of conch shell containers (or by a stable load of subsistence resources ballasted by conch shell containers) of similar mass or volume. There may have been a number of complex Late Archaic formulae of personnel and/or material assemblages which would yield equivalent hydrodynamic (and/or socioceremonial) stability. Perhaps one further implication of these analyses is that exchange systems (using craft such as the Ringler dugout canoe) which in this area must have been seasonally limited, may also have been limited to particular segments of river and/or lake systems (c.f. McDonald in Willis, n.d.).

The analyses of Fig. 13 suggested that the relationships of stability and cargo characteristics can change significantly if crew size or minimal freeboard conditions are altered. However, there is a continuum of stable cargo density to cargo mass ratios possible with a crew size of either two or three if the minimum freeboard is raised or lowered. While a 10-cm freeboard requirement appears reasonable for navigation upon rivers such as the Ohio at any time or upon either the Vermilion or Muskingum system from late spring through midsummer or again from mid-autumn to early winter, 10 cm appears to be too little freeboard for ideal navigation on the often choppy waters of the open Great Lakes, and would result in a draft too deep for easy navigation along the headwaters of either the Vermilion or Muskingum at other times of the year. The weight of the dugout itself (320 kg) further suggests that it would not have been easily portaged across interfluvies, and only with difficulty could it have been navigated upstream in fluvial systems with high current velocities with a crew of two or three. If we may hypothesize that for any voyage the crew size remained constant, then we may suspect that either the cargo mass or cargo density would have to be altered in order to adjust the parameters of freeboard and draft wherever the dynamic characteristics of the aquatic system differ significantly. Thus we feel that the Ringler dugout represents a craft whose role in transportation was probably confined to the larger rivers, to coastal and inter-island regions of the Great Lakes, and seasonally to their connecting waterways. To a large extent the transmission of any volume of material by any single prehistoric group would also have been limited, and would coincide with watershed boundaries rather than with theoretically spaced geographical nodes inferred for isotropic routes (as suggested by Struver and Houart 1972). This again suggests that the "exchange" system, in which late Archaic peoples were engaged, was likely to involve long voyages by single populations only along the middle section of the major river systems.

Conclusions

It may be argued that the foregoing socioeconomic inferences are predicated upon a mathematical reconstruction of performance quite at
variance with the known operation of dugout canoes in the early historic (and by inference in the late prehistoric) period. Examination has been made of over 20 dugout canoes (in person and via mailed photographs and drawings). These craft, from Michigan (2); southern Ontario (2); Mississippi; Kentucky (3); Alabama (4); South Carolina, Georgia (2); Louisiana; and Florida (11), have all been recovered from terminal prehistoric or historic contexts, and/or have been radiocarbon dated to periods less than 600 B.P. Although several are nearly as long as the Ringler dugout, all are of broader beam below waterline. Many have a more V-shaped hull with a deeper draft, a few of which have a distinct keel. All appear to have a narrower breadth at their gunwhale with some degree of sidewall sheer. Some even display stem and/or stern raking. Their overall waterline morphology is thus quite different from that of the Savannah Lake dugouts, and the distribution of less mass within them could have been more stable. While recent dugout canoes appear to have been relatively efficient for light loads (see Kidd 1959; Neill 1953; Knipmeyer 1956; Gregory 1964; Willis n.d.), the Ringler dugout might not.

The Late Archaic period in the Eastern Woodlands yields the first unambiguous evidence for regionally specific (and spatially restricted) subsistence and settlement systems; for the trade and/or transmission of exotic materials destined for ceremonial contexts; and for status distinctions within populations (Caldwell 1958; Caldwell and Hall 1964; Winters 1968; Greber 1976; Brose 1979). Beyond some question as to the role of canoes in the mundane economies, Late Archaic trade and transmission presumably involving such craft represents the inception of systems which appear, in many ways, to have culminated in the Midwest with the rococo Hopewelian interaction sphere. Understanding the potentials of such Late Archaic processes appears necessary to reconstruct the trajectory of much socioceremonial organization of the succeeding 2500 years throughout Eastern North America (Brose 1979). It appears that this exchange, at least in its earlier stages, was geographically restricted for any group rather than long-distance travel by single parties involved in some rite de passage. Further, the amounts of differing materials that could be moved in any such transaction were apparently both complex and limited, although the overall volumes involved may well have been greater than the capacity of a single such boat.

An alternative hypothesis (lacking supporting data) is that since watercraft designed to move material in one direction may not have been effective in moving other materials in a reverse direction, differing types of watercraft were employed. In either case, it would appear that the transmission of exotic raw materials, at least in the known watercraft of the Late Archaic period, is unlikely to have involved "trade" as direct exchange as much as it may have involved "trade" through mechanisms of delayed reciprocity (viz. Sahlins, 1965, 1972).

In light of the analyses presented, the location of the major ceremonial
(distribution or exchange) centers in the periods following the Late Archaic represents modification to a system: unlike major Woodland sites Late Archaic sites were located to minimize to some degree the technological limitations of their transportation systems. Without evidence of technological improvements, we must infer the introduction of nonlogistic considerations into the cultural decisions affecting locations of the far more complex Woodland ceremonial sites. This hypothesis is based upon the "worst case" analyses of a single dugout. While it is unlikely that the wide-ranging birchbark canoe routes of the Early Historic period in the Midwest were possible as early as the Late Archaic, we have, as yet, no information concerning the watercraft of the Early or Middle Woodland periods.

Acknowledgments

This report would remain sadly incomplete without a formal expression of gratitude to those who have substantially contributed to whatever value it has. Thanks are due to Donald and Mary Ringler of Bailey Lake Village, Ohio, for their concern, their numerous courtesies, and their unfailing interest; to Harold Slessman of Willard, Ohio, for his recognition and careful extrication of the dugout from its matrix; to Mr. and Mrs. Charles Landefeld of Shaker Heights, Ohio, for contacting the Cleveland Museum of Natural History; to the Cotter Moving and Storage Company of Akron, Ohio, for their unreimbursed, careful, and expeditious transfer; to the Dow Chemical Corporation of Midland, Michigan, for donating to the Museum sufficient Carbo-Wax for the preservation of the dugout canoe; and to David Morse, Regional Ohio Archaeological Preservation Officer, OSU, Mansfield, Ohio, who has freely shared data from subsequent investigations of the site area.

Within the Museum itself grateful thanks are offered to James Bissell, Curator of Botany, for species identification, site inspection, and assistance in archaeological surface collections; to Paul Clifford, Curator of Minerology; to N'omi Greber, Associate Curator of Archaeology and Keeper of Collections, for reading and commenting on earlier versions of this manuscript; and especially to Brant Gebhart, Conservation Department and Ellen Walters, Head of Exhibits, for the magnificent and fully successful preservation and replication of the Late Archaic Ringler Dugout canoe.

Cleveland Museum of Natural History
Case Western Reserve University
Fig. 1. Map of Ohio Major Drainage Systems. Savannah Lake area in inset box.
Fig. 2. Map of Savannah Lake, Ashland County, Ohio: A, location of Ringler Dugout; B, location of 1957 dugout; C, location of 1962 dugout.
Fig. 3. Looking SSE across Savannah Lake, Ashland County, Ohio. Location of Ringler Dugout in foreground.
Fig. 4. The Ringler dugout as first photographed December 2, 1976.
Fig. 5. De Bry engraving after John White painting of Virginia Indians making dugout (Harriot 1590).
Fig. 6. Above, charred area on inner sidewall of dugout with polished area on bottom. Below, rear (?) deck or platform with peat in bottom.
Fig. 7a. Deepest waterline and cross-sections of Ringler Dugout.
Fig. 7b. Deepest waterline and cross-sections of Ringler Dugout.
Fig. 7c. Deepest waterline and cross-sections of Ringler Dugout.
Fig. 7d. Measured waterline and cross-sections of Ringler Dugout at stations with deeper rounded bottom.
Fig. 8. Typical mathematical cross-section for Ringler Dugout.

Fig. 9. Nomenclature for end region.
Fig. 10. Freeboard/Load relationship for Ringer dugout.
Fig. 11. Metacentric Height nomenclature for mathematical model.

- **M**: metacenter
- **G**: center of mass
- **P**: center of buoyancy
- **P'**: center of buoyancy in heeled position
Fig. 12. Minimal Metacenter Height/Stability relationship for Ringer dugout.
Fig. 13. Relationships of Cargo mass and Density for Neutral Stability and 10-em freeboard for Ringer Dugout assuming deep sections are typical of bottom morphology.
TABLE 1

Density of Potential Cargo

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>8.8-8.9</td>
</tr>
<tr>
<td>Galena</td>
<td>7.4-7.6</td>
</tr>
<tr>
<td>Hematite</td>
<td>4.9-5.3</td>
</tr>
<tr>
<td>Mica</td>
<td>2.7-3.3</td>
</tr>
<tr>
<td>Soapstone, Serpentine, Steatite</td>
<td>2.5-2.8</td>
</tr>
<tr>
<td>Obsidian</td>
<td>2.5-2.7</td>
</tr>
<tr>
<td>Flint, Chert, Chalcedony</td>
<td>2.3-2.6</td>
</tr>
<tr>
<td>Salt</td>
<td>2.2</td>
</tr>
<tr>
<td>Grit-tempered Pottery</td>
<td>1.6-2.7</td>
</tr>
<tr>
<td>Conch shell, fresh</td>
<td>1.6-1.9</td>
</tr>
<tr>
<td>Conch shell, weathered</td>
<td>1.3-1.6</td>
</tr>
<tr>
<td>Meat</td>
<td>1.1-1.3</td>
</tr>
<tr>
<td>Furs, Skins (tanned without chromium)</td>
<td>1.0-1.3</td>
</tr>
<tr>
<td>Nuts, fresh</td>
<td>0.6-0.8</td>
</tr>
<tr>
<td>Nutmeats, dried</td>
<td>0.3-0.6</td>
</tr>
<tr>
<td>Seeds, sunflower</td>
<td>0.2-0.8</td>
</tr>
</tbody>
</table>

TABLE 2

Some Stability and Cargo Relationships for the Ringler Dugout Available Space (assuming minima of neutral stability and 10 cm freeboard)

<table>
<thead>
<tr>
<th>Cargo</th>
<th>Crew = 2</th>
<th>Crew = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Copper (SG = 8.85)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>120</td>
<td>530</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>0.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Obsidian (SG = 2.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>160</td>
<td>530</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>5.7</td>
<td>13.6</td>
</tr>
<tr>
<td>Meat (SG = 1.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>500</td>
<td>530</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>27.7</td>
<td>29.4</td>
</tr>
<tr>
<td>Conch shell (SG = 1.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>380</td>
<td>530</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>16</td>
<td>22.1</td>
</tr>
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</table>
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Appendix: Preservation and Replication of the Ringler Dugout Canoe

On the 30th of November, 1976 a clam-bucket scoop cut through 3 1/2 feet of peat below Savannah Lake (Fig. 3), and caught in the end of the bucket a large, wooden dugout canoe. The canoe was eased to the shore, and Brose visited the property on the afternoon of December 2, 1976, and Dr. Harold D. Mahan, director of The Cleveland Museum of Natural History, approved permission to transfer the canoe to the museum.

The canoe was moved from the edge of the lake to a protected location and covered with straw and plastic. The extreme cold, with nighttime temperatures of -15° F and daytime highs of less than 5° F, preserved the canoe until it could be treated by preventing either moisture loss or alternate freezing and thawing. By the afternoon of December 6, 1976, the dugout canoe had been transferred to a temporary tank of acidic water in the garage of The Cleveland Museum of Natural History (Brose, 1978).
With the canoe’s condition thus stabilized, Brant Gebhart, museum conservator, began searching for information for long-term preservation. He contacted Steve Brooke, conservator of the Maine State Museum; Carolyn Rose, of the Conservation Laboratory of the Smithsonian Institution; Peter Van Geersdaele, Thomas Bryce, and Victoria Jackson of the Canadian Department of Parks and Northern Affairs; Charles Hett and Lorne Murdock of the Canadian Conservation Institute; and, eventually, the Royal Swedish Academy in Stockholm.

As Gebhart described the situation in his subsequent report (April 19, 1977), the canoe was in a “water degraded condition” with considerable loss of solid organic contact. He noted that “Growth rings are deteriorated, but medullary rays are intact. The water in the more deteriorated areas is acting as a bulking agent preventing cell collapse and also providing a surface tension helping bond the cells together,” and further, noted that in drying “bulking water would be removed, and the small amount of surface attached water which is bound to the enormous internal surface area would remain causing gradual tensional collapse. Condensation of additional moisture when exposed to normal air would cause a continuum of contraction and damage to the weakened wood.”

Gebhart explored the problems associated with a number of potential preservation methods including slow drying (Oddy, 1975; Muhlethaler, 1973); freeze drying (Ambrose, 1975; Anonymous, 1976); solvent exchange (Bryce, 1976); and polymer solvented solid replacement (Ambrose, 1975; Bryce, 1976; Oddy, 1975). Gebhart also offered a tentative comparative cost estimate of the various techniques.

The most effective, reversible, and affordable treatment appeared to be initial saturation with polyethylene glycol followed by freeze drying. Unfortunately no freeze drying units large enough were known to exist. The decision was made to proceed with replacement in a gradually concentrated solution of polyethylene glycol. This technique was relatively inexpensive and safe, and would gradually stabilize the cell structure of the canoe by replacing air and water with a waxy substance. However, as Gebhart noted in his report,

Any preservation treatment can and probably will alter the appearance and dimensions of the canoe. Details of cutting, carving, and burn scars are present on the interior. To preserve such details casting is often practiced by conservators to insure a record of this invaluable ethnographic evidence. Waterlogged wood stands the greatest chance of alteration after treatment.

In order to provide a permanent record for comparative study, Gebhart and Ellen Walters, Director of Exhibits, began to cast the Ringler dugout canoe during the period in which the holding tank was permanent. The waterlogged dugout canoe, weighing nearly one ton, was swung out of its acidic water onto pads upon the garage floor. It was cleaned of peat and
dirt, using fine brushes. During this time a series of detailed measurements and photographs was taken. The canoe was then coated with several fine layers of latex which were in turn covered with fiberglass matting and resin and finally with a “mother” mold of polyurethane foam. Once this hard shell had dried, it was carefully cut apart. The original dugout was replaced in permanent treatment, and the mold was filled with a polyurethane plastic resin. When this had hardened, the mold was removed, revealing an accurate, full-size cast. The entire casting process was accomplished within two months. The solvent replacement process is expected to be completed within the year.