TOWARD AN ANALYSIS OF THE EXCHANGE OF METEORITIC IRON IN THE MIDDLE WOODLAND

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Comparison of the distribution of Middle Woodland meteoritic iron artifacts to that of meteorite falls over the eastern United States, chemical analyses of several of the artifacts, and archaeological evidence indicate the diverse nature of Hopewellian "interaction" and differing relationships of various Southeastern Middle Woodland complexes to Ohio or Illinois Hopewell groups. Chemical analyses of meteoritic iron artifacts from the Tunacunnhee and Mandeville sites (Georgia), using energy dispersive X-ray spectrometry, are presented. The data are consistent with the proposed diverse nature of interaction. They also suggest the working of the particular specimens by cold hammering, a method that did not obliterate the original heterogeneous nature of the material, and some methodological difficulties in the analysis of weathered, foil-covered specimens.

Over the past fifteen years, reconstructions of the nature of regional exchange systems in the Eastern Woodlands during the Middle Woodland period have changed considerably. What was once seen as a highly structured, temporally regular exchange system, to be identified as the mechanism defining the Hopewell Interaction Sphere (Struever 1964; Struever and Houart 1972), is now considered by some a more sporadic, less integrated series of events (e.g., Griffin 1973; Seeman 1977; Toth 1979:199; Walthall 1979:204). Very systematic study of patterns of covariation and spatial distribution of classes of exchange items among Middle Woodland sites over the whole eastern U.S. by Seeman (1977) and chemical studies of the sources of archaeological specimens of particular exchanged raw materials (Walthall et al. 1979, 1980; Goad 1978, 1979; Spence in Brose and Greber 1979: 252–253), as well as some regionally less comprehensive distributional studies (e.g., Toth 1979; Johnson 1979), point toward this conclusion.

Among the raw materials often thought to have been exchanged over the Eastern Woodlands during the Middle Woodland is meteoritic iron (Struever and Houart 1972). In this paper, we summarize distributional and chemical data for artifacts and sources of this raw material and provide further insight into the nature of Hopewellian exchange. A chemical analysis of several iron specimens from the Tunacunnhee and Mandeville sites—the only prehistoric iron artifacts in the southeastern United States yet to be analyzed—is reported. The analyses confirm the meteoritic nature of the iron and indicate that the specimens probably were worked by cold hammering. We also define some potential methodological problems in the analysis and interpretation of Middle Woodland iron artifacts which need to be considered when using X-ray dispersive spectrometry procedures.

Overview of Likely Iron Artifacts in the Eastern United States

Prehistoric Indians of the eastern U.S. used and traded a variety of metallic substances over the course of time. Among these are native copper (the most common), galena, silver, gold, pyrite, hematite, and meteoritic iron (Putnam 1903:49; Willoughby 1903). The use of meteoritic iron is restricted almost entirely to the Middle Woodland period (Prufer 1961:341), dating approximately from 200 B.C. to A.D. 450. One exception is its occurrence in some later Weeden Island contexts at the Kolomoki site, Georgia (W. Sears 1956:28; Prufer 1962; cymbal-shaped ornaments reminiscent of Hopewellian earspools).[1]

Specimens thought or identified to have been made partly or totally of meteoritic iron take a variety of forms. These include: (*a*) *jewelry and ornamental items* like beads, probable buttons, earspools, and headdresses; (*b*) *nonutilitarian ceremonial tools* like celts and adzes; (*c*) *other ceremonial items* such as panpipes, cones, and symbolic cutouts; and (*d*) *utilitarian tools* such as awls, chisels, and drills. Unworked nuggets of meteoritic iron also are known. Table 1 provides a list of all the kinds of artifacts that potentially contain iron and that have been found in Middle Woodland sites, along with pertinent bibliographic references.

All known worked items appear to have been manufactured by cold-hammering procedures (sometimes with annealing) rather than by casting, which was not known to native Americans north of Mexico

Table 1. Middle Woodland Archaeological Specimens Probably Containing Iron.

Regional Tradition: Site Name (Location)	Archaeological Specimens, Grouped by Site	Iron Tested?	Reference[a]
Scioto Hopewell:			
Tremper (Scioto Co., Ohio)	iron-foil-covered solid slate cone	no	Prufer 1961
Mound City (Ross Co., Ohio)	iron-foil-covered button	no	Prufer 1961
	sheet-rolled cylindrical bead	no	Prufer 1961
	iron- and copper-foil-covered marine shell beads	no	Prufer 1961
Seip (Ross Co., Ohio)	sheel-rolled iron awl	no	Shetrone and Greenman 1931:456; Prufer 1961; Seeman 1977
	sheet-rolled cylindrical bead	no	Prufer 1961
	iron-foil-covered button	no	Prufer 1961
	boat-shaped hollow object	no	Shetrone and Greenman 1931:456; Prufer 1961
	saucer-shaped disk	no	Shetrone and Greenman 1931:456
	inclusion in hollow bear canine	no	Shetrone and Greenman 1931:456
Harness (Ross Co., Ohio)	iron-foil-covered copper button	no	Prufer 1961
	celt	no	Prufer 1961
	disk-shaped sheets	no	Prufer 1961
	iron-foil-covered copper bicymbal earspool	no	Prufer 1961
	iron-foil circular cut-out over textiles	no	Mills 1907:187; Seeman 1977
Hopewell (Ross Co., Ohio)	iron-foil-covered copper bicymbal earspool	no	Shetrone 1926:167; Prufer 1961
	copper- and silver-foil-covered iron bicymbal earspool	no	Shetrone 1926:167; Prufer 1961
	sheet-rolled iron (and copper?) awl	no	Seeman 1977; Prufer 1961
	iron-foil-covered button	no	Shetrone 1926:170; Prufer 1961
	iron-foil-covered solid cone	no	Prufer 1961
	iron-sheet headplate (fragments)	no	Prufer 1961
	adze	no	Prufer 1961
	chisels, straight-sided and curved	no	Shetrone 1926:123, 124; Prufer 1961
	drill		Prufer 1961
	iron-foil-covered human ulna	no	Prufer 1961
	panpipes of copper and iron	no	Seeman 1977
	"nugget"	yes	*Farrington 1902*; Prufer 1961; Seeman 1977
	perforator	no	Shetrone 1926:46
Turner (Hamilton Co., Ohio)	earspool entirely of iron	no	Prufer 1961
	iron-foil-covered copper bicymbal earspool	no	Willoughby 1922:46; Prufer 1961; Seeman 1977
	sheet-rolled cylindrical bead	no	Prufer 1961
	iron sheet headplate (fragments)	no	Willoughby 1922:50; Prufer 1961; Seeman 1977
	panpipe	no	Prufer 1961
	nugget	yes	*Kinnicutt 1887*; Prufer 1961; Seeman 1977
Mariott-1 (Hamilton Co., Ohio)	iron-foil-covered copper bicymbal earspool	no	Putnam 1887:465; Prufer 1961
Marietta (Washington Co., Ohio)	nugget	no	Griffin 1970:103, quoting Atwater 1820: 168–178; Prufer 1961; Seeman 1977
Ft. Ancient (Warren Co., Ohio)	iron-foil-covered copper bicymbal earspool	no	Prufer 1961
Campbell (Clark Co., Ohio)	nugget	no	Altick 1941; Prufer 1961; Seeman 1977
Circleville(?) (Pickaway Co., Ohio)	iron sheet (breast plate?) with mica mirror	no	Atwater 1820; Prufer 1961; Seeman 1977
Esch (Erie Co., Ohio)	iron and copper bicymbal earspool	no	Greenman n.d.; Seeman 1977
Porter (Ross Co., Ohio)	earspool entirely of iron	no	Moorehead 1892; Prufer 1961
	iron-foil-covered copper bicymbal earspool	no	Moorehead 1892; Prufer 1961
Havana Hopewell:			
Gibson (Calhoun Co., Illinois)	iron-foil-covered copper bicymbal earspool	no	Perino 1968:119–120; Prufer 1961

Table 1. Continued.

Regional Tradition: Site Name (Location)	Archaeological Specimens, Grouped by Site	Iron Tested?	Reference[a]
Havana (Mason Co., Illinois)	bead	yes	*Grogan 1948*; McGregor 1952:56,60,66; *Kimberlin and Wasson 1976*
Albany (Whiteside Co., Illinois)	nugget	no	Harold 1971:65,76; Seeman 1977
Southern Appalachian, Copena:			
Tunacunnhee (Dade Co., Georgia)	sheet-iron inset on copper earspool sheet-iron coverplate of earspool	yes yes	Jefferies 1979:164,166; *this paper* Jefferies 1975:21, Plate VII; *this paper*
Santa Rosa–Swift Creek, St. Johns:			
Crystal River (Citrus Co., Florida)	iron-foil-covered copper bicymbal earspool	no	Moore 1907:421,422; Prufer 1961; Seeman 1977
Murphy Island (Putnam Co., Florida)	awl	no	Moore 1896:514; Prufer 1961; Seeman 1977
Mandeville (Clay Co., Georgia)	iron and copper bicymbal earspool	no	Kellar et al. 1962a:352, 1962b:67, 69; Prufer 1961; Seeman 1977; *this paper*

[a] References describing chemical tests for iron are italicized.

(Driver 1969:166–197). For specimens made of meteorites having nickel contents in the range of about 70 to 100 mg/g (Group IIIAB, IVA, and some IAB specimens), this can be confirmed by microscopic examination of polished and etched sections cut through unweathered portions of the objects. Meteorites of this composition usually display the Widmanstätten structure, which consists of a regular, laminar distribution of crystalline kamacite (a nickel-poor iron-nickel alloy, body-centered cubic structure) and interstitial crystalline taenite (a nickel-rich iron-nickel alloy, face-centered cubic structure). After cold hammering of meteoritic iron, the material displays a marbelized laminar structure as a result of stretching and folding during the hammering process rather than the more regular distribution of the two phases. Heat treatment is apparent by the recrystallization and shape changes in kamacite grains that it causes. Grogan (1948:Plate 28) illustrates these alterations in a meteoritic iron bead from the Havana site, Illinois. Meteoritic specimens having nickel contents outside the stated ranges do not have the Widmanstätten structure but would display other petrographic evidence for cold hammering if they had been subjected to such treatment.

Middle Woodland artifacts of iron sometimes have only a veneer of iron foil placed over another material (frequently copper) that has been worked to a proper shape. Other items are composed entirely of iron—formed either as a solid mass, or as a rolled, cut, and bent sheet. Veneer artifacts are as common as those composed entirely of iron for the eastern U.S. as a whole, and predominate in southeastern U.S. assemblages (see Table 1). They pose methodological problems when trying to identify their source or composition (see below).

Quantitatively, artifacts of meteoritic iron are rare compared to other classes of Hopewellian burial furniture in the eastern U.S. (Figure 1). They also have a more restricted spatial distribution. Most specimens come from 13 Scioto Hopewell sites in southern and central Ohio. A few specimens come from the lower and central Illinois valley (Havana Hopewell), the middle Tennessee valley (Copena), and southwest Georgia (Santa Rosa–Swift Creek) and northern Florida (St. Johns). No meteoritic iron artifacts have been found in the many other regions of Hopewellian ceremonial flamboyance, including the Point Peninsula, Trempeleau, Kansas City, Marksville, Porter, and Miller regions.

Distribution and Source Determination

In the archaeological literature, there are conflicting opinions as to the source(s) of meteoritic iron used in making Hopewellian artifacts. Struever and Houart (1972) locate only one possible source—the Brenham meteorite fall in Kiowa County, south-central Kansas—implying the distribution of iron from here to various Middle Woodland sites over the Eastern Woodlands through the Hopewell Interaction Sphere. Seeman (1979:301) argues for the likely local availability of meteoritic iron and the use of these many sources. He goes on to suggest (1979:301), following a more generally stated argument by Prufer (1961:348), that meteor falls or ground scatters of meteorites would have been more easily noticed in regions of open prairie or desert than in forest vegetation. This would imply that the greater abundance of Middle Woodland iron artifacts in northern Hopewell sites than in southeastern sites relates to the ease of collecting meteorites locally. Prufer (1961:343–347) takes an intermediate position. On the basis of early chemical analyses of a few iron artifacts from the Turner and Hopewell sites (Kinnicutt 1887; Farrington 1902), he suggests that meteoritic iron with-

Figure 1. Distribution of Middle Woodland sites having artifacts presumed to be composed of meteoritic iron.

in Scioto Hopewell sites came from at least two or possibly three different sources, with the evidence being unclear as to whether the Brenham fall was involved. Continent-wide trade is evoked as the scale and mechanism of procurement (Prufer 1961:347). None of these authors, however, make reference to the distribution of documented meteorites over the U.S. in drawing their conclusions.

A comparison of the distribution of Middle Woodland sites having probable iron artifacts to the distribution of currently known meteorite falls is informative. Figure 1 plots the archaeological distribution. Figure 2 shows the location of only those meteorites that are iron or stony-iron pallasites—not stone meteorites lacking iron or other types of stony-iron meteorites that are unsuitable for the manufacture of artifacts for lack of coherent metal. Also excluded from the plot are meteorites observed to have fallen historically, which postdate the time of interest.

Figure 2 cannot be taken to indicate the specific meteorite falls known as iron sources to Middle Woodland Indians; many falls probably were not known. Also, some known meteorites may have been completely consumed prehistorically or never found by white settlers, and thus may be absent from the map. Currently known meteorite falls comprise a very small proportion of the meteors that have impacted the earth—perhaps as small as 1% for the prairie states (Sears and Mills 1974). Thus, the value of Figure 2 is not as a map of specific potential aboriginal sources

Figure 2. Distribution of iron meteorites and stony-iron meteorites (pallasites) that fell prior to Euro-american settlement. Distributional data are from Buchwald (1968), and data on the mass of the meteorites are from Hey (1966).

of meteoritic material, but rather as a map of regions generally lacking or generally having an abundance of exploitable meteoritic iron, on a probabilistic basis.

The natural meteorite distribution exhibits two regions where meteorites are strikingly infrequent: (*a*) Ohio, Indiana, Illinois, northern Missouri, Iowa, Minnesota, eastern South Dakota, and eastern North Dakota, and (*b*) southern Arkansas, eastern Texas, Louisiana, Mississippi, southern Alabama, southwest Georgia, and Florida. In neither case do these distributional anomalies appear attributable to intensive prehistoric collection. Both areas lack not only large, visible specimens, which might be attributed to collection, but also smaller ones that would possibly have been overlooked prehistorically but recovered through historic plowing, had meteorites once been common there. Moreover, given the small numbers of meteoritic iron artifacts known from Middle Woodland sites, Hopewellian procurement and consumption must have been infrequent—too infrequent to explain the anomalously low density of meteorites in the two regions.

Instead, the origins of these distributional anomalies are probably natural. The infrequency of meteorites in the northern region probably reflects the burial of most pre-Holocene falls by glacial action. The southern terminus of Wisconsin and earlier glacial advances (Flint 1971:490, Figure 18.11) corresponds well with the southern edge of this low me-

Table 2. Large (≥99 kg) Meteor Falls in the Eastern and Central United States.

Meteor Name	Location	Mass (kg)
Pittsburgh	southwest Pennsylvania	132
Mount Joy	southeast Pennsylvania	847
Kenton County	northern Kentucky	163
Mount Vernon	western Kentucky	159
Carthage	north-central Tennessee	127
Babbs Mill	northeast Tennessee	142
Cosby's Creek	east-central Tennessee	958
Ider	northeast Alabama	140
Social Circle	central Georgia	99
Sardis	south-central Georgia	800
St. Genevieve	southeast Missouri	244
Brenham	south-central Kansas	907
Pierceville	west-central Kansas	180
Knowles	northwest Oklahoma	161
Lake Murray	south-central Oklahoma	268
Guffey	central Colorado	309
Glorieta Mountain	north-central New Mexico	145
Grant	west-central New Mexico	480
Sacramento	southeast New Mexico	237
Ysleta	west-central Texas	141
Odessa	west-central Texas	>294
Davis Mountain	west-central Texas	689
Chico Mountain	west-central Texas	ca. 1,814
Red River	east-central Texas	741

teorite density region (Figure 2). Implicit in this argument is the assumption that the terrestrial residence time of iron meteorites is significantly greater than the duration of the Holocene and that the observed meteorite distribution represents primarily pre-Holocene falls that would have been affected by glaciation. This assumption seems reasonable within the limited data available on terrestrial ages of iron meteorites (Wasson 1974:131). (Note that stony meteorites weather much more quickly and have much shorter terrestrial residence times than do iron meteorites [Sears and Mills 1974; Wasson 1974:131] but are not pertinent to this study.)

The paucity of meteorites in the southern region could well be due primarily to its generally moister soils. This would allow meteorites that may have fallen there to have penetrated deeply and remained hidden to prehistoric and historic collectors.

Finally, it is possible that the infrequency of meteorites in both the northern and southern regions relates partially to an additional natural process: the random distribution of meteor falls on a world-wide scale. This factor by itself, however, seems insufficient, given the noticeable correspondence between geomorphological provinces and meteorite distribution.

Several patterns are apparent in comparing the prehistoric and natural meteorite distributions. The patterns suggest several hypotheses about the nature of Hopewellian procurement of meteorites and give insight into the nature of the Hopewell Interaction Sphere in general. Not all of the hypotheses are compatible.

1. *Possible Use of Southeastern Meteorite Sources by Southeastern Middle Woodlanders.* In the southeastern U.S., iron meteorites of large size, approaching or greater than the size of the Brenham fall (ca. 900 kg), are fairly common. Table 2 lists all falls greater than 99 kg in the east and their locations and masses. Table 3 lists the sizes of meteorites of given masses, assuming a spheroidal shape, to give the reader a feeling for the magnitude of the falls shown in Figure 2. Note that a number of large falls occur in the immediate vicinity of Tunacunnhee (northwest Georgia) and not far from Mandeville (southwest Georgia). The commonness and distribution of large meteorites in the Southeast suggests that meteoritic iron could have been obtained within this area (sometimes locally) rather than through long-distance logistic trips outside the region or through interregional trade systems. It suggests that material from Brenham need not have been exploited by southeastern populations.

2. *Possible Reasons for Rarity of Iron Artifacts in the Southeast.* Despite the occurrence of many sizable meteorites in the Southeast, known iron artifacts from southeastern sites are relatively rare. This could reflect one or more of several factors: (*a*) the difficulty of locating meteorites in a forested environment prior to plow agriculture, as Seeman suggests; (*b*) given this, then also the limited exchange from northern to southeastern Woodland populations of iron derived from more obvious grassland contexts (but see 5, below); (*c*) the lesser symbolic-ceremonial demand for meteoritic iron among southeastern Middle Woodlanders than midwestern Hopewellians; and (*d*) the more limited amount of excavation of Middle Woodland mounds in the Southeast compared to Ohio and Illinois.

3. *Nonlocal Procurement of Meteorites by Ohio and Illinois Hopewellians through Logistic Expeditions.* In the Ohio and Illinois areas, where meteorite falls are scarce and small, archaeological specimens are more numerous. This makes it seem likely that meteoritic iron in Ohio and Illinois was obtained through interregional logistic trips or exchange systems rather than by local collecting. Indeed, Wasson and Sedwick (1969) have identified specimens from Turner Mound 4 (the Anderson meteorite) and Hopewell Mound 25 as having been derived from the Brenham fall. It is more probable, though not demonstrable, that these specimens were obtained by long-distance logistic expeditions than through an interregional trade system of the form pictured by Struever and Houart, given the lack of any meteoritic artifacts (and the paucity of interaction sphere goods generally) in Kansas City Hopewell sites (Johnson 1979:90–92). If so, then the means of procurement (i.e., long-dis-

tance logistic trips) of meteoritic iron by midwestern Hopewellians would be the same as that of another interaction sphere resource with a western origin and a similar riverine route of access: Yellowstone obsidian (Griffin 1965, 1973, 1983; Griffin et al. 1969). The mutual concentration of these two raw materials at the Hopewell site is supportive of their similar patterns of procurement.

4. Presence of Meteoritic Artifacts in Ohio and Illinois Sites from Sources Other than the Brenham Fall. Kimberlin and Wasson (1976) have found, using trace element (neutron activation) analysis, that a meteoritic bead from Havana Mound 9 was derived from a Group IIICD source distinctly different from Brenham. Among the known meteorites it resembles is the Edmonton fall (south-central Kentucky), and more distantly, the Anoka fall (Minnesota), the Carlton fall (Texas), and the Mungindi fall (Australia) (Buchwald 1975:637). At least two large falls (Kenton County, Mt. Vernon; Table 3) are known to occur in the Kentucky area, and it is possible that Ohio or Illinois Hopewell peoples made trips to this area to obtain meteoritic iron at least occasionally.

5. Possible Procurement of Meteorites by Ohio and Illinois Hopewellians from the Southeast via Exchange. The complementary distribution of meteorite sources (concentrated south of the Ohio River) and Middle Woodland sites bearing likely meteoritic artifacts (concentrated north of the Ohio) suggests the possibility of *systematic* interregional exchange of meteoritic iron from south to north, along with other interaction sphere goods. This pattern of procurement would be in addition to any long-distance logistic trips made to the Plains by midwestern Hopewellians.

Some support for this position is found in Seeman's (1979:306–308, 382–385) factor analyses describing patterns of covariation among interaction sphere items within eastern sites. The first analysis uses unworked interaction sphere goods only. With high to moderately high loadings on factor 3 is a group of materials known to have sources in the southern Appalachians (though not exclusively) or Gulf coast and distributed archaeologically in Ohio Hopewell sites. These include not only steatite, quartz crystals, and sharks teeth, which Seeman mentions, but also meteoritic iron, the distributional significance of which apparently was not realized. The second factor analysis considers both finished and unworked interaction sphere goods. With high to moderately high loadings on factors 3 and 4 are raw materials having sources in the southern Appalachians (not exclusively) or Gulf Coast, and finished goods that are concentrated in southern sites yet found together in some Ohio Hopewell sites. These include alligator teeth, shark teeth, steatite, plummets, Copena pipes, circular pendants, and, again, iron.

Table 3. Sizes of Iron Meteorites of Various Masses, Assuming a Spherical Shape and Density of 7.8 g/cc.

Mass	Diameter
1 kg (2.204 lb)	6.26 cm (2.44 in)
10 kg (22.04 lb)	13.5 cm (5.26 in)
100 kg (220.4 lb)	29.0 cm (11.3 in)
1,000 kg (2204 lb)	62.6 cm (24.4 in)

These factor analytic results, however, are to be viewed cautiously, given large incongruences between the factor analytic procedures used and the data to which they were applied. The data include primarily presence-absence variables and secondarily count variables rather than the required ratio-scale variables, a high percentage of zero cells, and rare observations. All of these can strongly distort the correlation coefficients upon which factor procedures are based (Speth and Johnson 1976).

6. Likely Procurement of Meteorites by Santa Rosa–Swift Creek and St. Johns Groups through Regional or Interregional Exchange or Logistic Trips. Just as the complementary distributions of meteorites and meteoritic artifacts suggest the procurement of meteoritic iron by Ohio and/or Illinois Hopewell groups through interregional exchange or distant logistic trips, so do the distributions point to the procurement of meteoritic iron by groups in southwest Georgia and northern Florida by regional or interregional exchange or logistic trips. There currently are few known meteorites that might have been collected locally in the vicinity of Mandeville, Crystal River, and Murphy Island—sites in southwestern Georgia and northern Florida that have meteoritic or meteoritic-looking artifacts. If the iron was obtained through exchange, it is probable that more northerly Middle Woodland groups in the Southeast or Midwest would have been involved. The source of the iron in artifacts from Mandeville, Crystal River, and Murphy Island has never been determined, but should prove particularly interesting.

Thus, the maps of distribution of known meteorite falls and Middle Woodland meteoritic artifacts, as well as limited chemical sourcing of meteoritic artifacts and Seeman's statistical analyses, suggest not one pattern of procurement of iron by Middle Woodlanders in the eastern U.S., but several. These include possible local collecting of meteoritic iron in the Southeast around Tunacunnhee (Copena area), regional or interregional exchange or long distance logistics procurement for Santa Rosa–Swift Creek and St. Johns groups, and long-distance logistic procurement and possibly exchange involving at least two sources for midwestern Hopewellian groups. The

Hopewell Interaction Sphere probably does not represent a single mechanism of material and information exchange (Struever and Houart 1972), but rather a diverse set of processes and intergroup relationships.

An additional aspect of the structure and structural diversity of the Hopewell Interaction Sphere can be posited from the two distribution maps.

7. Variable Relationships of Southeastern Middle Woodland Populations to Ohio or Illinois Hopewellians. The lack of any iron artifacts within Middle Woodland sites in the Marksville, Miller, and Porter areas compared to their presence in some Copena and Santa Rosa–Swift Creek sites suggests a difference between these two sets of complexes in the relationship of their peoples with Ohio Hopewellians, who amassed a relatively large quantity of iron objects. This difference could pertain to economic exchange patterns and/or to belief and symbolic systems and mortuary practices.

Such differences have been noted by other researchers working with a wide diversity of evidence. Toth (1979:199) notes that imported interaction sphere goods are very rare in Marksville sites and that Marksville mortuary ceremonialism is more akin to that in Illinois than Ohio. Similarly, Smith (1979:186) notes a number of material similarities between Ohio Hopewell and Santa Rosa–Swift Creek sites, and Walthall (1979:250) links Copena stylistically to Ohio Hopewell. Jefferies (1979:170) and Goad (1979:244–245) have stressed the probable use of a system of historic Indian trails (Myer 1928) during the Middle Woodland, connecting the Copena, Santa Rosa–Swift Creek, and St. Johns complexes to the Ohio area, based on correspondences between trail location and site location. Walthall (1979:249–252) suggests the use of this trail system for the southward exchange of galena obtained by Ohio Hopewellians in bulk from Upper Mississippi Valley sources, as does Goad (1979:245) for the southward exchange of Great Lakes copper. Seeman (1979:313) has tabulated data on the presence and absence of various classes of finished interaction sphere goods among different cultural complexes which show at a glance the greater similarities of the Copena and Santa Rosa–Swift Creek complexes than the Marksville, Porter, and Miller traditions to Ohio Hopewell. This pattern is borne out in his factor analysis of finished and unworked items (Seeman 1979:383). Two factors (4 and 2) are characterized by artifact classes that are shared among Ohio Hopewell, Copena, and/or Santa Rosa–Swift Creek sites, or that occur in Scioto Hopewell sites but have sources in the greater southern Appalachian–Gulf Coast region.

All of the above propositions should be seen as hypotheses to be tested using chemical methods of sourcing iron artifacts where possible. As will be seen, however, this process can be difficult, particularly when the artifacts are covered with iron foil, as so many of them are.

Analysis of Iron Specimens from Tunacunnhee and Mandeville

Of the tens of Middle Woodland artifacts thought to be composed of meteoritic iron, only a few have actually been analyzed chemically and have had their meteoritic composition confirmed: three nuggets from Turner Mounds 3 and 4 in Hamilton County, Ohio (Kinnicutt 1887; Wasson and Sedwick 1969), a nugget from Hopewell Mound 25 (Farrington 1902; Wasson and Sedwick 1969), and several beads from Havana Mound 9 in Mason County, Illinois (Grogan 1948; Kimberlin and Wasson 1976). Each specimen was found to be meteoritic on the basis of its nickel and iron content. Reliable information on the source of some of these specimens, derived by trace element activation methods, have been discussed above.

To date, no specimens from the southeastern U.S. have been analyzed for their chemical composition or source. Minimally, confirmation of the meteoritic nature of the specimens is desirable, given the foil or sheet nature of most of them (Table 1). It is easy for the archaeologist not trained in metallurgy or artifact conservation to mistake other materials for an iron foil or sheet (e.g., copper corrosion products, adhering organic materials such as leathers or mastics that have absorbed iron hydroxides from the soil).

During the course of a study of the morphology of Middle Woodland earspools from the southeastern U.S. by one of us (Carr), the opportunity arose to test several specimens thought to be meteoritic iron for their chemical composition. The items come from the Tunacunnhee site in Dade County, northwest Georgia, and the Mandeville site in Clay County, southwest Georgia.

Tunacunnhee (Jefferies 1976, 1979) is the most complex site in the Lookout Valley region (Figure 1), falling only a few miles from the junction of several major historic Indian trails running between northern and central Georgia and the Midwest, as described previously. It is composed of four burial mounds of limestone and soil construction, off-mound burials, and an associated village 180 m southwest of the mounds. Each of the mounds yielded burials with Hopewellian ceremonial artifacts. Radiocarbon dates of A.D. 150 ± 95 (UGA-ML-8), A.D. 280 ± 125 (UGA-ML-10), and A.D. 440 ± 395 (UGA-ML-9) were obtained from one mound and two village proveniences, respectively (Jefferies 1979).

Mandeville (Kellar et al. 1962a, 1962b; Smith 1979) is located in a side valley of the north–south trending Chattahoochee River valley (Figure 1) and along an east–west oriented, major historic Indian trail

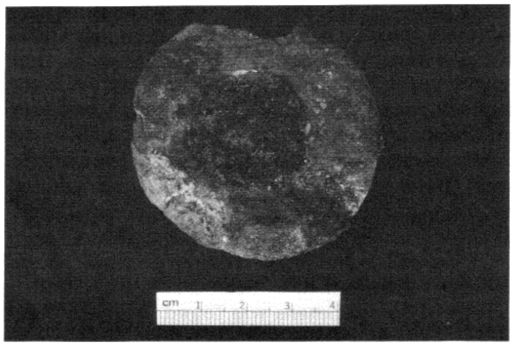

Figure 3. Copper earspool with iron-foil insert, from Mound E, Tunacunnhee, Georgia (University of Georgia catalog number 244).

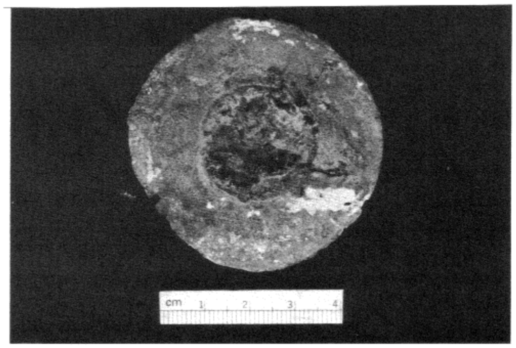

Figure 4. Copper earspool with iron foil insert, from Mound E, Tunacunnhee, Georgia (University of Georgia catalog number 244).

(Myer 1928). Both potential routes of communication intersect the network of historic trails that connect northern and central Georgia with the Midwest, as mentioned previously. The Middle Woodland component of the site is composed of one flat-topped mound (A), which was built of midden and associated with a village, and one burial mound (B), which was built of earth and located 305 m to the northwest. The burial mound produced numerous Hopewell Interaction Sphere artifacts and raw materials, some of which derive from the Midwest (Ohio Flint Ridge chert) or are of types that may have been traded to the Midwest (certain simple-stamped ceramics) (Smith 1979:185–186). Radiocarbon dates from the two mounds range between approximately A.D. 250 and 450. The Middle Woodland village predates the earliest mound construction by about 100 years and was occupied through the period of mound building (Smith 1979:182–183).

Five of the specimens from Tunacunnhee and Mandeville, kindly made available by the University of Georgia, appeared to be made of iron, or to have iron foil coverings/inserts upon visual examination. Two (*a*, *b*) are earspool plates from Tunacunnhee Mound E. They are made of copper and apparently have iron-foil inserts in their central depressions (Figures 3, 4; Jefferies 1975:Plate 7f, 1979:Figure 22.6f). One (*c*) is possibly an exterior plate of an earspool from Mandeville Mound B, Feature 5. The plate seems to be made entirely of iron (Figure 5b–c; Kellar et al. 1962a:352, 1962b:67, 69). Another (*d*) is possibly an interior plate of an earspool from Mandeville Mound B, Feature 5. The plate is copper and has iron-like stains on its outer surface, possibly from contact with the previous specimen (Figure 5a; Kellar et al. 1962a: 352, 1962b:67, 69). The last specimen (*e*) is a portion of an annular-looking object, too large in diameter to be an earspool, from Tunacunnhee Mound A, N180E90. It turned out to be tarnished copper upon taking a sample, reinforcing our questioning of the iron identity of these and other "iron-foil-covered" specimens.

Three specimens (*a*, *b*, and *c* above) that were thought to have metallic iron on them, not simply iron stain, were sampled. From each were taken one or more small fragments of iron-like material that could be pried off without leaving any conspicuous scars—a restriction on analysis. In all, five samples were removed. These were mounted in resin, and ground and polished to provide a flat surface for analysis. A well-analyzed metal grain from the Saratov meteorite also was included in the mount; this served as a secondary standard against which our procedures could be checked. After carbon coating, the samples were analyzed for nickel and iron using a Tracor Northern energy dispersive X-ray spectrometer (NS880) attached to a Cambridge Instruments scanning electron microscope (S600). Standards of pure iron and pure nickel were used. Regions of the metal flakes that looked flat and free of soil particles were counted for 5 minutes. Only one flake proved

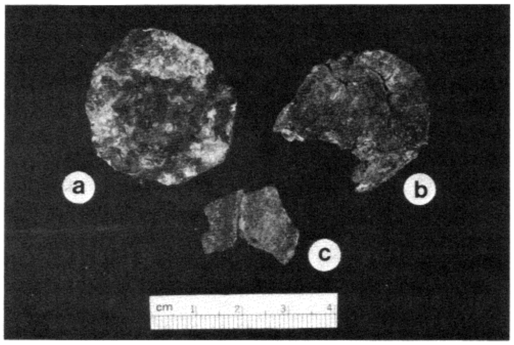

Figure 5. Plates of earspools from Feature 5, Mound B, Mandeville, Georgia: (a) possible interior plate of copper with iron-like stains on its outer surface, possibly from contact with the item represented by b or c; (b, c) possible exterior plate of iron. (All three have University of Georgia catalog number 8620.)

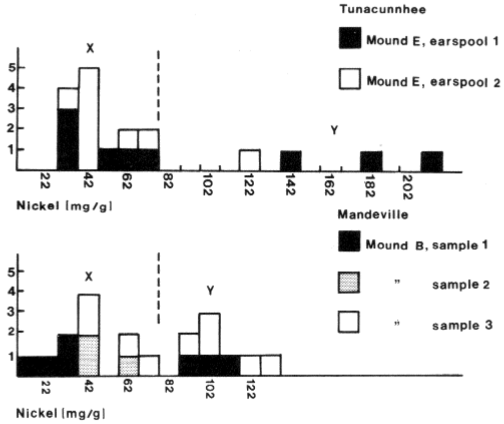

Figure 6. Histograms of observed nickel content for samples of artifacts from Tunacunnhee Mound E and Mandeville Mound B, Georgia. Mode X probably represents the weathered, kamacite (nickel-poor) phase of the specimen in each case. Mode Y probably represents the taenite (nickel-rich) phase and the kamacite phase combined. See text for explanation.

difficult to analyze this way and all the regions examined yielded spectra with aluminum and copper peaks produced by electron scattering in the apparatus; its data were rejected. Correction for matrix effects were made using Tracor Northern's version of the ZAF correction procedure of Sweatman and Long (1969). Because of beam drift problems inherent to the S600 and the presumed presence of considerable amounts of water of hydration, our analyses have been normalized to 100%.

The quality of our data can be assessed from the measurements on the metal grain from the Saratov meteorite. Six analyses of the Saratov metal were made, spaced throughout the period when the earspool metal was being analyzed. The mean nickel content was determined to be 56 mg/g, with a standard deviation of 3.1 mg/g. This compares well with the mean and standard deviation of 56.1 and 1.5, respectively, determined by Sears and Axon (1976).

Each of the specimens was found to have a characteristic X-ray spectrum indicating the presence of iron and nickel. The nickel contents of the samples, given in mg/g, are shown in Table 4. A histogram of the observed nickel content of samples taken from both earspool plates from Tunacunnhee Mound E has been constructed (Figure 6, top) under the assumption of the similar source of the iron materials comprising the two plates. A second histogram has been constructed (Figure 6, bottom) for the specimen from Mandeville Mound B, combining the nickel content observations for the three samples taken of it.

Table 4. Nickel Content of Samples of Meteoric Iron from Artifacts from the Tunacunnhee and Mandeville Sites.

	Bulk Nickel Content (mg/g)[a]		
Specimen	Individual Measurements	Mean	Standard Deviation
Earspool, Tunacunnhee Mound E (Figure 3; U. of Georgia catalog no. 244)	37, 38, 40, 60, 69, 75, 143, 185, 219	96	69
Earspool, Tunacunnhee Mound E (Figure 4; U. of Georgia catalog no. 244)	34, 43, 44, 46, 49, 49, 62, 77, 129	59	29
Earspool(?), Mandeville Mound B, sample 1 (Figure 5b; U. of Georgia catalog no. 8620)	46, 49, 66, 81, 100, 106, 111, 126, 150	93	35
Same as above, sample 2	21, 23, 34, 34, 96, 105, 115	61	42
Same as above, sample 3	46, 51, 70	56	13

[a] Divide by 10 to obtain the percentage of bulk content that is nickel. Values have been normalized to 100% to remove the effect of the addition of water of hydration through weathering of the specimens.

Substantive Results

On the basis of the data reported in Table 4 and Figure 6, a number of conclusions can and cannot be drawn:

1. All three specimens sampled are composed of meteoritic iron. The specimens contain 21 to 219 mg/g of nickel (Table 4)—proportions that are not known in terrestrial iron ores. Terrestrial iron generally contains either very little or very much nickel, and moreover is very rare. The meteoritic nature of the specimens is apparent also in the spread of the nickel content observations made for each specimen and most of the individual samples taken from them (Figure 6). This spread, tending toward bimodality, probably indicates that vestiges of the two-phase Widmanstätten structure, which is characteristic of meteorites with bulk nickel contents in the 60 to 140 mg/g range, remain in the specimens. The lower mode (X in Figure 6) represents wide, nickel-poor, kamacite laminae that have been monitored in isolation by the SEM Beam. The higher values (Y in Figure 6) represent the monitoring of thin, nickel-rich, taenite laminae by the SEM beam with some overlap onto adjacent nickel-poor laminae. Overlap of the SEM beam focused on taenite laminae onto adjacent kamacite laminae is evident by the fact that the nickel content of the observations so identified is lower than would be expected if only taenite had been monitored (100–200 mg/g rather than an expectable 200–500 mg/g).

2. The evidence for the Widmanstätten structure of the specimens indicates that they were worked by

cold hammering rather than casting. The amount of working they received was incapable of homogenizing the original material. This result parallels the identification of residual Widmanstätten structures in Havana Mound 9 meteoritic iron beads, which appear to have been worked by cold hammering (Grogan 1948).

3. It was not possible to specify the precise bulk nickel content of the specimens, given their heterogeneity and the limited number of observations made. Nevertheless, their range of nickel contents and the evidence for their Widmanstätten structures suggest that they were derived from meteorites of Group IIIAB, IVA, or IAB. Large meteorites belonging to these classes are scattered in abundance throughout the meteorite distribution in the eastern U.S. (see Wasson 1974), so it is not possible to narrow the range of source areas for the specimens. It would not be possible even if membership in a single group were clear. Sourcing of a specimen requires the tracking of its nickel, galium, germanium, and iridium contents, and may still prove very difficult (Scott and Wasson 1975; Wasson and Sedwick 1969).

4. Though the precise source(s) of the specimens is unclear, it is likely that the meteoritic iron on the earspools from Tunacunnhee Mound E comes from a different source than the iron comprising the specimens from Mandeville Mound B. The Mandeville specimen appears to have a Widmanstätten structure with significantly thinner taenite laminae. This allowed the SEM beams that focused on taenite laminae to overlap more onto nickel-poor kamacite laminae, giving the Mandeville specimen a lower taenite–kamacite mode (Figure 6). The lower taenite–kamacite mode of the Mandeville specimen cannot have resulted from the specimen having been cold hammered more intensively, given the very similar means of the kamacite modes of the Tunacunnhee and Mandeville materials.

This result provides additional evidence of the use of more than one meteorite fall by Middle Woodlanders (see also Kimberlin and Wasson 1976) and of greater diversity in the pattern of exchange of meteoritic iron in the east than acknowledged by Struever and Houart (1972). It is not possible to determine whether this diversity reflects synchronic spatial variation or temporal variation in use of meteoritic iron sources. Chronological control over the proveniences from which the specimens come is not precise enough.

More General, Methodological Results

The analysis of the Tunacunnhee and Mandeville specimens suggests some methodological problems that need to be considered or overcome when using X-ray spectrometry to study the nature of Middle Woodland iron artifacts:

1. If the specimens have a Widmanstätten structure, spectrometry observations must be numerous and representative, forming a *well-defined* frequency distribution, if stable estimates of bulk nickel and iron contents of the sample are to be obtained. The heterogeneity of such meteoritic material being at a scale significantly larger than the spectrometry observations mandates this. Our analyses, limited by the extremely fragmentary nature of the samples that we could remove and examine, did not include enough observations to allow precise estimates of bulk nickel and iron contents. In a similar vein, the sample must be sufficiently large (on the order of 150 mg) to obtain credible estimates of the composition of the material from which the sample was drawn (for a further discussion, see Wasson 1974; Wasson and Sedwick 1969).

2. The absolute and relative effects of weathering must be taken into consideration when sampling and analyzing the specimen. This is particularly true of artifacts that have only a thin foil or sheet covering over some other base, as do many potentially iron Woodland artifacts, especially those in the southeastern United States. Foil specimens are more likely to be weathered through a considerable portion of their profile, making it impossible to obtain unaltered metal. (For artifacts made of solid meteoritic iron—e.g., awls, adzes, beads—the effects of weathering may be overcome simply by obtaining samples from beneath the zone of decomposition, as Wasson and Sedwick [1969] have done.)

At least three weathering processes are of concern. First, weathering lowers the apparent abundance of all elements in the meteoritic material by adding water of hydration. This effect can be removed from the data by normalization to 100%, as was done in this analysis. It is unclear whether earlier data have been treated similarly. The unlikely low nickel content (4.64%) reported by Farrington (1902) for an iron specimen from Hopewell Mound 25 possibly reflects this effect. The specimen was heavily hydrated (Prufer 1961:345).

Second, the weathering of a meteoritic specimen involves a preferential leaching of some elements over others. This has the effect of upsetting its *bulk* elemental proportions, which may hamper its identification to proper meteoritic class and potential sources. Preferential leaching also disturbs the *distribution* of a specimen's elements over its profile. In the case of iron and nickel, it is well known that iron is chemically more reactive. As a consequence, within a weathering meteoritic specimen, water and air will react with iron more readily than nickel at the current frontier of weathering. The hydrated iron may be transported to the surface of the specimen, causing the surface material to be iron-enriched (nickel-impoverished) and leaving the material at the zone of weathering iron-impoverished (nickel-rich). To the extent that the transported iron is removed to the environment of the specimen rather than deposited near its surface, the specimen as a whole will have a lower bulk iron content and higher nickel content, as well as exhibit the redistribution of these elements over its profile.

This process seems to be evidenced in the histograms of the nickel content for the samples analyzed by us (Figure 6). While the modal nickel values for the kamacite phase of the Tunacunnhee and Mandeville specimens are 46 mg/g each, the expected, cosmic nickel content for unweathered kamacite is 55 mg/g, based on phase equilibria. The lower modal nickel values of the artifacts suggest that our surface samples were taken from scale, which is enriched in hydrated iron that has been transported to the artifacts' surface and that consequently is somewhat nickel-impoverished. Some of the higher nickel values in the kamacite mode may represent the residual, iron-impoverished, nickel-rich metal at the current frontier of weathering. Thus, some of the scatter in the kamacite modes of Figure 6, on the order of 20 to 30 mg/g above and below the expected 55 mg/g cosmic nickel content, is probably attributable to weathering.

The occurrence of this kind of weathering process and its influence on the classification of a specimen to meteoritic group and potential source has implications for the analysis of iron-foil-covered artifacts. These typically are weathered over a considerable portion of their profile, if not completely, and will not easily be sampled for unweathered metal. To obtain a best estimate of the material's original bulk composition, class, and potential sources, it is necessary to analyze a *cross-sectional* sample from outer to inner surface, as opposed to a more easily removed surface sample, as was done here under the constraints of examination.

A third potential source of error from weathering is the differential rate of weathering of kamacite and taenite laminae. Kamacite decomposes more quickly than does taenite, the higher nickel content of which acts as a protective agent. This can result in the determination of a bulk nickel content that is higher for the weathered specimen than the original material. It also may obscure the bimodal to skewed nature of the frequency distribution of nickel observations that is characteristic of the Widmanstätten structure. These effects may hamper the classification of the specimen to meteoritic class and potential sources.

Conclusion

Regional distributions of likely meteoritic artifacts from Middle Woodland sites and natural specimens suggest a number of testable hypotheses about the structure and nature of Hopewellian exchange systems and their diversity over the east. These include: (*a*) the possibility of procurement of meteoritic iron in some parts of the southeastern U.S. (Copena area) through local collecting; (*b*) the procurement of meteoritic iron in the Santa Rosa-Swift Creek and St. Johns regions probably through exchange with more northerly Middle Woodland groups in the Southeast or Midwest or (less likely) through long-distance logistic trips; (*c*) the probability of procurement of meteoritic iron in the Midwest typically through logistic trips or trade, involving multiple sources (in Kansas, and possibly Kentucky or the northern Southeast); (*d*) a possible similarity in the means of procurement (long-distance logistic trips) and the riverine access routes for Yellowstone obsidian and Plains meteoritic iron—materials that were exploited by Ohio Hopewellians; and (*e*) the stronger connections of economic exchange and/or greater similarity in belief systems and mortuary practices linking Ohio Hopewellians with Copena, Santa Rosa-Swift Creek, and St. Johns groups than with Marksville, Miller, and Porter groups. These propositions suggest a more diverse pattern of procurement and exchange of meteoritic iron over the East than admitted by the Struever-Houart model.

Analysis of the specimens from Tunacunnhee and Mandeville provides additional evidence of this diversity. The artifacts from these different sites probably differ in the meteorite sources of their iron.

The analysis also indicates that the artifacts were worked by cold hammering. It further suggests some methodological problems in determining the precise nickel content of iron foil-covered artifacts when using X-ray spectrometry procedures. These include sampling problems and several effects of weathering.

Notes

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Collections. All the artifacts analyzed here for their nickel content or examined visually are currently housed in the Laboratory of Archaeology, Department of Anthropology, University of Georgia (Athens). The two earspools from Tunacunnhee Mound E (Figures 3, 4), the two earspool plates from Mandeville Mound B (Figure 5), and the annular object from Tunacunnhee Mound A have catalog numbers 244, 8620, and 21676, respectively. The two earspool plates from Mandeville Mound B are stored with a tag that identifies their provenience (mistakenly?) as Feature 4; Kellar et al. (1962b:66–67) clearly refer these iron plates to Feature 5. Presumably the iron-stained copper plate with catalog number 8620 also came from Feature 5.

[1] A second exception, recently brought to our attention (Richard Polhemus, personal communication, 1985), is a probably meteoritic iron nugget, unmodified or slightly flattened, 39 × 30 × 24 mm, from the Ebenezer site (40GN6), Greene County, Tennessee (Square 220 L100, 1.0–1.5 ft below surface). It was directly associated with the Early Woodland ceramic types Long Branch Fabric Impressed and Watts Bar Cord Marked. The specimen is in private hands; notes are filed at the Frank H. McClung Museum in Knoxville. The site is located in a region with a relatively high density of iron and stony-iron meteorites (Figure 2).

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