PREHISTORIC SELECTION FOR INTENTIONAL THERMAL ALTERATION: TESTS OF A MODEL EMPLOYING SOUTHEASTERN ARCHAEOLOGICAL MATERIALS

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ABSTRACT

Properties of altered as opposed to unaltered silica materials, and requirements of the alteration process are employed to develop a model delimiting circumstances under which intentional thermal alteration might be expected to obtain (and *not* obtain) on archaeological specimens. Heat treated artifacts will occur on archaeological sites either by accident or because of intentional prehistoric selection for one or more of the following attributes: appearance, improved quality, sharp cutting edges, improved soft hammer or pressure flaking efficiency, or as part of conservation measures. The model is tested employing archaeological materials from sites in South Carolina and Arkansas, with alteration experiments conducted on local source and site materials to provide experimental controls. The occurrence of intentional thermal alteration on a range of debitage and tool categories was noted, with a patterning in general agreement with that predicted by the model.

Introduction

In recent years it has been established that some prehistoric populations intentionally thermally altered chert and other silica minerals. A widespread occurrence for the phenomonon is indicated both temporally and spatially. Unfortunately, while the physical and chemical effects of alteration are well documented, its behavioral implications—the circumstances under which intentional thermal alteration is likely to occur—are not well understood. The occurrence of thermally altered chert in the southeastern United States is examined, with an emphasis on materials recovered from two areas: Arkansas and South Carolina. This paper discusses the circumstances under which alteration of chert might occur, based on a review of the southeastern literature, and the properties of altered as opposed to unaltered chert; and there is an examination of archaeological collections. Throughout this paper, the terms "heat treatment," "intentional thermal alteration," and "ITA" are used interchangeably in reference to the process and archaeological occurrence.

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While the discussion is limited to chert artifacts, many of the arguments presented should be generally applicable in the study of other silica minerals.

Alteration Effects and Requirements

Although anthropologists have long recognized that fire or heat were at least occasionally used in conjunction with stone working or quarrying (Holmes 1919; Hester 1973; Gregg and Grybush 1976), discussion of the process and advantages of intentional thermal alteration did not appear until the early 1960s (Crabtree and Butler 1964; Shippee 1963). During the remainder of the decade the phenomenon was intermittently recognized on prehistoric remains from 1966:17, 24, 122ff; Irwin-Williams and Irwin 1966:60; MacDonald 1968:61–62). In the early 1970s detailed technical investigations were published that emphasized the physical, chemical, and mechanical consequences of thermal alteration (Purdy and Brooks 1971; Purdy 1974; Mandeville 1973; Flenniken and Garrison 1975). Partially as a consequence, recognition of the phenomenon has become increasingly commonplace. Lithic artifact descriptions are beginning to incorporate the attribute, and reports of heating experiments to test for possible alteration effects on local materials are appearing in many areas (Chapman 1976:97–99; DeJarnette and others 1975a:18; House and Smith 1975; Purdy 1974; Oakley and Futato 1975; Hood and McCollough 1976).

Prehistoric selection for intentional thermal alteration can be best understood in terms of the properties of altered as opposed to unaltered cherts, and the requirements of the alteration process. Thermal alteration is believed to occur with the melting of microscopic impurities in the intercrystalline spaces of chert at temperatures above about 300°C (Purdy and Brooks 1971:323; Mandeville 1973:188–189). The melted impurities act as a flux, fusing together the individual cryptocrystals of the chert mass. Altered chert is more homogeneous than unaltered material, with an increased elasticity and a greater tendency to fracture like glass (Purdy and Brooks 1971:324).

A number of distinct advantages are conferred by thermal alteration. The first, somewhat subjective in nature, is the marked change in appearance (luster and texture) associated with alteration and subsequent flaking. Altered cherts exhibit (upon flaking) a much glossier surface than unaltered cherts, and are smoother or "waxier" to the touch (Crabtree and Butler 1964:2). A pronounced color change may occur in the material, although this is not dependent upon alteration, and may occur for other reasons. Weathering or low or accidental heating, for example, may produce reddish colors in cherts of other colors containing sufficient iron compounds (Purdy and Brooks 1971:323).

Other advantages are mechanical in nature, and are directly related to structural changes (greater homogeneity and elasticity) brought about by alteration. The greater homogeneity of altered cherts facilitates reduction-manufacturing processes. This is directly manifested by the marked reduction in point tensile strength needed to break altered as opposed to unaltered cherts (Purdy and Brooks 1971:324). Altered cherts are more easily worked than unaltered cherts; flakes are easier to detach; and pressure flaking is easier to control. Pressure flakes, furthermore, can be much larger than is possible using unaltered cherts (Crabtree and Butler 1964:1; Mandeville and Flenniken 1975:148). Altered cherts can also be worked with less shatter and waste than unaltered cherts, because the effects of internal flaws are reduced. Force travels through the cryptocrystals, instead of around them, as in the case of unaltered material, and flakes tend to feather rather than step out (Purdy and Brooks 1971:323–324). Finally, the glass-like fracture produces a much sharper cutting edge than is possible with unaltered material (Crabtree, reported in Gregg and Grybush 1976:189).

The process of thermally altering chert has a number of distinct requirements that act to constrain the occurrence of the phenomenon. Cherts must be heated slowly, to avoid crazing or descrepitation (Purdy 1974:40–41). Temperatures of at least 300°–400°C are needed to alter the material, and should be maintained for several hours (Mandeville 1973:188–189; Purdy and Brooks 1971). Slow cooling is also essential to avoid breakage due to thermal shock (Purdy and Brooks 1971:324). Also, the material being altered should be relatively thin to promote even heating and cooling and to ensure complete alteration (Crabtree and Butler 1964:2). Finally, heating to temperatures over 600°C may result in the crazing or calcination of the material (Mandeville 1973:171; Crabtree and Butler 1964:2).

Recognition and Reporting Intentional Thermal Alteration

A word of caution is needed concerning the recognition of heat treatment. Accidental alteration should not be confused with intentional thermal alteration. Because the texture and luster of the outer surface of chert remain unchanged (or actually dulled) by heating, only materials worked *after* heating will exhibit the characteristic glossy flake scars. Color (i.e., reds or pinks) should not be used by itself to distinguish altered from unaltered materials. A number of experiments, including those reported here, demonstrate that color change can occur independent of structural alteration (i.e., at lower temperatures), and that color change does not always accompany the alteration process (Purdy and Brooks 1971:323; Mandeville 1973:197–198).

Reporting standards on the subject of thermal alteration currently vary greatly and need to be more uniform. In many cases, the presence of alteration is incidentally reported as part of artifact-inventory descriptions. Considerable confusion arises, however, in reports where the phenomenon is indicated for some artifacts but not for others. Only rarely is this clearly attributed to an absence of alteration. If a report indicates that one or a few artifacts were heat treated, one should not assume that all of the others were not unless this is clearly stated. Whenever possible, both the presence *and* absence of intentional thermal alteration should be unambiguously reported.

A second reporting problem concerns a lack of experimental controls. Many reports indicate the possibility of thermal alteration, but provide little information on how this conclusion was reached. Statements made about thermal alteration without reference to experiment should be viewed, at best, as untested hypotheses. Ideally, following criteria established by Purdy and Brooks (1971:324), controlled heating experiments should be conducted using materials from local sources. If the probable source is unknown, the experimental heating of site materials, as demonstrated here, can provide some measure of control. Even if the source is misidentified, the reactions observed on site artifacts can prove a useful guide.

Thermoluminescent analysis is another method of determining intentional thermal alteration (Melcher and Zimmerman 1977). Thermoluminescent analysis can, for example, provide a means of checking for altered as opposed to unaltered material in buried excavation assemblages. Its costs, however, make it impractical for analyses of large assemblages. In addition, potential determination errors suggest that the process may be only comparable in accuracy, in some respects, to comparative experimental procedures. Thermoluminescent analysis cannot, for example, differentiate intentional from accidental thermal alteration (Melcher and Zimmerman 1977:1361). Also, artifacts exposed to sunlight for several hours at any time since deposition (including in the field or laboratory) will, on analysis, yield readings suggestive of intentional thermal alteration (Melcher and Zimmerman 1977:1360); therefore, the procedure is of limited value for surface collections or for materials of questionable depositional or laboratory history. The procedure is valuable, however, because once analytical controls are met, the possibility that an artifact has undergone heating can be examined and answered. Short of the complete processing of an assemblage, thermoluminescent analysis is comparable to the experimental procedures outlined above, providing a basis for further comparative analyses.

Intentional Thermal Alteration in the Southeast

In the southeast, intentional thermal alteration of chert has been noted at a number of sites from widely scattered areas and encompassing almost all time periods. In northeast Arkansas, for example, the phenomenon appears to have been common prehistorically, as indicated by recent regionally oriented surveys along the Cache (House 1975a:84) and Village Creek (Stanfill 1977) drainages. Archaeological investigations along the Duck River in Tennessee, in the Normandy Reservoir area, indicate the presence of intentional alteration on a wide range of artifact classes (Faulkner and McCollough 1973:53, 87–155; Hood and McCollough 1976). The Duck River research indicates that the phenomenon occurs at least occasionally during much of the Archaic and

Woodland in that area. At the Thom's Creek site in central South Carolina, Trinkley (1974:18) reported the occurrence of heat-treated debitage, although period affiliations could not be determined. Ferguson (1976) has also noted the occurrence of heat treatment on artifacts from sites in the vicinity of the Fall Line in South Carolina. The probable occurrence of intentional thermal alteration has been reported at sites in Mississippi, at the Cofferdam site (Blakeman and others 1976:48), Self site (Wynn and Atkinson 1976:24), and Okashua site (Wynn and Atkinson 1976:59), although specific artifact counts were not given. Lewis (1975:29, 45–58) reported the incidence of heat treatment of artifact categories from four sites in Panola County, Mississippi.

Probable heat treatment has been reported from sites in Florida. At the Silver Springs site, Hemmings (1975:148) noted the presence of a heat-treated microcore of probable Late Archaic date. Heat treating of microlithic debitage and tools was suggested by Morse and Tesar (1974:95,97) at the Weeden Island Palm Court site in northwest Florida. Intentional thermal alteration has been noted at other Weeden Island sites in Florida, including the Scholtz Steam Plant site (Percy 1976:89–90) and the Sycamore site (Milanich 1974:22). Purdy (1975:182–183) reported the presence of intentional alteration in some lithic debris from the Senator Edwards workshop in Marion County, a site attributed to the Archaic, and she (1973) has noted also that many preceramic Archaic projectile points from Florida exhibit evidence for thermal alteration. Restriction of the phenomenon to the prehistoric period is not indicated; Milanich (1972:49) noted the occurrence of thermal alteration on early historic (seventeenth century) Potano Indian lithics from the Richardson site in north-central Florida.

Emphasis on heat treatment in recent reports from the Southeast appears to be shifting from the level of recognition and description determining the role of heat treatment in specific reduction-manufacturing processes and during specific occupational periods. Percy's (1976:90) investigations at the Scholz site, for example, indicated a greater incidence of heat treatment in debitage from advanced rather than initial stages of chert nodule reduction. Lewis (1975:29) noted a somewhat different alteration-reduction strategy on Archaic-Woodland sites in Mississippi. In this instance, pebbles were apparently heat treated before reduction occurred. An investigation of alteration by specific tool types and core reduction stages at the late prehistoric Sister Grove site in north-central Texas failed to delimit differential selection for the process, although a high overall incidence was noted (Lynott 1975:60). At the George C. Davis site, a nucleated Caddoan settlement near the Neches River in east Texas, Shafer (1973:236) observed that heat treatment sometimes occurred during quarry block or preform reduction. Where heat treatment had occurred, subsequent reduction had apparently employed soft hammer percussion, as opposed to the use of either hard or soft hammer percussion prior to alteration.

The association of heat treatment with both advanced core reduction stages and biface manufacture has been noted at a number of sites in the southeast.

Collins and Fenwick (1974:41), in an examination of chert artifacts from twelve Kentucky sites, noted a higher incidence of intentional thermal alteration on bifacial preforms and flakes detached from unheated cores than on other artifact categories. Futato (n.d.) reported a similar high incidence of intentional thermal alteration on bifacial preforms and finished bifaces on sites in the Cedar Creek basin in Alabama. An examination of possible Paleoindian artifacts from the Wells Creek Crater site in western Tennessee indicated a high incidence of heat treatment on bifacial preforms and bifacial tools (Dragoo 1973:14,17). At Wells Creek Crater the altered specimens were reportedly reduced by soft hammer percussion and pressure flaking, not hard hammer flaking on the unaltered materials (Dragoo 1973:20).

A similar linkage of thermal alteration with advanced core reduction and biface manufacture has been noted elsewhere in Alabama, at the Crump and Stuck's Bluff sites (DeJarnette and others 1975a:18; 1975b:108). At both sites most core tools and cores were of unaltered chert, while almost all of the flakes from subsequent core reduction exhibited evidence for thermal alteration. Rough core tools involving little modification of the parent material were rarely heated, but almost all of the materials subsequently reduced into bifaces were altered. Of particular interest is the observation that pebble tools of the Lively Complex are on unaltered chert, although most other chert artifacts on Lively Complex sites are altered (DeJarnette and others 1975a:18;1975b:117). The pebble tools, formed by hard hammer percussion and involving little reduction of parent material (Josselyn 1965), fit the alteration-reduction pattern observed at Crumps and Stuck's Bluff. Adherence to a perspective emphasizing temporal separation of Lively Complex tools from other site artifacts on the basis of purported raw material or technological differences (Josselyn 1965:4; Dragoo 1976:5–6) may be somewhat unsubstantiated.

It is apparent that heat treatment of chert was prevalent in many areas of the southeastern and eastern United States, although its extent is only beginning to be recognized. Crabtree's and Butler's (1964:2) original statement on thermal alteration, for example, mentioned the occurrence of the phenomenon on finely made Hopewellian artifacts from central Ohio. A similar pattern has been observed by Streuver on Middle Woodland artifacts from the lower Illinois River (Mandeville 1973:185). It is possible that other southeastern Hopewellian sites exhibit a similar pattern. Many more references for the presence of heat treatment in the Southeast are available than are noted here. This review is not intended to be exhaustive, but rather only to suggest the extent of prehistoric intentional thermal alteration in the Southeast and to delimit some of the circumstances where it has been noted.

Prehistoric Selection for Intentional Thermal Alteration

The southeastern literature indicates that intentional thermal alteration occurs over a wide geographic and temporal range, and that it tends to be associated with specific artifact categories. In particular, the process appears linked with advanced stages of raw material reduction, soft as opposed to hard hammer percussion, biface manufacture, and fine workmanship (with an inferred emphasis on pressure flaking). The differential occurrence of the phenomenon in many areas implies intentional selection. Changes brought about by thermal alteration are of a specific nature and relate to raw material appearance, mechanical fracture, and durability. The process of alteration, though not complex, required minimal controls. It follows that selection for thermal alteration will occur (assuming a basic knowledge of the process exists) where these controls can be efficiently met and where raw materials with properties similar to those of altered chert are desired but are not readily available by other means.

Evidence for intentional thermal alteration of chert may occur on prehistoric archaeological sites for one or more of the following reasons:

1. Accident
2. Specific appearance
3. Improved quality (overall knappability or workability)
4. Sharp cutting edges
5. Soft hammer or pressure flaking efficiency
6. Raw material conservation

Each reason will be discussed in turn, and possible test implications will be proposed, indicating lithic site-data conditions that may obtain if thermal alteration occurs. Known or suspected corroborative archaeological examples are cited from the Southeast or elsewhere. Finally, lithic materials from three areas—the Coastal Plain of South Carolina, the Knapp Mound Group in central Arkansas, and the Brand site in northeast Arkansas—are examined in a partial test of these criteria.

Point 1: Accident

Description. Chert may accidentally alter thermally during natural forest or brush fires, or in human-agency generated fires. If these materials are then flaked, without preselection, lithic debris with the vitreous scars indicative of alteration will obtain. Recycling of thermally altered cherts, again without preselection for the altered nature of the stone, is included in this category. Gregg and Grybush (1976:191) have recently suggested that some cherts will be unintentionally altered thermally as a result of quarrying techniques when fire is used. Cherts in or near campfires, or in burning structures, may also accidentally alter and be subject to later use.

The requirements of the alteration process—slow heating and cooling and the presence of high temperatures for relatively extended periods, together with some kind of insulation protecting the materials from direct heat—argue for a rather minimal production of accidentally altered chert. Exposure of chert to rapid heating (as in the case of open fires) is more likely to result in explosion or thermal destruction—crazing or calcination—than in alteration (Purdy 1974:40–42; Crabtree and Butler 1964:2). Similar effects are produced by rapid cooling—crazing or thermal destruction due to thermal shock, particularly if water is poured over the heated chert (Purdy 1974:42). Possible alteration agencies employing open flames would be likely to alter only those raw materials sufficiently insulated by either earth or other debris.

Possible Test Implications. (a) Infrequent occurrence (low incidence) of intentional thermal alteration in lithic assemblages; (b) random distribution of intentional thermal alteration among finished chert artifacts; and (c) association of intentionally thermally altered artifacts with fire damaged cherts.

Archaeological Examples. Gregg and Grybush (1976) make a case for the possible occurrence of thermally altered siliceous materials on prehistoric archaeological sites due to the use of fire in quarrying activity, but give no specific examples of altered remains that can be clearly attributed to such a process. Reports of fire-damaged chert on prehistoric sites are common enough in the literature (Fitting and others 1966:24; House and Smith 1975; Collins and Fenwick 1974:142), but whether the damaged material was actually altered, and was then subsequently worked, is not often delimited.

Point 2: Specific Appearance

Description. Intentional thermal alteration and subsequent flaking produces a glossy, vitreous surface that is smooth or waxy to the touch. Additionally, a striking color change may accompany the alteration; this color change may be from some other color to a pink or red due to the oxidation of iron compounds. This change in appearance may be selected without concern for, or in addition to, other advantages conferred by alteration. Specific colors, or other aspects of apearance on lithic artifacts, may function as status indicators, for example, demarcating individual or group ownership or membership (Gould and others 1971). Appearances may differ on otherwise identical artifacts used in ritual, ceremonial, or mortuary foci, as opposed to those in the secular sphere.

Possible Test Implications. (a) Differential (status-linked) occurrence or distribution of altered and unaltered cherts on the same artifact categories; and (b) high incidence of intentional thermal alteration on particular artifact classes (with no evidence for selection for other possible alteration advantages).

Archaeological Examples: Behm and Faulkner (1974:275) report the possible use of thermal alteration to improve the appearance of Hixton siliceous sandstone material in Wisconsin.

Point 3: Improved Quality

Description. The greater homogeneity and elasticity of altered, as opposed to unaltered cherts, manifested in the glass-like fracture, permit both better control and decreased effort in the reduction process. The flux-fusion of the cryptocrystals reduces the deleterious effects of internal flaws, such as those caused by fossiliferous inclusions or microfractures, by permitting a more even transmission of force through the stone. Where coarse-grained cherts occur, alteration effects producing fracture through as opposed to around cryptocrystals would be particularly advantageous, since it would greatly improve the knappability of the stone. Fine-grained cherts, in contrast, might be improved less by alteration. It follows that thermal alteration might be more likely where naturally occurring cherts are of poor knapping quality.

Possible Test Implication. Overall high incidence of thermal alteration on cherts from specific sources, regardless of artifact category.

Archaeological Examples. Lynott's (1975:60) report of a high incidence of intentional thermal alteration on all chert artifacts at the Sister Grove site in Texas may reflect alteration to improve otherwise poor knapping materials. Additionally, DeJarnette and others's (1975a, 1975b) observations at Crump and Stuck's Bluff, where virtually all cherts past initial core reduction were altered, may reflect a general concern with raw material improvement.

Point 4: Sharp Cutting Edges

Description. The glass-like fracture pattern of thermally altered cherts permits the production of sharper cutting edges than obtained from unaltered cherts of the same material. The increased elasticity and homogeneity of altered materials, however, though rendering knapping easier, also make the materials more susceptible to damage. The reduction in force needed to break altered as opposed to unaltered cherts, therefore, would argue against their use in tools subjected to strong stresses, such as in battering, pounding, or chopping functions. While light-duty cutting tools would undoubtedly benefit from alteration, the use-life of heavy-duty tools might be considerably shortened by such a selection. This would suggest that multipurpose cutting-butchering tools may be less likely to be heat treated than purely cutting tools, with heavy-duty tools the least likely of all to be of altered chert.

Possible Test Implications. (a) High incidence of intentional thermal alteration on possible cutting tools (e.g., blades, knives); and (b) low incidence of intentional thermal alteration on heavy-duty tools subject to extensive stress (e.g., adzes, hammerstones, choppers).

Archaeological Examples. The widespread association of intentional thermal alteration with biface manufacture (DeJarnette and others 1975a, 1975b; Dragoo 1973; Collins and Fenwick 1973, Futato n.d., Stanfill 1977) may be partially accounted for by the sharper cutting edges that could be produced, assuming the bifaces were used in cutting functions. The lack of alteration observed on heavy-duty chopping or battering tools on sites where considerable alteration is observed (Dragoo 1973; DeJarnette and others 1975a, 1975b) may be related to the altered chert's greater susceptibility to damage or breakage. The larger size of these tools, and hence greater alteration difficulty, is of course a factor of some importance as well.

Point 5: Soft Hammer or Pressure Flaking Efficiency

Description. Experimental analysis has demonstrated that thermally altered cherts are much more amenable to controlled pressure flaking than unaltered cherts (Crabtree and Butler 1964:1; Mandeville and Flenniken 1974:148). Less force is needed to detach flakes from altered materials. In some cases, unaltered cherts that are extremely difficult to pressure flake may be markedly improved by alteration. The efficiency of soft hammer percussion, involving a relatively diffused point of contact, is also related to the ease with which the raw material will break (Crabtree 1972:9). The homogeneous, glass-like altered cherts are less likely to shatter if soft hammer (as opposed to hard hammer percussion) with a small, focused force-contact point is used (Crabtree 1972:9). Because heat treated raw materials may be knapped with greater control, knapping procedures permitting greater control are more likely to be used.

Possible Test Implications. (a) Higher incidence of intentional thermal alteration on finished artifacts exhibiting soft hammer or pressure flaking than on artifacts produced by hard hammer percussion; and (b) higher incidence of intentional thermal alteration on manufacturing debris produced by soft hammer or pressure flaking than on debris produced by hard hammer percussion.

Archaeological Examples. Streuver observed that finely made Middle Woodland artifacts from the lower Illinois River frequently exhibited intentional thermal alteration, while poorly made artifacts were rarely altered (Mandeville 1973:185). The association of heat treatment with soft hammer or pressure flaking has been frequently noted (Dragoo 1973; Shafer 1973; Crabtree and Butler 1964), and several reports mention altered artifacts that required one or both of these procedures in manufacture (Lewis 1975; Lynott 1975; DeJarnette and others 1975a, 1975b).

Point 6: Raw Material Conservation

Description. The increase in knapping control resulting from intentional thermal alteration promotes efficient use of raw materials, since unintentional manufacturing failures due to internal flaws are minimized. While *any* use of thermal alteration reflecting selection for improved raw material quality (see above) may be considered a conservatory effort, conservation may by itself by an important consideration. If raw materials are difficult to obtain, conservation measures might be likely. Greater control would mean less waste. Negative selection for intentional thermal alteration would be expected where the process would weaken tools and shorten use-life (see "sharp cutting edges" above) reflecting conservatory as well as functional considerations.

Possible Test Implication. (a) Higher incidence of intentional thermal alteration at greater distances from sources (assuming no intervening, closer raw material sources).

Archaeological Examples. None are reported that specifically relate heat treatment to raw material conservation, although increased knapping efficiency is frequently mentioned.

Spatial Correlates of Alteration

The six points outlined above delimit what kinds of *artifacts* may exhibit ITA; it should also be possible to infer the kinds of *sites* where the process should occur. The effort required to thermally alter cherts, while not extensive, does suggest that the process will occur only in certain areas or on certain site types. Alteration may rise in incidence with increasing distance from the raw material source on all sites, for example, as a conservatory measure (Point 6). As raw material replacement becomes difficult, maximizing procedures (to reduce waste), such as bipolar flaking or heat treatment, might be increasingly called into play.

Given the time requirements of the alteration process, heat treatment might be likely to occur at the raw material source. At quarry sites, for example, heat treatment might occur if raw material quality was poor, or if the extraction process was arduous. Quarrying-associated alteration (*not* the use of fire to extract stone, but the intentional alteration of mined material) would promote the removal of undamaged high quality stone from the area. If quarrying was difficult, the time required to alter the stone may be a minor factor. Quarrying operations lasting more than one or two days would provide ample time to conduct alteration runs. If raw materials were easily obtained, however, heat treatment might be more probable at sites removed from the source. In this case, even if the alteration process was unsuccessful, replacement of the raw material would pose little problem. Crabtree and Butler (1964:3), for example, noted that heat treatment did not occur at the debris-rich Antelope Creek quarry site in southern Idaho, although it was noted at a "nearby campsite."

The time and care required to successfully alter chert suggests that evidence for the process will occur at relatively stable sites (i.e., base camps), not at temporary extraction stations. At the Holcombe Beach locality in Michigan, for example, Fitting and others (1966:112) noted that heat treatment was restricted to what appeared to be relatively permanent sites, and was only rarely noted at temporary camps. This does not suggest that intentionally thermally altered artifacts will not be found at temporary sites, but only that evidence for the alteration process will be unlikely. Even on temporary sites, lost or discarded tools of thermally altered chert would be expected, as well as debitage from resharpening and reworking. It is at base camps, however, where extensive manufacturing-reduction debris would be expected (Stanfill 1977), that most evidence for the alteration process would obtain. This evidence would probably take the form of fire-damaged rock, caches and firing areas, and extensive altered reduction-manufacturing debris (also see Purdy 1971:12–15).

One final observation should be made. Several authors have noted that intentional thermal alteration is associated with advanced core reduction. This may reflect quarrying activities where cortical material is removed to facilitate efficient transport of raw material. Recent experiments by Chapman (1976:99) indicate that the alteration process neither heals nor improves patinated stone, so the presence of a patination layer (cortex) would be irrelevant. Cortex may also have been deliberately avoided when alteration was attempted if the added thickness produced uneven heating and cooling of the interior, unweathered chert. Low incidence of intentional thermal alteration on initial stages of core reduction may, therefore, be due in part to negative properties of the cortex itself, in addition to selection for advanced decortication-reduction products.

A Test of the Model (1): Knapp (Toltec) Mounds, Arkansas

The Knapp (Toltec) Mound Group is located in central Arkansas approximately 25.6 km southeast of Little Rock, near the Arkansas River. The site is a 34-ha mound and embankment complex that Thomas (1894:243) described as "the most interesting group in the state, and, in fact, one of the most important in the United States." Several mounds on the site were tested by the Bureau of Ethnology in 1884, and the vicinity of one of the three surviving major mounds, Mound C, was tested in 1966 by the Arkansas Archeological Society/University of Arkansas Museum. The site was recently purchased by the state of Arkansas for conversion into a state park, and an extensive program of data collection and analysis has been initiated under the direction of Martha Rolingson (1977) of the Arkansas Archeological Survey. While reconstruction of the site occupational history has barely begun, it is apparent that the major periods of occupation were during the Woodland-Early Mississippian. A Coles Creek-like ceramic complex predominates all available collections, suggesting relationships with other Coles Creek sites in the lower Mississippi valley.

The 1966 test excavations on and near Mound C consisted of 112-m squares and produced a great quantity of chert debitage but relatively few finished tools (Anderson n.d. a). This sample, fortunately, has been complemented by an extensive collection of finished stone artifacts made available for study through the courtesy of Mr. Frank Chowning of Little Rock (Anderson n.d. b). Mr. Chowning's collection numbered several thousand items. He is a member of the Arkansas Archeological Society and has collected and cataloged materials from the site for 35 years. Initial examination of the Mound C area lithics suggested that many were intentionally thermally altered. Reddish cherts with glossy flake scars were a prominent minority in the assemblage. Alteration experiments were performed, employing materials from the site, on both materials that were suspected to be altered and unaltered (see Table 1); the results confirmed suspected color and texture changes and strongly supported the probability of alteration. Although the specific sources of the Knapp cherts—gravels and small cobbles—have not been determined, alteration experiments have been conducted on materials similar in appearance from several localities in the Ozarks and along Crowley's Ridge in northeast Arkansas. The alteration effects noted are comparable to those observed on the Knapp material (Michael Sierzchula, personal communication). All of the figures reported here for intentional thermal alteration are based on comparative inspection, and are thus subject to error; figures for heat treatment are best viewed as reflecting "apparent incidence of alteration."

Table 2 delimits the incidence of intentional thermal alteration observed by decortication-reduction stages on nonretouched chert artifacts in the 1966 excavation units which, however, reflect only a very small portion of the site area. It is apparent that incidence of intentional thermal alteration increases with advanced reduction. Small, fine-grained chert cobbles appear to have been brought intact onto the site; some were then altered and extensively reduced. Unaltered cherts, while present in far greater quantities, appear to have been proportionally less frequently reduced beyond initial (primary and secondary) decortication stages. Corroboration of this patterning has been noted by Stanfill (n.d.) in an analysis of lithics from across the surface of the site.

An inspection of finished chert artifacts (in the Frank Chowning collection) recovered from the surface of the site was conducted to delimit possible alteration selection practices (see Table 3). The collection procedure entailed the recovery of *all* apparent tools, broken or otherwise, which would argue for a low incidence of collector bias. To minimize this possibility, however, only clear and unambiguous tool forms of bifacial nature, and hammerstones, were examined. In particular, the incidence of intentional thermal alteration was examined on all chert arrow points, arrow preforms, dart points, miscellaneous thick bifaces, adzes, adze-like bifaces, and hammerstones. The 1966 Mound C totals, although low, are also reported, for both comparative and control purposes. The location of the site in a stoneless alluvial plain makes the recognition of hammerstones and other tools fairly easy.

The typology used generally follows that proposed by House (1975b). Thus, dart points were considered to be: "Any symmetrical pointed biface with preparation to facilitate hafting and any classifiable basal fragment of the same, not modified subsequent to breakage. Maximum thickness must be greater than 5 mm" (House 1975b:60). Arrow points were defined as: "Symmetrical pointed bifaces with a sharp tip and low edge angle (less than 45 degrees) on blade edges. Preparation for hafting . . . may not be distinct. Maximum thickness is 5 mm" (House 1975b:60). Arrow preforms are small triangular bifaces and fragments characterized by a convex, notchless base and a thickness rarely exceeding 5–6 mm. While manufacturing-replication experiments have not been accomplished, the similar size and thickness of these artifacts, together with a common high incidence of pressure flaking and thermal alteration, suggest their placement as an intermediate step in arrow manufacture (Anderson n.d. a). Definitions for hammerstones, miscellaneous thick bifaces, adze-like bifaces, and adzes are identical to those given by House (1975b:61,68).

Distinct selection preferences were indicated in the use of thermally altered and unaltered cherts on finished artifact categories in both the Chowning collection and the smaller 1966 excavation sample. Arrow points and preforms show a high incidence of intentional alteration; dart points (most of which were Late Archaic or Woodland Gary-like forms) show a low-to-intermediate incidence; miscellaneous thick bifaces, adzes and adze-like bifaces, and hammerstones exhibit a very low incidence. The high incidence of alteration observed on arrow points and preforms may be related to the fine pressure flaking employed on these artifacts, as opposed to the somewhat poorer workmanship noted on the other categories (Point 5). The probable use of the arrow and dart forms in cutting and piercing functions may also partially account for alteration selection (Point 4). The lower incidence of alteration observed on the dart points may be accounted for by a more multipurpose functional orientation, as a cutting-butchering implement (Ahler 1971) (Point 4). The high incidence of intentional thermal alteration observed on the arrow points and preforms may reflect a selection for the glossy reddish (bloodlike?) appearance (Point 2). A similar selection for altered, reddish arrow points has been noted in northeast Arkansas, on Nodena phase sites (Dan F. Morse, personal communication), and, as will be seen, in coastal South Carolina.

The low incidence of intentional thermal alteration observed on tool categories traditionally associated with heavy-duty tasks—adzes, adze-like bifaces, and hammerstones—is as expected (Point 4) because alteration would probably markedly shorten the use-life of these tools, and hence be negatively selected for. The modest incidence of alteration observed on the miscellaneous thick bifaces may reflect the loss or discard of altered bifaces that otherwise might have been further reduced. The data from the Knapp Mounds, while neither an extensive nor definitive sample, suggest that intentional thermal alteration, at least on this site, is associated with advanced core reduction and arrow point manufacture. Evidence for a negative selection on heavy-duty tools is also indicated.

A Test of the Model (2): South Carolina

In a second test of the model, the incidence of (apparent) intentional thermal alteration was recorded over a number of projectile point and tool categories from 56 sites located in the Coastal Plain of South Carolina and Georgia. All but one of these sites are located in the Coastal Plain of South Carolina, between the Savannah and Santee Rivers. The exception is the Theriault chert quarry (Brockington 1971), located a few miles west of the Savannah along Brier Creek in the lower Coastal Plain of Georgia. Chert outcroppings are reported from a number of areas in the Coastal Plain of South Carolina but only one source, the Rice site (38AL14) in Allendale County, is known to have been extensively exploited prehistorically (Stoltman 1974:173). Located about midway between the Fall Line and the ocean, the site is only a few miles from the Theriault quarry across the Savannah in Georgia. While stone from the two quarries is similar in appearance and easily confused, it is quite unlike cherts observed from other outcrops in Coastal South Carolina. Raw materials from these quarries are thus easily recognized and appear to be almost the only chert present on sites between the Savannah and the Santee. Though raw material from the Allendale quarry is occasionally of excellent quality, the majority is both highly fractured and fossiliferous, of poor quality for knapping.

A variety of materials from each quarry site was subjected to heating experiments to determine alteration effects and to facilitate recognition of altered materials on prehistoric sites in the region (see Table 1). All of the artifacts reported are from surface collections located at the Institute of Archeology and Anthropology, University of South Carolina, or in the collections of Sammy T. Lee, A. Robert Parler, and Tommy Charles, members of the Archeological Society of South Carolina. Only bifaces and biface fragments and steep-angled end or side scrapers are reported here because these artifacts were retained by all collection practices.

A number of projectile point categories were delimited on typological grounds, including Savannah River Stemmed, Gary, Guilford Lanceolate, Brier Creek Lanceolate, Morrow Mountain I and II, Kirk Stemmed, Kirk Corner Notched, and Palmer (after Coe 1964; Newell and Krieger 1949:164–165; and Michie 1968). Woodland points refer to arrow points, using House's (1975b:60) criteria, and include South's (1959:151–152) Thelma type. Use of a descriptive typology permitted relative dating of some of the artifacts, in an attempt to delimit temporal patterning in popularity or use of the alteration process. One goal was to test the hypothesis proposed by James L. Michie (personal communication) that alteration had been common in the South Carolina Coastal Plain during the Early Archaic, particularly on Kirk forms.

It is apparent that intentional thermal alteration was popular on biface forms throughout much of the Archaic in the Coastal Plain of South Carolina (see Table 3). A particularly high incidence was observed on Kirk forms, supporting Michie's contention. Only at the end of the Archaic and in the succeeding Woodland and Mississippian is there a marked decrease in the occurrence of intentional thermal alteration. This patterning has received additional corroboration from excavations conducted at the Cal Smoak site (38BM4), located along the Edisto River in the mid-Coastal Plain of South Carolina (Anderson, Lee and Parler 1979). The site produced a stratified excavation assemblage spanning the Archaic and Woodland. A high incidence of intentional alteration was observed on chert tools and debitage in levels attributable to the Archaic, with a sharp decrease noted in the higher Woodland levels.

A few Archaic point types observed in the 56 surface collections had an atypically low incidence of alteration. In these cases, however, there appear to be overriding post-depositional or functional explanations. The relatively low incidence of thermal alteration reported for Palmer projectile points (39.1%), an Early Archaic form, for example, may reflect patination. Most of the Palmer's were lightly to heavily weathered, and it was difficult to determine alteration in many cases. The low incidence of alteration noted on Late Archaic Savannah River Stemmed points may be related to the crude hard hammer percussion procedure that is believed to have been used in the manufacture of many of these points (Coe 1964:44) (Point 5). Additionally, the Savannah River Stemmed—notorious for its crudeness—appears to have been a common multipurpose tool during the Late Archaic. The low incidence of alteration may reflect this functional diversity, since unaltered material would probably have a longer use-life (Point 4). Finally, the low incidence of alteration on Savannah River Stemmed points may reflect the beginning of the pronounced decrease noted during the succeeding Woodland period.

The somewhat lower incidence of intentional thermal alteration observed on steep angled tools than on dart points in the South Carolina sample (see Table 4) may reflect the functions of each category—heavy-duty scraping (wood-bone working) as opposed to cutting and multipurpose tools (Point 4). The overall incidence of alteration on the steep angled tools is still fairly high (34.2%), however, considerably above the Woodland point average. These tool forms appear to be associated with dart rather than arrow points in the general region (Coe 1964:51, 73–79), and may reflect the overall high incidence of heat treatment during the Archaic.

The South Carolina data were also examined to determine if heat treatment was related to conscious raw material conservation (Point 6). The incidence of alteration was noted on points recovered at increasing distances from the Allendale-Theriault quarries (see Table 5). A much lower incidence of alteration was observed on points found at quarry sites than at sites a short distance away. Little difference, however, was noted with increasing distance: approximately the same incidence of alteration was observed on sites 32–80 km from a quarry as on sites over 80 km away. An admittedly crude test, the data neither strongly support nor refute the conservation model. More extensive work, employing better collected and more representative materials, is needed to test this point.

A Test of the Model (3): The Brand Site, Arkansas

The Brand site (3PO139) is a small multicomponent site near the L'Anguille River in the western lowlands of northeast Arkansas. The site has Late Archaic, Late Woodland, and Mississippian components, but is best known for its extensive Early Archaic Dalton assemblage (Morse 1973; Goodyear 1974). Excavations were conducted on the site in 1970 under the direction of Dan F. Morse, and were extensively reported by Albert C. Goodyear (1974), who provided a detailed analysis and discussion of the Dalton toolkit. The site materials form the only extensively described Dalton excavation assemblage, and their interpretation has, in part, generated an extended debate on the nature of Dalton settlement patterning, primarily between Morse (1973, 1975a, 1977) and Goodyear (1974, 1975) on the one hand and Michael Schiffer (1975; n.d.) on the other. In brief, Morse and Goodyear view Brand as an example of a specialized extraction station, with site use focusing on hunting-butchering activities performed by male task groups. Schiffer, in contrast, believes Brand served as a base camp, with extended occupations by both sexes. Arguments have arisen over the nature of the toolkits expected at each type of site, the interpretation of the remains found at Brand and other sites, the size and orientation of Dalton territories, and the nature of Dalton subsistence. Brand is clearly important to the understanding of Early Archaic lifeways in the Southeast, although the literature spawned from it is perhaps somewhat disproportionate to the amount of actual analysis that has been accomplished.

Chert sources are common in the general vicinity of Brand, and three materials appear to comprise most of the site assemblage: Crowley's Ridge gravels, Boone, and Pitkin cherts (Morse 1973:25; House 1975a:90). Crowley's Ridge gravels are exposed in erosional channels along the margin of Crowley's Ridge, located about 16 km to the east of the site; Boone and Pitkin cherts outcrop in the Ozarks approximately 64 km to the west (House 1975a; Mathis 1977). The quality of these cherts varies considerably, although fine grained materials well suited for knapping are readily available within most outcrops or erosional situations. Under the direction of Michael Sierzchula of the Arkansas Archeological Survey, a number of controlled thermal alteration experiments have been conducted with these materials (Michael Sierzchula, personal communication; also see Stanfill 1977). House (1975a:84) also reported briefly on heating experiments involving Crowley's Ridge gravels. Altered and unaltered source materials were available, and were used as a guide in the inspection of the Brand site collections.

Goodyear's (1974) summary of the Brand excavations focused on two areas: (1) the definition, description, and techno-functional analysis of the Dalton toolkit and (2) the demonstration of assemblage similarities over five apparently spatially discrete artifact concentrations found on the site. The analysis was directed toward the examination of the following hypothesis: "the five tool concentrations represent functionally equivalent working floors or activity areas occupied by males exclusively involved with butchering and bone working of white-tailed deer" (Goodyear 1974:xiii). The acceptance of this hypothesis by Goodyear and Morse, as noted, constitutes one position in the so-called Dalton settlement controversy. It is assumed, for the purposes of this analysis, that the floors at Brand are discrete, although recent work by Goodyear (personal communication) suggests that some redefinition may be necessary.

The presence and absence of intentional thermal alteration was examined over the 33 tool types that Goodyear (1974:82) defined as the principal chipped stone forms within the Brand-Dalton toolkit (see Table 6). All typed artifacts from the five floors, and specimens recovered from disturbed upper levels and from the site surface were examined. Floor assignments and tool type were obtained from Goodyear and Morse's notes on each specimen bag. It was possible to account for all 415 toolkit items found within the 5 floors, permitting an examination of the incidence of intentional thermal alteration by these proveniences, as well as over the entire assemblage (see Table 7). There are, however, minor discrepancies between Goodyear's (1974:19–63) site totals and those reported in Table 6. The differences appear to reflect final cataloging decisions, as well as the inclusion here of subsequent (post-excavation) collections from the site surface. An inventory of the artifacts examined in the present analysis, including catalog number, tool type, and the author's alteration-analysis judgment, is on file, with the site collections, at the Jonesboro station of the Arkansas Archeological Survey.

The incidence of intentional thermal alteration at Brand was reported using three categories: (1) probable alteration, (2) possible/questionable alteration, and (3) unaltered. The use of three categories instead of the altered/unaltered dichotomy used previously in the South Carolina and Toltec analyses reflected the difficulty of determining alteration on local cherts. Almost all of the Dalton artifacts were on fine-grained materials; attributing surface glossiness to alteration was risky. Difficulties in determining heat treatment on northeast Arkansas materials have been previously noted by House (1975a:84, 1977:31), who indicated that extensive experimentation would be needed to reliably sort altered and unaltered specimens. In the present analysis "probable alteration" refers to artifacts characterized by a glossy, vitreous surface coupled with a pink to reddish color. "Possible/questionable alteration" refers to artifacts with a suspicious pink or reddish hue, an unusually glossy surface (beyond the range expected from inspection of local cherts), or possessing other signs of heating, such as potlid fractures. The alteration totals from Brand, 25.6% (see Table 6), given the aforementioned difficulties, are probably high. Some of the assemblage was almost certainly accidentally heated or fire-damaged, rather than intentionally thermally altered. The actual incidence of intentional prehistoric thermal alteration is believed to be somewhere around the lower figure indicated in Table 6 (9.4%), under "Probable Alteration."

The Brand assemblage is characterized by a very low overall incidence of intentional thermal alteration on finished tools, at least when compared with the South Carolina and Toltec examples. Fewer than 10% of the tools exhibit good evidence for alteration, and even when doubtful cases are added the incidence is still only about 25%. The Dalton tools are almost uniformly made on high quality, fine-grained cherts, suggesting careful raw material procurement and a corresponding reduced need for intentional thermal alteration as a procedure to improve resource quality (Point 3). Some selection for alteration was observed, however, with the highest incidence on Dalton points and point fragments, *pièces esquillées*, and adze fragments. Steep angled scraping tool forms, in contrast, exhibit a very low incidence of alteration, possibly reflecting avoidance to deter a possible decrease in tool use-life, particularly if these tools were used in strenuous, heavy-duty tasks (Point 4).

The incidence of intentional thermal alteration observed at Brand appears to reflect selection for sharp cutting edges (Point 4) and possibly improved pressure flaking ability (Point 5). Dalton points have been demonstrated to be highly efficient butchering tools (Michie 1973), while *pièces esquillées* may have been used for splitting bone (MacDonald 1968:88–89; Goodyear 1974:63). Both are functions where sharp cutting edges would have been desirable. The detailed case Goodyear (1974:19–33) presents for Dalton resharpening is a strong argument for sharp cutting edge selection. The moderate incidence of alteration observed on the adze fragments, in contrast, may reflect improvement of the knapping quality of the parent stock to facilitate reuse in another form (Point 3). Some of the Brand adze fragments were used as cores, knives, and wedges (Goodyear 1974:41), and thermal alteration may have been employed at this stage. One adze butt knife (Cat. No. 2112) exhibits a dull finish over the original adze surface, with glossy flake scars indicative of intentional thermal alteration in several locations: this strongly implies alteration and reduction *after* use as an adze had ceased. The low overall incidence of intentional thermal alteration in the Dalton toolkit at Brand is almost certainly related to the local availability of high-quality stone. Some alteration is evident, however, and it appears that the process was a technological option available to and understood by local Dalton groups. Intentional thermal alteration, it should be noted, is strongly suspected on other Dalton remains from northeast Arkansas, notably from the Sloan site (3GE94), a possible cemetery assemblage currently undergoing detailed analysis (Morse 1975b; personal communication). Knowledge of the alteration procedure appears to have been spread throughout the local population; none of the Brand floors, assumed to be discrete behavioral loci, exhibit unusual high or low incidence of the phenomonon (see Table 7).

This paper can add little to the Dalton settlement debate, except a plea for more analysis of, rather than speculation over, existing collections. The thermal alteration evidence does reinforce two of Goodyear's contentions: (1) that the floors are similar and (2) that the presence of adze fragments on the site appears related to recycling phenomenon. Inspection of site debitage indicates a low incidence of heat treatment, suggesting some on-site reduction of altered material; but whether the actual process of alteration (a possible base camp activity) occurred could not be determined.

Test Results

The examples demonstrate that intentional thermal alteration in the Southeast is not rigidly linked to certain time periods or tool forms. The high incidence of intentional thermal alteration observed on coastal South Carolina Archaic dart forms, and the low incidence observed on arrow forms, for example, is exactly opposite the pattern noted at the Knapp Mounds in Arkansas. Furthermore, the low overall incidence of intentional thermal alteration observed in the Early Archaic assemblage at Brand contrasts with the high incidence noted on Early Archaic materials from coastal South Carolina. Selection for thermal alteration to improve local raw material quality (Point 3) appears to be a partial explanation for these apparently contradictory situations. The cherts from South Carolina are coarse grained, highly fossiliferous, and difficult to knap unless altered. The cherts employed at Brand and Knapp, however, are fine grained and fairly easy to work (although their quality was also improved by alteration). High overall incidence of thermal alteration appears to reflect a general attempt to improve the knapping quality of the stone.

Manufacturing procedures and tool function also appear to be considerations behind aboriginal selection for altered material: sharp cutting edge (Point 4), improved pressure flaking (Point 5), and, to a lesser extent, appearance (Point 2) are the principal desired attributes. No evidence for the accidental occurrence of thermal alteration (Point 1) was noted, and attempts to test for the possible use of the technique as a conservation measure (Point 6) by examining the incidence of the phenomonon with distance from raw material sources proved inconclusive. The South Carolina arrow points initially posed a problem for many are as finely worked as those from Knapp, yet differ in lacking evidence for alteration. Again, raw material quality appears to be a partial consideration. South Carolina arrow points are almost invariably made from fine-grained cherts, reflecting careful quarrying activity, thus reducing the need for alteration. The high incidence of alteration observed on the Knapp arrows, given the excellent quality of local materials, also appears partially related to selection for the reddish luster. Interestingly, some 10% of the South Carolina arrow points exhibit reddish colors indicative of heating, yet lack evidence for subsequent chipping in the form of vitreous flake scars. This may reflect post manufacture heating specifically for the color change. Selection for reddish colors on southeastern tool forms, particularly on late prehistoric arrow points, bears additional investigation.

Conclusion

The archaeological materials from Brand, Knapp, and coastal South Carolina, and the general review of the regional literature, indicate that intentional thermal alteration may occur in different and seemingly contradictory circumstances for a number of reasons. Though it is improbable that hard-and-fast rules are likely to appear encompassing every occurrence of the phenomenon, some degree of explanation and prediction does seem possible. Heat treatment in the southeastern United States is not a phenomenon rigidly restricted to particular time periods or artifact categories, rather, it appears to be related to local raw material quality and to perceived functional/manufacturing objectives.

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TABLE 1

Summary Data for Thermal Alteration Experiments, Arkansas and South Carolina Cherts

Specimen	*Equipment*	*Method*	*Temp.*	*Time*	*ITA?*	*Color Changes*	*Comments*
Knapp Mounds: Misc. flakes and cores	Electric kiln w/ precision temp. control (5°C)	Sand bath, slowly heated and cooled	250°C	12 hrs	No	Light brown or gray to pink or pinkish red, interiors of some unchanged	On several specimens only the exterior (cortex) changed color, with the interiors unchanged
Knapp Mounds: Misc. flakes and cores	"	"	375°C	20 hrs	Yes	"	Most specimens turned a dark pinkish-red to red throughout
Theriault Quarry Misc. flakes and chunks	Electric enameling kiln, w/20°F temp. control	Wrapped in foil, slowly heated and cooled	375°C	36 hrs	Yes	No change, light reddish brown, dark red, light grayish brown	Most of the material did not alter or markedly change color (some took on a slight pinkish-gray hue)
Allendale Quarry: Misc. flakes and chunks	"	"	"	"	"	"	"
Allendale Quarry: Core A, Misc. flakes	Electric kiln w/ precision temp. control (5°C)	Sand bath, slowly heated and cooled	300°C	20 hrs	No	No change, slight bluish gray	Little color change apparent
Allendale Quarry, Core A, Misc. flakes	"	"	350°C	14 hrs	Yes	Light bluish gray, light pinkish red	Little color change, all material altered
Allendale Quarry, Core B, Misc. flakes	"	"	325°C	19 hrs	No	Light pinkish white, dark red	Pronounced color change (yet no alteration)
Allendale Quarry, Core B, Misc. flakes	"	"	360°C	23 hrs	Yes	Light pink, dark red	Pronounced color change, all material altered

(Additional information in Anderson n.d. a and Anderson, Lee and Parler 1979).

TABLE 2

Incidence of Apparent Intentional Thermal Alteration, 1966 Mound C Excavations
Knapp Mound Group

	Cores	*Primary Dec.*	*Secondary Dec.*	*Interior*	*Totals*
Number of altered pieces	13 (12.6%)	9 (14.5%)	178 (20.8%)	173 (30.4%)	373 (23.5%)
Number of unaltered pieces	90 (87.4%)	53 (85.5%)	677 (79.2%)	396 (69.6%)	1216 (76.5%)
Totals	103	62	855	569	1589

TABLE 3

Chert Tools, Knapp Mound Group: Incidence of Apparent Intentional Thermal Alteration

CHOWNING COLLECTION

	Dart Points	*Arrow Points*	*Arrow Preforms*	*Misc. Thick Bifaces*	*Adzes and Adze-like bifaces*	*Hammer-stones*
Number of altered pieces	19 (21.6%)	154 (56.8%)	40 (85.1%)	4 (13.3%)	3 (9.4%)	2 (2.6%)
Number of unaltered pieces	69 (78.4%)	117 (43.2%)	7 (14.9%)	26 (86.7%)	29 (90.6%)	75 (97.4%)
Totals	88	271	47	30	32	77

1966 EXCAVATION SAMPLE

	Dart Points	*Arrow Points*	*Arrow Preforms*	*Misc. Thick Bifaces*	*Adzes and Adze-like bifaces*	*Hammer-stones*
Number of altered pieces	1 (16.7%)	9 (64.3%)	4 (66.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Number of unaltered pieces	5 (83.3%)	5 (35.7%)	2 (33.2%)	2 (100.0%)	1 (100.0%)	0 (0.0%)
Totals	6	14	6	2	1	0

TABLE 4

Incidence of Intentional Thermal Alteration by Specific Point and Tool Types:
Summary Data from 56 Sites in the Coastal Plain of South Carolina and Georgia
(from Anderson, Lee, and Parler 1979)

	WOODLAND MISSISSIPIAN				*LATE ARCHAIC*			*MIDDLE ARCHAIC*			*EARLY ARCHAIC*		
	Steep Marginal Tools	*Nondiagnostic Bifaces and fragments*	*Woodland (a)*	*Savannah Stemmed (b)*	*Gary (c)*	*Guilford Lanceolate (b)*	*Brier Creek Lanceolate (d)*	*Morrow Mtn II (b)*	*Morrow Mtn I (b)*	*Kirk Stemmed (b)*	*Kirk Corner Notched (b)*	*Palmer (b)*	*Totals*
Number of altered pieces	39 (34.2%)	221 (42.7%)	9 (4.6%)	12 (14.6%)	44 (51.8%)	20 (80.0%)	6 (85.7%)	47 (66.2%)	4 (57.1%)	25 (75.8%)	48 (67.4%)	18 (39.1%)	493 (39.3%)
Number of unaltered pieces	75 (65.8%)	297 (57.3%)	188 (95.4%)	70 (85.4%)	41 (48.2%)	5 (20.0%)	1 (14.3%)	24 (33.8%)	3 (42.9%)	8 (24.2%)	23 (32.4%)	28 (60.9%)	763 (60.7%)
Totals	114	518	197	82	85	25	7	71	7	33	71	46	1256

(a, "Arrow points" (after House 1975b:60), including South's (1959:151–152) Thelma; b, from Coe 1964; c, from Newell and Krieger 1949:164–165; d, from Michie 1968)

TABLE 5

Incidence of Intentional Thermal Alteration with Increasing Distance from Raw Material Source: Analysis of Coastal S.C. Bifaces and Biface Fragments

Distance	*# of sites*	*Altered Bifaces*	*Unaltered Bifaces*	*Totals*
Quarry (9BK2)	1	19 (25.3%)	56 (74.4%)	75 (6.6%)
20–50 miles from quarry	44	345 (40.7%)	503 (59.3%)	848 (74.3%)
More than 50 miles from quarry	11	90 (41.4%)	129 (58.9%)	219 (19.1%)
Totals	56	454 (39.8%)	688 (60.2%)	1142 (100.0%)

TABLE 6

Incidence of Apparent Intentional Thermal Alteration by Tool Type Brand Site (3PO139), Arkansas

Tool Type No.	Artifact Type	Probable Alteration		Possible/ Questionable	Unaltered	Total	% Prob/Poss.
1 & 2	Preform & Completed Preform	0	(0.0%)	4	8	12	(33.0%)
3	Initial Dalton	3	(20.0%)	1	11	15	(26.7%)
4	Advanced Dalton	2	(3.8%)	7	44	53	(17.0%)
5	Final Dalton	4	(16.7%)	5	15	24	(37.5%)
6	Dalton Pt. Endscraper	1	(14.3%)	2	4	7	(42.9%)
7	Dalton Pt. Burin	3	(21.4%)	3	8	14	(42.9%)
8	Dalton Pt. Spokeshave	0	(0.0%)	0	1	1	(0.0%)
9	Dalton Pt. Perforator	0	(0.0%)	1	0	1	(100.0%)
10	Dalton Pt. Tip	2	(4.8%)	1	39	42	(7.1%)
11	Dalton Pt. Body	5	(10.0%)	8	37	50	(26.0%)
12	Dalton Pt. Base	6	(18.8%)	6	20	32	(37.5%)
13	Dalton Pt. Ear	0	(0.0%)	9	21	30	(30.0%)
14	Hafted Endscraper	1	(5.9%)	3	13	17	(23.5%)
15	Hafted Endscraper with Spur	0	(0.0%)	0	6	6	(0.0%)
16	Unhafted Endscraper	1	(7.7%)	3	9	13	(33.3%)
17	Discoidal Endscraper with Spurs	0	(0.0%)	2	1	3	(66.6%)
18	Side Scraper with Steep Retouch	3	(12.5%)	2	19	24	(20.8%)
19	Side Scraper with Steep Retouch on Decortication Flake	0	(0.0%)	0	1	1	(0.0%)
20	Hafted Spokeshave with Spurs	0	(0.0%)	0	4	4	(0.0%)

21	Unhafted Spokeshave	0	(0.0%)	1	5	6	(16.7%)
22 & 23	True Blade Knive & Blade-like Flake w/Marginal Retouch	4	(6.6%)	10	47	61	(23.0%)
24	*Pièce Esquillée*	12	(11.3%)	21	73	106	(31.1%)
25 & 26	Graver on Flake & Blade-like Graver	4	(7.1%)	11	41	56	(26.8%)
27	Dulled Complete Adze	1	(50.0%)	0	1	2	(50.0%)
28	Adze-Wedge	0	(0.0%)	0	3	3	(0.0%)
29	Adze-Knife	6	(21.4%)	1	21	28	(25.0%)
30	Plain Butt	1	(14.3%)	1	5	7	(28.6%)
31	Adze Core	0	(0.0%)	1	2	3	(33.3%)
32	Adze Bit	1	(12.5%)	0	7	8	(12.5%)
33	Butt Fragment	0	(0.0%)	0	8	8	(0.0%)
Totals		60	(9.4%)	103	474	637	(25.6%)
			29				

TABLE 7

Incidence of Apparent Intentional Thermal Alteration by Concentration Units at the Brand Site (3PO139): Chi-Square Contingency Analysis

	Floors A	Floors B/C	Floors C/D	Floors F	Floors G	Totals
Unaltered	75 (67.2)	70 (70.3)	53 (58.5)	60 (64.8)	70 (67.2)	328
Altered	10 (17.8)	19 (18.7)	21 (15.5)	22 (17.2)	15 (17.8)	87
Totals	85	89	74	82	85	415

H_0 = There is no difference in the occurrence of altered and unaltered chert tools between the concentration units (floors) at Brand.
Alpha (level of significance) = 0.05
$X^2 = 9.0$ df = 4 $0.10 < p < 0.05$
H_0 is accepted (no significant difference occurs)

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