COMPOSITION AND PROVENANCE OF GREENSTONE ARTIFACTS FROM MOUNDVILLE

Daniel G. Gall
and Vincas P. Steponaitis

Greenstone was commonly used at Moundville for petaloid celts, which comprise 96% of the greenstone artifacts in the collections. Artifact greenstones are fine- to medium-grained, massive to crudely foliated metabasites composed of actinolite, epidote, and albite. Mineralogy, chemistry, and metamorphic and relict igneous textures indicate that the artifact greenstones were obtained from the Hillabee Metavolcanic Complex of eastern Alabama. Two principal sources were the outcrops along Hatchet Creek in Clay County and Gale Creek in Chilton County, both of which are within 150 km of Moundville. Moundville peoples may have obtained greenstones by direct procurement rather than long-distance exchange.

Located on the Black Warrior River in west-central Alabama, Moundville is one of the largest Mississippian sites in the Eastern Woodlands. The site was occupied from about AD 1000 to 1650, during which time it grew to become the political and religious capital of a paramount chiefdom (Knight and Steponaitis 1998). Over the past 30 years, archaeologists have tried to reconstruct the economic and social factors that played a role in this chiefdom's development. One factor that has garnered considerable attention in this regard is the procurement of nonlocal raw materials that were used in the production of craft items. Archaeologists have generally assumed that these raw materials (or the items crafted from these materials) were obtained by means of long-distance exchange, but such interpretations have often been made in the absence of good data on the geological sources of these materials (e.g., Steponaitis 1991; Welch 1991). One such material is greenstone, which was commonly used to make celts. Our objectives are to describe the mineralogy and chemical composition of greenstone artifacts found at Moundville, and to determine as closely as possible their geological sources.

Greenstone is a very general term used in geology to describe a great variety of lithologies usually formed from the low-grade (e.g., greenschist-facies) metamorphism of mafic and ultramafic igneous rocks (e.g., basalt, dunite) or their sedimentary equivalents. In an archaeological context, these lithologies often share several characteristic features (Dunning 1960): they are green in color, are easily shaped by pecking and grinding, and yield serviceable tools that hold their shape and polish. The physical properties of toughness (resistance to breakage), high density (>3.0 g/cm^3), and moderate hardness (6 to 7 on the Mohs' hardness scale) are the primary factors considered in the selection of stone for polished percussion tools, such as axes and celts. Rocks with this combination of physical properties are typically found in greenstone belts of folded mountains. The mechanical competency of greenstone and its widespread distribution account for its popularity as a material from which to make stone axes, particularly among people who lacked metal (Heizer 1959; Burton 1984; McBryde 1984).

Prehistoric exchange networks have been reconstructed by matching petrographic and geochemical profiles of stone artifacts to their geologic sources (e.g., Earle and Ericson 1977). One of the earliest successful stone provenance studies was conducted by W. Stukeley in 1740. Using petrologic data on Stonehenge megaliths, he determined that local and distant sources of rock were exploited (Rapp 1985). Provenance studies on British Neolithic stone axes conducted during the 1930s and 1940s utilized petrologic data obtained from over 3,000 axes to identify 24 geologic sources distributed across the British Isles (Hodder and Lane 1982). Stone materials that have been the subject of recent provenance studies include marbles from the Mediterranean region (Herz 1990), turquoise from southwestern North America and Mesoamerica (Harbottle and Weigand 1992), and native copper and galena found in southeastern North America (Goad 1978; Walthall et al. 1982).

Like other Mississippian peoples, Moundville's inhabitants used a variety of stone artifacts (e.g., celts, disks, gorgets, palettes, pipes, points, and spatulates) made from numerous raw materials (e.g., amphibolite, basalt, chert, diabase, diorite, granite, greenstone, limestone, metadiorite, siltstone, sandstone, shale, and slate). Greenstone was one of the preferred materials used for ground-and-polished stone items, and was often fashioned into petaloid celts (Peebles 1970, 1971; Steponaitis 1991; Welch 1991). Socially valued craft items made from greenstones may have been imported into the area as finished goods via long-distance trade, or they may have been produced at or near the Moundville site by individuals who obtained materials from nearby Piedmont sources. Locally manufactured goods would have been used within the Moundville polity and sometimes traded abroad (Goad 1978; Peebles 1971; Steponaitis 1991; Welch 1991). Determining the origins of the various rock types used to make craft items such as celts provides archaeologists with the data necessary to describe the procurement methods and exchange systems operating at or near Moundville during Mississippian times.

In the course of this research, the greenstone artifacts from Moundville were examined first, and then the likely geological sources were located and compared. For the sake of clarity, however, it is convenient to begin this article with a consideration of the geological background, then to characterize the artifacts, and finally to discuss how greenstones may have been obtained by Moundville's ancient inhabitants.

Greenstones of the Alabama Piedmont

The greenstone (e.g., metabasite, serpentinite) belts of the Southeast typically occur as isolated, long, narrow outcrops in the Piedmont province (Figure 1). Even though there are several localities in eastern North America from which greenstones can be obtained, their number is few and they are separated by relatively large distances.

A survey of the geological literature (e.g., Griffin 1951; Higgins et al. 1988; Jones 1939; Pallister 1955; Stow et al. 1984; Tull et al. 1978), inspection of geologic maps (e.g., Larrabee 1966; Osborne et al. 1989; Szabo et al. 1988), and field work established that there are three sources of greenstone within 500 km of Moundville: (*a*) the metabasites of the Hillabee Metavolcanic Complex of the greenschist-facies lithologies of the Northern Piedmont of Alabama (Tull et al. 1978; Tull 1979); (*b*) the slates of the Talladega Group (Tull 1982), which are also part of the greenschist-facies lithologies of the Northern Piedmont of Alabama; and (*c*) the amphibolite schists, which are part of the amphibolite-facies lithologies of the Inner and Southern Piedmonts of Alabama (Stow et al. 1984).

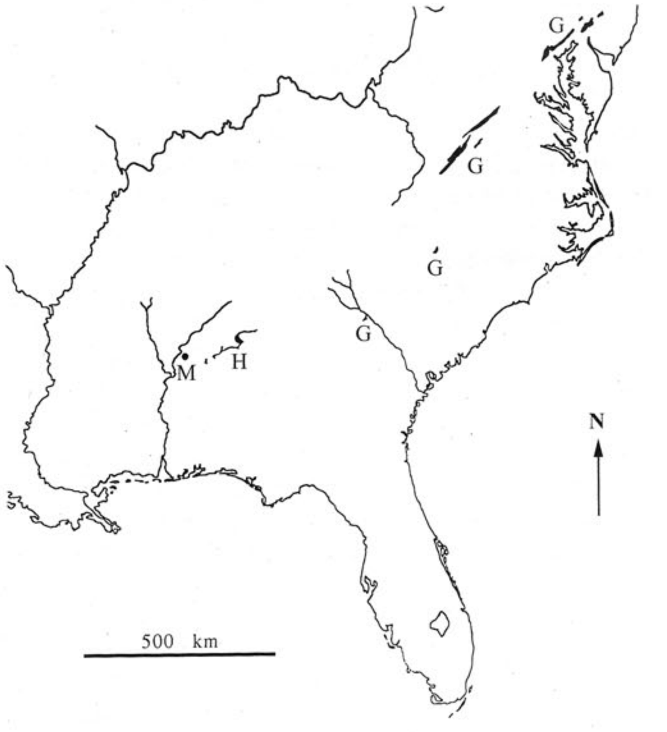

Figure 1. Map of southeastern North America showing the locations of the Hillabee Metavolcanic Complex (H), the metamorphosed mafic and ultramafic rock units (G) that may contain greenstones similar to the Hillabeee greenstones, and the Moundville site (M) (Larrabee 1966).

These slates and amphibolites are very different petrographically from the Moundville celt greenstones. Greenstones of the Talladega Group are very-fine-grained pelitic slates and sericite phyllites with well-developed rock cleavage (Tull 1982). The amphibolites of the Inner and Southern Piedmonts formed from basaltic rocks that experienced amphibolite-grade metamorphism, not greenschist-facies metamorphism like the Moundville celt greenstones. The amphibolites are medium-grained schists composed of hornblende and plagioclase feldspar, and they also have well-developed rock cleavage (Stow et al. 1984). Metamorphic grade, mineralogy, and schistosity eliminate these lithologies as possible celt-stone candidates.

The mineralogy, petrography, and chemistry of the Moundville celt greenstones match descriptions of the actinolite-epidote-albite metabasites found in the erosionally resistant portions of the Hillabee Metavolcanic Complex as reported by Griffin (1951) and Tull et al. (1978). Field investigations conducted in the Alabama Piedmont and examination of hand specimens support this conclusion. Hence, the remainder of this discussion focuses on the mineralogy and chemistry of the Hillabee lithologies.

Hillabee Metavolcanic Complex

The Hillabee Metavolcanic Complex is a long, narrow, discontinuous belt (Figure 2) of metamorphosed basalt flows, associated volcaniclastics (metabasite), and their differentiates (metadacites) that emerges from beneath Coastal Plain sediments in Chilton County, Alabama, trends in a northeasterly direction for approximately 170 km, and ends abruptly at the Goodwater-Enitachopco-Allatoona fault system in Cleburne County, Alabama.

The best recent characterization of the Hillabee Metavolcanic Complex is based on the stratigraphic, petrologic, geochemical, and structural data of Tull and his associates (Tull et al. 1978; Tull 1979). However, descriptions of the Hillabee greenstone date back as far as the mid-1800s. Toumey (1858) described the Hillabee greenstone as a light-green hornblende rock formed from the alteration of basalt. Hitchcock (1885) and others considered the Hillabee greenstone to be a chlorite schist similar to the greenstones of the Green Mountains in Vermont. Phillips (1892) described the rocks of the Hillabee Metavolcanic Complex as schists composed of various combinations of chlorite, epidote, and actinolite, and concluded that the protolith was a basaltic rock. Prouty (1923) published the first report that included a map showing the outcrop traces of the Hillabee greenstone. Adams (1933) described the Hillabee greenstone as a chlorite schist in the form of an igneous sill that intruded along the thrust fault that separates Ashland lithologies from rocks of the Talladega Slate Belt. Griffin (1951) described the Hillabee as a chlorite-epidote-hornblende-albite schist formed by the alteration of a mafic sill that was injected between the Talladega Slate Belt and Ashland Formation lithologies along the Whitestone fault. He believed that the thrust faulting, intrusion, and metamorphic alteration took place at the end of the Paleozoic Era during the Appalachian Revolution.

Tull et al. (1978) conducted a detailed survey of the Hillabee Metavolcanic Complex utilizing petrographic, mineralogical, stratigraphic, structural, and chemical data to interpret its geology and history. They recognized three major lithologies: (*a*) mafic phyllite, (*b*) massive greenstone (metabasite), and (*c*) a hornblende-bearing siliceous phyllite/gneiss (metadacite). The first two are composed of actinolite (40-60%), albite (20-30%), and epidote (10-40%); the third is a hornblende-bearing quartz-sericite schist. Supported by chemical and petrographic data, they concluded that the protoliths for the mafic lithologies were low-potassium tholeiitic and spilitic basalt flows (80%), and that the parent rock of the more siliceous member was an ignimbritic dacite formed from the fractionation of a basaltic magma. They argued that these rocks were part of a continental-bound volcanic arc or a volcanic mountain chain that was in place by the middle of the Ordovician period, that the basaltic rocks experienced low-grade regional metamorphism which changed them to greenschist-facies greenstones during the Acadian Orogeny of the Devonian period, and that imbricate thrust faulting occurred during the Alleghenian Orogeny of late Permian age. This interpretation is nowadays generally accepted and remains the best explanation of the current evidence.

The Hillabee rocks rest conformably atop the Talladega Slate Belt lithologies (Tull 1979, 1982; Tull et al. 1978; Tull and Stow 1982). A conformable stratigraphic contact occurs, therefore, between foliated Devonian Jemison Chert (and its lateral facies) of the Talladega Group and overlying mafic phyllites of the Hillabee Metavolcanic Complex (Figure 3). The uppermost limit of the Hillabee Metavolcanic Complex is marked by the Hollins Line thrust fault that separates the greenschist metamorphic-facies metavolcanic rocks of the Hillabee lithologies from the overlying Ashland Supergroup

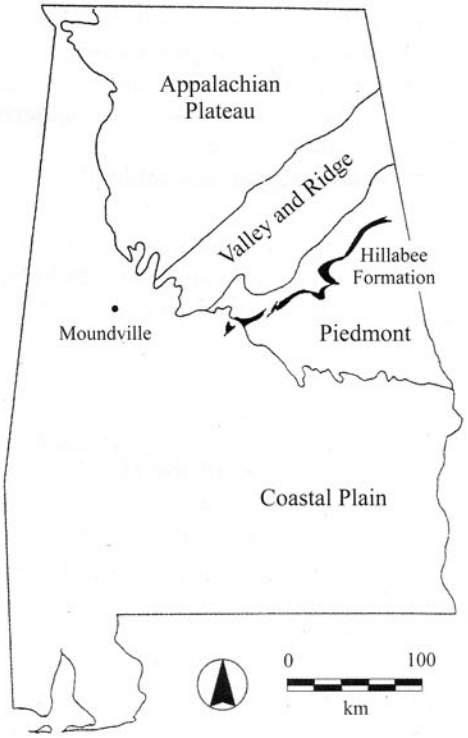

Figure 2. Map of Alabama showing the locations of the Moundville site, the outcrop trace of the Hillabee Metavolcanic Complex, and the physiographic provinces of Alabama (Osborne et al. 1989).

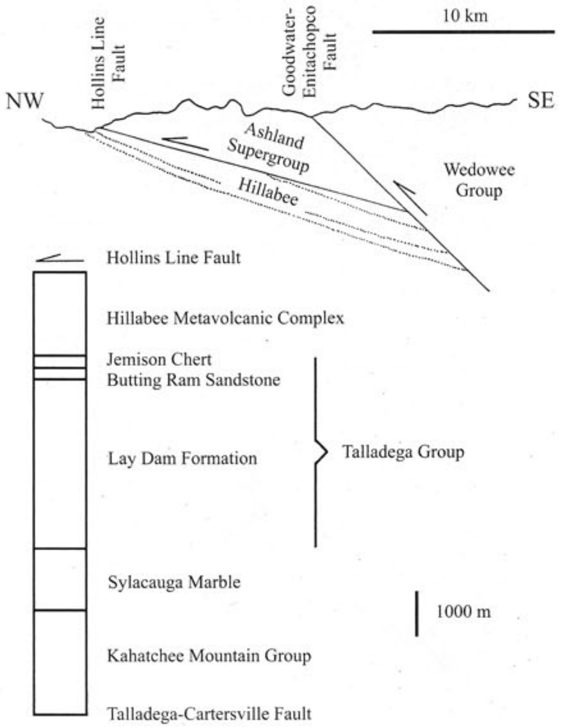

Figure 3. Generalized stratigraphic cross sections of the Talladega Group, Hillabee Metavolcanic Complex, Ashland Supergroup, and Wedowee Group (Tull et al. 1978; Tull and Stow 1982). The top diagram illustrates the upper portion of the stratigraphic sequence, and the bottom diagram shows the lower portion of the sequence. The two diagrams overlap at the Hillabee Metavolcanic Complex.

lithologies of amphibolite metamorphic facies (Tull 1979; Tull et al. 1978; Tull and Stow 1982). The Hollins Line fault, therefore, forms a discordant contact between the Hillabee Metavolcanic Complex and Ashland Supergroup lithologies. Hillabee lithologies are absent where the Hollins Line fault cuts down into Talladega Group lithologies placing them directly under Ashland Supergroup amphibolites. For the greater part of the outcrop length of the Hillabee Metavolcanic Complex, the Hollins Line fault is located in the basal mafic phyllite forming narrow belts (outcrop widths of less than 0.5 km) of easily weathered phyllite. Mafic phyllites weather to red clay, which is easily eroded, forming elongate valleys between erosionally resistant rocks of the Talladega Group to the northwest and the Ashland Supergroup to the southeast. Parallel valleys separated by narrow ridges of Talladega Group lithologies occur where imbricate faulting along the Hollins Line fault has produced a series of slices that contain narrow belts of Hillabee phyllite that also erode to produce valleys (Tull 1979). According to Griffin (1951:48), "Over the greater part of its area of outcrop the Hillabee sill is deeply weathered and is expressed topographically as a valley belt." At several localities (e.g., the Millerville area), the Hollins Line fault cuts upward in the stratigraphic section, increasing the section thickness of the Hillabee Metavolcanic Complex to a maximum of 2.7 km and resulting in outcrop widths of up to 4 km (Tull et al. 1978). In these areas of thicker section, erosionally resistant lithologies of the Hillabee Metavolcanic Complex form low hills and ridges, and small waterfalls and rapids in stream channels.

Of the three primary lithologies of the Hillabee Metavolcanic Complex, two can be readily eliminated as sources for the greenstone artifacts found at Moundville. Mafic phyllites have well-developed rock cleavage and so cannot be used for celts because they lack the toughness required for percussion tools. Siliceous phyllite/gneisses cannot be the sources because they are very different mineralogically from the Moundville artifacts. The only Hillabee lithologies tough enough to be used as celts and compositionally similar to the Moundville specimens are the massive greenstones (Tull et al. 1978:16-19). They are, in fact, massive to crudely foliated, fine- to medium-grained, actinolite-epidote-albite metabasites that exhibit subconchoidal to hackly fracture because of the interlocking mosaic of grains and the low abundance of platy minerals like chlorite. Because neither of the other two lithologies are viable candidates, we focus in the following section on the composition of the massive greenstones.

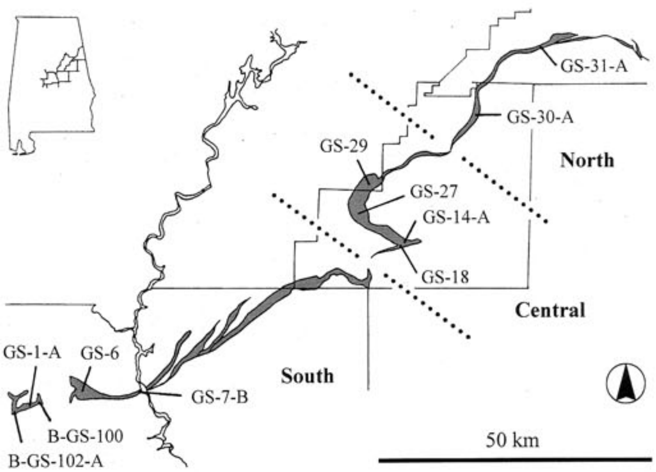

Figure 4. Map showing the outcrop trace of the Hillabee Metavolcanic Complex, the Northern, Central, and Southern Hillabee areas, and the locations of greenstone samples that were chemically analyzed.

In summary, most of the Hillabee Metavolcanic Complex is composed of mafic phyllite that erodes to form long, narrow valleys. Within these long, narrow valleys are small hills and ridges of erosionally resistant greenstone (metabasite) that are suitable raw materials for axes. In other words, only a very small portion of the overall Hillabee formation contains the kinds of greenstones that may have been used for this purpose at Moundville and other Mississippian sites.

For analytical purposes, the Hillabee Metavolcanic Complex can be divided into three geographical segments (Figure 4), comparable to those originally defined by Tull et al. (1978). The Northern Hillabee segment stretches across southern Cleburne County and northern Clay County; the Central Hillabee segment is located almost entirely within Clay County; and the Southern Hillabee segment extends from southernmost Clay County, across northern Coosa County, and into Chilton County.

Greenstone samples that resemble the Moundville celt varieties were collected during field investigations. Sixty-two samples were obtained along the 170-km length of the Hillabee outcrop trace, including rocks from all three geographical segments (Gall 1995: Appendix C).

Mineralogy

Macroscopic examination of the Hillabee greenstone samples determined that they are fine- to medium-grained, massive to crudely foliated greenstones that vary in color from greenish gray (5G 6/1) to dark greenish gray (5G 4/1) to medium dark gray (N 4), according to the Munsell color system.

The 62 greenstone samples were examined using a binocular microscope, and 27 thin sections were constructed and examined using a petrographic microscope. Data obtained from the microscopic examination of petrographic thin sections and hand specimens were used to place the mafic rocks of the

Hillabee Metavolcanic Complex into five textural categories:

metadiabasic greenstone (n = 5) with fine-grained (<1.0 mm), lath-shaped, relict plagioclase phenocrysts in a fine-grained matrix (Figure 5a);

granoblastic greenstone (n = 16) with a fine-grained (≤0.1 mm), massive, granoblastic texture (Figure 5b);

crudely foliated greenstone (n = 14) with fine- to medium-grained (≤1.0 mm), granular to crudely foliated texture (Figure 5c);

mylonitic greenstone (n = 8) with a fine-grained (<1.0 mm), flinty, banded, granulated texture; and

phyllitic greenstone (n = 19) with a very fine-grained, foliated texture and sheen on the foliation surfaces.

Pyrite and its alteration products, dark-colored veins and aggregates of epidote, and fine-grained aggregates of chlorite also occur frequently in the Hillabee greenstones.

Rock powders prepared from the samples selected for thin-sectioning were used for X-ray diffraction analysis (XRD). Mineral Powder Diffraction File cards and results from mineral standards were used to interpret XRD data. XRD results confirm that all of the Hillabee greenstone samples contain actinolite, epidote, albite, and minor amounts of chlorite (Gall 1995: Appendix C). Absence or presence of quartz in detectable amounts is the only difference among the samples; only six (23.1%) contain enough quartz for it be detected. The amount of quartz present, however, is very small because the strongest diffraction line (*hkl* = 101) is just discernible above background and no other quartz diffraction lines are present. Because quartz is so scarce, the range in greenstone densities (2.8 to 3.2 g/cm^3) must be due to variations in the relative abundances of albite, actinolite, and epidote.

Relative proportions of minerals in the greenstones could not be obtained by point-counting thin sections because of the fine-grained texture of most of the samples. Instead, abundances of the major constituents were investigated by comparing the whole-rock densities of the greenstone samples with the reported densities of actinolite, epidote, and albite. Whole-rock densities were determined using the immersion technique and a hydrostatic balance constructed from a Harvard Trip Balance. Samples' weights in air and water were measured, and densities were calculated using the following formula (Mason and Berry 1968):

$$D_s = [W_a/(W_a - W_w)]\, D_w$$

where D_s is the density of the sample, W_a is the weight of the sample in air, W_w is the weight of the sample in water, and D_w is the density of water.

The 26 samples have densities ranging from 2.8 to 3.2 g/cm^3, with an average density of 3.0 g/cm^3 (Gall 1995: Appendix C). The density of actinolite varies from 3.1 to 3.3 g/cm^3, the density of epidote varies from 3.35 to 3.45 g/cm^3, and the density of albite is 2.62 g/cm^3 (Klein and Hurlbut 1985). Equal amounts of actinolite (3.20 g/cm^3), epidote (3.40 g/cm^3), and albite (2.62 g/cm^3) in a compact aggregate would result in a greenstone with a density of 3.07 g/cm^3. This figure falls close to the midpoint of the narrow range of densities measured in the greenstone samples. Thus, similar mineralogy and roughly similar proportions of the three major minerals (i.e., on the same order of magnitude) are consistent with both the whole-rock densities and the XRD data.

All in all, petrography and XRD show that, even though Hillabee greenstones differ in color and texture, they do not differ significantly in mineralogy. The greenstones are all composed of roughly similar amounts of actinolite, epidote, and albite. Relict igneous (e.g., diabasic) textures of some of the Hillabee greenstones positively confirm their protoliths' igneous mode of origin. Uniformity of greenstone mineralogy indicates that the different types of greenstones without relict igneous features had a protolith with a similar initial composition. The mineral assemblage of the greenstones and their fine-grained textures are indicators of

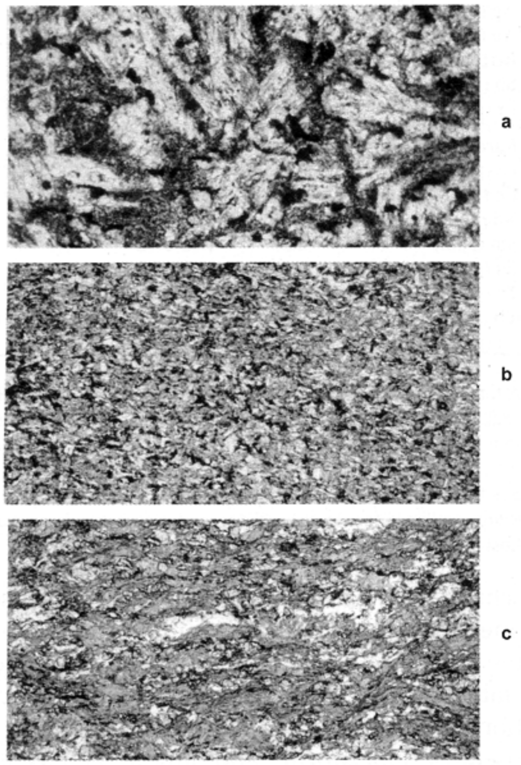

Figure 5. Thin sections of geological samples showing characteristic textures of Hillabee greenstones: (a) metadiabasic; (b) granoblastic; and (c) crudely foliated. The long dimension of photograph (a) corresponds to 1 mm on the thin section; the long dimensions of (b) and (c) correspond to 5 mm. All photographs were taken in plane-polarized light. (Sample numbers: a, B-GS-104; b, GS-23; c, B-GS-100.5).

Table 1. Elemental composition of Hillabee greenstone samples.[a]

Category:	Overall Hillabee		Northern Hillabee		Central Hillabee		Southern Hillabee	
Element[b]	Mean	Range	Mean	Range[c]	Mean	Range	Mean	Range
Major:								
SiO_2 (%)	47.62	43.00-52.70	43.3	43.00-43.60	48.28	47.20-49.60	48.82	45.60-52.70
Al_2O_3 (%)	14.38	13.20-15.80	15.15	14.50-15.80	13.8	13.20-14.70	14.54	13.70-15.00
CaO (%)	12.03	8.16-18.20	15.65	13.10-18.20	11.57	9.87-13.10	10.95	8.16-15.50
MgO (%)	2.65	4.25-8.43	6.76	5.08-8.43	7.36	7.08-7.81	5.98	4.25-7.75
Na_2O (%)	6.63	0.38-4.30	0.7	0.38-1.02	2.18	1.84-2.54	3.81	3.28-4.30
K2O (%)	0.18	0.05-0.70	0.08	0.05-0.10	0.36	0.06-0.70	0.07	0.06-0.10
Fe_2O_3 (%)	11.62	7.27-14.70	13.6	12.50-14.70	12.35	11.40-13.40	10.25	7.27-12.20
MnO (%)	0.23	0.14-0.53	0.19	0.17-0.21	0.21	0.18-0.22	0.26	0.14-0.53
Cr_2O_3 (%)	0.03	0.02-0.06	0.04	0.02-0.06	0.03	0.02-0.03	0.02	0.02-0.03
TiO_2 (%)	1.05	0.53-1.38	1.2	1.16-1.24	1.21	1.02-1.38	0.87	0.53-1.12
P_2O_5 (%)	0.11	0.07-0.13	0.1	0.07-0.12	0.12	0.10-0.13	0.1	0.08-0.13
L.O.I. (%)[d]	2.67	1.15-7.05	2.13	1.35-2.90	2.03	1.70-2.25	3.4	1.15-7.05
Trace (Misc.):								
Sr (ppm)	209.1	90.0-1160.0	665	170.0-1160.0	107.5	100.0-110.0	108	90.0-140.0
Ba (ppm)	67	30.0-140.0	30	45.9-47.6	95	40.0-140.0	52	40.0-60.0
Sc (ppm)	43	31.9-49.8	46.8		47.4	44.7-49.8	38	31.9-40.2
V (ppm)	281.8	250.0-330.0	275	270.0-280.0	290	260.0-320.0	278	250.0-330.0
Cr (ppm)	225.5	61.0-490.0	370	250.0-490.0	237.5	120.0-330.0	158.2	61.0-240.0
Y (ppm)	16.7	10.0-30.0	20		15	10.0-20.0	17.5	10.0-30.0
Zr (ppm)	51.8	20.0-80.0	45	30.0-60.0	70	50.0-80.0	40	20.0-60.0
Nb (ppm)	15	10.0-20.0	20		13.3	10.0-20.0	15	10.0-20.0
Hf (ppm)	2.4	1.8-2.9	2.2	1.8-2.6	2.4	2.1-2.7	2.5	2.0-2.9
W (ppm)	61.6	24.0-110.0	55.5	46.0-65.0	59	31.0-94.0	66.2	24.0-110.0
Co (ppm)	54.4	36.0-70.0	56	43.0-69.0	60.8	54.0-70.0	48.6	36.0-58.0
Ni (ppm)	70.6	34.0-210.0	122	34.0-210.0	63.5	47.0-97.0	55.8	34.0-68.0
Cu (ppm)	87.9	10.4-211.0	13		139.7	83.9-211.0	61.4	10.4-93.8
Zn (ppm)	76.3	33.0-110.0	52.5	33.0-72.0	89.8	75.0-98.0	75	50.0-110.0
Ag (ppm)	0.4	0.2-0.5	0.4	0.4-0.4	0.4	0.3-0.5	0.3	0.2-0.5
Au (ppm)	0.015	0.005-0.066	0.037	0.008-0.066	0.009	0.005-0.013	0.009	0.006-0.017
Be (ppm)	1.1	1.0-2.0	1.5	1.0-2.0	1	1.0-1.0	1	1.0-1.0
Sb (ppm)	1	0.1-3.1	1.7		1.5	0.3-3.1	0.2	0.1-0.4
Br (ppm)	2.8	2.0-3.7	3.6	3.4-3.7	2.5	2.0-3.1	2.7	2.1-3.0
Rare Earths:								
La (ppm)	3.9	1.3-6.0	3.8	3.3-4.3	5.2	4.5-6.0	3	1.3-4.7
Ce (ppm)	11	5.0-16.0	11	9.0-13.0	14	12.0-16.0	8.6	5.0-11.0
Nd (ppm)	7.6	4.0-10.0	9	8.0-10.0	9.3	8.0-10.0	5.8	4.0-7.0
Sm (ppm)	2.53	1.55-3.32	3.06	2.79-3.32	2.81	2.43-3.20	2.1	1.55-2.70
Eu (ppm)	1.13	0.68-1.86	1.52	1.17-1.86	1.26	1.06-1.51	0.88	0.68-1.19
Tb (ppm)	0.6	0.3-0.9	0.8	0.7-0.9	0.6	0.6-0.7	0.5	0.3-0.7
Yb (ppm)	2.35	1.28-2.95	2.61	2.45-2.77	2.37	2.05-2.70	2.24	1.28-2.95
Lu (ppm)	0.36	0.21-0.48	0.4	0.37-0.42	0.36	0.31-0.42	0.35	0.21-0.48

[a] A total of 11 samples were analyzed: two from the Northern Hillabee area, four from the Central Hillabee area, and five from the Southern Hillabee area. Elements that were analyzed but generally not detected were: cesium (Cs), beryllium (Be), tantalum (Ta), molybdenum (Mo), iridium (Ir), cadmium (Cd), boron (B), germanium (Ge), lead (Pb), arsenic (As), selenium (Se), thorium (Th), and uranium (U). Data from Gall 1995: Appendix C.

[b] See text for key to element abbreviations.

[c] Range not listed for elements that were detected in only one sample.

[d] Lost on ignition.

greenschist-facies metamorphism. Under greenschist-facies metamorphic conditions, epidote and albite form from the alteration of calcium-rich plagioclase feldspar (e.g., labradorite), and actinolite forms from the alteration of augite (Philpotts 1990). An igneous rock composed of labradorite and augite is basaltic in composition; therefore, the Hillabee greenstone lithologies formed from a basaltic parent rock that experienced greenschist-facies metamorphism. Relict igneous features, mineralogy, and published geologic reports support this conclusion (e.g., Griffin 1951; Tull et al. 1978).

Based on rock texture, mineralogy, and protolith, the Hillabee greenstones can be classified as very-fine- to medium-grained, massive to crudely foliated, actinolite-epidote-albite metabasites. The toughness of these greenstones results from the low abundance of platy minerals (e.g., chlorite), and from the interlocking network of grains, not from a lack of foliation. The fine-grained, interlocking network of grains is responsible for the occurrence of subconchoidal to hackly fracture instead of rock cleavage.

Chemistry

Eleven samples of Hillabee greenstone were selected for chemical analysis, based on their similarity to mineralogical and petrographic characteristics of Moundville celts (Gall 1995: Appendix C). The samples were taken from well-exposed, naturally occurring outcrops that were eroding and releasing boulders; therefore, they were also good candidates based on their potential to be exploited. The sample localities were widely distributed (Figure 4), but they were not uniformly spaced because only mafic phyllites occur along most (ca. 80%) of the Hillabee's strike. In other words, large portions of the Hillabee contain no stone suitable for celts, and the small number of samples reflects the limited number of outcrops composed of celt-grade material. Five of the greenstone samples came from the Southern area, four from the Central area, and two from the Northern area.

Rock powders were analyzed for 50 elements, of which 37 were generally detected (Table 1): silicon (Si), aluminum (Al), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), manganese (Mn), titanium (Ti), phosphorus (P), strontium (Sr), barium (Ba), scandium (Sc), vanadium (V), chromium (Cr), yttrium (Y), zirconium (Zr), niobium (Nb), hafnium (Hf), tungsten (W), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), silver (Ag), gold (Au), beryllium (Be), antimony (Sb), bromine (Br), lanthanum (La), cerium (Ce), neodymium (Nd), samarium (Sm), europium (Eu), terbium (Tb), ytterbium (Yb), and lutetium (Lu). The quantitative analyses used multiple instrumental techniques—instrumental neutron activation analysis (INAA), X-ray fluorescence (XRF), inductively coupled plasma emission spectrometry (ICP), and direct current plasma emission spectrometry (DCP)—to provide the best possible data for each element (Gall 1995: Appendix C).

The 11 Hillabee samples are basaltic in composition because their SiO_2 contents are between 45% and 52%, and because their sodium and potassium content (Na_2O + K_2O) is less than 5% (Le Bas et al. 1986). As shown in Table 2, these samples match the compositions of basalts reported by Wilkinson (1986) and Le Maitre (1976). The Hillabee samples have an average K_2O/Na_2O ratio of 0.06; therefore, because the K_2O/Na_2O ratio is less than 0.5, the protolith can be further classified as low K/Na basalt (Wilkinson 1986). Mid-ocean ridge basalts (MORB) are very-low-potassium tholeiites ($K_2O < 0.3\%$), according to Wilkinson (1986). Only two of the ten Hillabee samples have K_2O values that exceed 0.3%; therefore, eight of the Hillabee samples are similar to MORB types. The average aluminum (Al_2O_3) content of the Hillabee samples, less than 16%, is consistent with low-aluminum tholeiitic basalts (Wilkinson 1986). Hillabee greenstone samples from the Southern area have greater amounts of sodium and correspondingly lower amounts of calcium (Table 2). This fact led Tull et al. (1978) to conclude that the Southern Hillabee greenstones are more closely affiliated with spilitic basalts than with tholeiitic basalts. The "extreme chemical variability" of spilites (Vallance 1960:35) makes this differentiation somewhat tentative. In sum, the average chemical compositions of Hillabee greenstones match those of low-potassium, low-aluminum tholeiitic basalts.

Table 2. Average chemical compositions of the greenstones from the Northern, Central, and Southern Hillabee areas and selected tholeiitic basalts.[a]

	Average Abundance (weight %)					
Oxide	Northern Hillabee	Central Hillabee	Southern Hillabee	Total Hillabee	Low K-Al Tholeiitic Basalt	Tholeiitic Basalt
SiO_2	43.30	48.28	48.82	47.62	50.08	49.58
Al_2O_3	15.15	13.80	14.54	14.38	15.07	14.79
CaO	15.65	11.57	10.95	12.03	11.51	10.36
Na_2O	0.70	2.18	3.81	2.65	2.53	2.37
K_2O	0.08	0.36	0.07	0.18	0.14	0.43
Fe_2O_3	13.6	12.35	10.25	11.62	10.78	11.41
MgO	6.67	7.36	5.98	6.63	8.12	7.30
TiO_2	1.20	1.21	0.87	1.05	1.55	1.98
MnO	0.19	0.21	0.26	0.23	0.10	0.18
P_2O_5	0.10	0.12	0.10	0.11	0.13	0.24
L.O.I.[b]	2.13	2.03	3.40	2.67	- -	1.44
Total	98.84	99.44	99.06	99.16	100.01	100.08

[a] Number of samples: Northern Hillabee, 2; Central Hillabee, 4; Southern Hillabee, 5; total Hillabee, 11; low K-Al tholeiitic basalt, 1; and tholeiitic basalt, 202. Hillabee data from Gall 1995: Appendix C. Data for low-K, low-Al (low K-Al) tholeiitic basalt reported by Wilkinson 1986; and the average chemical compositions of 202 tholeiites reported by Le Maitre 1976.
[b] Lost on ignition.

Intraformational Variability

As we have just seen, a number of elements within the samples show consistent patterns of correlation with each other, and vary systematically with respect to geography (Table 2). This finding forms the basis for locating more precisely the sources of artifacts made from these materials.

By far the most important pattern for present purposes is the strong negative correlation between sodium and calcium. As the amount of sodium decreases, the amount of calcium increases. This change in chemistry correlates strongly with location along the Hillabee formation's strike, from north to south (Figure 6).

Other elements also show interesting patterns of covariation (Figure 7). Iron correlates positively with calcium, and negatively with sodium and cobalt. Zinc seems to correlate positively with sodium and negatively with calcium and iron. Hafnium and chromium also show a pronounced negative correlation. Given the small sample size, however, some of these correlations may be spurious. A number of these elements show a tendency to vary along strike (Table 2), but none do so as consistently as sodium and calcium. Stow (1979) attributes the north-to-south decrease in elements such as iron and chromium to magmatic fractionation.

It is also worth noting that strong positive correlations exist among the rare-earth elements in the Hillabee greenstone samples (Figure 8). If, as Stow suggests, fractionation is responsible for the north-to-south decrease in iron, then one would expect a north-to-south *increase* in the rare earths (Davis 1977). Actually, the rare earths tend to correlate positively with iron; to the extent that the rare earths vary geographically, they tend to decrease from north to south (Table 2). This finding calls Stow's interpretation into question.

Summary

The greenstones of the Hillabee Metavolcanic Complex are chemically similar to low-potassium, low-aluminum tholeiitic basalts, a conclusion supported by both mineralogical and chemical data. Within the Hillabee Metavolcanic Complex, chemical trends occur that correlate with position along the length of the Hillabee outcrop belt (particularly in the values of calcium and sodium). Given these characteristics, the Hillabee rocks can now be compared to the celt greenstones from Moundville.

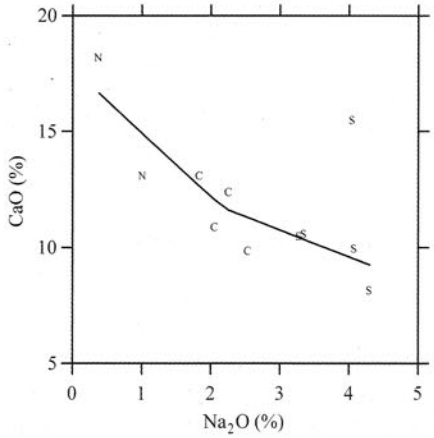

Figure 6. Scatterplot of calcium (CaO) versus sodium (Na$_2$O) in geological specimens of Hillabee greenstone. Resistant line fitted by LOWESS smoothing, *f*=1 (Cleveland 1994:168-180). Key: N, Northern Hillabee; C, Central Hillabee; S, Southern Hillabee.

Greenstone Artifacts at Moundville

Of the 578 ground-and-polished greenstone artifacts in the Moundville collection, 556 artifacts (96%) are whole petaloid celts, petaloid celt fragments, and celt bit chips (Table 3). A petaloid celt is an ungrooved ax head that has a bifacially abated bit and a tapered body. The petaloid (flower-petal-shaped), tapered body fits into a club-like handle with a socket that accepts the celt's tapered poll (Figure 9). When used, the force of impact drives the celt firmly into the handle's socket, eliminating the need of hafting with cordage. Such celts may also be removed from the haft and used as wedges (Kinsella 1993). This implement was used primarily as a woodworking tool but it would have served also as a weapon.

The remaining 22 greenstone artifacts (4%) consist of disks, polished slabs, spatulates (spuds), celt preforms or blanks, a monolithic ax pendant, and a pin (Table 3). Because these types of artifacts and whole celts are rare, they were not included in samples utilized in destructive analyses nor were celt bit chips used

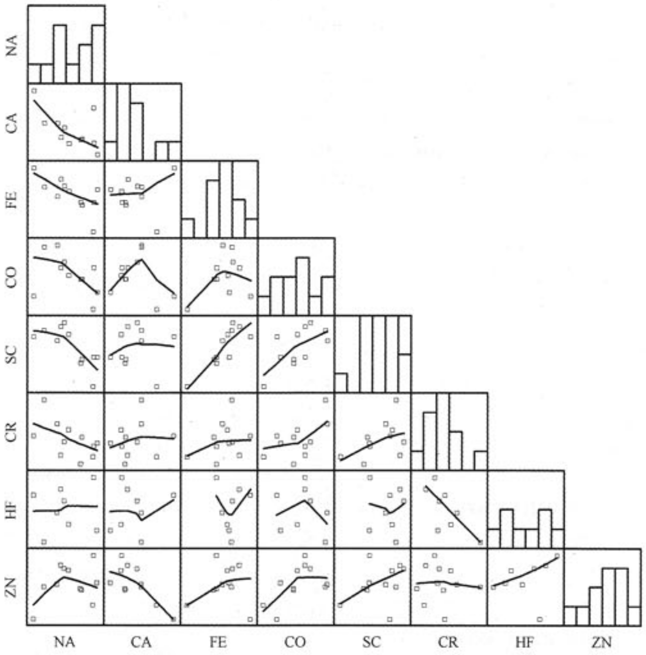

Figure 7. Scatterplot of selected elements, excluding rare earths, in geological specimens of Hillabee greenstone. Resistant line fitted by LOWESS smoothing, *f*=1 (Cleveland 1994:168-180).

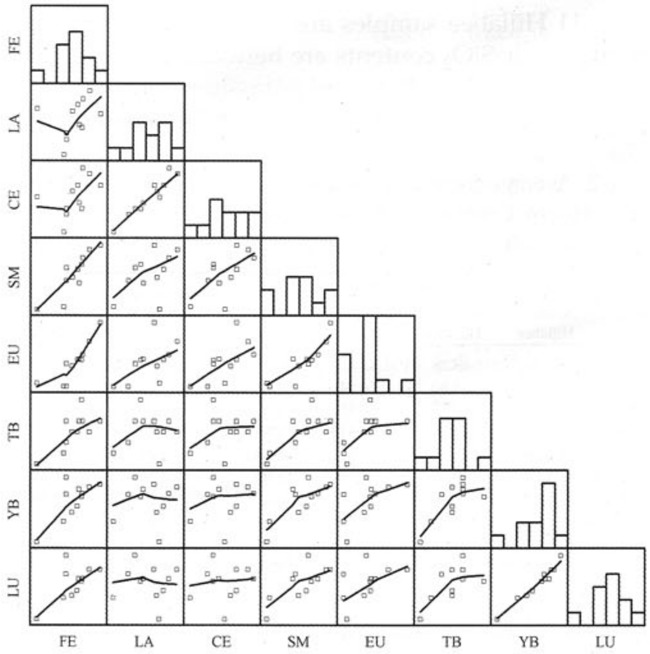

Figure 8. Scatterplot matrix of iron and rare-earth elements in geological specimens of Hillabee greenstone. Resistant line fitted by LOWESS smoothing, *f*=1 (Cleveland 1994:168-180).

because they do not provide enough rock material for multi-instrumental analyses.

Of the 578 artifacts originally cataloged as "greenstone," 568 (98%) are composed of minerals typical of the greenschist metamorphic facies. The remaining 2% are composed of diabase (n = 1), granite/diorite (n = 7), and gneiss (n = 2), which are not usually considered to be varieties of greenstone and so were not included in the sample that underwent petrographic analyses. This macroscopic determination was confirmed by inspection under a binocular microscope. With macroscopic observations on texture and mineralogy, diabase, granite, and gneiss are easily distinguished from fine-grained metabasite (greenstone) even without a freshly broken surface to inspect. Artifact surfaces were studied while they were wet because this treatment substantially improved mineral and texture visibility without harming the artifacts.

Of the greenstone artifacts examined, 23% (n = 130) were too small and 29% (n = 166) were too deeply weathered or stained to be assigned confidently to a specific greenstone category by nondestructive macroscopic observations on color, texture, and mineralogy.

The remaining 48% of the artifacts (n = 272) were examined macroscopically and subdivided according to color, texture, and other features (e.g., epidote-rich veins) into six types, defined as follows:

> Type A is a fine-grained, light to dark greenish- to bluish-gray, massive metabasite with dark veins and zones (Figure 10a-d);
>
> Type B is a medium-grained, greenish-gray to gray mottled, massive to slightly foliated metabasite with distinct to indistinct, equigranular to slightly elongate grains (Figure 10e-i);
>
> Type C is a fine-grained, massive, speckled, greenish-gray metabasite with dark and light colored veins (Figure 10j);
>
> Type D is a fine- to medium-grained, bluish-gray to grayish-black metabasite with medium gray bands delineating foliation, and dark and light colored veins (Figure 10k-l);
>
> Type E is a fine-grained, massive grayish-black metabasite (Figure 10m-n); and
>
> Type F is a metabasite with relict phenocrysts that produce a distinctly bimodal grain-size assemblage (Figure 10o).

Colors vary from greenish (5GY 6/1) to bluish gray (5B 5/1), and from medium gray (N 3) to grayish black (N 2), according to the Munsell system. These six macroscopic types were then subsampled to obtain specimens for further analysis. In all, 28 celts were selected for more detailed (and destructive) mineralogical, petrographic, and chemical studies (Table 4).

Mineralogy

Examination of thin sections with a petrographic microscope revealed four distinct textural types, ranging from very fine to medium grained. Fourteen exhibited a metadiabasic texture (Figure 11a), ten had a granoblastic texture (Figure 11b), and three had a crudely foliated

Table 3. Counts of greenstone artifacts from Moundville in the Alabama Museum of Natural History collections.[a]

Locality [b]	Celt Fragment	Celt Chip	Whole Celt	Disk	Slab	Spud	Celt Preform	Pendant	Pin	Total
Rho	18	2	4					1		25
Rw	110	94	15	2		2	1		1	225
SD	9	2	8	1	1					21
NE	3	3	2	1	1		1			11
EE	7		6	3	1					17
NG	3		1							4
SEH	3	1	1							5
SWM	7	1	3							11
WP	3									3
NR	32		2		2					36
WR	7	1	3							11
W	15	1	1	1		1				19
Surface	86	45	2		1					134
Miscellaneous	28		25	1		2				56
Total	331	150	73	9	6	5	2	1	1	578

[a] Data from (Gall 1995: Appendix A).

[b] Key to abbreviations: Rho, Rhodes site; Rw, Roadway excavation; SD, south of Mound D; NE, north of Mound E; EE, east of Mound E; NG, north of Mound G; SEH, southeast of Mound H; SWM, southwest of Mound M; WP, west of Mound P; NR, north of Mound R; WR, west of Mound R; W, Mound W.

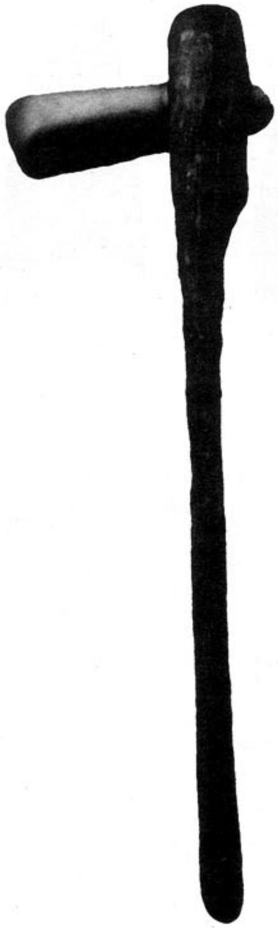

Figure 9. Hafted greenstone celt found in the Black Warrior River near Moundville (Gyllenhaal-Davis and Walling 1983; Oakley 1982; Walling 1982). The wooden handle is approximately 70 cm long.

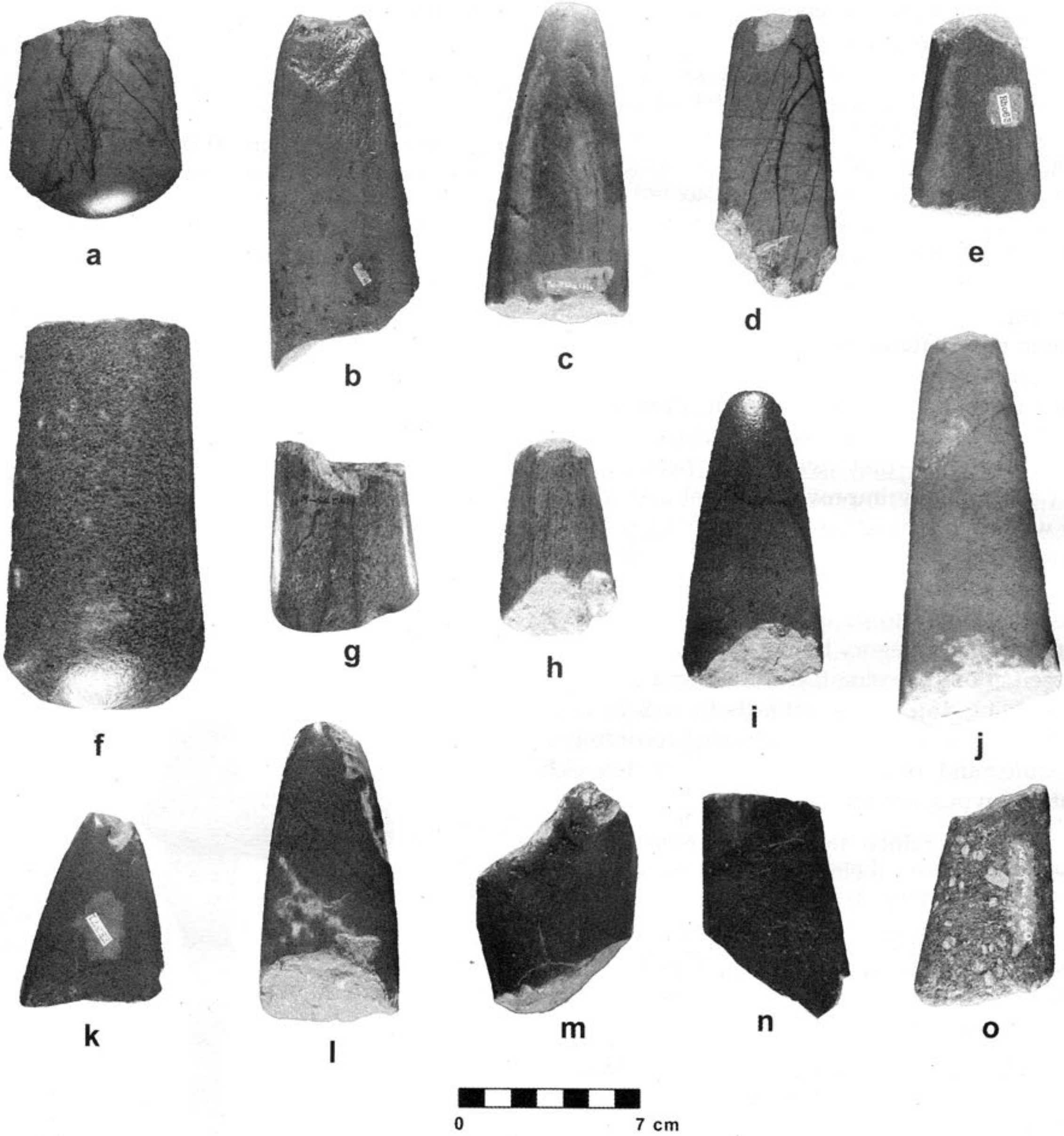

Figure 10. Typical greenstone celts from Moundville, all showing signs of breakage and wear: (a-d) Type A; (e-i) Type B; (j) Type C; (k-l) Type D; (m-n) Type E; and (o) Type F. (Alabama Museum of Natural History catalog numbers: (a) A930.3.51; (b) A931.2.106; (c) A939.2.441; (d) A941.3.75; (e) A930.2.145; (f) A930.2.148; (g) A941.3.108; (h) A941.3.167; (i) A941.4.244; (j) A930.2.149; (k) A931.1.184; (l) A930.1.52; (m) A931.2.91; (n) A939.2.546; (o) A939.2.487).

Table 4. Total and sampled abundances of macroscopic greenstone types from Moundville in the Alabama Museum of Natural History collections.[a]

	All Artifacts		Sampled Artifacts	
Type	Count	% of Total	Count	% of Type
A	108	39.7	9	8.3
B	68	25.0	8	11.8
C	28	10.3	3	10.7
D	41	15.1	5	12.2
E	23	8.5	2	8.7
F	4	1.5	1	25.0
Total	272	100.0	28	

[a] Data from Gall (1995: Appendix A).

texture (Figure 11c)—all types already described among the Hillabee geological specimens. In addition, a single celt was characterized by a *porphyritic* texture, with relict phenocrysts that produced a distinctly bimodal grain-size assemblage (Figure 10o); this type was not found among the Hillabee geological samples collected in this study. Pyrite and its alteration products often added distinctive features to the celt rock types as did dark-colored veins and aggregates of epidote, and fine-grained aggregates of chlorite. The mylonitic and phyllitic textures observed among the Hillabee samples did not occur among the Moundville celts.

Interestingly, the textural types discerned petrographically did not correlate well with the macroscopic types that had been used as the basis for sampling (Table 5). Types A-D each subsumed at least two of the petrographic categories. Type E contained only specimens with a metadiabasic texture, but this coincidence could well be the result of small sample size. Only in the case of Type F, with its large and obvious phenocrysts, was the correspondence between the macroscopic and petrographic categories clear-cut. In general, features that defined petrographic types could not be discerned with the naked eye (or even with a hand lens) because of the fine-grained textures and weathered surfaces of most artifacts.

XRD was used to identify the major mineral components in powdered samples of the celt greenstones. The results confirmed that all of the celt greenstones were composed of actinolite, epidote, and albite with minor amounts of chlorite and sometimes quartz. The absence or presence of quartz in detectable amounts was the only significant mineralogic difference among the celt samples: of the 28 samples, only 25% (n = 7) contained enough quartz to be detected. And in these cases, the amount of quartz was relatively small, as the strongest diffraction line was barely discernible.

Whole-rock densities were determined for the 28 celt samples using the procedure described earlier. These samples have densities that range from 3.0 to 3.1 g/cm^3, and their average density is 3.0 g/cm^3 (Gall 1995: Appendix B). As with the geological specimens discussed previously, these results are consistent with the presence of actinolite, epidote, and albite in roughly similar proportions.

Petrography and XRD show that all the artifact greenstone varieties have essentially the same mineralogy. The celts are all composed of approximately equal amounts of actinolite, epidote, and albite. Relict igneous textures (e.g., diabasic, porphyritic) occur in approximately 60% of the samples, affirming their igneous origin; similarity in composition indicates that the remaining 40% also had a similar protolith. Mineral components of the greenstones and their fine-grained textures indicate metamorphism of basalt under greenschist-facies conditions at temperatures of about 300-400° C and pressures probably no greater than 0.5 gigapascals. Like the Hillabee samples discussed previously, celt greenstones formed from a basaltic parent rock that experienced greenschist-facies metamorphism.

Thus, the Moundville artifact greenstones can be classified as very-fine- to medium-grained, massive to crudely foliated, actinolite-epidote-albite metabasites. In terms of texture, mineralogy, and protolith, they are identical to greenstones found within the Hillabee Metavolcanic Complex.

Chemistry

Chemical analysis of the 28 Moundville celt fragments was greatly constrained by sample size. Each celt fragment contains a small and finite amount of

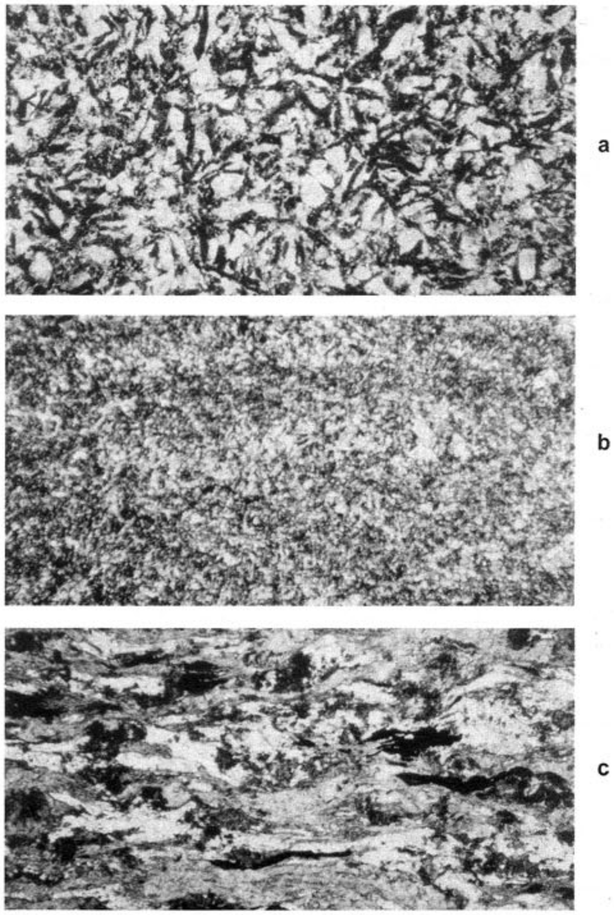

Figure 11. Thin sections of Moundville celts showing characteristic textures of Hillabee greenstones: (a) metadiabasic; (b) grano-blastic; and (c) crudely foliated. The long dimension of each photograph corresponds to 5 mm on the thin section. Photographs (a) and (c) were taken in plane-polarized light; photograph (b) was taken in cross-polarized light. (Alabama Museum of Natural History catalog numbers: a, A931.1.184; b, A931.2.90; c, A930.2.148).

Table 5. Cross-tabulation of petrographic and macroscopic greenstone types among Moundville celts.[a]

Petrographic Greenstone Type	Macroscopic Greenstone Type						
	A	B	C	D	E	F	Total
Metadiabasic	4	3	2	3	2		14
Granoblastic	5	4	1				10
Crudely foliated		1	1	1			3
Porphyritic						1	1
Total	9	8	4	4	2	1	28

[a] Data from Gall (1995: Appendix B).

material, not all of which was available for analysis. Because neither the broken nor shaped ends were to be used, only the midsections of celt fragments were available for analysis. The celt fragments also have weathered and stained exteriors which were removed prior to analysis. Removing the weathered rinds from the celt fragments exposed the best-preserved material for analysis but significantly reduced the sample volume. After trimming, the amount of sample available for analysis was typically no more than 3 cm³. This small volume of rock provided material for a petrographic thin section, x-ray diffraction, and whole-rock chemical analyses.

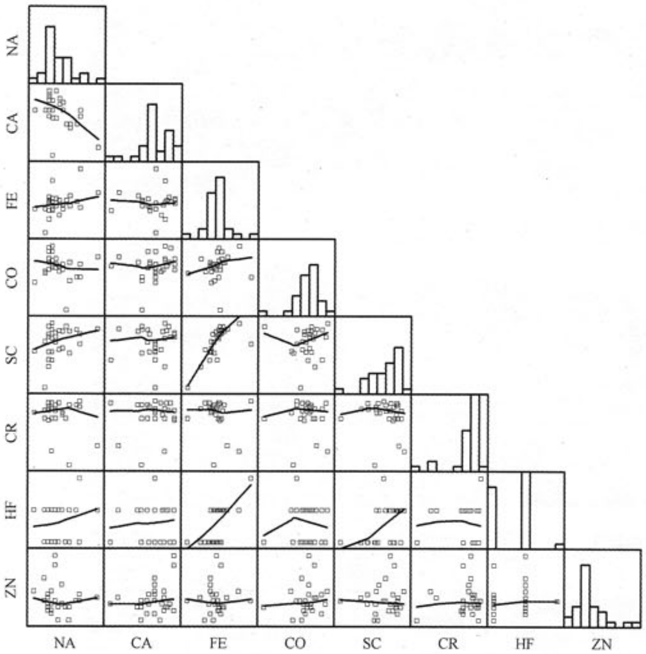

Figure 12. Scatterplot matrix of selected elements, excluding rare earths, in archaeological specimens from Moundville. Resistant lines fitted by LOWESS smoothing, *f*=1 (Cleveland 1994:168-180).

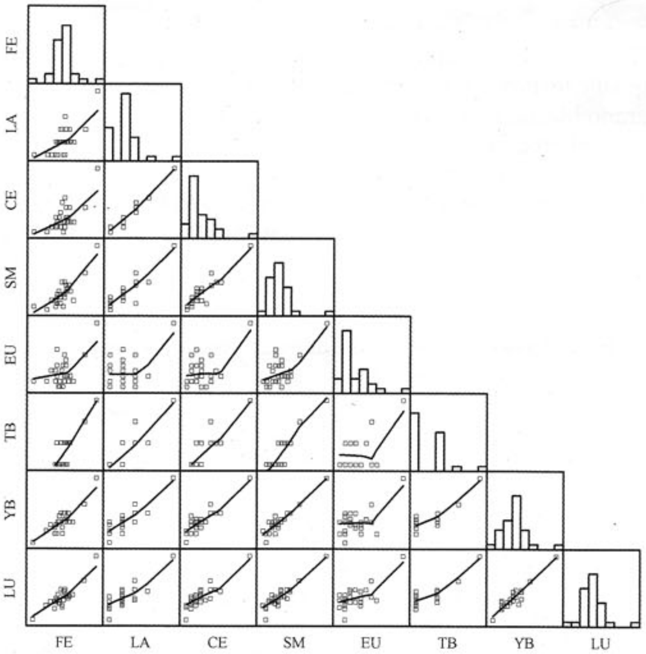

Figure 13. Scatterplot matrix of iron and rare-earth elements in archaeological specimens from Moundville. Resistant lines fitted by LOWESS smoothing, *f*=1 (Cleveland 1994:168-180).

The chemical composition of the powdered artifact samples was determined using INAA (Gall 1995: Appendix B). Of the 33 elements that the analytical protocol was capable of determining, only 15 were found in the samples: sodium (Na), calcium (Ca), iron (Fe), cobalt (Co), scandium (Sc), chromium (Cr), hafnium (Hf), zinc (Zn), lanthanum (La), cerium (Ce), samarium (Sm), europium (Eu), terbium (Tb), ytterbium (Yb), and lutetium (Lu). The relative abundances of these 15 elements were used to identify similarities and differences among the celt greenstones.

Based on the elements measured in the analytical protocol, the Moundville celts clearly have the same composition as the Hillabee geological samples; all the same constituents are present in very similar concentrations (Table 6). Moreover, the elements in the celts also show very similar patterns of association. Just as in the Hillabee samples, sodium correlates negatively with calcium (Figure 12) and the rare earth elements correlate positively with each other and with iron (Figure 13).

Table 6. Elemental composition of Moundville celts in comparison to Hillabee greenstones.

Category:	Moundville Celts [a]		Overall Hillabee [b]	
Element [c]	Mean	Range	Mean	Range
Major:				
Na_2O (%)	2.25	1.35-3.78	2.65	0.38-4.30
CaO (%)	11.13	7.97-12.59	12.03	8.16-18.20
Fe_2O_3 (%)	10.85	8.01-14.16	11.62	7.27-14.70
Trace (Misc.):				
Co (ppm)	47.8	24.0-59.0	54.4	36.0-70.0
Sc (ppm)	43.2	30.7-48.4	43	31.9-49.8
Cr (ppm)	278.9	20.0-350.0	225.5	61.0-490.0
Hf (ppm)	1.6	1.0-3.0	2.4	1.8-2.9
Zn (ppm)	103.9	40.0-240.0	76.3	33.0-110.0
Rare Earths:				
La (ppm)	4.1	3.0-8.0	3.9	1.3-6.0
Ce (ppm)	10.9	8.0-21.0	11	5.0-16.0
Sm (ppm)	2.2	1.7-3.8	2.53	1.55-3.32
Eu (ppm)	0.9	0.6-1.8	1.13	0.68-1.86
Tb (ppm)	0.6	0.5-0.8	0.6	0.3-0.9
Yb (ppm)	2.2	1.5-3.7	2.35	1.28-2.95
Lu (ppm)	0.33	0.20-0.56	0.36	0.21-0.48

[a] A total of 28 samples were analyzed. Elements that were analyzed but generally not detected were: rubidium (Rb), cesium (Cs), strontium (Sr), tantalum (Ta), molybdenum (Mo), tungsten (W), nickel (Ni), iridium (Ir), silver (Ag), gold (Au), arsenic (As), antimony (Sb), selenium (Se), bromine (Br), neodymium (Nd), terbium (Tb), thorium (Th), and uranium (U). Terbium (Tb), values for which appear in this table, was detected in only 22 samples. Data from Gall (1995: Appendix B).

[b] Hillabee data from Table 1.

[c] See text for key to element abbreviations.

Chemical data support the conclusion that the protoliths of the celts were basaltic in composition. For example, the average calcium, sodium, and iron concentrations in the celts (11.13%, 2.25%, and 10.85%, respectively; Table 6) agree well with the reported values for low-potassium tholeiite basalts (11.51%, 2.53%, and 10.78%, respectively; see Table 2). The potassium contents of the celts were not determined by INAA; however, the very low abundance of potassium minerals (e.g., potassium feldspar, muscovite) and the relatively large quantity of albite (sodium feldspar) in the celt greenstones indicate that the potassium content of the samples must be significantly lower than the sodium content. The inverse relationship between calcium and sodium in the celts is also similar to that in igneous rocks.

These striking parallels in color, texture, mineralogy, density, chemistry, and protolith suggest that most, if not all, of the Moundville artifact greenstones came from the Hillabee Metamorphic Complex. Let us now turn to a consideration of where along the Hillabee's trace the sources may have been.

Intraformational Provenance

We have already established that sodium and calcium are the two elements that vary most consistently with geographical position within the Hillabee formation. From north to south, the abundance of sodium increases, and that of calcium decreases. These elements provide the key to locating more precisely the sources of the Moundville greenstones.

In terms of sodium concentrations, most of the Moundville celts compare favorably with the geological specimens from the Central Hillabee area (Figure 14). The one exception (Rho229) has much more sodium than the rest, a value consistent with the Southern Hillabee area.

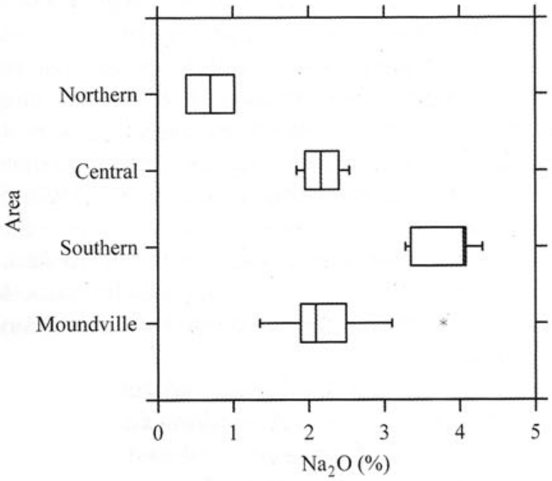

Figure 14. Boxplot of sodium (Na_2O) concentrations in geological specimens from the three Hillabee areas and in archaeological specimens from Moundville.

Calcium concentrations show a generally similar pattern (Figure 15). The overall distribution of values for Moundville celts is most similar to that for the Central Hillabee samples, although there are a few outliers that seem to fall within the range of the Southern Hillabee samples.

A bivariate plot of calcium versus sodium shows the relationships between the Moundville and Hillabee samples even more clearly (Figure 16). All of the Moundville greenstones cluster with the Central and Southern Hillabee specimens; none group with the Northern Hillabee samples, thereby eliminating this area as a possible source. More specifically, 24 celts cluster in

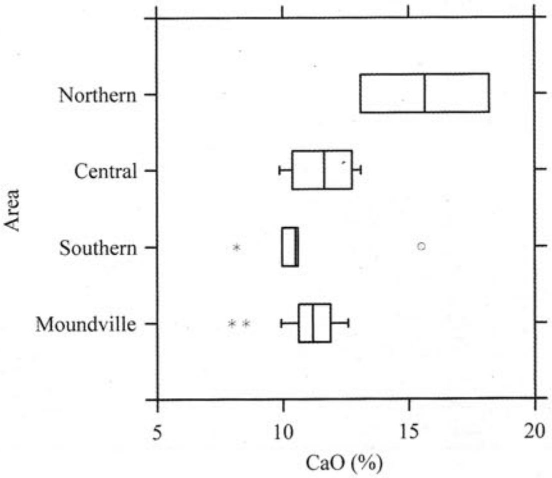

Figure 15. Boxplot of calcium (CaO) concentrations in geological specimens from the three Hillabee areas and in archaeological specimens from Moundville.

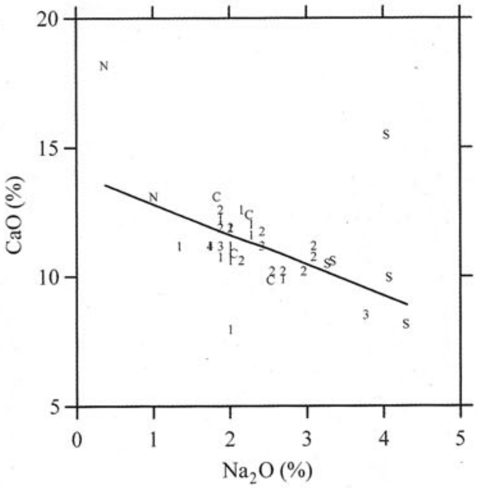

Figure 16. Scatterplot of calcium (CaO) versus sodium (Na_2O) in geological specimens of Hillabee greenstone and in archaeological specimens from Moundville. Resistant line fitted by LOWESS smoothing, f=1 (Cleveland 1994:168-180). Key for geological specimens: N, Northern Hillabee; C, Central Hillabee; S, Southern Hillabee. Key for archaeological specimens: 1, metadiabasic texture; 2, granoblastic texture; 3, crudely-foliated texture; 4, prophyritic texture.

the neighborhood of the Central Hillabee samples, one celt falls squarely in the midst of the Southern Hillabee samples, and three celts seem to fall right on the boundary between the Central and Southern groups. Although the chemical signatures of these three "borderline" celts are ambiguous, petrography provides an additional clue. All three have a granoblastic texture, which is common in the Central area but absent (or at least very rare) in the Southern area. (Of the 62 geological samples collected for this study, 16 have a granoblastic texture: one from the Northern area, 15 from the Central area, and none from the Southern area.) Thus, only one celt (Rho229) can be assigned confidently to the Southern Hillabee area.

Table 7 summarizes the inferred source areas of the 28 Moundville celts in relation to their petrographic characteristics. Celts associated with the Central area exhibit metadiabasic, granoblastic, crudely foliated, and porphyritic textures (in order of decreasing abundance). All these types but the last are well represented among the geological specimens from this area. The only celt assigned a Southern Hillabee provenance has a distinctive, medium-grained, crudely foliated texture. Greenstones of this particular kind were observed only in the Gale Creek valley in Chilton County, located at the southern terminus of the Hillabee outcrop trace, where 10 of the 14 Hillabee samples with crudely foliated textures were collected.

Table 7. Distribution of chemically analyzed Moundville celts by textural type and inferred source area.

Textural Type	Grain Size	Inferred Source Area Northern Hillabee	 Central Hillabee	 Southern Hillabee	Total
Metadiabasic	fine	0	14	0	14
Granoblastic	fine	0	10	0	10
Crudely foliated	fine to medium	0	2	1	3
Porphyritic	medium	0	1	0	1
Mylonitic	fine	0	0	0	0
Phyllitic	very fine	0	0	0	0

It should not be surprising that no examples of mylonitic or phyllitic textures were found among the Moundville greenstones (Table 7). Because of their limited toughness, these types of rock are marginal, at best, for celt manufacture.

Summary and Discussion

In sum, the main sources of Moundville greenstone are located in the Central portion of the Hillabee Metavolcanic Complex. A small amount of Moundville greenstone came from the Southern Hillabee area, and no greenstones at all were used from the Northern Hillabee. This conclusion is supported by mineralogical, petrographic, and chemical evidence. It is also consistent with the fact that the Central Hillabee area contains the largest amount of celt-grade greenstone. All of the localities in the Northern and Southern areas combined do not come close to offering the opportunities for greenstone exploitation that the Central Hillabee offers with respect to the abundance of readily available material.

Within the Central Hillabee area, most of the celt-grade greenstone outcrops occur along the Hatchet Creek valley in Clay County, about 150 km east-northeast of Moundville (Figure 17). The upper reaches of this valley are drained by the east and west forks of Hatchet Creek, which are separated by a divide composed of erosionally resistant Hillabee greenstone. Moundville's ancient inhabitants probably made most of their celts out of greenstones from these deposits. In colonial times, an Upper Creek town named *Pochushåchi* was located in this valley; Read (1984:35) suggested that the name was derived from either *pochuswuchi håchi*, "hatchet creek," or *pochuswa håchi*, "ax creek." Evidently, Hatchet Creek owes its name to the Indians who for centuries exploited its greenstone outcrops for celt stone.

The best sources of celt-grade material in the Southern Hillabee area are located along Gale Creek in Chilton County, only 85 km east-southeast of Moundville (Figure 17). Here, outcrops of greenstone form rapids within the creek itself, and greenstone boulders occur throughout the alluvial deposits.

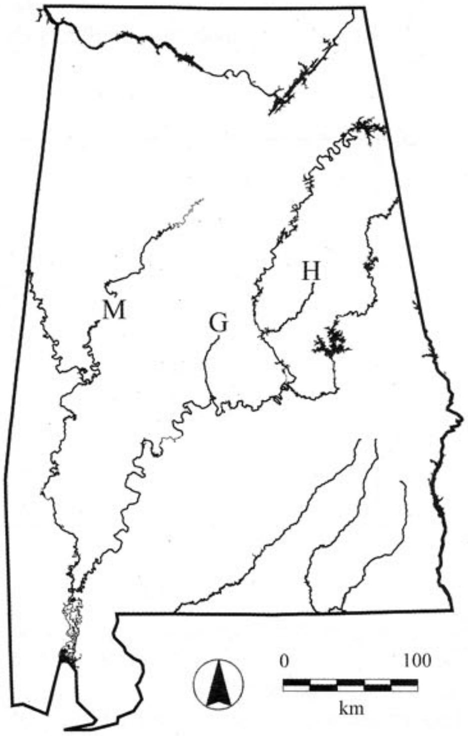

Figure 17. Map of Alabama showing the locations of the ax-grade Hillabee greenstone outcrops at Gale Creek (G) and Hatchet Creek (H) in relation to Moundville (M).

No evidence of ancient quarrying or mining activity has been found anywhere along the strike of the Hillabee greenstone; however, small pits and well-like openings have been reported that probably date to historic times (Dunning 1960). Quarrying and mining would not have been necessary to obtain celt blanks since erosion produces boulders of mechanically competent greenstone at low waterfalls and rapids (Figs. 18-19). Celt blanks were, therefore, properly proportioned boulders obtained at stream sites where downcutting has been effectively halted by erosionally resistant deposits of greenstone. Removed from channel deposits, greenstone boulders were then reduced into celts by chipping, pecking, and abrasion. The outcrops of Hillabee greenstone that are mechanically competent enough to serve as celt stone are incredibly tough. Typically, blows with a sledgehammer are deflected and hammer falls ring like a bell. It would have been very difficult to mine the Hillabee greenstone without the benefit of steel tools, which the ancient Indians did not possess.

Because the greenstone outcrops of the Hillabee Metavolcanic Complex are eroding, cobbles of this material may also have been available in river beds downstream from the sources. Hatchet Creek empties into the Coosa River and Gale Creek empties into Mulberry Creek; both the Coosa River and Mulberry Creek, in turn, flow into the Alabama River. Therefore, it is possible that greenstone boulders could have been obtained from the Alabama River or any of its tributaries that cross Hillabee lithologies (see Figure 17). No greenstone boulders occur in the Black Warrior River because its drainage basin does not intersect the Hillabee deposits (see Figure 2).

Speculations on the Nature of Greenstone Procurement and Exchange

Many of the rocks utilized by Moundville's inhabitants could be found in geological deposits within a 150-km radius of the site (Pallister 1955). Among the stone materials *not* readily available within this radius were Mill Creek chert from southern Illinois (Welch 1991:173-174); Fort Payne, Bangor, and Pickwick cherts from the middle Tennessee Valley (Scarry 1986:154-168; 1995:66-69); native copper from the Great Lakes and the southern Appalachians (Goad 1978); limestones from the lower Mississippi Valley (Steponaitis and Dockery 1997); and galena from the lead-zinc ore deposits of southeast Missouri and the upper Mississippi Valley (Walthall 1981). The presence of rocks and minerals from distant sources indicates that some sort of exchange system was operating during Mississippian times, yet it does not appear necessary to invoke exchange as a mechanism to account for all of the nonlocal stone materials recovered at Moundville (Welch 1991).

The terms "local" and "nonlocal" are usually used to describe the wide range of materials that traveled various distances into a specified territory or polity. Harbottle (1982:16) states, "*Local* is generally taken to mean near or associated with the production center. *Imported* (nonlocal) is usually everything else, at least operatively." With respect to Moundville stone artifacts, Welch (1991) and others consider rocks from the Alabama Piedmont (e.g., greenstone) and the Great Lakes (e.g., native copper) to be nonlocal materials. Obviously, researchers do not consider Piedmont greenstone and native copper from the Great Lakes region to be equivalent, but general terms such as "local" and "nonlocal" do not differentiate between the two, and so do not adequately describe the procurement situation. Use of such terms also implies that the locations of the quarry sites and production centers, as well as the boundaries of the polity exploiting the raw material, are known.

Figure 18. An outcrop of Hillabee greenstone forming rapids in Gale Creek, Chilton County, Alabama.

Figure 19. Gale Creek alluvium containing greenstone cobbles and boulders, Chilton County, Alabama. The hammer in the center of the photograph is 27 cm long.

The expression "long-distance exchange" is also used when discussing procurement of nonlocal materials by ancient peoples. For example, in the case of Mississippian chiefdoms, Goad (1978) considered both native copper and marine shell to have been acquired by means of long-distance exchange. The actual distance, difficulty and limitations in transportation, and the number of transactions are not indicated by such terms, nor has the *exchanging* of items been proven. Furthermore, the movement of a relatively common, low-density substance like marine shell several hundred kilometers from the south between similar cultures cannot be equated with the movement of rare and dense substances like native copper and galena from northern sources more than 1,000 km away. As before, researchers do not consider marine shell obtained from the Gulf of Mexico and native copper from the Great Lakes region to be equivalent, but simply alluding to long-distance exchange tends to obscure the differences.

The concepts embodied in the terms "local," "nonlocal," and "long-distance exchange" could be better conveyed if stone sources were considered with respect to proximity to the site, availability of the material (rare or plentiful), and control of access to the resource (Stone 1994). The following categories can be defined when proximity, availability, and control are considered.

1. *Within-Polity Procurement.* In the simplest of cases, the resource is close to the site, plentiful, and under the undisputed control of the polity. Stone materials at Moundville that fall in this category include kaolinite-illite clays, siltstones, sandstones, some varieties of chert, quartzite, hematite, and limonite. These materials would have been available upon demand and easily procured since geologic sources are located close to Moundville. Moundville's inhabitants probably got these materials directly from nearby sources with no risk, relatively little expense of time and energy, and without invoking transferal mechanisms; therefore, this is the simplest means of procuring stone materials.

2. *Procurement Expedition.* In this case, the resource is plentiful and not extremely distant from the site, but the geologic deposit is located in a buffer zone that separates neighboring polities. Stone materials found at Moundville that possibly belong in this category are amphibolite, basalt/diabase, graphite, granite, greenstone, metadiorite/diorite, muscovite (sheet mica), and shale/slate (Pallister 1955). Although resources are plentiful, procurement is made difficult due to the lack of an allied, resident population near the stone resource. Stone procurement would thus be achieved by means of collecting expeditions into the buffer zone. Overland expeditions into the Piedmont of Alabama undertaken by Indians of the Black Warrior River valley would have required a great deal of time and expenditure of manpower. Because these expeditions would not be assured of success, supply shortfalls, and the potential of periodic shortages would inflate the value and importance of the raw material, possibly require periodic recycling of heavily used items or substitutions of less desirable materials, and thus create problems. Procurement expeditions into buffer zones might also create confrontations between neighboring polities that might otherwise not have occurred, thereby creating military crises.

3. *Simple Transferal.* In this case, the resource is plentiful and not extremely distant, but it is under the control of an independent ally. Stone materials at Moundville that might be placed in this category include native asphalt, some varieties of chert, glauconite, limestone, and psilomelane/wad. These materials were relatively easy to acquire and plentiful. A mechanism for procurement (e.g., trade, tribute extraction) and transferal (e.g., portage, canoe) would have been required; therefore, there would be a greater expense of time and energy expended on the procurement of these types of materials, possibly a debt or obligation created, or an exchange of goods might have occurred.

4. *Complex Transferal.* In this instance, the material does not occur near the site or is not plentiful, it is in great demand, and acquisition may require transferal from distant sources. Stone artifacts from Moundville that can be placed in this category are native copper, galena, and some varieties of chert. These materials would be of greatest value with respect to time and energy expended in procurement, and because supplies may be frequently curtailed due to breakdowns in the transferal mechanisms. Ownership of these materials may have been an indicator of status, wealth, and power, or their use may have been restricted to ceremonial contexts.

Within-polity procurement, procurement expeditions, and simple and complex transferal better define procurement situations, and alleviate the ambiguities and implications caused by the exclusive use of terms such as local, nonlocal, and long-distance exchange. With respect to Moundville, within-polity procurement, procurement expeditions, and simple and complex transferal of stone materials all occurred. Apparently the Moundville Indians and the Indians to the north, south, and west of the territory controlled by the Moundville polity engaged in simple transferal. This is indicated by the presence at Moundville of foreign pottery from the north, south, and west, and of stone materials from these areas (Steponaitis 1991:208-212). The Moundville Indians' access to stone materials from the east was probably by direct procurement only and not by the transferal of material from the Indians of northeastern Alabama and northwestern Georgia (Welch 1991). The absence of settlements in the buffer zone east of Moundville and the rarity of eastern pottery types at Moundville both support this conclusion (Steponaitis 1991:208).

The lack of transferal interactions between the Indians of Moundville and the Indians of northeastern Alabama and northwestern Georgia is also supported by celt greenstone compositions. Moundville celts are composed of Hillabee metabasite lithologies, most of which were obtained from outcrops exposed in the upper portions of the Hatchet Creek valley. Indians that occupied northeastern Alabama and northwestern Georgia during Mississippian times not only used Hillabee metabasite for ax bits (Little 1999:52-54), but they also used phyllite (metasiltstone) from the Heflin Formation (Vaughn 1993). None of the Moundville greenstone artifacts are composed of metasiltstone or phyllite. The lack of Heflin celts in the Moundville inventory suggests that the people of northeastern Alabama were not trading their celts westward.

A recent study of greenstone artifacts at Moundville sheds further light on how celts were acquired and used (Wilson 2001). Virtually all the greenstone flakes at Moundville are the result of use-related breakage rather than manufacture, which suggests that celts were brought to the site either finished or as late-stage preforms and were used there, presumably for woodworking. Moreover, the recycling of broken greenstone celts was "expedient" or casual, and many broken celts were not recycled at all. This pattern strongly suggests that greenstone was readily available and not difficult to replace.

In summary, the available evidence suggests that greenstone was obtained by Moundville's inhabitants directly, by means of procurement expeditions to sources located along Gale Creek in Chilton County and Hatchet Creek in Clay County. These sources are 85 km and 150 km from Moundville, respectively. The toughness of greenstone makes it very difficult to mine (in the sense of breaking pieces directly from outcrops), especially without metal tools. Thus, the ancient Indians probably collected weathered cobbles of the appropriate size and shape, which can be readily found in stream beds near the outcrops. The initial stages of reduction probably took place near the sources, and the celts eventually were brought to Moundville in a finished or partly finished state. Exactly where the intermediate and late stages of production occurred is still not known.

Now that the geological sources of the greenstones found at Moundville have been determined, future research should focus on identifying the loci of celt production and also on mapping the distribution of artifacts made from Hillabee greenstone in other parts of the Mississippian world. Such studies will help us better understand how and how far this raw material moved across the social landscape, which in turn will sharpen our interpretations of the domestic and political economies that characterized the chiefdoms of this period.

Notes

Acknowledgments. First and foremost, we wish to express our gratitude to Eugene Futato and the late J. Robert Butler for their support and advice; this research could not have been completed without their help. P. Geoffrey Feiss, Daniel Textoris, Donald Brockington, Richard Mauger, Vernon Knight, William Meurer, Harry Holstein, Lewis Larson, Keith Little, John Rogers, H. Stephen Stow, James Tull, Paul Welch, Gregory Wilson, one anonymous reviewer, and editor Gregory Waselkov provided many helpful suggestions and other contributions to this work. Institutional support was provided by the Department of Geology and the Research Laboratories of Archaeology, University of North Carolina at Chapel Hill; Moundville Archaeological Park, University of Alabama; the Department of Geology, Duke University; and North Carolina Wesleyan College. Special thanks to the Independent College Fund of North Carolina and the Burroughs Welcome Science Faculty Scholarship Program for their contribution towards analysis expenses. Thanks are also due to Lindsay Myers, owner of the Down East Camera Shop in Rocky Mount, North Carolina, for his contributions with the photographic component of the project.

References Cited

Adams, G. I.
1933 General Geology of the Crystallines of Alabama. *Journal of Geology* 41:159-173.

Burton, J.
1984 Quarrying in a Tribal Society. *World Archaeology* 16:234-247.

Cleveland, William S.
1994 *The Elements of Graphing Data,* revised edition. Hobart Press, Summit, NJ.

Davis, P. A., Jr.
1977 Trace Element Model Studies of Late Precambrian-Early Paleozoic Greenstones of Virginia, Maryland and Pennsylvania. Unpublished Ph.D. dissertation, Department of Geology, University of Kentucky, Lexington.

Dunning, Arthur B.
1960 Lithic Factors Affecting Selection For Tools: Greenstone. *Journal of Alabama Archaeology* 6(2):65-70.

Earle, Timothy K., and Jonathon E. Ericson
1977 Exchange Systems in Archaeological Perspective. In *Exchange Systems in Prehistory,* edited by Timothy K. Earle and Jonathon E. Ericson, pp. 3 -12. Academic Press, New York.

Gall, Daniel G.
1995 Petrography and Provenance of Mississippian Greenstone Artifacts from the Moundville Site, Alabama. Unpublished Ph.D. dissertation, Department of Geology, University of North Carolina, Chapel Hill.

Goad, Sharon I.
1978 Exchange Networks in the Prehistoric Southeastern United States. Unpublished Ph.D. dissertation, Department of Anthropology, University of Georgia, Athens.

Griffin, Robert H.

1951 Structure and Petrography of the Hillabee Sill and Associated Metamorphics of Alabama. *Geological Survey of Alabama, Bulletin* 63. Tuscaloosa.

Gyllenhaal-Davis, Charlotte, and Richard Walling

1983 A Hafted Greenstone Celt from West Central Alabama. Paper presented at the annual meeting of the Alabama Academy of Science, Tuscaloosa.

Harbottle, Garman

1982 Chemical Characterization in Archaeology. In *Contexts for Prehistoric Exchange,* edited by Jonathon E. Ericson and Timothy K. Earle, pp. 13-51. Academic Press, New York.

Harbottle, Garman, and Phil C. Weigand

1992 Turquoise in Pre-Columbian America. *Scientific American* 266:78-85.

Heizer, Robert F.

1959 *The Archaeologist at Work: A Source Book on Archaeological Method and Interpretation.* Harper and Row, New York.

Herz, N.

1990 Stable Isotope Geochemistry Applied to Archaeology. In *Archaeological Geology of North America, Centennial Special,* volume 4, edited by Norman P. Lasca and Jack Donahue, pp. 585-595. Geological Society of America, Boulder, CO.

Higgins, M. W., R. L. Atkins, T. J. Crawford III, R. F. Brooks, and R. B. Cook

1988 The Structure, Stratigraphy, Tectostratigraphy, and Evolution of the Southernmost Part of the Appalachian Orogen. *U.S. Geological Survey, Professional Paper* 1475. Reston, VA.

Hitchcock, C. H.

1885 The Crystalline Rocks of Alabama. *American Journal of Science* 130:278-283.

Hodder, Ian, and P. Lane

1982 Chemical Characterization in Archaeology. In *Contexts for Prehistoric Exchange,* edited by Jonathon E. Ericson and Timothy K. Earle, pp. 213-235. Academic Press, New York.

Jones, Walter B.

1939 Geology of the Tennessee Valley Region of Alabama, with Notes on the Topographic Features of the Area, and the Effect of Geology and Topography on Aboriginal Occupation. In An Archaeological Survey of the Wheeler Basin on the Tennessee River in Northern Alabama, by William S. Webb, pp. 9-20. *Bureau of American Ethnology Bulletin* 122. Government Printing Office, Washington, DC.

Kinsella, Larry

1993 Personal Notes on Celt Use. *Illinois Antiquity* 28(3):9.

Klein, Cornelis, and Cornelius S. Hurlbut, Jr.

1985 *Manual of Mineralogy* (after James D. Dana), twentieth edition. Wiley, New York.

Knight, Vernon J., Jr., and Vincas P. Steponaitis

1998 A New History of Moundville. In *Archaeology of the Moundville Chiefdom,* edited by Vernon J. Knight, Jr. and Vincas P. Steponaitis, pp. 1-25. Smithsonian Institution Press, Washington, DC.

Larrabee, D. M.

1966 Map Showing Distribution of Ultramafic and Intrusive Mafic Rocks from Northern New Jersey to Eastern Alabama. *U. S. Geological Survey, Miscellaneous Geologic Investigations Map* I-476. Reston, VA.

Le Bas, M. J., R. W. Le Maitre, A. Streckeisen, and B. Zanettin

1986 A Chemical Classification of Volcanic Rocks Based on the Total Alkali-Silica Diagram. *Journal of Petrology* 27:745-750.

Le Maitre, R. W.

1976 The Chemical Variability of Some Common Igneous Rocks. *Journal of Petrology* 17:589-637.

Little, Keith J.

1999 The Role of Late Woodland Interactions in the Emergence of Etowah. *Southeastern Archaeology* 18(1): 45-56.

McBryde, I.

1984 Kulin Greenstone Quarries: The Social Contexts of Production and Distribution for the Mt. William Site. *World Archaeology* 16:267-285.

Mason, Brian H., and L. G. Berry

1968 *Elements of Mineralogy.* W. H. Freeman, San Francisco, CA.

Oakley, Carey B.

1982 Indian Axe Found in Warrior River. *Stones and Bones Newsletter* 24(3):1-3. Alabama Archaeological Society.

Osborne, W. Edward, Michael W. Szabo, Charles W. Copeland, Jr., and Thornton L. Neathery

1989 Geologic Map of Alabama. *Geological Survey of Alabama, Special Map* 221. Tuscaloosa.

Pallister, Hugh D.

1955 Index to the Minerals and Rocks of Alabama. *Geological Survey of Alabama, Bulletin* 65. Tuscaloosa.

Peebles, Christopher S.

1970 Moundville: The Social Organization of a Prehistoric Community and Culture. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Santa Barbara.

1971 Moundville and Surrounding Sites: Some Structural Considerations of Mortuary Practices II. In Approaches to the Social Dimensions of Mortuary Practices, edited by James A. Brown, pp. 68-91. *Society for American Archaeology Memoir* 25.

Phillips, W. B.

1892 A Preliminary Report on Part of the Lower Gold Belt of Alabama, in the Counties of Chilton, Coosa, and Tallapoosa. *Geological Survey of Alabama, Bulletin* 3. Tuscaloosa

Philpotts, A. R.

1990 *Principles of Igneous and Metamorphic Petrology.* Prentice Hall, Englewood Cliffs, NJ.

Prouty, W. F.

1923 Geology and Mineral Resources of Clay County. *Geological Survey of Alabama, Report* 1. Tuscaloosa.

Rapp, George, Jr.

1985 The Provenance of Artifactual Raw Materials. In *Archaeological Geology,* edited by George Rapp, Jr. and John A. Gifford, pp. 353-375. Yale University Press, New Haven, CT.

Read, William A.

1984 *Indian Place Names in Alabama,* revised edition. University of Alabama Press, Tuscaloosa.

Scarry, C. Margaret

1986 *Change in Plant Procurement and Production during the Emergence of the Moundville Chiefdom.* Ph.D. dissertation, Department of Anthropology, University of Michigan, Ann Arbor. University Microfilms, Ann Arbor, MI.

1995 Excavations on the Northwest Riverbank at Moundville: Investigations of a Moundville I Residential Area. *Office of Archaeological Services, University of Alabama Museums, Report of Investigations* 72. Tuscaloosa.

Steponaitis, Vincas P.

1991 Contrasting Patterns of Mississippian Development. In

Chiefdoms: Power, Economy, and Ideology, edited by Timothy K. Earle, pp. 193-228. Cambridge University Press, New York.

Steponaitis, Vincas P., and David T. Dockery

1997 The Geological Source of the Emerald Effigy Pipes and Its Implications for Mississippian Exchange. Paper presented at the 54th meeting of the Southeastern Archaeological Conference, Baton Rouge, LA.

Stone, Tammy

1994 The Impact of Raw-Material Scarcity on Ground-Stone Manufacture and Use: An Example from the Phoenix Basin Hohokam. *American Antiquity* 59(6):680-694.

Stow, Stephen H.

1979 Igneous Petrology of the Hillabee Greenstone. In The Hillabee Metavolcanic Complex and Associated Rock Sequences, edited by James F. Tull and Stephen H. Stow, pp. 14-29. *Guidebook for the 17th Annual Field Trip of the Alabama Geological Society.*

Stow, Stephen H., M. J. Neilson, and Thornton L. Neathery

1984 Petrography, Geochemistry, and Tectonic Significance of the Amphibolites of the Alabama Piedmont. *American Journal of Science* 284:416-436.

Szabo, Michael W., W. Edward Osborne, Charles W. Copeland, Jr., and Thornton L. Neathery

1988 Geologic Map of Alabama. *Geological Survey of Alabama, Special Map* 220. Tuscaloosa.

Toumey, M.

1858 *Second Biennial Report on the Geology of Alabama.* Geological Survey of Alabama, Tuscaloosa.

Tull, James F.

1979 Stratigraphic and Structural Relationships of the Eastern Talladega Slate Belt of Alabama. In The Hillabee Metavolcanic Complex and Associated Rock Sequences, edited by James F. Tull and Stephen H. Stow, pp. 3-13. *Guidebook for the 17th Annual Field Trip of the Alabama Geological Society.*

1982 Stratigraphic Framework of the Talladega Slate Belt, Alabama Appalachians. *Geological Society of America, Special Paper* 191. Boulder, CO.

Tull, James F., and Stephen H. Stow

1982 Geologic Setting of the Hillabee Metavolcanic Complex and Associated Strata-Bound Sulfide Deposits in the Appalachian Piedmont of Alabama. *Economic Geology* 77: 312-321.

Tull, James F., Stephen H. Stow, Lamar Long, and Bertram Hayes-Davis

1978 The Hillabee Greenstone: Stratigraphy, Geochemistry, Structure, Mineralization and Theories of Origin. *University of Alabama Mineral Resources Institute, Report* 1. Tuscaloosa.

Vallance, T. G.

1960 Concerning Spilites. *Proceedings of the Linnean Society of New South Wales* 85:8-52.

Vaughn, D. M.

1993 An Analysis of Prehistoric Greenstone Artifacts in Northeastern Alabama. *Geoarchaeology* 8:515-529.

Walling, Richard

1982 A Hafted Greenstone Celt from Alabama: The One that Didn't Get Away. Paper presented at the 39th meeting of the Southeastern Archaeological Conference, Memphis, TN.

Walthall, John A.

1981 Galena and Aboriginal Trade in Eastern North America. *Illinois State Museum, Scientific Papers* 17. Springfield.

Walthall, John A., Clarence H. Webb, Stephen H. Stow, and Sharon I. Goad

1982 Galena Analysis and Poverty Point Trade. *Midcontinental Journal of Archaeology* 7(1):133-148.

Welch, Paul D.

1991 *Moundville's Economy.* University of Alabama Press, Tuscaloosa.

Wilkinson, J. F. G.

1986 Classification and Average Chemical Compositions of Common Basalts and Andesites. *Journal of Petrology* 27:31-62.

Wilson, Gregory D.

2001 Crafting Control and the Control of Crafts: Rethinking the Moundville Greenstone Industry. *Southeastern Archaeology* 20(2):118-128.