

2026 Mississippi Archeological Association/Alabama Archeological Society Joint Meeting Field Trip Guidebook: Tallahatta Formation Lithic Procurement Site

In archaeology, lithics are stone artifacts that have been purposefully modified, or worked, by human hands. In this science, where anthropological theory of the cultural past is pondered and debated largely on the examination of worked stone objects, an understanding of the presence and source of naturally occurring stones or native materials throughout the local geology is vital information when investigating indigenous archaeological sites. Natural availability and quality of geologic resources are not equally distributed. Therefore, understanding the source of these native lithic materials provides the archaeologist insight into the relationships of past cultures with each other, their available geological resources, and how these relationships may have evolved.

Quantifying the breadth of exotic trade of geologic material into this region throughout the thousands of years of the archaeological past would be an exhaustive study. Cultural boundaries undoubtedly changed much throughout history. For the sake of this webpage, the following characterizes natural lithic resources that exist within the artificial borders of the state of Mississippi.

Mississippi's geology at the surface resides entirely in the Gulf Coastal Plain. This means that all the deposits found at the surface are sedimentary in origin. Mississippi is comprised of alternating layers of a variety of sand, silts, limestones, and clays that may only locally form into hard rock. Gravel deposits were brought by rivers that crossed the coastal plain, carrying with them chert along with a host of other rock types from distant bedrock regions.

Gravel deposits occur sporadically in geologic units which outcrop only in the northeast, western, and southern portions of Mississippi. Characterizing, describing, and differentiating gravel resources has been the focus of strategic geologic mapping efforts in recent years by the Mississippi Geological Survey. Previous literature by geologists once placed most outcrops of heavily oxidized, red sand and/or gravel-bearing deposits in Mississippi in the waste-basket term "Citronelle Formation." This erroneous characterization was broadly applied for over a hundred years with disregard to the age, stratigraphic position, and even petrology of the deposits. Archaeologists furthered this

misconception by confusing brown to honey-colored chert, “Citronelle Chert” as a chert type, regardless of the geologic province. Brown to honey-colored chert is ubiquitous to all of Mississippi’s chert-bearing gravel deposits. The “Citronelle Formation” is no longer recognized in Mississippi by the Mississippi Geological Survey. Outcrops once referred to as “Citronelle” have now been differentiated and properly attributed stratigraphically by geologic mapping. This work is being replicated by other state surveys where the “Citronelle Formation” had been previously mapped.

Varieties of chert and quartzite were the most utilized materials to produce knapped stone tools in Mississippi. This is due to their inherent mechanical property to propagate a predictable conchoidal fracture and their local availability as a geologic resource. Other geological resources were also modified and utilized in various ways according to their own suitability and physical properties.

Chert is microcrystalline to cryptocrystalline quartz that forms from the migration, concentration, and precipitation of silica. This primarily occurs as a diagenesis of limestone. This geochemical process results in silica crystallizing in the form of nodules or, in some cases, entire beds. Chalcedony is a term given to a more pure, often translucent, form of chert that forms from precipitation of silica-rich groundwaters. Though it can also form in limestones, it is often found in other lithologies as a void-filling mineral growth or replacement of fossils, such as in petrified wood.

Understanding sandstones, quartz, and quartzite can be quite confusing for both the collector and professionals alike. Sandstones are sedimentary rocks that can be made up of any sand-size particles. In Mississippi, most sandstones are made up of quartz grains. Sandstones can be cemented to various degrees of competence by a few different methods. Types of cement such as opal, chert, chalcedony, and quartz typically form the strongest bonds between the quartz grains. Iron-rich minerals can run the spectrum from weakly cemented limonite to much stronger bonded mineral cement such as siderite and goethite. Sandstones can also form by mineral re-growth of the individual quartz grains in the sand by filling neighboring pore space. The degree of cementation by this method also runs the spectrum due to the amount of pore space that is filled to interlock them.

The mechanical properties of sandstone are very important when describing lithic materials. Quartzite is a special term used for a sandstone that is cemented to such a high degree that it fractures preferentially across its sand grains. Whereas common sandstone preferentially breaks around the grains, disaggregating the stone. Because of this, quartzite can be knapped while sandstone cannot. This is an important distinction to make because all geologic resources in Mississippi that contain quartzite also contain sandstone and are utilized and processed differently based on their mechanical properties.

Quartzites can form in two different rock types, either sedimentary or metamorphic. Quartzites that formed as sandstones in sedimentary environments and were cemented by sedimentary processes are termed orthoquartzites while metaquartzites are sandstones that formed in sedimentary environments and were cemented by metamorphic processes. Because Mississippi's geology at the surface is all sedimentary rock, quartzites in sandstone-bearing geologic formations are all classified as orthoquartzites. Quartzite constituents from gravel, however, can contain clasts of both metaquartzite and orthoquartzite depending on the bedrock from which they were derived. Some of Mississippi's orthoquartzites are unstable over both time and environment, particularly those that rely on an abundance of opaline-silica as a cement. Artifacts made of an opaline-cemented quartzite can degrade, resulting in a once competently knapped artifact reducing back to a friable sandstone.

Quartz varieties are also a common constituent of all gravel resources in Mississippi. They are typically white-to-pinkish, translucent to even clear. Quartz gravel originates from a variety of igneous, metamorphic, or even other sedimentary bedrock sources. Varieties of crystalline quartz may also warrant clarity in differentiating from a quartzite when describing lithic materials in the archaeological record. Vein quartz, igneous quartz, and metamorphic quartz can often be misdiagnosed as quartzite because they commonly exhibit similar, grainy textures. This can be caused by crystals crowding one another and twinning during formation, like what is commonly exhibited in varieties of vein quartz. Metamorphic and igneous quartz sources can also exhibit grainy textures caused by extensive fracturing of quartz crystals.

Tallahatta Orthoquartzite

Tallahatta Quartzite was mined extensively from outcrops in east-central Mississippi and west-central Alabama. Tallahatta Quartzite is a silica-cemented, nearly pure quartz sand. Silica cement is predominantly opal-CT with varying amounts of chalcedony, and quartz. Tallahatta quartzite is often translucent and ranges in color from white, green, yellow-to reddish-brown, and black. Mineral inclusions of glauconite and mica are common. Fossil inclusions such as invertebrate burrows typically occur within quartzite beds. Glauconite impurities manifest into “snowflake” patterns in the stone as these mineral inclusions weather from the quartzite. Tallahatta Quartzite varies highly in stability and can weather



back to friable sandstone. Because of this, artifacts of Tallahatta Quartzite are commonly referred to as “sugar-quartz” by some collectors. Some Tallahatta Quartzite artifacts remain stable and retain their vitreous appearance. This can be attributed to several factors including a higher stability of silica cement, the lack of glauconite inclusions, or artifacts that are deposited in a consistently wet environment. Tallahatta Quartzite in Mississippi is concentrated, but not restricted to the Basic City Member of the Tallahatta Formation and occurs along the outcrop belt from Neshoba County to the Alabama line. Concentrations of

quarry sites can be found along the Chunky River and its tributaries in Lauderdale County, Tallahatta Creek in Newton County, and the Chickasawhay River in Lauderdale and Clarke County. The utilization of Tallahatta Quartzite originated in the Paleolithic cultural period in the absence of other geologic materials suitable for knapping in east-central Mississippi. Tallahatta Quartzite had a wide cultural distribution and has been found on archeological sites throughout Mississippi.



Tallahatta Orthoquartzite in Basic City Member of the Tallahatta Formation on Mount Barton in Meridian Mississippi.



*Kosciusko Orthoquartzite hammerstone used for mining Tallahatta Orthoquartzite at the David Thompson Quarry
(22Ne579)*

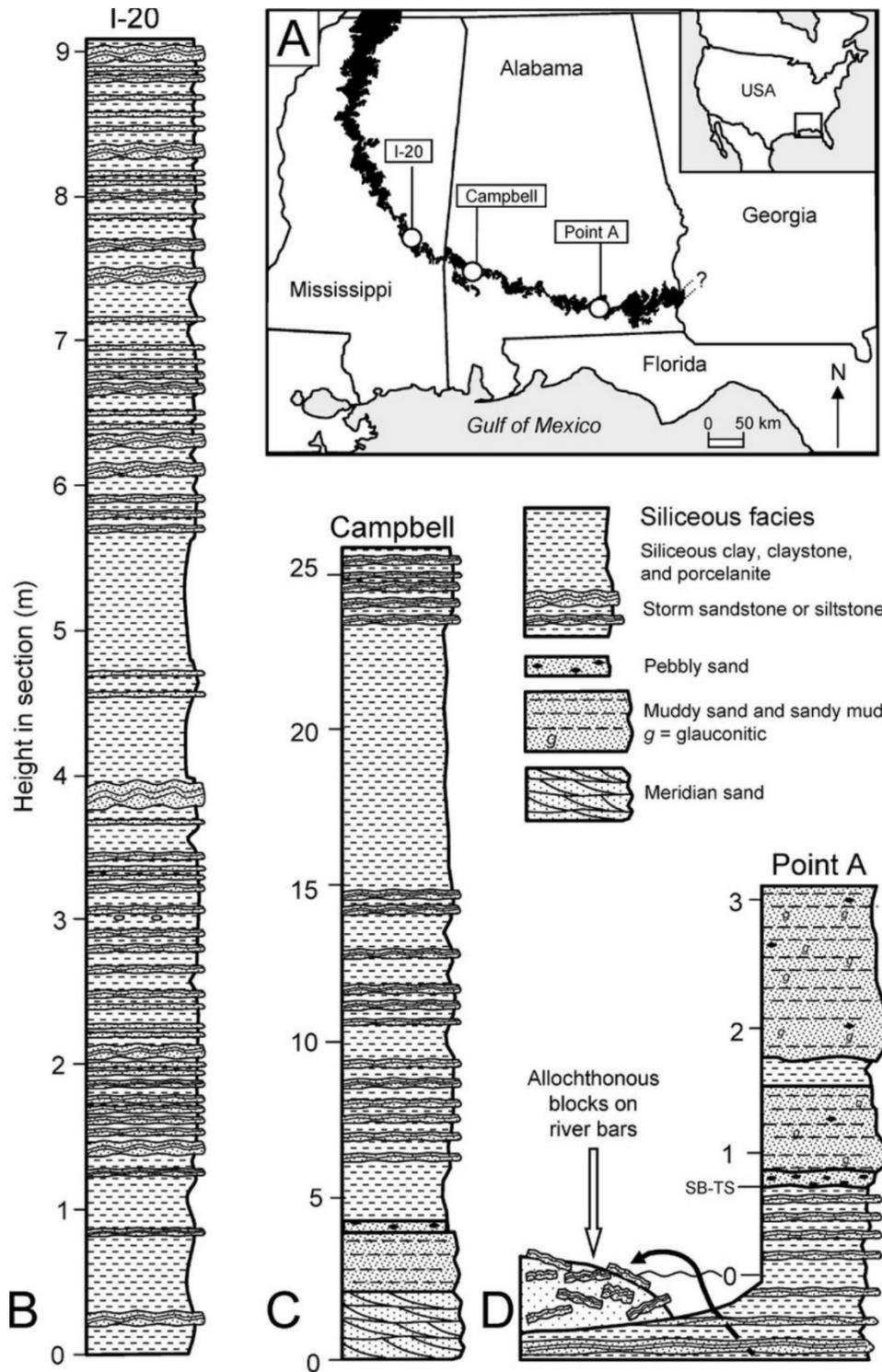
Tallahatta Agate

Tallahatta Agate is an opaline-rich chalcedony found in the Basic City Member of the lower Eocene age Tallahatta Formation in east-central Mississippi and west-central Alabama. This high-quality lithic material is found associated with occurrences of Tallahatta Quartzite as mineralized fillings of joint fractures, fossil burrow casts, and mollusk fossil molds. The stone is translucent yellow to orange in most circumstances but owes its other variations in color to mineral impurities. The natural occurrence of Tallahatta Agate is far scarcer than that of Tallahatta Quartzite and constitutes a rare occurrence in the archaeological record. Because it can be found at the same outcrops, its distribution may mirror that of Tallahatta Quartzite. Tallahatta Agate is remarkably similar in appearance to Florida's intensely utilized Agatized Coral. Tallahatta Agate can be differentiated by laminar bedding that often inhibits the knapping properties of the stone.

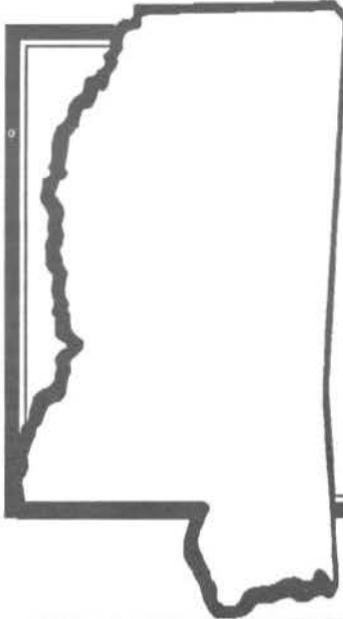




Tallahatta Agate from a prehistoric lithic procurement site Monroe County, Alabama.



Ichnology of Siliceous facies in the Eocene Tallahatt formation (Eastern United States Gulf coastal plain): Implications for Depositional conditions, storm processes, and diagenesis; Charles Savrda, et. al; Sept. 2010 Palaios



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INDIAN ARTIFACTS OF TALLAHATTA QUARTZITE FROM TALLAHATTA CREEK SITE 22-LD-645, EAST-CENTRAL MISSISSIPPI

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INTRODUCTION

Hard silicic rock was the "industrial" material of Mississippi's native Indian population before the advent of European settlers and metal implements. The Indians sought rocks of rigid specifications to be used in the knapping (chipping) of stone tools and projectile points. These specifications included a conchoidal fracture for knapping, a hard and durable stone that could maintain a sharp point and cutting surface, and sufficient size to provide a core from which preforms could be cleaved. Such rock was especially prized in the Gulf Coastal Plain Province of Louisiana, southern Arkansas, Mississippi, and southern Alabama where the surface consisted largely of unlithified Tertiary and Cretaceous sediments. In Mississippi, Indians generally sought these rocks in the chert gravels of certain rivers and streams. An exception to this was an industry that developed between 9000 and 3000 years ago in east-central Mississippi where Indians quarried and worked quartzites from the Tallahatta Formation to make preforms, points, and other tools. These implements were widely traded and are readily recognizable as to their rock type and source. One site at which the Tallahatta quartzite was worked into implements,

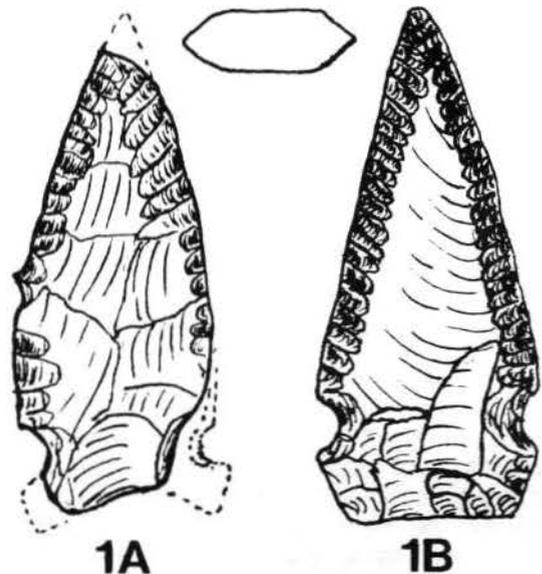


Figure 1. Early Archaic side-notched projectile points. Illustrated at actual size.

site 22-LD-645, was recently noted along Tallahatta Creek in Lauderdale County, Mississippi. The differing types of points found at this site suggest that it was an active work site between 9000 and 3000 years ago.

TALLAHATTA QUARTZITES

The name Tallahatta comes from an Indian term meaning white rock. This name is appropriate for the formation, which is light in color where it is exposed at the surface. Perhaps the most noted exposures of this formation are the off-white claystones seen in the vertical road cuts west of Meridian, Mississippi, on Interstate 20. Outcrops of erosion-resistant Tallahatta lithologies form a series of ridges and hills known as the Tallahatta cuesta. This cuesta extends from the formation's type locality in the Tallahatta Hills of southern Alabama northwestward through Lauderdale County and into north-central Mississippi. The Tallahatta Formation is Middle Eocene in age and consists of silicic claystones, sands, and sedimentary quartzites of marine origin. The quartzites contain quartz sand and some glauconite cemented together by silica. This cementation binds the grains together so strongly that when broken the fracture cuts through individual grains rather than around them as it would in a sandstone. Tallahatta quartzites have a characteristic gray to white sugary texture with scattered dark grains of glauconite. Along a broken surface, fracture surfaces of individual quartz sand grains are slightly inclined to that of the matrix. This gives fracture surfaces a sparkling appearance.

Tallahatta quartzites are unique among coastal plain rocks for their hardness and durability. Early settlers used these rocks for millstones. While quartzite ledges of a foot or less in thickness are common in the Tallahatta Formation, only a few are of the quality needed for knapping tools. For this reason, the Indians prospected for outcrops or stream beds with the high quality stone. Sites for this stone were discovered and rediscovered over a period of several thousand years by various Indian groups.

PREHISTORIC UTILIZATION OF TALLAHATTA QUARTZITE

The prehistoric utilization of Tallahatta quartzite is an interesting phenomenon to archaeologists for several reasons. Perhaps of greatest interest is the fact that this distinctive-looking stone became widely dispersed from the area where it naturally occurs in east-central Mississippi and adjacent parts of Alabama. How it came to be so widely dispersed is not known at present. It is generally assumed that it was traded from one group to another. It appears at least as far away as Louisiana and Arkansas.

Most of the flaked stone tools used by aboriginals in Mississippi were made from gravel chert which was abundant in many of the state's rivers and streams. This material was collected on gravel bars where it was tested, roughed out into blanks or preforms, and transported back to other locations where it was worked into finished tools or cached at strategic locations until it was needed. Although the gravel

deposits contain minorities of workable quartzite, it is invariably stained brown, tan, or yellow as is most of the chert and is not to be confused with Tallahatta quartzite.

The concentration of large amounts of flakable stone in a fairly restricted area has resulted in some interesting archaeological situations. In some locations along the Tallahatta quartzite outcrops, massive mining operations were undertaken at least as early as the Middle Archaic Period (ca. 8000-5000 years ago). Great slabs or boulders of quartzite were reduced on the spot (for instance at sites 22-LD-550 and 22-LD-552) into flakes of various sizes and transported in bulk to more permanent sites (such as 22-LD-521) where they were further reduced into blanks or preforms for ultimate transportation to distant sources, cached locally, or worked into finished tools on the spot (O'Hear and Lehmann, 1983, p. 2-5). The quarry and workshop sites of this industry exhibit much greater lithic debris than any sites where gravel chert was worked.

Two interesting caches of Tallahatta quartzite have been reported to the Department of Archives and History. Each consisted of between two and three dozen artifacts. One cache, discovered in Simpson County, was composed of large blanks that were actually flakes of quartzite that had been trimmed on one or both sides into roughly triangular pieces about 4-5 inches long, 3-4 inches wide, and as thick as one inch (Figure 4A is a similar specimen). The other cache, found near Hattiesburg in Forrest County, contained what are termed advanced stage preforms. In other words, these were almost completed tools, which in this case were probably intended as projectile point/knives. The finished tools may have been Shumla or similar projectile points probably dating between 4000 and 2500 years ago.

Large Tallahatta quartzite tools of the Middle Archaic Period are commonly found cached with blue-gray Fort Payne chert tools in the upper reaches of the Tombigbee River watershed and in one site in Lauderdale County. Tallahatta quartzite blanks or preforms at the latter site were being prepared presumably for trade. Here several completed Middle Archaic projectile points of blue-gray Fort Payne chert were discovered (site 22-LD-521). The chert probably came from the Tennessee River area of northern Alabama. Commodities other than stone could well have been traded, but evidence of that trade, such as food and basketry, decomposed with time.

Tallahatta quartzite was used throughout all of the cultural periods recognized by archaeologists. There are Paleo-Indian (ca. 12,000-10,000 years ago) and Early Archaic (ca. 10,000-8000 years ago) tools of this material. The Paleo-Indian tools are very rare and apparently the potential of the concentrated quantities of material was not recognized during that period. Subsequent periods saw rapid increases in its utilization. Most of the artifacts of Tallahatta quartzite found great distances from the outcrop areas are Middle Archaic with representation remaining strong in the Late Archaic Period (ca. 5000-2500 years ago). Trade apparently diminished considerably after that time although tools of the later periods are occasionally found at great distances from the source area.

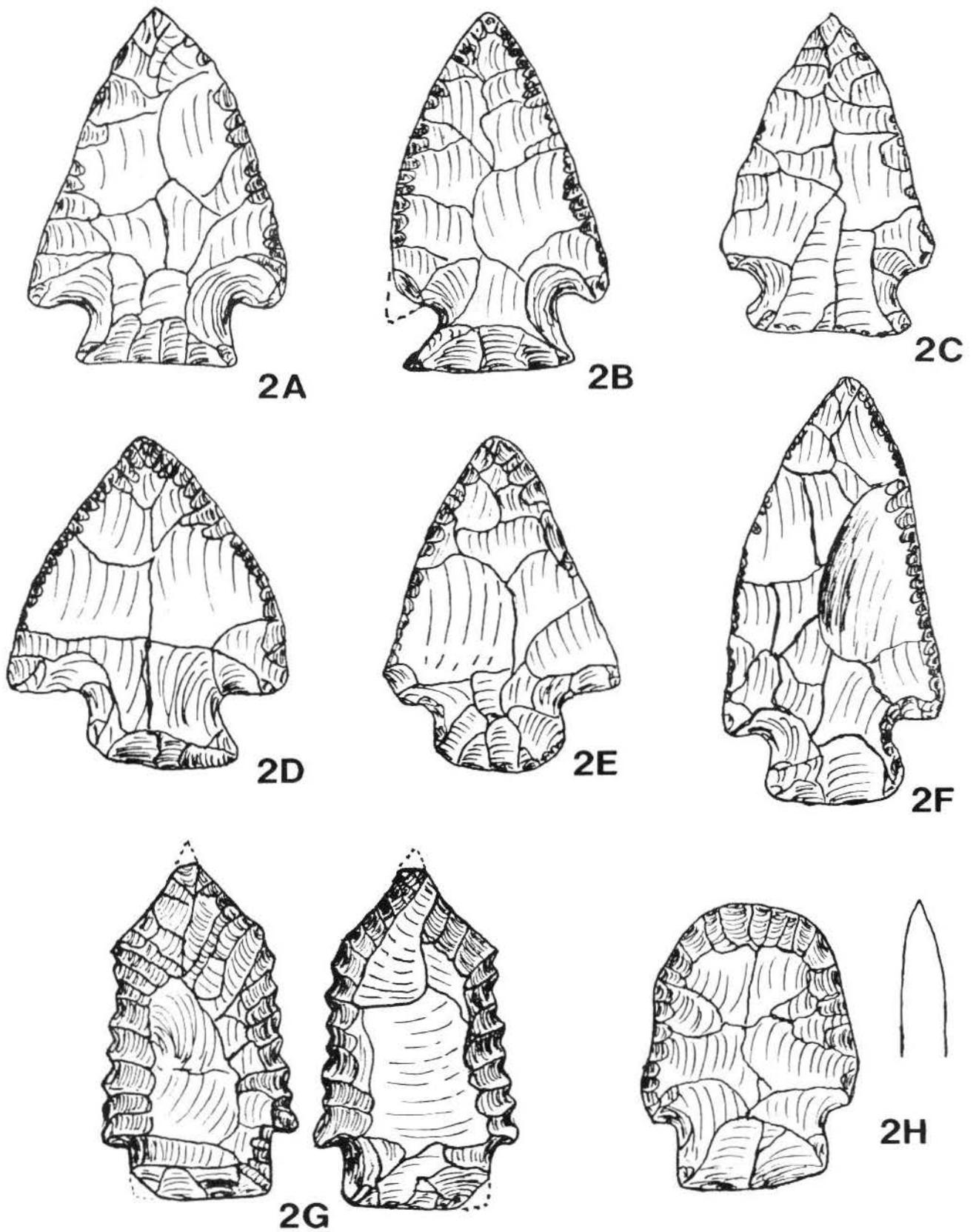


Figure 2. Middle Archaic projectile points and/or knives. Illustrated at actual size.

The discovery of site 22-LD-645 expands our knowledge of Tallahatta quartzite procurement and processing. The site is confined to a rock and sand bar in Tallahatta Creek. A considerable portion of it is covered by a sand deposit of comparatively recent origin. Artifacts are most abundant at the edge of the deposit and may be concentrated beneath it. No measurements of the rock bar were taken, but the portion of it which was exposed at the time of our visit (April 3, 1992) was probably no more than 60-70 feet long by 20-30 feet wide. There were considerable quantities of workable quartzite visible. On close examination (most of it was covered by shallow running water), we collected 3 projectile point/knives (one Middle Archaic and two Late Archaic in age), 3 final stage preforms, 5 early stage preforms, 3 unifacial blanks, 15 biface thinning flakes, and 84 flakes. Other collections from the site were examined and recorded. Blanks, preforms and finished tools from the combined collections are illustrated in figures 1-4.

The earliest material recorded consists of two side-notched projectile points (Figure 1A and B), which most closely fit the type description of Big Sandy points. These points should be 9000+ years old (Cambron and Hulse, 1975).

The Middle Archaic Period is represented by the specimens illustrated in Figure 2. Of special interest among these specimens is Figure 2G. This form has been named Kirk, variety St. Tammany by Gagliano (1967, p. 3). The type has rarely been recorded outside of southwestern Mississippi and the adjacent Florida Parishes of Louisiana. Its occurrence in east-central Mississippi suggests that the predominantly heavily wooded areas of eastern Mississippi may hold many more surprises. The typology of the other specimens in Figure 2 is not as easily identified, but this is not essential for purposes of this paper. Suffice it to say that on a technological basis, they are Middle Archaic, having the typical broad stems of that period. Specimen 2H is interesting in that it exhibits a typical Middle Archaic modification of the distal end. It has been bifacially reworked, apparently into a knife form, which was intended to cut with the distal end instead of the blade edges.

The Late Archaic Period is represented by the specimens in Figure 3. The named types are: Pickwick - specimens A, B, C, I, and K (Cambron and Hulse, 1975, p. 103), Flint Creek - specimens F and G (Cambron and Hulse, 1975, p. 51), Shumla - specimen E (Bell, 1960, p. 86), and Gary - specimen H (Bell, 1958, p. 28). Specimen D is unidentified, but on the basis of shape and stem width is Late Archaic.

Figure 4 represents earlier stages in the reduction sequence. Specimen A, which is 24 mm thick, closely resembles items included in the previously mentioned Simpson County cache. This specimen would probably have been further reduced into a projectile point or knife such as specimen 2F. Specimen 3J would appear to be the final preform of the Pickwick points illustrated in Figure 3. Specimen 4C had apparently had one notch completed and another started when it broke and was discarded. Specimen

4E is of the same general size and degree of completion as the previously mentioned cache from the Hattiesburg vicinity.

CONCLUSIONS

The nature of site 22-LD-645, if indeed it is a site in the usual sense of the term, is not adequately understood at this time. What is obvious is that it is a mixed deposit with material from many different prehistoric periods. It is also obvious that there was a considerable quartzite reduction industry nearby, and possibly in the stream bed itself. Several knappable pieces of unaltered quartzite were observed in the stream bed. The availability of workable quantities of quartzite in the stream bed has not been assessed at this point. There are several possible explanations for the occurrence of so much cultural material in the stream bed:

1. Raw quartzite was abundant in the stream bed for thousands of years and was processed there with many of the tools being completed there.

2. Raw quartzite was processed in the stream bed, which accounts for the cores, blanks, and preforms, and in addition other tasks were performed in the stream bed, which necessitated the presence of projectile point/knives.

3. Most or all of the cultural material has arrived at this site because of stream action and was originally deposited at other sites upstream or near the stream banks.

It seems likely that all of the alternatives listed above contributed to the situation in the stream bed today. Obviously there were many resources in the stream and contiguous to it in prehistoric times. The flora and fauna were surely exploited, and stone tools were essential in killing and processing game, in manufacturing tools of their bones and antlers, and in cutting and processing plants into food, containers, and utensils.

Given the tremendous quantities of quartzite available in the uplands of this area, it seems likely that much of it found its way into stream beds through natural geological processes. It would certainly make sense to take advantage of easily accessible raw material such as this before pursuing it in a quarrying or mining operation, which surely consumed vast amounts of energy.

A present day analogue of Mississippi's prehistoric quartzite industry may be that observed by Toth et al. (1992) at the village of Langda in New Guinea. In their article "The Last Stone Ax Makers," these authors observed the stone ax industry of a modern stone age society living on the cloud-shrouded southern slopes of western New Guinea's central cordillera in Irian Jaya. Villagers of this society hiked to the valleys where they knapped preforms from boulder and cobble cores found in the stream beds. Preforms were carried back to the village and finished into axheads.

There is no doubt that cultural material such as that recovered from Site 22-LD-645 often found its way into stream beds through the erosion of sites near the stream. Most permanent or semi-permanent aboriginal settlements were not too far removed from a dependable water supply. However, the evidence gathered so far suggests that most of the material is from a quartzite procurement and reduction

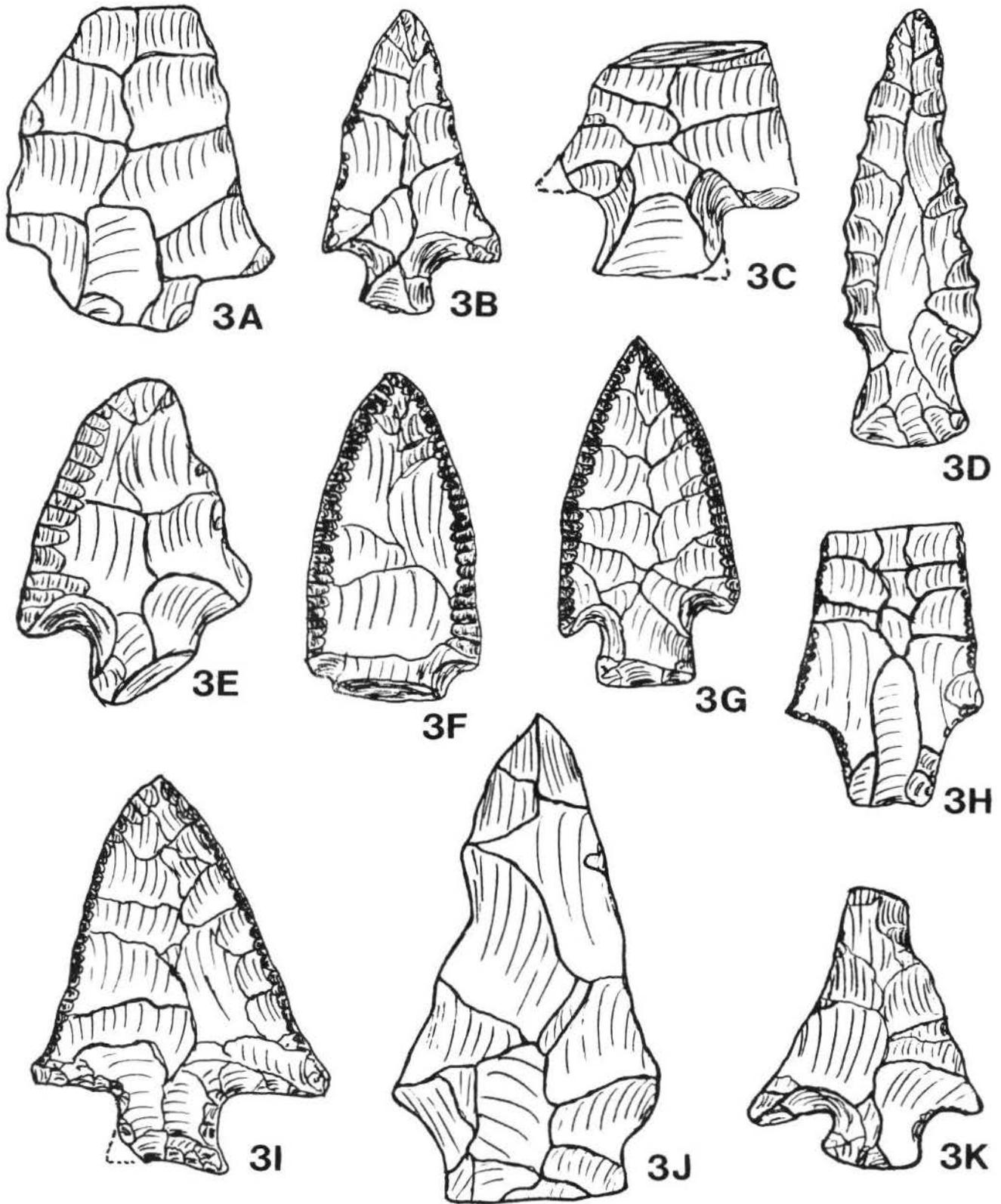


Figure 3. Late Archaic point types including Pickwick (B, C, I, and K), Gary (H), Shumla (E), and Flint Creek (F and G). D is unidentified but is placed as Late Archaic based on shape and stem width. Specimens 3A and 3J are Pickwick preforms. Illustrated at actual size.

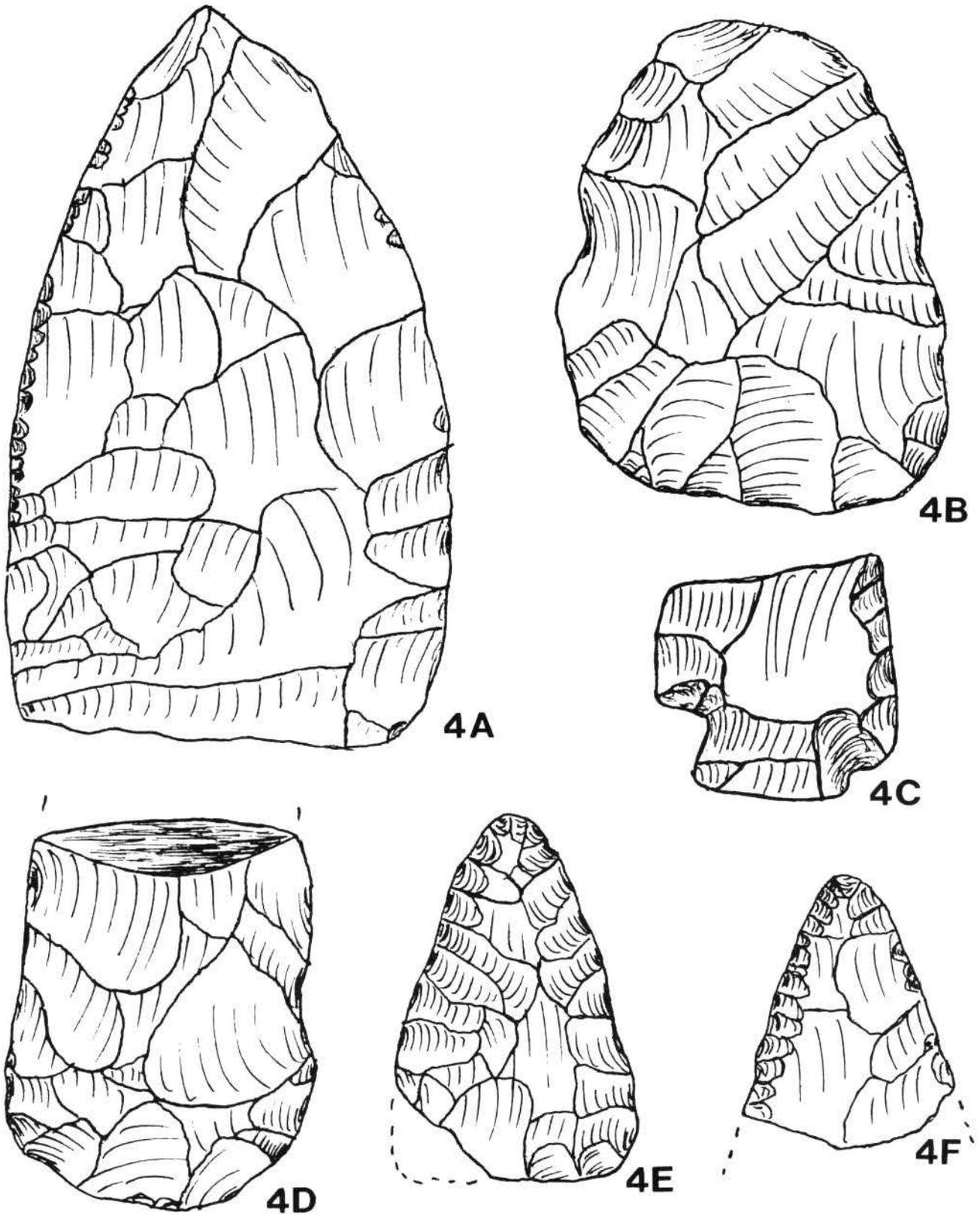


Figure 4. Blanks and preforms. Illustrated at actual size.

industry that was conducted at the site. Careful inspection of gravel-bearing streams will usually reveal prehistoric cultural material and an occasional finished tool, but the vast majority of the worked stone is of tested pebbles and cobbles and blanks and preforms. Keeping in mind that most of the material illustrated in this report was selected in favor of whole, finished projectile points and/or knives, we are left with the fact that most of the worked lithics at site 22-LD-645 are from the process of quartzite reduction prior to the completion of the tools. What differs at this site from the situation in most gravel-bottomed streams is the concentrated quantity of workable material present. Further field work should be done in the area to determine if in fact most streams near quartzite deposits exhibit a similar pattern of artifacts.

ACKNOWLEDGMENTS

The writers thank James D. Dubuisson for pointing out the site and for the use of his artifacts in the figure illustrations.

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THE GEOLOGY OF THANKSGIVING FIELD

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Mississippi Office of Geology

INTRODUCTION

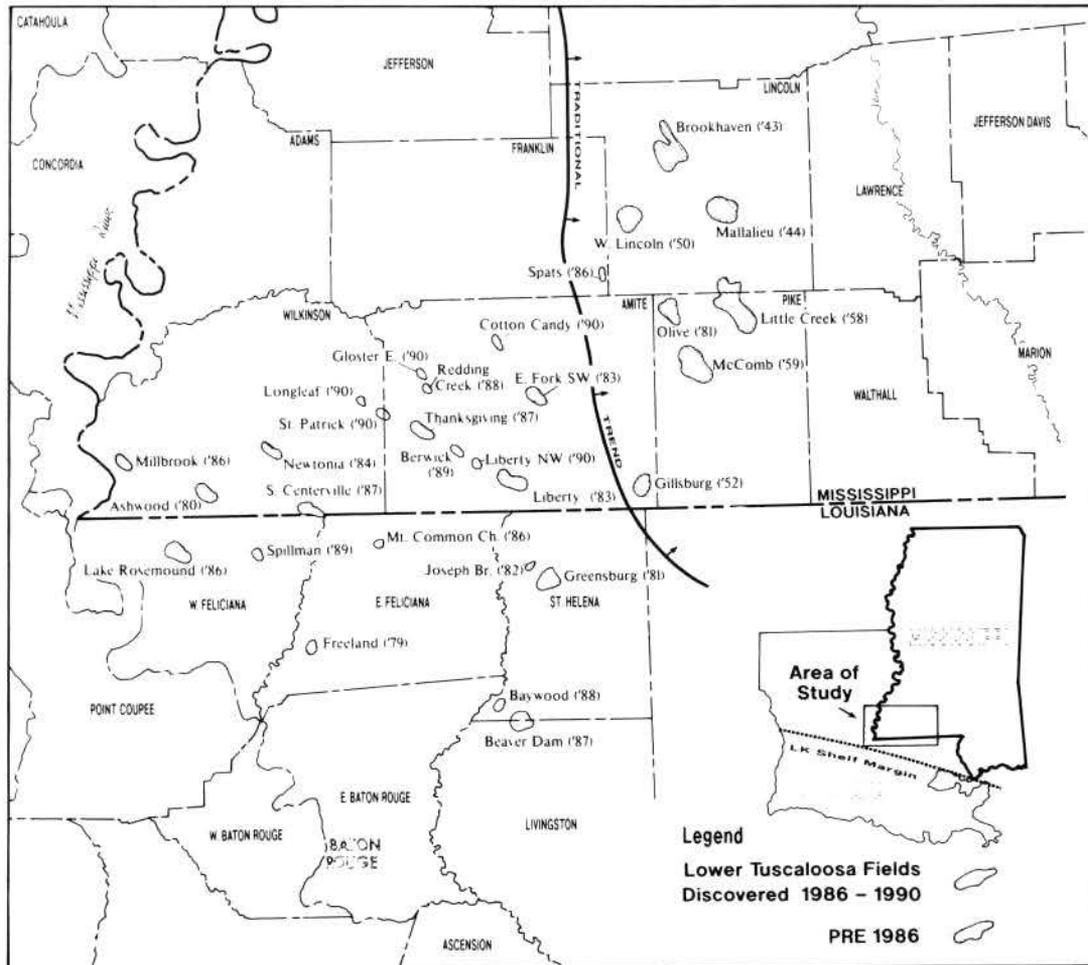
Thanksgiving Field is located in Township 2 North, Range 2 East, in Amite County, Mississippi (Figure 1). It was discovered in December 1987 by Oxy USA, Inc., through the use of stratigraphic seismic exploration. The discovery well, the Jackson A No. 1, was perforated from the interval of 12,042 - 12,052 feet. The well tested at 501 barrels of oil per day (BOPD) and 1.9 million cubic feet of gas (MMCF) on a 16/64" choke, gauged at a flowing tubing pressure of 3055 psi, with a gas to oil ratio of 3750/1. By the end of 1990, the field had produced 1,318,549 BO and 7,247,308 MCF from

15 wells out of the Tuscaloosa Group, 152,134 MCF of Frio gas from 4 wells (9-13-89, New Pool Discovery), and 51,774 BO and 16,150 MCF from one Wilcox well (10-21-88, New Pool Discovery). Since 1987, nine additional Tuscaloosa fields have been found in Amite and Wilkinson counties.

STRATIGRAPHY

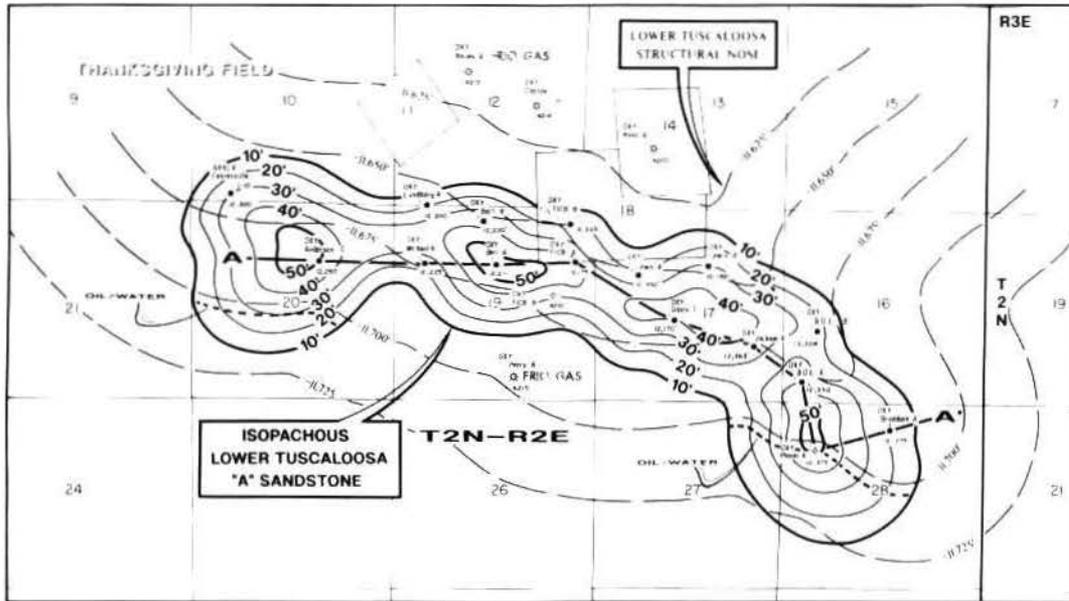
The Tuscaloosa Group, which is stratigraphically above the Lower Cretaceous unconformity and beneath the Eutaw Formation, consists of three formations: Lower Tuscaloosa, Middle Marine Shale, and Upper Tuscaloosa (Gruebel, 1985).

* The Lower Tuscaloosa trend has been an exploration target since the 1940's. Current drilling activity and recent wildcat successes illustrate that southwestern Mississippi still has attractive potential.



LT-2

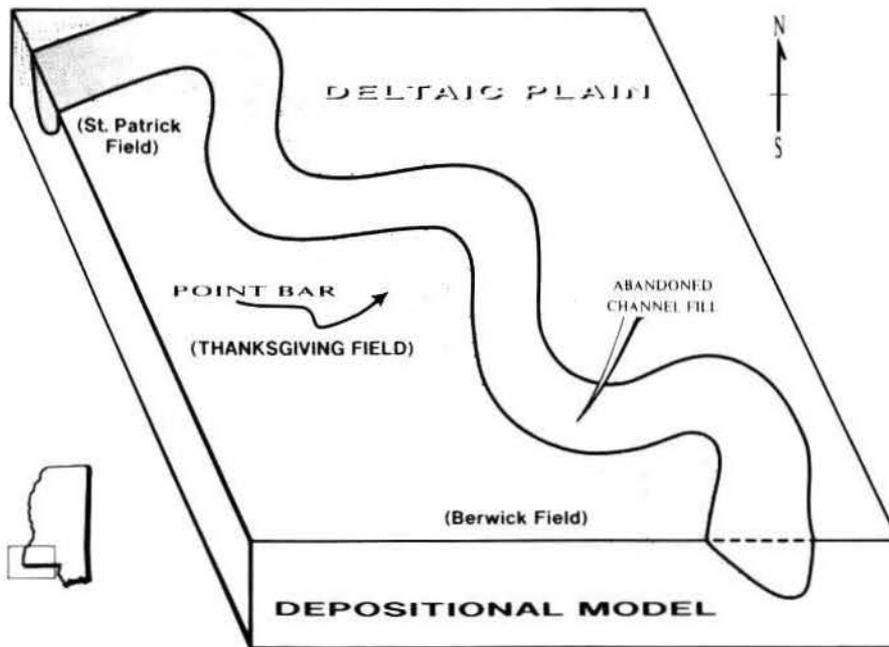
Figure 1.



* Thanksgiving Field is a classic example of a shaleout in three directions against regional dip. The sand pinches out into an abandoned shale-filled channel. This channel plug provides the lateral seal when located on the updip side north of the point-bar sand.

LT-5

Figure 2.



* The Stringer Member of Lower Tuscaloosa primarily consists of fluvial point-bar deposits. Deltaic and marginal marine facies are also present in this region.

LT-4

Figure 3.

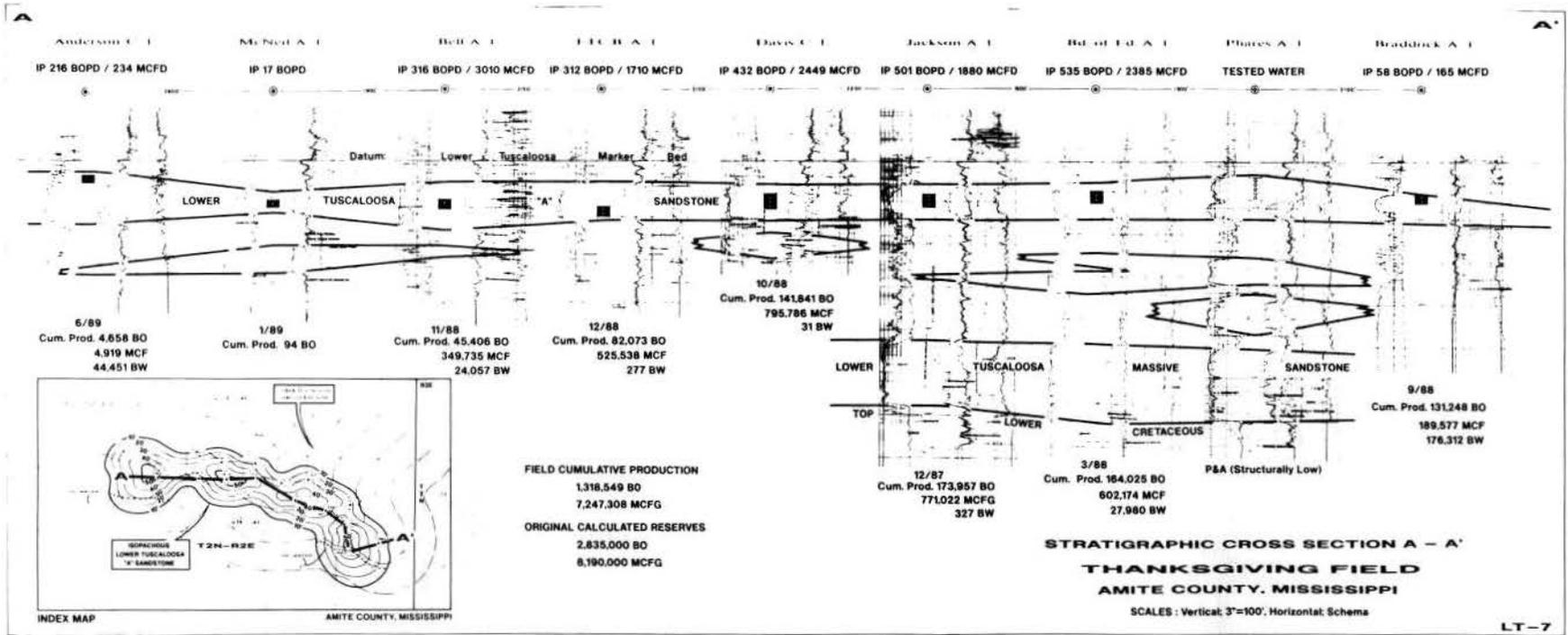


Figure 4.

THANKSGIVING FIELD

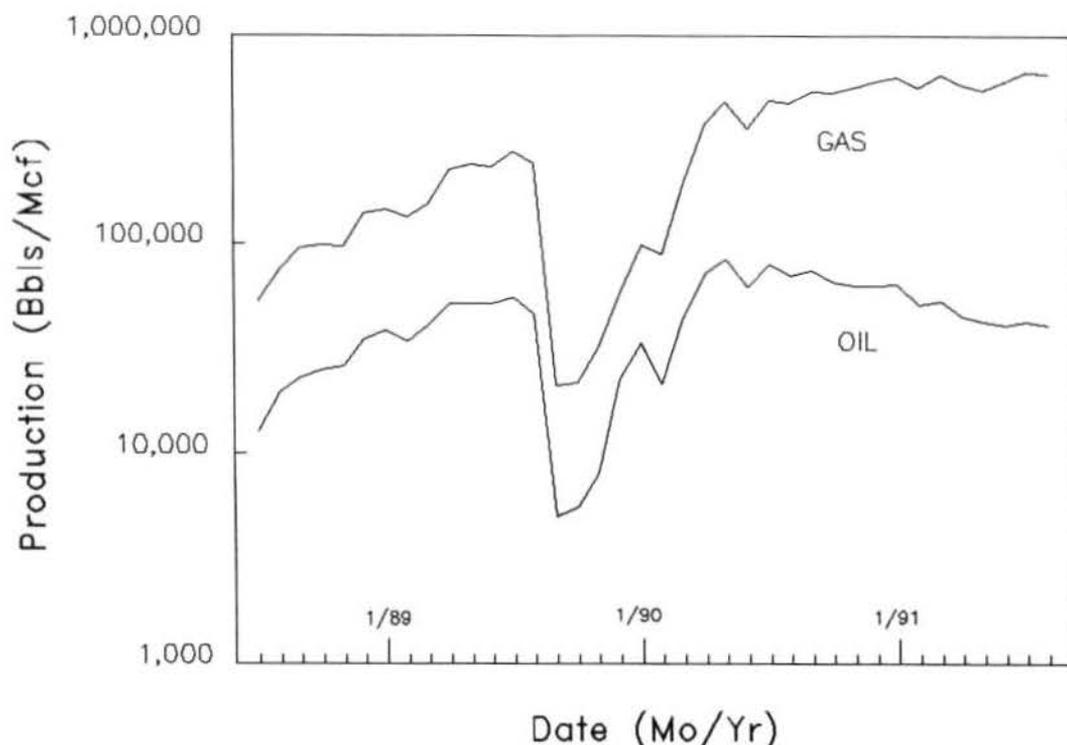


Figure 5.

The Lower Tuscaloosa is further divided into the Stringer Sand Member and the Massive Sand Member. The Lower Tuscaloosa contains good reservoir sands, with the Stringer Sand Member being the current primary objective.

TRAP AND RESERVOIR

The "A" Stringer Sand of the Lower Tuscaloosa formation is the producing zone at Thanksgiving Field. The present structural configuration is interpreted to consist of a gentle southward-plunging nose (Figure 2). The "A" sand was deposited in a fluvial-deltaic environment and occurs in a northwest-southeast trending meander belt that parallels structural strike (Figure 3). Thanksgiving Field exhibits a nearly ideal stratigraphic trap with sand shaling out in three directions against regional dip. The sand pinches out into an abandoned channel clay plug and flood-plain shales. This channel plug provides the lateral seal when oriented on the updip side to the north of the point-bar sands. The stratigraphic cross-section (Figure 4) shows the log correlations of these point bar sands. Log calculations can be misleading due to "bound water" clays which distort the resistivity values, reduce porosities, etc., making coring very helpful. In the producing zone, resistivities as low as 0.6 - 1.0 ohm are not uncommon and the production is water free. Conventional and sidewall cores in productive wells in southwestern Mississippi indicate porosities of 18-26%, permeabilities

that range from 50-350 millidarcies, and water saturations of 45-70%. Gross sand thicknesses vary from 20 to 70 feet, with average net pay being 23 feet.

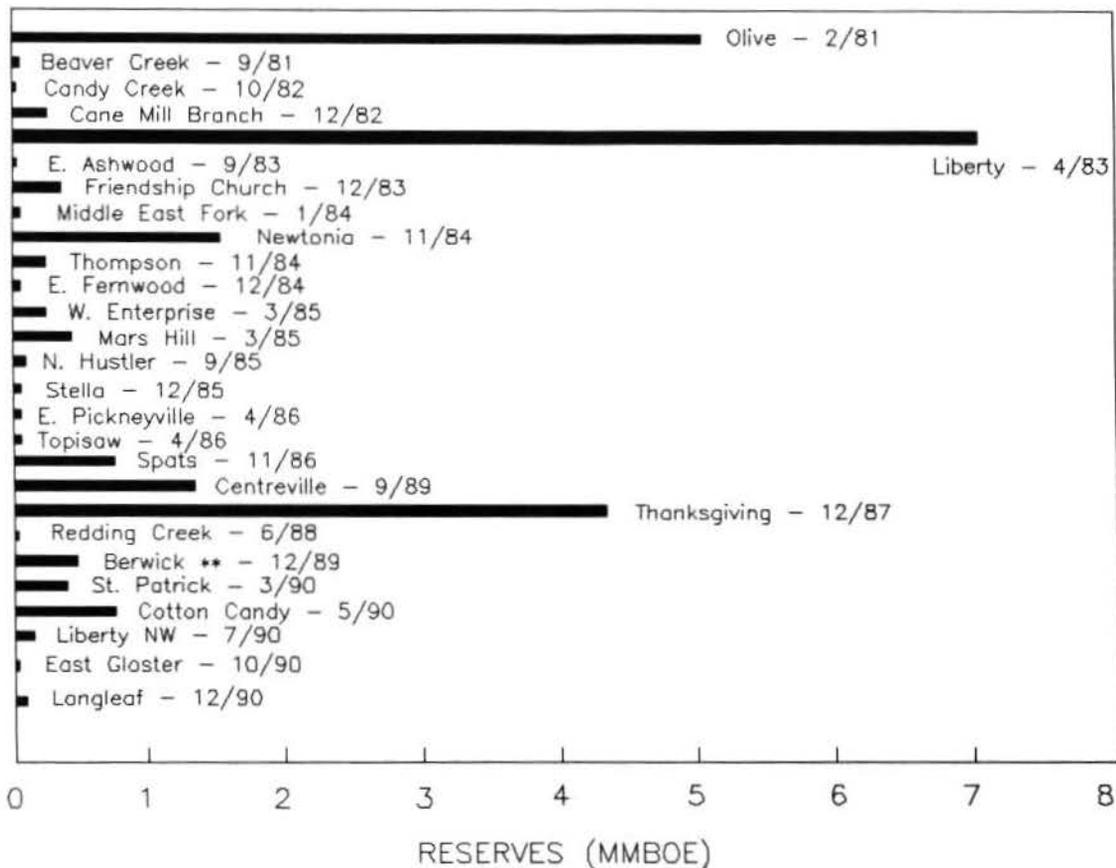
PRODUCTION

Prior to the implementation of a gas injection pressure maintenance program a decline curve analysis was run on twelve of the wells in Thanksgiving Field (source: Zorbalas, 1990). This analysis projected an ultimate primary recovery of 2,566,517 barrels of oil, assuming an average exponential decline of 25%. Using a 650 MCF/acre foot recovery, gas production should be over 8 billion cubic feet (BCF). The implementation of the pressure maintenance by gas injection should result in significantly higher recoverable oil reserves. The field is currently producing in excess of 40,000 BO/month (Figure 5).

CONCLUSION

A recent Tuscaloosa well of interest is a wildcat operated by Oxy USA, Inc. Oxy completed the No. 1 CMR "A" in Wilkinson County in August 1991; it tested 143 BO and 2674 MCF from perforations at 11,551 - 11,564 feet. The new field discovery, Freedom Field, is located five miles northwest of Longleaf Field, and is on strike with the Thanksgiving Field meander belt.

Tuscaloosa Fields (1980-1990)



** Development continuing

Figure 6.

Tuscaloosa trend activity will continue due to seismic stratigraphy and the reserve potential that remains. In the past ten years, major reserves have been found at Olive Field (1981), Liberty Field (1983), Thanksgiving Field (1987), and Berwick Field (1989) (see Figure 6). The success at Thanksgiving Field has shown there are still high quality prospects in the Tuscaloosa trend of southwestern Mississippi.

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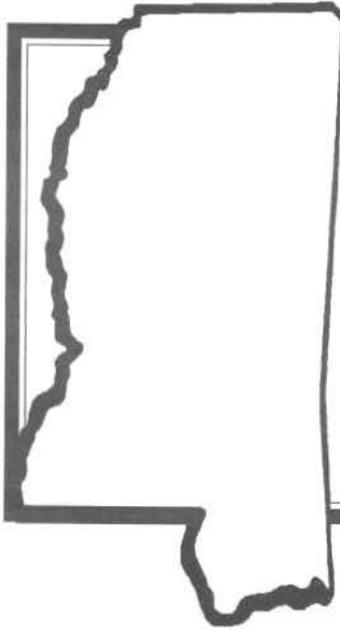
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ENVIRONMENTAL ANALYSIS OF SANDSTONES AND QUARTZITES FROM THE TALLAHATTA FORMATION, NEAR MERIDIAN, MISSISSIPPI

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ABSTRACT

The Tallahatta Formation, near Meridian, Mississippi, contains both muddy sandstones (with significant silt and clay content, but no silica cement) and quartzites (quartzose sandstones having silica cement), in close stratigraphic and geographic proximity. This paper presents granulometric suite data from both kinds of rock, to see if the use of hydrofluoric acid (HF), to remove silica cement, modified the grain size distribution in a significant way. The environment of deposition, deduced from the grain-size parameters, was in the zone of surf-and-swash action, under low-to-moderate energy waves, plus settling from water, coupled with some wind work. This is a common combination on sub-aerial beaches. The resulting data are not sufficient to prove that HF treatment did not modify grain diameters, but the evidence (now available) supports this proposition.

INTRODUCTION

This study of part of the Tallahatta Formation was undertaken in the hope of determining the validity of granulometric analyses of quartzites (silica-cemented quartz sandstones) that have been treated with hydrofluoric acid to remove the silica

cement. The Tallahatta Formation, in the vicinity of Meridian, Mississippi, contains both argillaceous sandstones (mudstones), and quartzites (quartzose sandstones with silica cement). Each represents a low-to-moderate-energy near-shore and beach environment plus settling from water, coupled with a significant component of wind work. They differ primarily in presence or absence of an important clay fraction. They also differ slightly in certain granulometric parameters. Ideally, the two kinds of sandstones might be expected to yield essentially identical grain-size results.

It is possible that the small differences between the two reflect the fact that the quartzites were disaggregated by using hydrofluoric acid. On the other hand, previous work indicates that the effect of this acid, on framework grains, should be slight, and differences among the samples might be environmental in nature. Until this uncertainty can be resolved, one does not know whether or not conditions of deposition oscillated between two slightly different environments. Clay content appears to have fluctuated in response to wave energy level changes, which may have been controlled by small sea level changes, but it must not be inferred that clay-content differences are necessarily mimicked by various grain-size parameters.

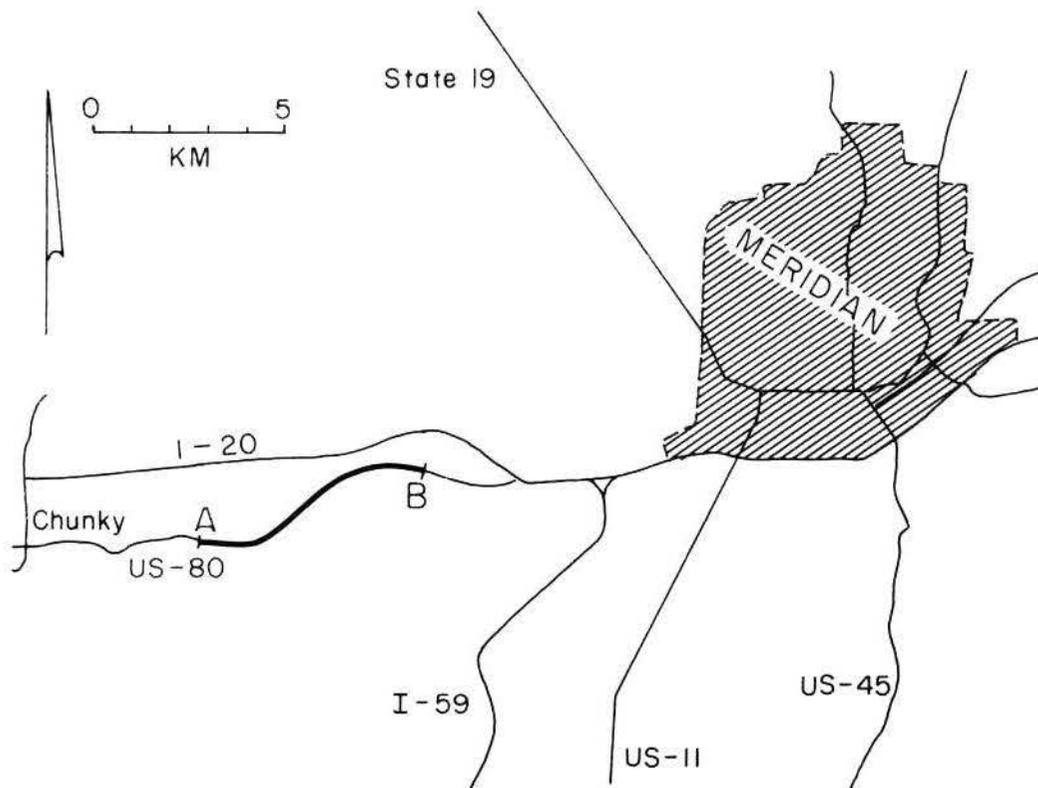


Figure 1. Map of the Meridian, Mississippi, area, showing where samples were collected: along U. S. Highway 80, between A and B, east of the village of Chunky.

METHODS

The Tallahatta Formation, of Eocene age, contains clay, argillaceous sandstones (mudstones) and quartzites (silica-cemented quartzose sandstones; cf. McGahey et al., 1992). This low-dip unit was inspected in the field at a number of localities south and west of Meridian, Mississippi, and samples were collected for granulometric work at several exposures along U. S. Highway 80, from about 12 km west of the center of Meridian (straight-line map distance) to about 17 km west of the city.

Samples included both quartzites and argillaceous quartzose sandstones. No truly clean, friable quartz sandstones were seen in the course of field work.

The purpose of this work was to compare the granulometries of more-or-less equivalent sandstones and quartzites. All of the samples discussed here came from the one formation, in a very small geographic area, and may represent a single environment, with only slight changes of depositional conditions.

Six samples of argillaceous sandstone were selected for processing. For these samples, the sand fraction, and the "finer than sand" fraction, were separated by wet sieving. The sand was dried, weighed and then shaken mechanically for 30 minutes in a stack of quarter-phi sieves (Socci and Tanner, 1980). The sand portion typically weighed 30-45 grams, and the fines, 8-11 grams. After sieving, each size fraction was

weighed to 0.0001 grams, and the raw weights from the sample were treated in the GRAN-7 computer program, which produces a tabulation of data, the first six moment measures, various other parameters, a histogram, and a probability plot. Then the weight of the fines was added, numerically, to the pan fraction data in the array of quarter-phi results, and the combined sample was also treated in the GRAN-7 program. This produced two sets of results for argillaceous sandstones: one composed of sand, silt and clay, and one with sand only. The latter had been washed in the lab, and can be described as clean sand.

The average silt-and-clay component was 23.31%, which is about what one expects in sediments in transit in large alluvial rivers, or in lakes, estuaries or low-energy near-shore areas where such rivers debouch. It is not representative of mature beaches, sand dunes, or the clean sand of certain rivers. Therefore the clay-and-silt content appears to indicate proximity to an alluvial river source.

Various parameters from the GRAN-7 analysis were employed for more elaborate testing, using the SUITES computer program. One of the products from the latter is a pair of tests for homogeneity within the suite: that is, do the data indicate that two suites, of different kinds, have been combined in the field work, inadvertently? This analysis shows that field and lab work did indeed produce consistent results, and that there has been no mixing of different suites, but it cannot absolutely exclude the possibility of a systematic field

error of some kind (at present not known). If this were a major problem, one could explore the possibility of some small systematic error by re-sampling the Tallahatta Formation in the same general area.

Six samples of quartzite were also selected for analysis. These were treated with dilute hydrofluoric acid until disaggregated, then washed, dried, sieved, and weighed, and the weights were processed in the GRAN-7 program. It was thought that the HF would attack the cement preferentially (Folk, 1989), and leave loose, essentially unaltered, quartz sand grains for further analysis. Orhan (1989) showed that the presence of pervasive silica cement indicates an initial absence of clay on the quartz grain surfaces or in the interstices. More recently Ehrenberg (1993) reported, from a totally different area, that clay (in his study, chlorite) inhibits silica cementation. Apparently a clay lattice does not provide a good template for initiating crystallization of proto-cement whiskers of SiO_2 .

Therefore we contrast two rock types: argillaceous quartzose sandstones (with 20-25% silt-and-clay), and more-or-less clean quartzose sandstones (with silica cement; hence quartzites). The significance of this comparison is very important. In the first case, deposition either took place in a protected environment, or involved such a large proportion of the clay fraction that the latter could not be eliminated or even reduced greatly, at or close to the depositional site. In the second case, deposition involved only clean quartz sand, from which the fines (assuming the same source) had been removed prior to deposition.

This means that there are now three data sets: one for argillaceous sand, one for artificially-cleaned sand, and one for quartzite (after treatment with HF). It is thought that silica-rich ground water later deposited cement on clean quartz grain surfaces, but did not affect clay-coated grains (Orhan, 1989; Ehrenberg, 1993). The argillaceous sandstone furnishes baseline data, because it has been subjected to a minimum of laboratory treatment.

RESULTS

Granulometric analysis and environmental interpretation for sands is best carried out on sample suites, where the numerical results are less erratic, less scattered and more nearly diagnostic, than are numbers from individual samples (Tanner, 1991a, 1991b). That is, there is a great deal of hydrodynamic (environmental) information in the sample suite, and this information cannot be obtained from a single sample, or by looking individually at single samples in a set. Statistically, this means that one should evaluate (among other things) measures of variability for the suite of samples, such as the standard deviation of the mean diameter, and the standard deviation of the kurtosis. As will be discussed below, suite statistics indicate that the Tallahatta sandstones represent a

low-energy beach or near-shore environment.

The mean diameter for the argillaceous sandstones (mudstones) was 2.91 phi (0.133 mm, which is not quite as small as 1/8 mm). For the washed sandstones, it was 2.377 phi (0.193 mm), and for the quartzites, 2.346 phi (0.197 mm); these last two should be compared. The mean diameters are small, in comparison with many modern beach and near-shore sands, but not as fine as the compact sand at Daytona Beach, Florida (2.48 phi; about 0.18 mm). The washed sands and the quartzites appear to have the same diameters, but this close similarity does not extend to all the other available parameters. The mudstone has a finer mean diameter than the other two

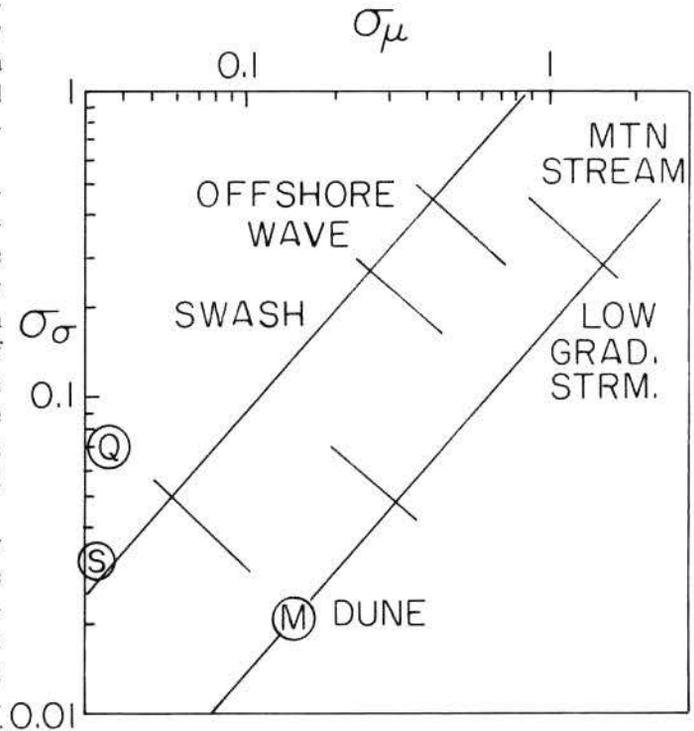


Figure 2. Variability diagram (standard deviation of standard deviations, vs standard deviation of mean diameters). Key: M = argillaceous sandstone (mudstone), S = artificially washed sandstone, Q = quartzite. Two of these three sample suites fit in the area marked "Swash or dune," and one of them (S = washed sand) indicates "Dune." Interpretation: beach and eolian, which is a common combination.

data sets because it contains a significant fraction of clay-and-silt, but this finer diameter can not apply to the sand fraction if the latter is taken by itself.

Further discussion of the quartzites will be deferred until a later section, because one does not know for sure to what extent the hydrofluoric acid may have attacked the separate grains. Hypothetically there should be no uncertainty: reduction of diameter, rather than smoothing of corners, is the critical question. Acid attack on corners or smaller projections

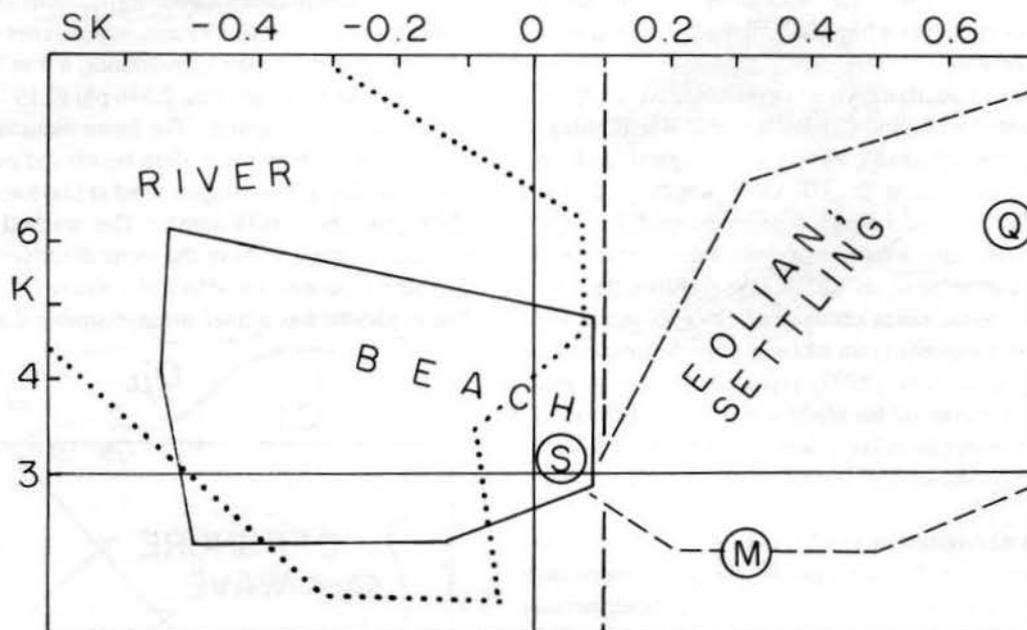


Figure 3. Kurtosis vs skewness. Key, as in Fig. 2. The washed sand indicates a beach, the other two suites indicate settling from water, or wind work. Interpretation: beach, settling from water, eolian.

would appear to do essentially nothing to the grain diameter, but in the case of the Tallahatta Formation, at least, this proposition has not been proven. The results of Schultz (1980) and Folk (1989) indicate that not even corners of framework grains in simple quartzites are attacked in any significant way by hydrofluoric acid. Quartzites in which there has been deformation of original grain shapes, such as by pressure solution or by shearing, pose a different kind of problem, but one that is not present in the low-dip Tallahatta Formation exposures, where structural deformation has been minimal.

Environments: Clean Sand

The clean sand (clay removed in the lab by washing), using suite-statistics procedures, produced the following results (hydrodynamic logic is discussed elsewhere: Tanner, 1991a, 1991b):

- i. Variances of means and of standard deviations of the tail of fines (weight percent, 4 phi and finer): mature beach or dune.
- ii. Skewness vs kurtosis of diameters: beach or settling (shallow water).
- iii. Variances of diameters and of standard deviations (total sample): beach or dune.

- iv. Relative dispersions of mean diameters and of standard deviations: dune.
- v. Kurtosis vs sixth moment measure: eolian.
- vi. Mean of kurtosis vs standard deviation of kurtosis: deep sea, or moderate-to-high energy beach. The first of these can be discarded.
- vii. Kurtosis vs standard deviation: settling from shallow water, or tidal flat.
- viii. Mean vs standard deviation: settling from water.

These results were obtained after washing in the laboratory; that is, the clay-and-silt fraction is not represented.

Environments: With Clay

The argillaceous sand gave, as was expected, slightly different results:

- i. Tail of fines: settling in a closed basin, or where energy levels were too low to winnow the sediment very much.
- ii. Skewness, kurtosis: settling in shallow water.

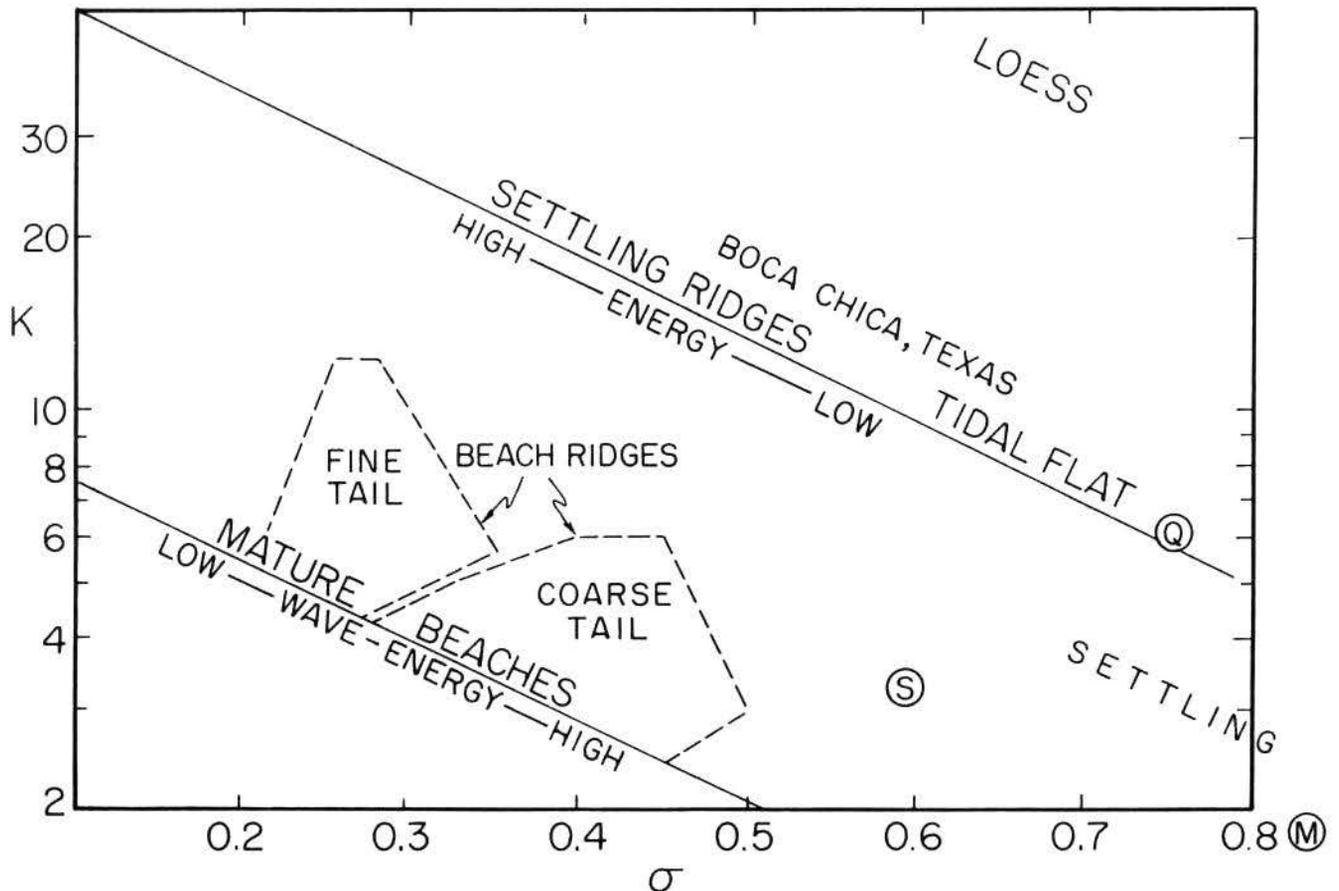


Figure 4. Kurtosis vs standard deviation. Key, as in Fig. 2. All three suites suggest settling from water (but not from air), and the washed sands show some evidence for swash work as well. Interpretation: beach, settling from water, tidal flat.

- iii. Variability of mean and of standard deviation: beach or dune.
- iv. Relative dispersions of mean and of standard deviation: dune.
- v. Kurtosis, sixth moment measure: eolian.
- vi. Mean and standard deviation of kurtosis: settling in deep water (relative to waves, which may have been small).
- vii. Kurtosis vs standard deviation: settling from shallow water, or tidal flat.
- viii. Mean vs standard deviation: settling from water.

These two lists show many items that are roughly evenly distributed among beach, dune (or eolian), and settling from water. The argillaceous sand shows much more evidence for settling from water than does the clean sand, but both indicate this origin. High clay content of the argillaceous sand necessarily shows settling from water, rather than traction (bed load)

transport of the clay, but the clean (washed) sand also has characteristics due to settling from water.

The probability plots of the clean-sand size distributions have two interesting characteristics: (a) each is faintly bimodal, which suggests a mixture of two sources or two transport mechanisms (perhaps incomplete reworking of sediment from one agency, by a second agency), and (b) some of them have the distinctive kink known as the "surf break," which appears to be diagnostic of the beach and surf-zone environment, generally with low-to-moderate wave energy (Tanner, 1966, 1991a).

It should be kept in mind that "beach" granulometric characteristics may be acquired by sediments fairly far out on the shelf, as well as on the sub-aerial beach, for at least two reasons: (a) storm waves break farther out on the shelf, and produce solitary wave transport (much like the swash) in water depths where fair-weather waves may not be effective, and (b) there are small (up to 4-5 m) and alternating changes in sea level which may be hard to identify in other ways, but which have the effect of subjecting deeper-water sand to fair-weather wave and surf action, or of temporarily removing shoaler-water sand from the effects of wave breaking (Tanner, 1992, 1993).

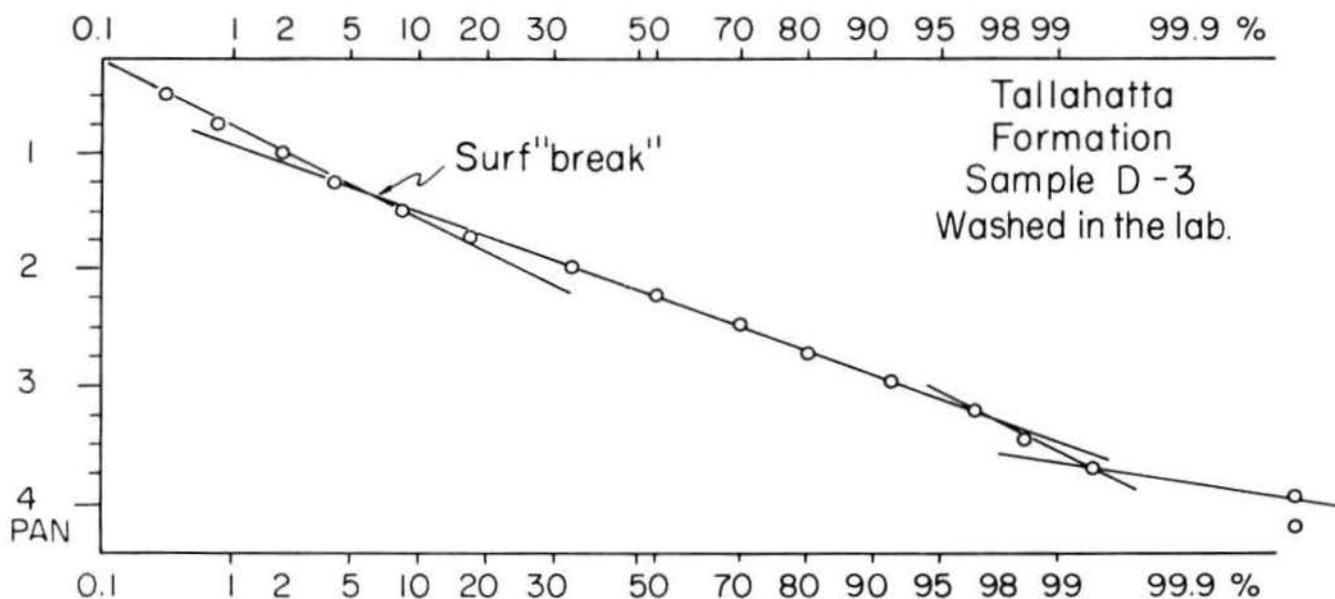


Figure 5. Probability plot for Sample D-3, an argillaceous sandstone, washed in the lab to remove silt and clay. Note the surf "break," which is a positive indicator of the surf-and-swash zone, having low-to-moderate wave energy. This kink, or "break," is located at about 1.30 phi (0.40 mm).

It should be kept in mind also that shallow-to-intermediate-depth near-shore sands commonly show (in the suite sense) evidence of both wave work and settling from water (the latter, during the waning phases of storms, or as evidence that waves were small most, but not all, of the time). Therefore "beach," "low energy" and "settling" indicators, taken together, identify a specific environment of deposition.

The evidence for wind work does not counter any of the foregoing: swash and wind influence are commonly combined on sub-aerial beaches. There is no evidence, in these data from the Tallahatta Formation, for non-coastal eolian activity (continental interior dune field).

INTERPRETATION

Do the results for the clean (washed) sand match any well-known environments of deposition? Yes, they do. One should infer a near-shore (and/or shallow shelf) environment, with episodes of settling, and also with non-trivial episodes of exposure to the air (wind work). The wave energy level (wave energy density) was low-to-moderate, rather than high. The sand-silt-clay results do not change the inferences any; they merely add the proviso that there must have been a good source of fine sizes (silt and clay), not too far away. "Not too far away" has to do with the local wave energy density (wave energy level), versus the volume-delivery-rate of fines introduced into the area. If the wave energy was high, then the source of fines must have been both large and in the immediate vicinity. If the wave energy was low, then the source of fines could have been much smaller, and/or much farther away. In the absence of evidence for well-developed channels, a large

nearby source is not indicated, therefore the second option (low wave energy) can be adopted. Some of the granulometric parameters, used here, also suggest low-to-moderate wave energy density.

The tidal-flat item in the lists above, much like the dune indications, supports the idea of exposure to the air, and these two kinds of results limit the possible general water depth. A broad estimate of depth of water would be in the range of some centimeters to a few meters, plus considerable variability from time to time. (For a discussion of tidal-flat-plus-wind-work, see Tanner and Demirpolat, 1988.) The presence of a few marine fossils in the Tallahatta is consonant with the interpretation given here.

Quartzites

Results from the quartzites are disappointing, in that they do not indicate precisely the same environment as the argillaceous sands. But they appear to represent a "settling" and near-shore environment, which is roughly what the sandstones showed. This is encouraging in the sense that all three sets of numbers should agree in a general way. However, the uncertainties are, unfortunately, still great.

It is not possible to say from the granulometric work that the quartzites represent exactly the same environment as the argillaceous sandstones (mudstones). The primary difference, of course, is the presence or absence of clay. The secondary difference is that the quartzites show a small but significant fraction of fines (apparently silt, because clay inhibits the development of silica cement): 2.5 to 4.5%. This is enough to change the "beach" indication, in some of the tests, to "set-

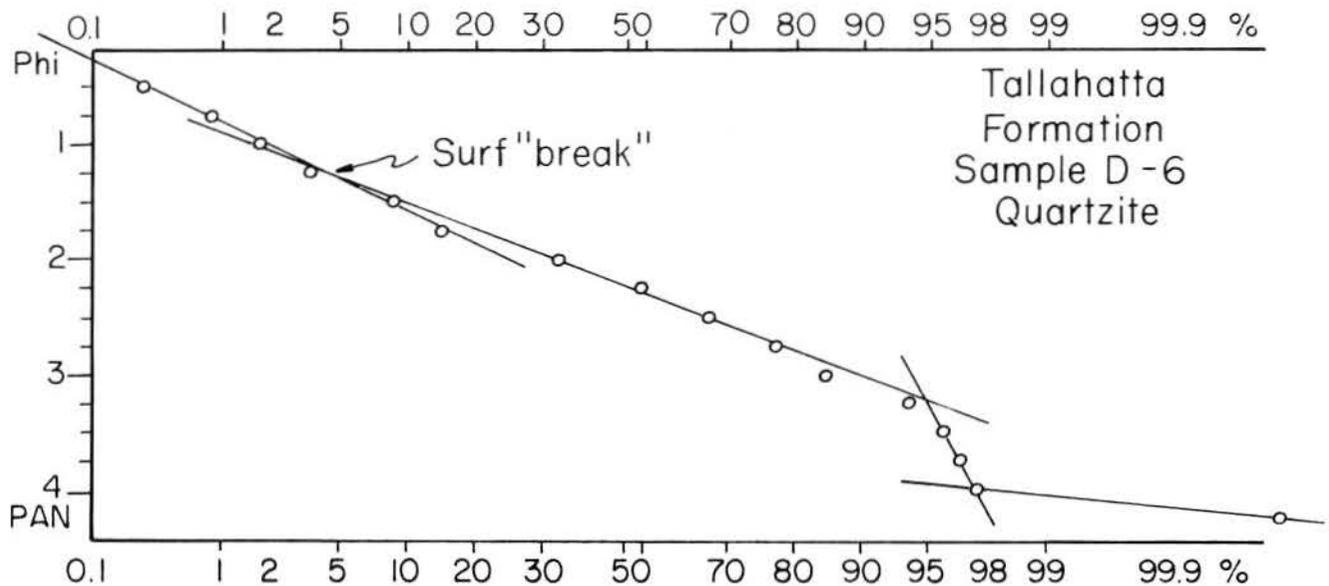


Figure 6. Probability plot for Sample D-6, a quartzite, after treatment with hydrofluoric acid. Note the surf "break" at about 1.25 phi (0.42 mm). It identifies low-to-moderate energy surf-and-swash. Compare with Figure 5, where the surf "break" is almost identical.

ting" or "eolian."

Therefore a fourth analysis was run; in this case, data from the acid-treated sandstones were analyzed after the pan-fraction (2.5 to 4.5%) had been set arbitrarily to zero. (This is a procedure which has been used previously on many occasions, commonly with valuable outcome: it focuses attention on the sand fraction.) The result is an almost perfectly Gaussian grain size distribution for each sample; this would be extraordinarily hard to get by direct artificial manipulation of the numbers, which in turn suggests that the procedure is a useful one. In the usual course of events, one might expect low standard deviation values to go along with the Gaussian distribution (e.g., $r = 0.25$ to 0.45), but the Tallahatta quartzites showed $r = 0.6$, which means less-than-excellent sorting. A tourist-type beach is not indicated.

The kurtosis and the sixth moment measure, for this fourth set of numbers, are almost identical with what was obtained for the washed (originally argillaceous) sand. These two parameters are especially sensitive to changes in the extreme tails, rather than in the middle part of the distribution. Their near-identity with the sand component of the argillaceous samples is encouraging, and provides a small amount of hope that perhaps the two do indeed represent the same depositional conditions, or nearly so. However, more work must be done before this proposition can be demonstrated.

Uncertainties

At this point in the study, we are unable to distinguish, in a completely satisfactory way, among several possibilities:

1. The environment of deposition for the quartzites WAS indeed different, at least in detail.
2. The HF treatment produced the apparent differences, and the environments were actually identical.
3. There were BOTH effects, which cannot be separated or evaluated individually, now.

The two environments did indeed differ, as far as clay deposition was concerned, and the hydrofluoric acid treatment could not have caused this one difference.

The presence or absence of clay provides some other pertinent information: at times when clay accumulation was large, wave energy levels must have been relatively low (perhaps, but not necessarily, on a tidal flat). Therefore the clay data, alone, suggest an oscillation between two sets of conditions. The question that remains is: Do any of the available granulometric parameters also indicate this, and, if they do, can they provide a better description than merely "change of energy level"?

Of 10 different granulometric cross-plots, five show no difference, four make clear distinctions (how much of this, if any, is due to the acid treatment?), and one is indeterminate. Some of the distinctions are due to the clay, which is not present in the quartzites, but not all of them can be explained so readily.

Z-test

The Z-test permits a comparison of two different data sets,

in an effort to see whether they are likely to have had either different, or similar, origins (Dixon and Massey, 1957, p. 23-ff). For the present study, the first four moment measures from the suite of washed sandstones (six samples), and the same four parameters from the suite of disaggregated quartzites (six samples), were compared with each other. The results are as follows (P is the probability that the similarities could be due to chance):

Mean	P<0.000 01
StdDev.	P<0.000 01
Skewn.	P<0.000 01
Kurtosis	P<0.000 01

The suite standard deviations for these parameters are very small, so the similarities that are indicated are not a matter of having so much scatter that anything and everything fits. For the first three moment measures, standard deviation values are less than 0.1, and for the kurtosis they are less than 0.6. On the other hand, the number of degrees of freedom is small ($12 - 2 = 10$), and a larger number of samples would be needed in order to make a better analysis.

For each parameter, the exceedingly low probability (P) indicates that the similarity between the two suites is not due to chance. That is, at the level of 0.00001, the two suites appear to be alike. It should be noted that not a single parameter supports the idea that similarities are due to chance. These numbers are taken as evidence that acid treatment did not cause a significant difference between the two suites, but the number of samples is so small that one cannot yet accept this proposition as proven.

CONCLUSIONS

The general environment of deposition of the Tallahatta Formation, at the places where it was sampled, includes: (a) low-energy beach and shallow near-shore marine water, (b) settling in shallow water, and (c) wind activity.

Two kinds of sandy rocks, quartzites (silica cement in quartzose sandstones) and argillaceous sandstones, are found in the exposures. The primary difference between these two is the presence or absence of silica cement (alternatively, the absence or presence of clay), and this in turn indicates that the initial deposit, in the one case, was a clean sand, whereas in the other case it was a dirty sand. The absence of clay, in the clean sand, permitted accumulation of silica cement at a later time.

The presence of clay in the argillaceous sands may indicate proximity to an important clay source, such as a stream, or perhaps changes in the local wave energy level. Channels in the Tallahatta would support the first of these two suggestions; none was seen. Therefore a change in wave energy level, from time to time, can be inferred.

Does the granulometry of the sand fraction in the quartzites differ significantly from that of the sands in the argilla-

ceous sandstones? If so, this fact might provide additional information about the environment of deposition. The Z-test does not provide any support for this idea, and it appears, at first glance, that the two data sets are essentially identical. Unfortunately, the number of samples is not very large, so it is not now possible to give a clear, simple answer to the question. But it is thought that hydrofluoric acid treatment had no significant effect on the framework grains (Schultz, 1980; Folk, 1989). If there was no important effect from the acid treatment, then the two rock types represent the same depositional conditions.

ACKNOWLEDGMENTS

David T. Dockery III, of the Mississippi Geological Survey, was kind enough to guide the writer to a number of Tallahatta exposures in the general vicinity of Meridian, Mississippi. This necessary assistance is greatly appreciated.

COMPUTER PROGRAMS

The two computer programs, GRAN-7 and SUITES, can be furnished upon request, without cost, as paper print-out, or on a high-quality 3.5" double density disc, formatted and supplied by the person making the request. Each of these two programs operates inside the system GWBASIC, on a DOS platform, but GWBASIC cannot be supplied by the present writer.

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Table 1. Muddy sandstone, Tallahatta Formation, Mississippi

	Mean	S.D.	Skew	Kurt.	Fifth	Sixth	T. of F.
1-M	3.117	1.373	.037	1.776	.02	3.495	.28898
2-M	2.793	1.386	.477	1.924	1.645	4.389	.23502
3-M	2.727	1.372	.475	2.055	1.739	5.138	.21245
4-M	3.034	1.407	.217	1.734	.488	3.459	.28383
5-M	2.767	1.359	.412	2.09	1.478	5.232	.21188
6-M	3.023	1.344	.311	1.809	.896	3.728	.26992

Table 2. Washed sands, Tallahatta Formation, Mississippi

	Mean	S.D.	Skew	Kurt.	Fifth	Sixth	T. of F.
S-1	2.525	1.007	.041	2.139	1.218	7.669	.06542
S-2	2.278	.983	.728	3.249	6	19.058	.05639
S-3	2.287	1.026	.616	3.103	4.876	16.637	.05986
S-4	2.387	.97	.443	2.971	3.984	15.738	.04797
S-5	2.314	1.002	.444	3.042	3.944	15.907	.05172
S-6	2.473	.959	.57	3.129	4.911	16.742	.06697

Table 3. Quartzites, Tallahatta Formation, Mississippi

	Mean	S.D.	Skew	Kurt.	Fifth	Sixth	T. of F.
Q-1	2.409	.727	1.254	6.293	17.613	68.419	.04169
Q-2	2.316	.778	1.16	5.722	15.18	57.939	.04048
Q-3	2.314	.696	1.196	6.786	19.687	85.182	.03065
Q-4	2.323	.759	1.047	5.623	14.616	58.195	.03588
Q-5	2.378	.903	1.184	5.008	11.423	37.176	.07219
Q-6	2.34	.71	1.138	6.333	17.577	74.355	.03279

Table 4. Quartzite, pan fraction removed; Tallahatta Fm., Miss.

	Mean	S.D.	Skew	Kurt.	Fifth	Sixth	T. of F.
R-1	2.323	.564	.05	3.24	.227	15.965	.01011
R-2	2.226	.613	.082	2.954	.007	13.787	.00825
R-3	2.247	.56	-.02	3.414	-.875	19.784	.00661
R-4	2.245	.615	.013	2.916	-.357	13.644	.0078
R-5	2.214	.641	.036	3.163	.226	14.445	.01434
R-6	2.272	.575	.013	3.262	-.688	17.622	.00788