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The Mississippi Mineral Resources Institute
University, Mississippi 38677

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by

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Abstract

PETROLOGIC CHARACTERIZATION OF POST-CATAHOULA SANDS AND GRAVELS IN FORREST AND LAMAR COUNTIES, MISSISSIPPI

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The Post-Catahoula, Miocene and younger, fluvial silts, sands, and gravels occurring in the southern portion of Mississippi are poorly defined in terms of their stratigraphy and the details of their composition. The lack of definition and the complexity of these sediments are due to similarity in depositional style and environment, apparent similarity in lithology, surficial alteration, and concealment by Quaternary age fluvial deposits. Petrologic analyses of samples representing the Hattiesburg Formation, Citronelle Formation, and Pleistocene and modern fluvial clastics were conducted in order to determine the composition of these materials and any significant differences between them. A mineralogical and textural data base consisting of non-clay light, heavy, and clay mineral suites; and grain-size statistical parameters was developed from 57 samples representing these four geologic units. Generally, the results of these analyses indicated overall mineralogical similarity between these units with the following exceptions. The Hattiesburg Formation contains a higher percentage of ultrastable heavy minerals and monocrystalline quartz with straight to slightly undulóse extinction; and a preponderance of smectite which is absent in the Citronelle. Textural differences were observed but are not significant. The mineralogical differnces were confirmed by discriminant analysis which showed that the most powerful discriminating mineralogical variables were, in descending order, black opaques, composite quartz, smectite, staurolite, semicomposite quartz, white opaques, rutile, tourmaline, kyanite, monocrystalline undulóse to strongly undulóse quartz, and zircon. Group centroids of these four units plotted on two-function graphs are separate and distinct and group membership was approximately 82% successful. On the basis of the statistical analyses, a fifth group was identified which represents sands overlying the Hattiesburg Formation and which may underlie an ancient terrace surface.

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INTRODUCTION

General Statement

The post-Oligocene sediments of southern Mississippi lack formation identity due to the absence of marine fossils, similarities in lithology, similarity in depositional style and environment, extensive surficial alteration, and concealment by Quaternary age fluvial deposits and are, therefore, very imperfectly understood.

Lack of guide fossils, coupled with inadequate shallow subsurface data, has resulted in the naming of formations that have no known upper or lower boundaries, which overlie or underlie other equally ill-defined formations. Where attempts have been made to differentiate these post-Oligocene sediments (included here are the Miocene and younger sediments of interest) into the Catahoula, Hattiesburg, Pascagoula, and Citronelle Formations, the upper and lower boundaries and areal extent are often arbitrary and vague. Because these Neogene formations lack clearly defined boundaries, it is difficult, for example, to distinguish gravel deposits of the Citronelle Formation from gravels of Quaternary alluvial materials and similarly to distinguish gravels of "post-Catahoula" (Hattiesburg-Pascagoula) from gravels of the Citronelle.

These statements regarding the absence of formation identity of the post-Oligocene sediments represent the brunt of the problem in terms of stratigraphy and the mapping of the formations over considerable distances. Because of the lack of diagnostic marine fossils, in addition to the previously mentioned problems regarding formation definition, and because little is known concerning the mineralogy and petrology of these Neogene clastic sedimentary units, a characterization in terms of texture and compositional parameters would undoubtedly aid greatly in the ultimate resolution of post-Oligocene stratigraphy of southern Mississippi.

Purpose

The primary objectives of this study are:

1. The mineralogic and petrologic characterization of sand and gravel deposits occurring in areas mapped as Hattiesburg, Citronelle, Quaternary terrace, and Holocene alluvium in Forrest and Lamar counties, Mississippi.
2. The identification of key mineralogic or petrologic properties of these sediments which can be used for their discrimination and mappability.
3. The identification of existing or potentially deleterious components which could adversely affect the utilization of these materials.

Previous Investigations

Little has been done in the form of detailed textural and mineralogic investigations of the Neogene sediments of southern Mississippi. Isphording (1977 and 1983) discussed the clay mineralogy and to a greater extent the heavy mineral assemblages of the Miocene and younger sediments of southern Mississippi, Alabama, and Florida. Smith and Meylan (1983) examined and correlated Citronelle sediments at Red Bluff, Mississippi, to those of the type area in Alabama using discriminant analysis of the heavy mineral suite. Self (1983) has recently studied grain sizes and chert to quartz ratios of Pliocene and Quaternary gravel fractions from the Florida Parishes of southeastern Louisiana. May (1980) reported on the surficial versus subsurface sediment texture, clay mineralogy, and non-clay, light mineral fraction of post-Oligocene sediments in the Mendenhall West Quadrangle of Simpson County, Mississippi.

A few studies have dealt with the mapping and stratigraphic field descriptions of these surficial post-Catahoula sediments. E. H. Rainwater (1964) presents a comprehensive report on the regional stratigraphy of the Gulf Coast Miocene. Bowen (1978 and 1981) reported on the stratigraphy and field descriptions of the Neogene sediments in addition to preparing a detailed geologic map of the Eastabuchie Quadrangle in portions of Forrest and Jones counties, Mississippi. Other studies which bear upon the field descriptions and local stratigraphy of these sediments include those of Foster and McCutcheon (1941) and Brown (1944).

Study Area

The study area is located in the northern half of Forrest County, the northeast portion of Lamar County, and extreme southwestern Jones County (Figure 1). It is within the parallels 31° 12'30" and 31 27'30" North latitude and the meridians 89° 12'30" and 89°27'30" West longitude. Portions of the Hattiesburg, Hattiesburg SW, Eastabuchie, Dixie, and Carterville quadrangles (7.5 minute series) are included.

Methodology

Fifty-seven samples were collected from 19 locations. Sample locations are shown on Plate 1 and outcrop descriptions are given in Appendix A. The geologic maps used as the basis for the sample collections are the State Geologic Map, the AAPG Southeastern Region Geological Highway Map, and Bowen's Eastabuchie Quadrangle Geologic Map.

At each sample location texturally distinct lithologic types were collected in an attempt to establish more meaningful comparisons between sampling sites. The lithologic types collected were: (1) gravels, (2) sands

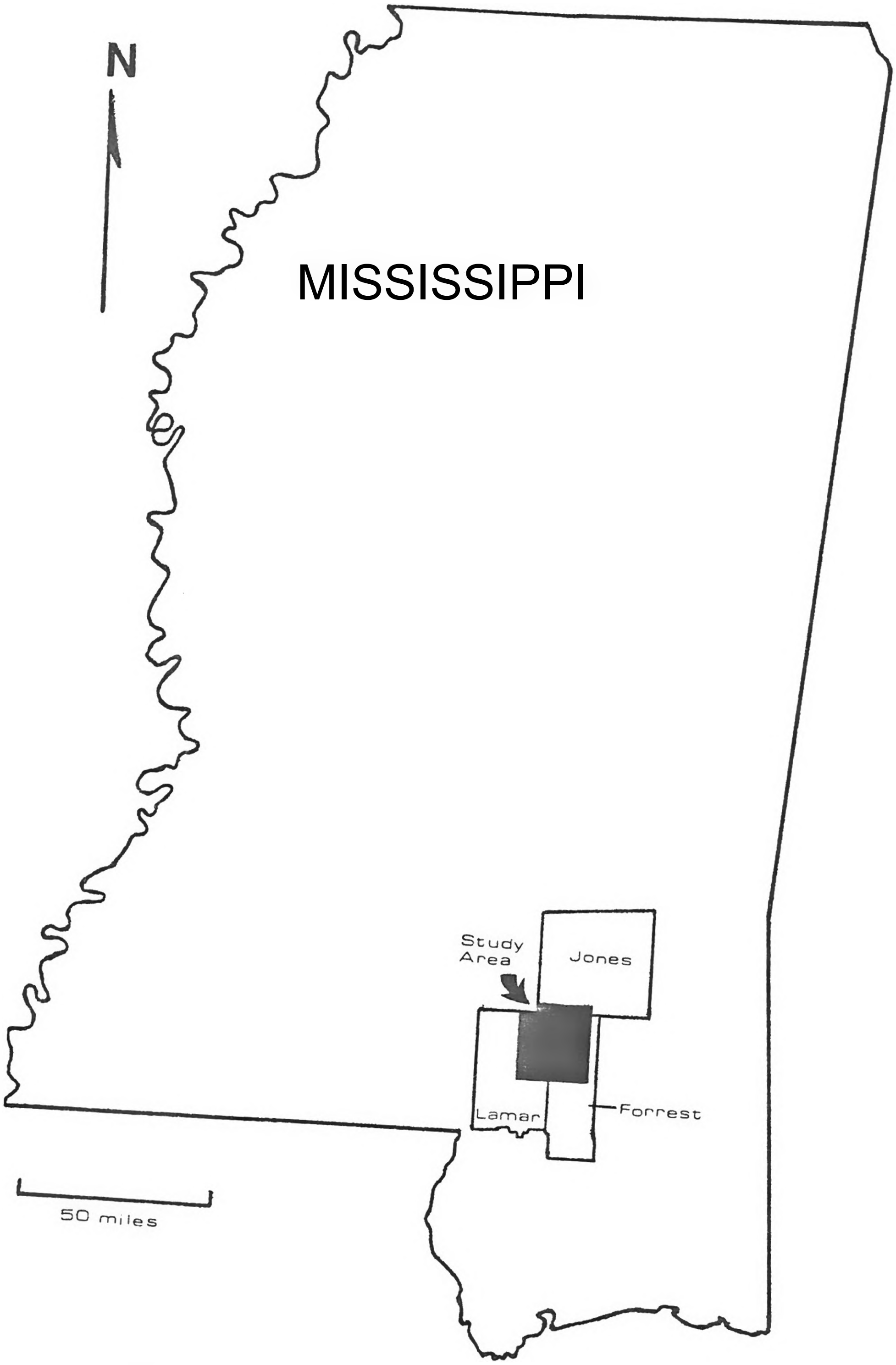

Figure 1. Location of study area.

(with or without gravel), (3) sands with appreciable fines, and (4) clays and relatively fine-grained materials. Samples are designated by these different lithologic types according to the sedimentary unit. The letters following a sample number correspond to the sedimentary unit and the lithologic type. For example, sample number 101CS corresponds to sample location 101 which is a mapped Citronelle (C) deposit, and the lithologic type is a sand (S). Likewise, if the first letter is (H), the sample is from the Hattiesburg Formation, (T) sub-terrace deposit, (A) alluvium, and the corresponding lithologic types are (G) gravel, (SF) sands with appreciable fines, and (CL) clays and relatively fine-grained materials.

All 57 samples were split and quartered in preparation for grain size analyses. The grain size analyses consisted of first determining the sediment size percentages by splitting the sediment into coarse and fine (fines equal smaller than 4 0) size fractions. Secondly, the coarse fraction was sieved and the distribution of the fine fraction was determined by hydrometer techniques. The subsequent grain size statistics were calculated using the methods advocated by Folk (1974,pp. 15-48).

For each sample collected the mineralogy of separate size fractions was determined. The mineralogy of the fine fractions (clay and silt) of light minerals was determined by oriented and powder x-ray diffraction. The mineralogy of the non-clay, light mineral and heavy mineral fractions was determined by statistical point counts using the petrographic microscope. The mineralogy of the pebble and granule gravel fractions was determined by examination with the binocular microscope.

Data analysis consisted of statistical comparisons of the textural and mineralogical characteristics to further assist in the identification of these clastic sedimentary units. This was largely accomplished by using the statistical procedure of discriminant analysis with the SPSS computer package (Kiecka, 1970, pp. 437-467).

REGIONAL STRATIGRAPHY

Post-Catahoula sediments exist throughout the southern one-fourth of Mississippi. Figure 2 shows the approximate updip limit of the post-Catahoula sediments.

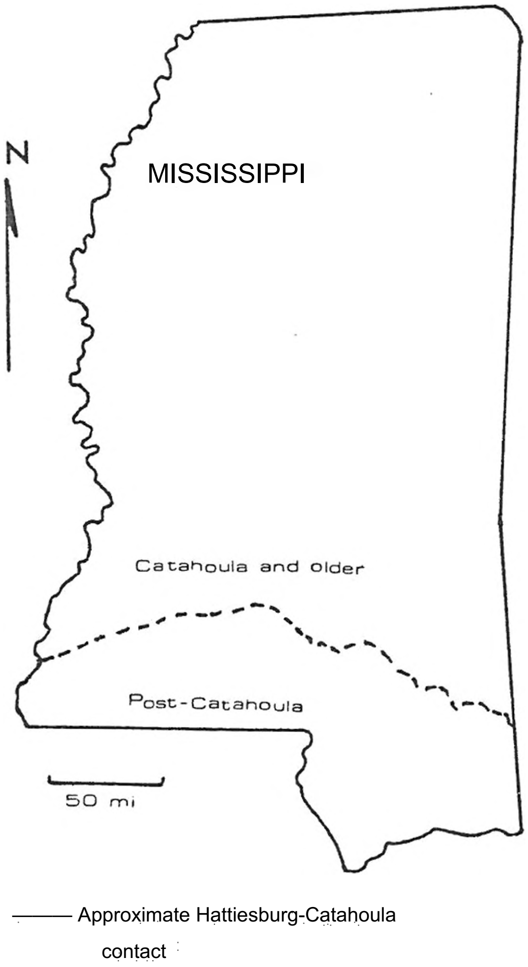

Figure 2. Location of the post-Catahoula contact (from the AAPG Southeastern Region Geological Highway Map).

in the study area, four partially distinguishable sedimentary units exist: (1) the Hattiesburg Formation, (2) the Citronelle Formation, (3) Quaternary Terraces, and (4) Holocene Alluvium. The Pascagoula Formation, whose northernmost definite outcrop is near the junction of the Leaf and Chickasawhay Rivers (Brown, 1944, p. 44), is absent in the study area and is therefore not included on the generalized stratigraphic column (Figure 3).

Hattiesburg Formation

The Hattiesburg Formation, so designated from its type area near Hattiesburg, extends across South Mississippi in a belt paralleling and south of the Catahoula Formation which it overlies (Brown, 1944, p. 27).

The Hattiesburg Formation is generally regarded as middle to late Miocene and represents a nonmarine sequence of fine-grained sediments. Rainwater (1964, p. 120) states that the Hattiesburg probably averages 300 feet thick; however, Bowen (1981, p. 2) indicates that in the bordering areas of the Eastabuchie Quadrangle a total thickness of not more than 150 feet is present, and Foster and McCutcheon (1941, p. 24) report thick beds of massive clays "150 or 200 feet thick" in the river bluffs in the study area.

Bowen (1981, p. 2) says that the Hattiesburg Formation consists of a set of dominantly fine-grained

SERIES	SEDIMENTARY UNIT	LITHOLOGIC CHARACTER
QUATERNARY ?Pleistocene-Holocene	ALLUVIUM	Fining-upward, light colored, clean, chert gravel and fine to medium-grained, clean sand. Light brown to reddish-brown, very fine-grained, silty sand; and grayish-white to light brown, clayey silt.
	DEPOSITS UNDERLYING TERRACES	Alternating layers of brown to tan, sandy, quartz-chert gravel and fine to medium-grained sand. Lesser amounts of fine-grained, reddish-brown, silty sand.
?MIOCENE- ? PLEISTOCENE	CITRONELLE FM.	Alternating layers of highly oxidized, reddish-brown to yellow chert gravel; red to reddish-purple, fine to medium-grained, uniform sand;highly weathered, grayish-brown to yellow, fine-grained, silty sand; and rather thin, reddish-purple to white, clayey silts with interbedded minute sand laminae; occasionally exhibits grayish-brown clay balls and ironstone concretions.
MIOCENE	HATTIESBURG FM.	Massive, greenish-gray to reddish-gray, clayey silts (lutite) with locally occurring large, crusty, calcareous nodules. Some fine-grained sand size material within lutite. Orange to brown fine-grained sand and gravel occur in association - overlie lutite.

Figure 3. Generalized stratigraphic column of sediments in study area (stratigraphic terminology of Foster and McCutcheon, 1941).

clastics best described as a lutite complex. Most authors have termed the Hattiesburg material as "clay", but as will be shown in later sections, the terminology of Bowen is correct.

Exposures of the Hattiesburg exist mainly in the road cuts in the study area and to a lesser extent in the valley walls of the Leaf and Bowie Rivers. These fine-grained clastics consist of massive, greenish-gray to reddish-gray, clayey silts with locally occurring large, crusty, calcareous nodules. Orange to brown fine-grained sand and gravel occur in association with the finer-grained silts and clays with the precise identification in terms of age relations of these coarser materials being most difficult. These coarse clastics that occur in association with the silts and clays usually overlie the finer-grained material; however, both Brown (1944, p. 32) and Foster and McCutcheon (1941, p. 24) also describe sand and gravel near the base of the formation.

Citronelle Formation

The Citronelle Formation, named from its type locality near Citronelle, Mobile County, Alabama, is commonly considered in most reports to rest upon the Hattiesburg Formation and other Miocene (?) to Early Pliocene (?) units. Bowen (1981, p. 4) indicates an irregular surface of unconformity on top of the Hattiesburg Formation in the Eastabuchie Quadrangle.

Brown (1944, p. 44), Foster and McCutcheon (1941, p. 26), and May (1980, p. 23) used the term "Citronelle" to describe the coarse, clastic sediments that are the highest topographically. Bowen (1981, p. 4) uses the informal term "Upland Graveliferous Deposits" to designate these coarse clastics that occur in the hilly portions across southern Mississippi. No reference section exists in the study area for the sediments mapped as the Citronelle Formation, and correlation between these sediments and those at its type locality in Southwest Alabama is as yet unproven. Nevertheless, to conform with the previously mentioned nomenclature of Foster and McCutcheon (1941) and state geologic maps, the name Citronelle will be used when referring to such deposits.

The age of the Citronelle Formation is highly controversial due to the lack of fossil evidence. Various investigators have given it late Miocene to Pleistocene ages. If the Citronelle Formation (using the term in its broadest sense) is but one facies of a major interfingering offlapping regressive sequence as some believe, then a Miocene age for these sediments in the northernmost counties of the mapped Citronelle outcrop would be acceptable. Isphording and Lamb (1971, p. 775) indicate that deposition of Citronelle deposits at the type section in Citronelle, Alabama, began in the middle Pliocene and continued into the pre-Nebraskan Pleistocene due to faunal evidence coupled with pollen data from the upper sediments of the Citronelle in Florida. Based on this evidence, the age of the Citronelle Formation will be referred to as Plio-Pleistocene in this report.

At its type locality, the Citronelle Formation ranges from a thin veneer to 340 feet in thickness (Cooke, 1926, p. 296). Maximum thicknesses near the study area indicate the formation is approximately 135 feet thick (Brown, 1944, p. 44). Bowen (1981, p. 6) states that the maximum thickness of the "Upland Graveliferous Deposits" in the Eastabuchie Quadrangle is 150 feet or slightly more.

Exposures of the coarse, clastic sediments mapped as the Citronelle Formation by Foster and McCutcheon and Brown are most clearly visible in commercial gravel pits existing at the higher elevations in the study area. These sediments consist of alternating layers of highly oxidized gravel, sand, silty sand, and clayey silt. The gravels are reddish brown to yellow and exhibit frequent liesegang banding. The gravel component consists of rather large percentages of chert pebble gravel. Most of the sand layers are red to reddish purple with small amounts of gravel present. The sands are generally fine to medium grained and quite uniform. Highly weathered, grayish-brown to yellow, fine-grained, silty sands occur in most cases at the top of the section. Precipitated ironstone concretions (sometimes thin layers) are somewhat common in this material. Very fine-grained, reddish-purple to white, clayey silts with interbedded minute sand laminae occur rarely as also do grayish-brown clay balls. Channel-fill structures and minor cross-bedding occur locally.

Quaternary Terraces

Sands and gravels exist as materials associated with fluvial terraces developed within the Leaf River strath. Although they are considered to be younger in age than the sands and gravels of the Citronelle Formation, they sometimes lie at topographically lower positions (Figure 4).

These sediments which occur in association with the fluvial terraces will be referred to as terrace (sub-terrace) deposits in this report because they occur in association with the river terraces which are the products of stream erosion and not of stream deposition. Although it is not unusual for the surface of a terrace to be a depositional surface, the terrace itself came into being only through the development by erosion of another valley flat below the top of the former valley floor (Thornbury, 1969, p. 156). The sands and gravels associated with the terrace surfaces are rather thin; however, Brown (1944, p. 44) states that the higher terrace deposits which are reworked Citronelle sediments range up to 100 feet thick. Bowen (1981, p. 7) indicates that the terraces are cut largely on the Hattiesburg Formation in Jones County and

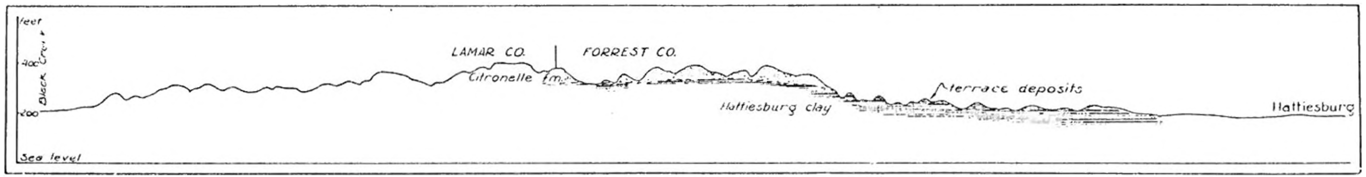

Figure 4. Topographic relation of terrace deposits to the Citronelle and Hattiesburg formations (after Foster and McCutcheon, 1941, p. 30).

on the east side of the Leaf River in Forrest County; however, they are underlain by fluvial and overbank deposits of probable Holocene age between the Leaf and Bouie Rivers in Forrest County.

Certainly the best exposures of sub-terrace deposits are in commercial gravel pits at the lower elevations within the Leaf River strath. These sediments consist of alternating layers of brown to tan, sandy gravel, fine to medium-grained sand of the same color, and lesser amounts of fine-grained, reddish-brown, silty sand. Very little clayey material was encountered in these deposits.

Holocene Alluvium

Alluvial deposits are the most recent sediments in the study area. They occur within the valleys of the major streams and smaller tributaries. These sediments, for the most part, consist of fining-upward sequences of gravel, sand, and very fine-grained silt and clay material. Basal gravels are coarse and relatively free of fines. Fine to medium-grained sands are light brown to tan and are also relatively clean. Very fine-grained, silty sands range from light brown to reddish brown in color. Clayey silts, occurring at the top of the sequence, are generally grayish white to light brown.

TEXTURAL PROPERTIES

Introduction

Sediment populations are mixtures which may consist of gravel, sand, and mud (silt and clay). The distribution of particle sizes in sediments relates to (1) the availability of different sizes of particles in parent material, (2) weathering processes, catastrophic mass-wasting events, and glacial activity on parent material, (3) sorting during transport, (4) processes operating where the sediments are deposited, particularly the competency of flow, and (5) diagenetic alteration after deposition (Friedman and Sanders, 1978, pp. 26-27, 70). Statistical measures of particle sizes can provide a great deal of information about the normal frequency distributions of sediment populations. These statistical measures, which can be determined graphically from a frequency distribution, supply information about average grain size, uniformity or sorting of sediments, and the symmetry and peakedness of the normal probability curve. Such statistical values are of primary concern in this study as a tool of stratigraphic/lithostratigraphic characterization and comparison. Each clastic sedimentary unit is described by average sediment size percentages and grain size statistics. Statistical data on individual samples are given in Appendix B.

Sediment Size Percentages and Grain Size Statistics

Hattiesburg Formation

The Hattiesburg Formation (Table 1) is characterized by a fine-grained, clayey silt best described as a lutite complex after Bowen (1981, p. 2). As previously mentioned, the sediment has been designated as a "clay" by most authors; however, these massive, fine-grained deposits contain only a small amount of very fine sand and almost twice as much silt as clay. This lutite has a mean grain size of 6.90 ϕ (medium to fine silt) and is very poorly sorted.

Sands and Gravels Associated with the Hattiesburg Formation

Sands and gravels associated with the Hattiesburg Formation usually overlie the lutite with the exception of a sand and gravel sampled below it at location 113H. The precise identification of these sediments is rather difficult; however, it seems most likely that they belong either to the Citronelle Formation (sensu lato) or more modern alluvial deposits.

These sediments associated with the Hattiesburg Formation (Table 1), more than any other sedimentary unit, are characterized by silty, clayey gravels having the lowest average gravel percentage by weight (29.8%) and the

Table 1

Average Sediment Size Percentages and Grain Size Statistics for the Hattiesburg Formation (Lutite) and for the Sands and Gravels Associated with the Hattiesburg Formation

		Sediment Size Percentages				Grain Size Statistics				
Lithologic Type	N	Gravel	Sand	Silt	Clay	Median 0	Mean ɸ	Graphic Standard Deviation ɸ	Graphic Skewness	Graphic Kurtosis
					Hattiesburg Formation (Lutite)					
Fine-grained silts & clays (lutite)	7	0	9.0	58.7	32.2	5.77	6.90	2.76	+0.54	0.90
					Sands and Gravels Associated with the Hattiesburg Formation					
Gravel	2	29.8	43.6	22.1	4.4	1.81	0.97	3.52	-0.24	0.71
Sand	4	0.9	78.7	17.2	3.1	2.25	2.46	1.27	+ 0.43	1.72
Sand with appreciable fines	4	0.3	59.6	31.2	8.8	3.23	3.67	2.01	+ 0.42	1.45

NOTE: N = number of samples

highest mud (silt and clay) percentage by weight (26.5%). They are texturally the finest (graphic mean, Mz = 0.97 0) of all gravels sampled and are negatively skewed. The sand is fine-grained (Mz = 2.46 Φ) and contains more silt and clay than sands from the other clastic sedimentary units but nevertheless is better sorted than any other material associated with the Hattiesburg Formation. The sand with appreciable fine-grained sediment has a relatively high sand to mud ratio (1.50), is very fine-grained (Mz = 3.67 Φ), and is very poorly sorted.

Citronelle Formation

The Citronelle Formation (Table 2) is characterized by gravel units containing the highest average gravel percentage by weight (63.3%). They are texturally the coarsest of all gravels sampled (Mz = -1.54 Φ). The sands are fine-grained (Mz = 2.10 0) and, although poorly sorted, are much better sorted than any of the other material sampled from the Citronelle deposits. The kurtosis of the sands (K_G = 2.36; very leptokurtic) is the highest of any material sampled from any of the clastic sedimentary units. The sands with appreciable fine material contain approximately subequal amounts of sand and mud. This material has a mean grain size of 4.51 Φ (coarse silt) and is very poorly sorted. The fine-grained silt and clay material contains more sand (23.7%) on average than similar sediments from the other clastic sedimentary

Table 2

Average Sediment Size Percentages and Grain Size Statistics
for the Citronelle Formation

		Sediment Size Percentages				Grain Size Statistics				
Lithologic Type	N	Gravel	Sand	Silt	Clay	Median 0	Graphic Mean 0	Standard Deviation 0	Graphic Skewness	Graphic Kurtosis
Gravel	5	63.3	30.5	*6.2		-2.55	-1.54	2.70	+ 0.50	0.63
Sand	5	3.0	87.8	*9.2		2.03	2.10	0.96	+ 0.11	2.36
Sand with appreciable fines	5	1.3	44.8	39.1	14.7	3.98	4.51	3.06	+ 0.37	1.71
Fine-grained silts & clays	5	0.5	19.5	52.4	27.6	5.00	6.20	3.31	+ 0.55	1.16

NOTE: N = number of samples

*silt and clay undifferentiated

units. The mean grain size of this material is 6.20 ϕ which represents the poorest sorted sediment type in the Citronelle Formation.

Quaternary Terraces

Sediment beneath topographic terraces somewhat resembles Hattiesburg gravels in terms of sediment size percentages but has a slightly higher gravel and lower mud content (Table 3). Sub-terrace gravels, like the Hattiesburg gravels, are negatively skewed and are the poorest sorted of all underlying terraces. Sands beneath terraces contain the greatest amount of gravel (6.1%), are the coarsest of all sands (Mz = 1.76 ϕ); medium sand) in any of the clastic sedimentary units, and are the best sorted of all terrace materials. These sands are also negatively skewed, which may be a distinguishing characteristic. The sands with appreciable fine-grained sediment contain slightly more silt and clay than sand, have a mean grain size of 4.22 ϕ (coarse silt), and are very poorly sorted.

Holocene Alluvium

Alluvial gravels are second only to Citronelle gravels in amount of gravel (Table 4), mean grain size (Mz = -0.97 0) , and like the Citronelle gravels are positively skewed. Alluvial sands are medium to fine (Mz = 2.03 Φ) and are moderately sorted. They are not only the best sorted alluvial material but are by far

Table 3

Average Sediment Size Percentages and Grain Size Statistics
for the Quaternary Terrace Deposits

		Sediment Size Percentages				Grain Size Statistics				
Lithologic Type	N	Gravel	Sand	Silt	Clay	Median 0	Graphic Mean 0	Standard Deviation 0	Graphic Skewness	Graphic Kurtosis
Gravel	3	36.2	49.9	12.6	1.3	0.71	0.19	2.98	-0.20	0.82
Sand	3	6.1	81.1	*12.7		1.78	1.76	1.41	-0.08	1.47
Sand with appreciable fines	1	0.5	44.6	42.6	12.2	4.13	4.22	2.72	-0.20	0.95

NOTE: N = number of samples

*silt and clay undifferentiated

Table 4

Average Sediment Size Percentages and Grain Size Statistics
for the Holocene Alluvial Deposits

Lithologic Type	N	Sediment Size Percentages: Gravel	Sand	Silt	Clay	Grain Size Statistics: Median Ø	Graphic Mean $	Standard Deviation /	Graphic Skewness	Graphic Kurtosis
Gravel	4	51.3	46.6	*2.1		-1.24	-0.97	2.32	+ 0.10	0.69
Sand	4	1.4	92.8	*5.7		1.85	2.03	0.78	+ 0.21	0.86
Sand with appreciable fines	2	0	67.6	28.4	3.9	3.08	3.18	1.22	+ 0.22	0.95
Fine-grained silts & clays	3	0.1	18.2	60.1	21.6	5.58	6.05	2.67	+ 0.34	1.45

NOTE: N = number of samples

*silt and clay undifferentiated

the best sorted of all the sands sampled. The sand with appreciable fine-grained sediment contains approximately twice as much sand as silt and clay with the highest sand to mud ratio of 2.10. These sands with appreciable fines are the coarsest (Mz = 3.18 ***(p)*** and are the best sorted of lithologically similar materials from all clastic sedimentary units sampled; nevertheless, they are still poorly sorted. The fine-grained silt and clay material contains approximately 60% silt with remaining subequal amounts of sand and clay. These sediments have a mean grain size of 6.05 **ϕ** (medium silt) and are very poorly sorted.

Textural Maturity

Folk (1974, p. 100) defines four stages of textural maturity. They are (1) the immature stage in which the sediment contains over 5% terrigenous clay matrix and the sand grains are usually poorly sorted and angular, (2) the submature stage in which the sediment contains under 5% clay, but the sand grains are still poorly sorted and are not well rounded, (3) the mature stage in which the sediment contains little or no clay and the sand grains are well sorted, but still not rounded, and (4) the supermature stage in which the sediment contains no clay and the sand grains are well sorted and well rounded.

Following Folk's system of textural maturity, the data compiled in this study indicate that the majority of the sediments sampled are, for the most part, immature with lesser quantities of mature sediments. The immature sediments are those deposits that are poorly sorted with subangular sand grains and a large percentage of silt and clay (over 5%). The mature sediments which contain less clay matrix and are better sorted are characteristic of certain individual sand and gravel lithologic types from, for the most part, the Citronelle and alluvial deposits. Individual sand grains in the sediments sampled are better rounded with increasing grain size. In fact, a rather common feature in these sediments is textural inversions that occur when a sediment is composed of poorly sorted but well rounded grains (Folk, 1974, p. 103).

MINERALOGY

Clay Minerals

The Citronelle sediments are characterized by a matrix in which the predominant clay minerals are kaolinite (KA) and illite (IL) with lesser amounts of vermiculite (?) (V?, Figure 5a) and mixed-layer clays. Although vermiculite has been reported in clays and soils from different locations by various investigators, when referred to here it is accompanied by a question mark because it is a rather rare clay mineral whose formation has been regarded as an alteration product of biotite or phlogopite (Carroll, 1970, p. 23). Since it commonly occurs interlayered with biotite, it would be reasonable to expect some indication of the presence of biotite in the x-ray powder diffraction data; however, there is no such evidence. Nevertheless, testing for the presence of chlorite and vermiculite (both have 14 angstrom x-ray diffraction peaks) by heating the material at 700* C for one hour resulted in the collapse of the 14 angstrom diffraction peak (Figure 5b), which is characteristic of vermiculite. The 14 angstrom clay mineral in question could, in fact, be a three-component clay mineral encompassing some of the characteristics of vermiculite,

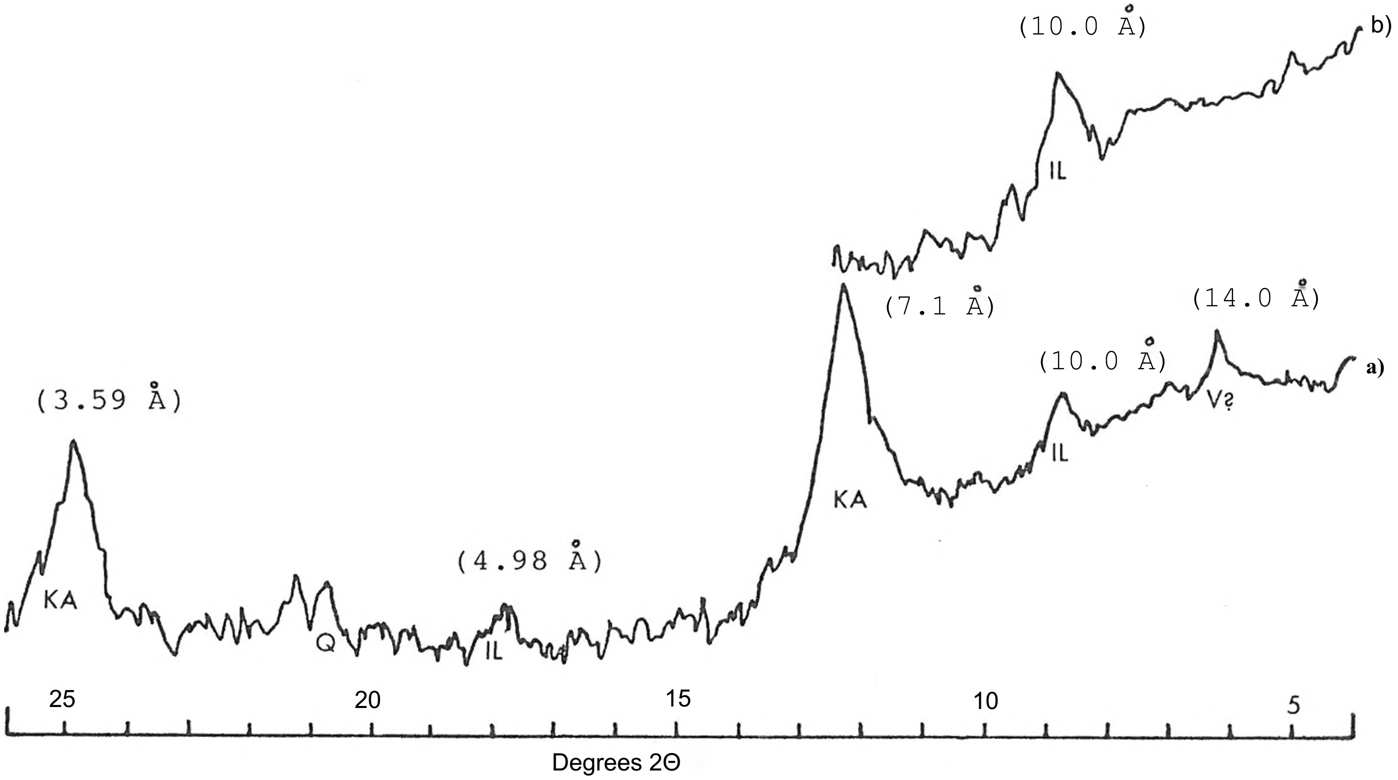

Figure 5. Characteristic Citronelle x-ray diffractogram of the clay fraction: (a) regular oriented, (b) after heating to 700 C for one hour (sample number 104CSF).

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chlorite, and smectite. The group name smectite as used throughout this study refers to the expandable clay minerals which include montmorillonite, beidellite, nontronite, hectorite, and saponite (Grim, 1968, p. 77).

To further quantify and to compare the x-ray data, the area beneath each clay mineral peak (from the x-ray diffraction pattern) has been calculated and reported as a ratio to that of illite (Table 5). This technique is a very rough, semi-quantitative approach to establishing a meaningful comparison of the x-ray data.

Table 5

Average Peak Area Ratios of the Major Clay Minerals to Illite

Clastic Sedimentary Unit	N	Smectite	Kaolinite
Hattiesburg Fm.	7	16.9	3.4
Sands and gravels associated w/ the Hattiesburg Fm.	9	0.4	7.1
Citronelle Fm.	14	-	12.2
Sub-terrace Deposits	6	12.2	10.6
Alluvium	13	6.1	4.4

NOTE: N = number of samples

The lutite, so characteristic of the Hattiesburg Formation, primarily contains smectite (S) with lesser amounts of kaolinite (KA) and illite (IL) (Figure 6).

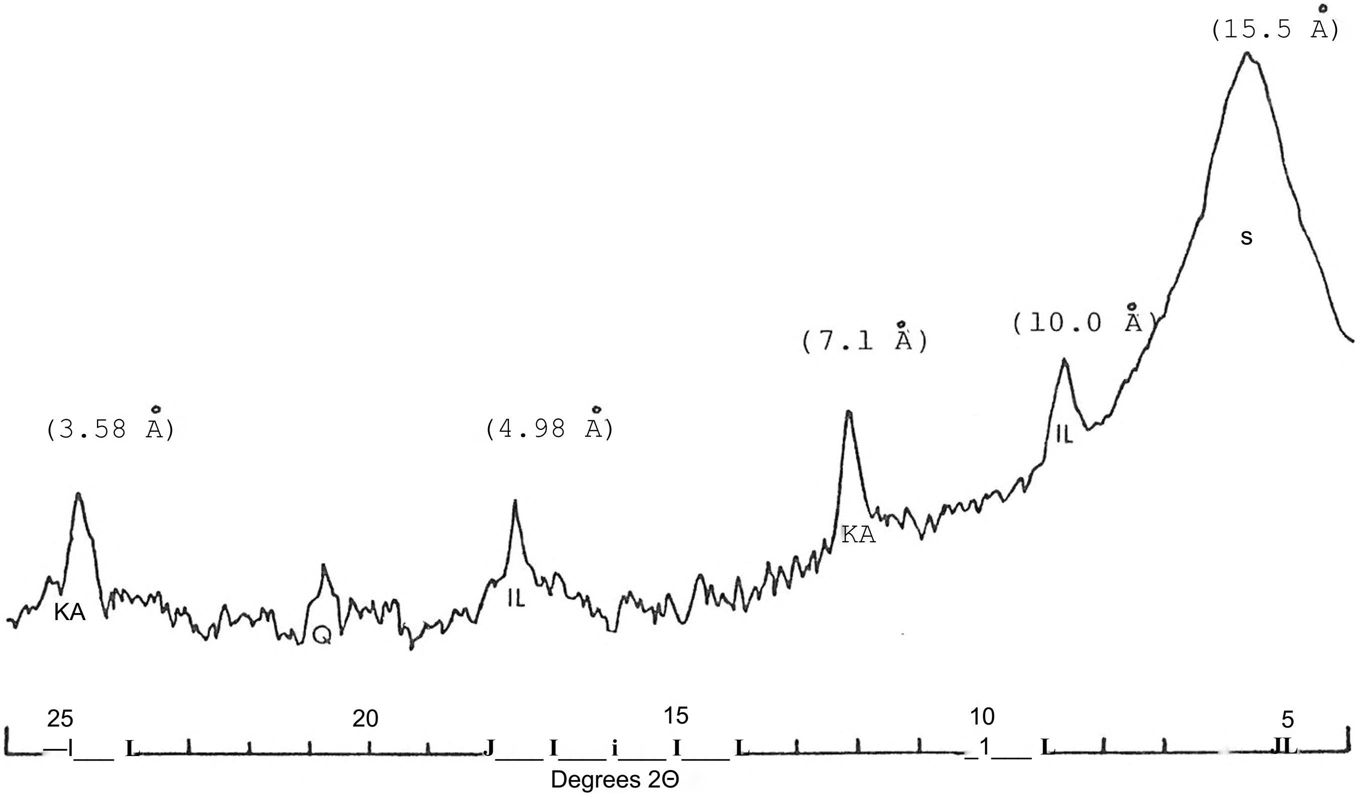


Figure 6. Characteristic Hattiesburg lutite x-ray diffractogram (sample number 109HCL).

Clay minerals from the sands and gravels associated with the Hattiesburg Formation resemble those of the Citronelle sediments. Again kaolinite (KA) and illite (IL) predominate with lesser amounts of vermiculite and mixed-layer clays (ML) (Figure 7).

Kaolinite (KA) and smectite (S) with lesser quantities of illite predominate in the sub-terrace sediments (Figure 8). Although the smectite to illite ratio averages 12.2, it is very misleading. X-ray diffraction patterns show, for the most part, small diffuse smectite peaks; however, one much larger peak increased the average considerably.

The alluvial deposits, like the sub-terrace material, show a predominance of kaolinite (KA) and smectite (S) with lesser amounts of illite (IL) (Figure 9); however, the average kaolinite to illite and smectite to illite ratios are much lower.

Mineralogy of the Silt Size Fraction

The predominant minerals present in the silt size fraction (of the suite of samples collected and studied) are quartz, feldspars, iron oxides and hydroxides, and mica. Quartz is the dominant mineral present in all samples. Feldspar and mica are present in roughly equal amounts and the iron oxides and hydroxides are the least abundant minerals.

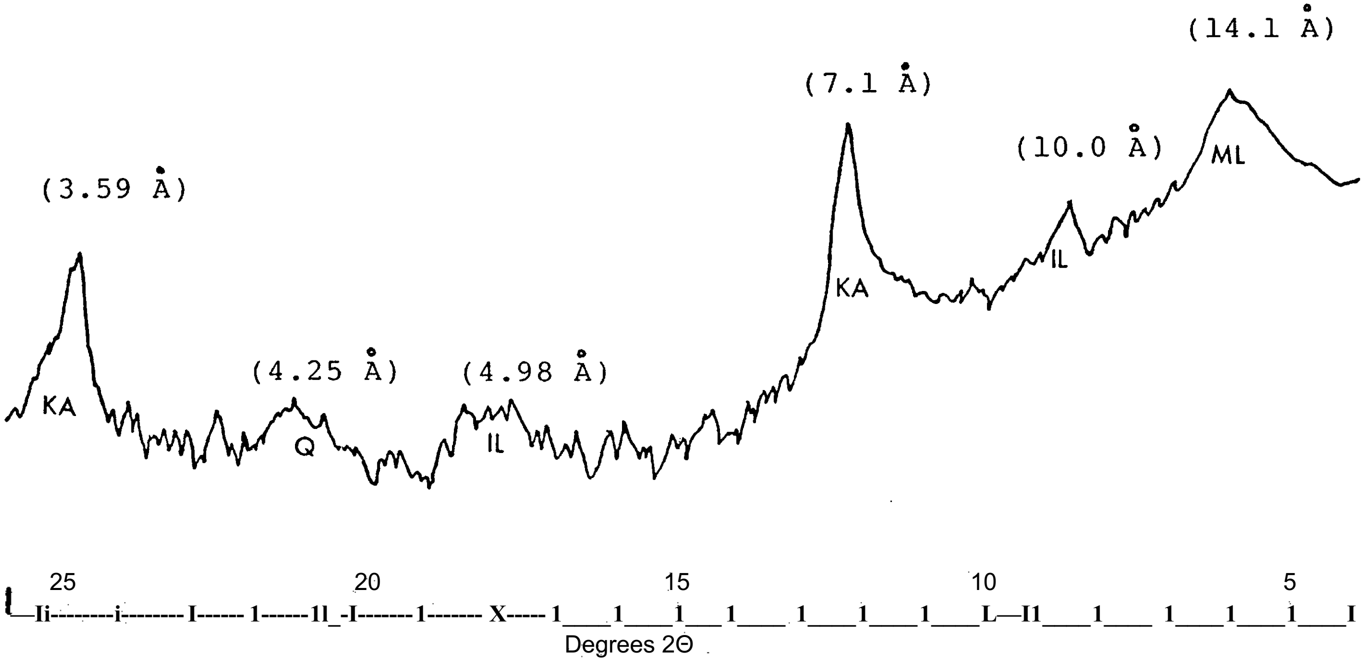


Figure 7. Characteristic x-ray diffractogram of the clay minerals from the coarse sediments associated with the Hattiesburg Formation: after glycolation (sample number 110HSF2).

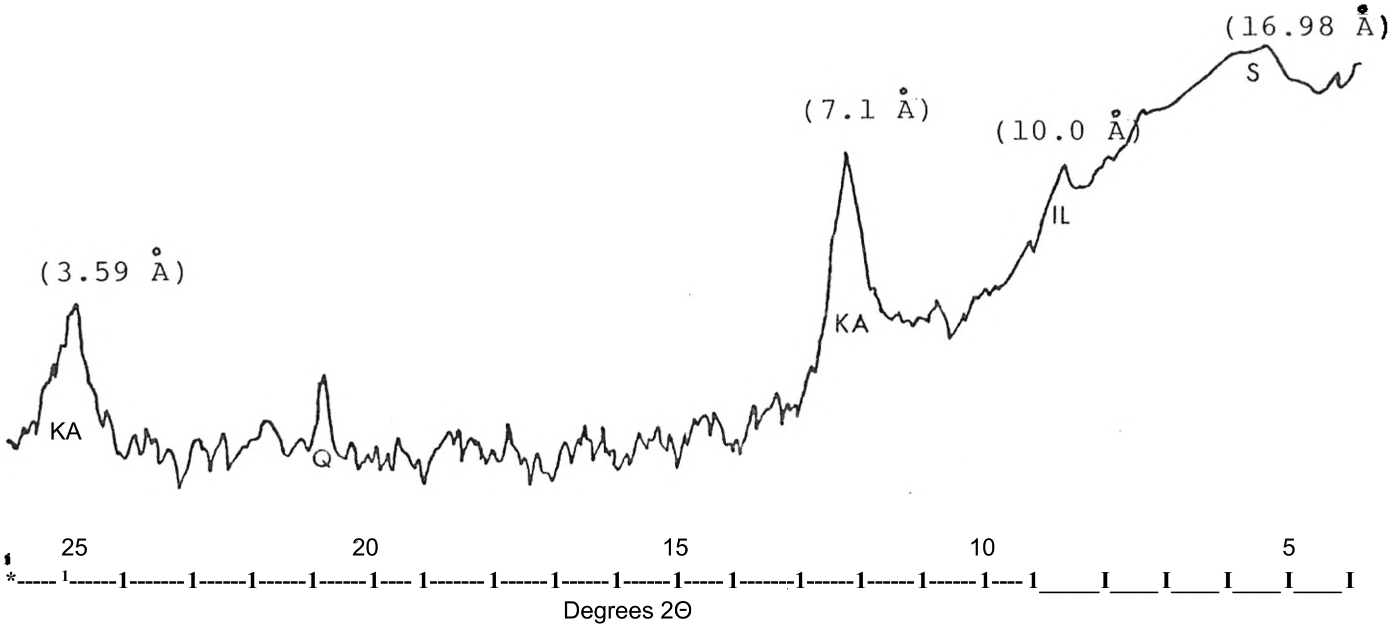


Figure 8. Characteristic x-ray diffractogram of the clay fraction from the sub-terrace sediments after glycolation (sample number 115TG).

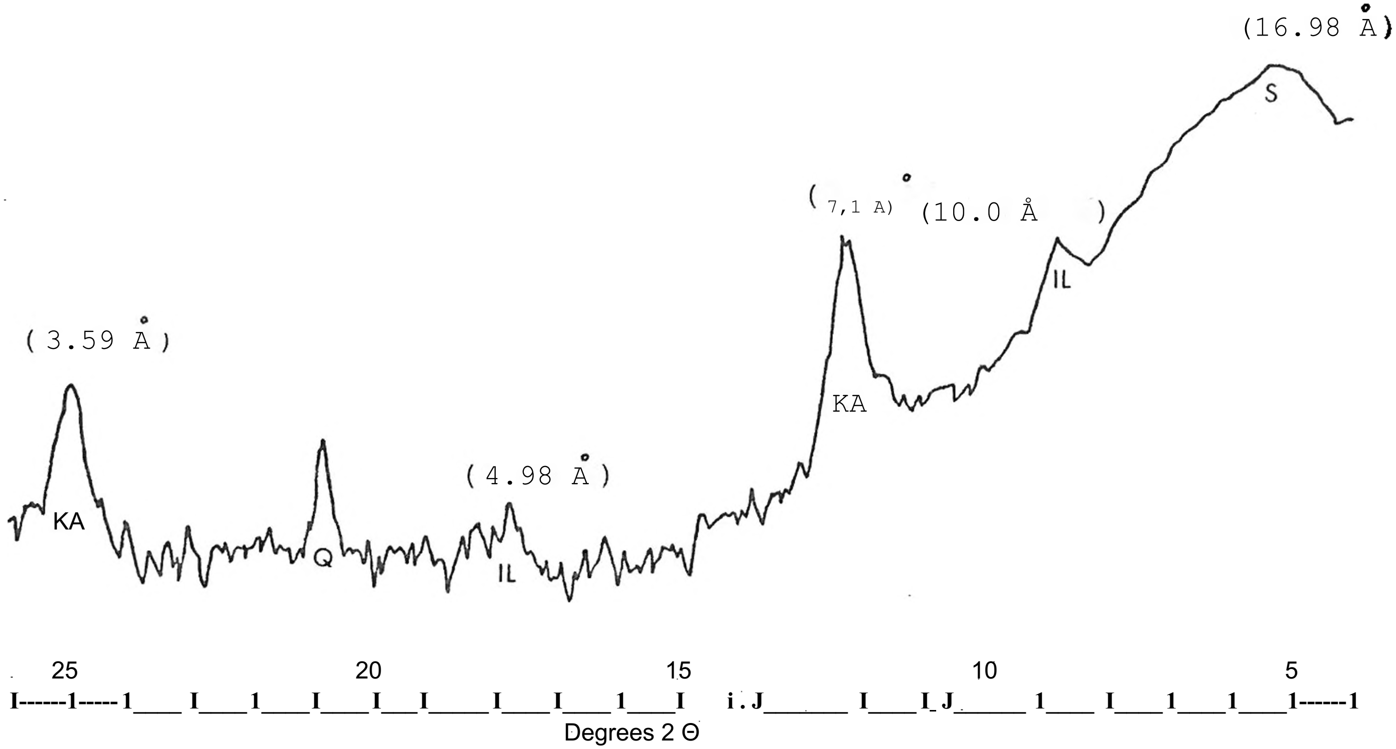


Figure 9. Characteristic x-ray diffractogram of the clay fraction from the Holocene alluvium after glycolation (sample number 119ASF).

As mentioned previously, quartz is the dominant mineral in all the silt-size sediments. Feldspars (undifferentiated) occur commonly in the Citronelle sand lithologic type, occasionally in the Hattiesburg lutite and associated sediments, and in nearly all terrace and alluvial samples. The iron oxides and hydroxides, which are less abundant, occur sporadically throughout the Citronelle, Hattiesburg, and sub-terrace deposits and are absent in the alluvial sediments. Mica (2M ?$_1$ muscovite), which generally occurs in minor amounts, is not restricted to any clastic sedimentary unit but does occur in a large percentage of all silt size sediments due to its flaky shape. Folk (1974, p. 87) states that because of its flaky shape, mica behaves hydraulically as a much smaller particle; therefore, large mica flakes are usually washed out of the coarser sands and deposited with finer silts.

Light Minerals

Five quartz types are recognized in this study by modification of the six quartz types of Folk's empirical classification (1974, p. 72). The number of samples analyzed from each unit and the number of grains counted are tabulated in Appendix G. Monocrystalline straight to slightly undulose grains (Figure 10) are single quartz grains in which the extinction shadow moves smoothly across the grain on very slight rotation of the microscope stage, usually one to five degrees (Figure 11). Mono-

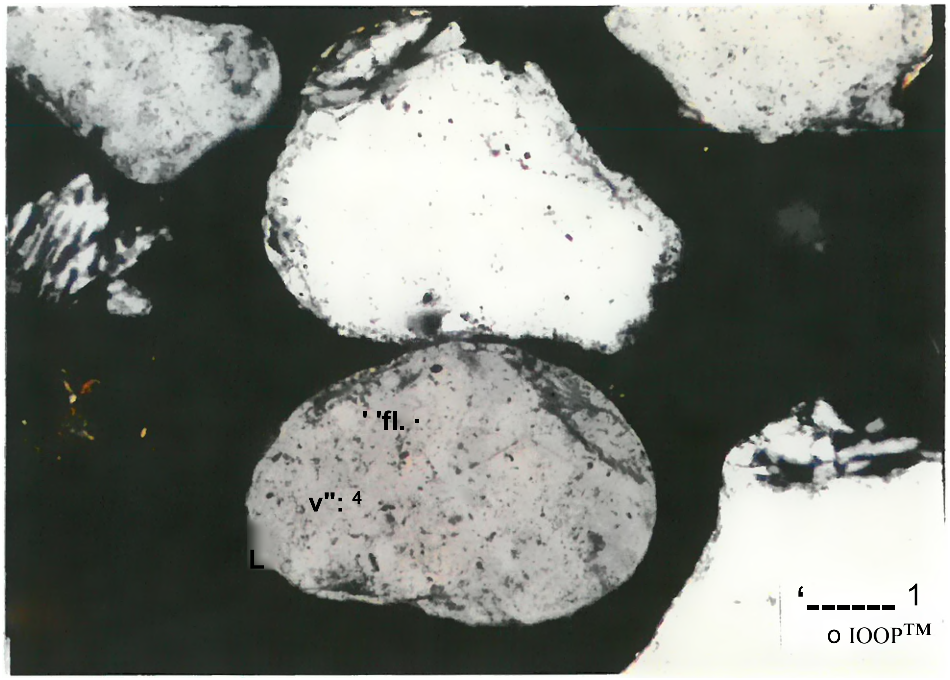


Figure 10. Photomicrograph of monocrystalline quartz grains from sample number 101CS. Bottom grain has straight to slightly undulóse extinction and the top grain has undulóse to strongly undulóse extinction (crossed polarizers).

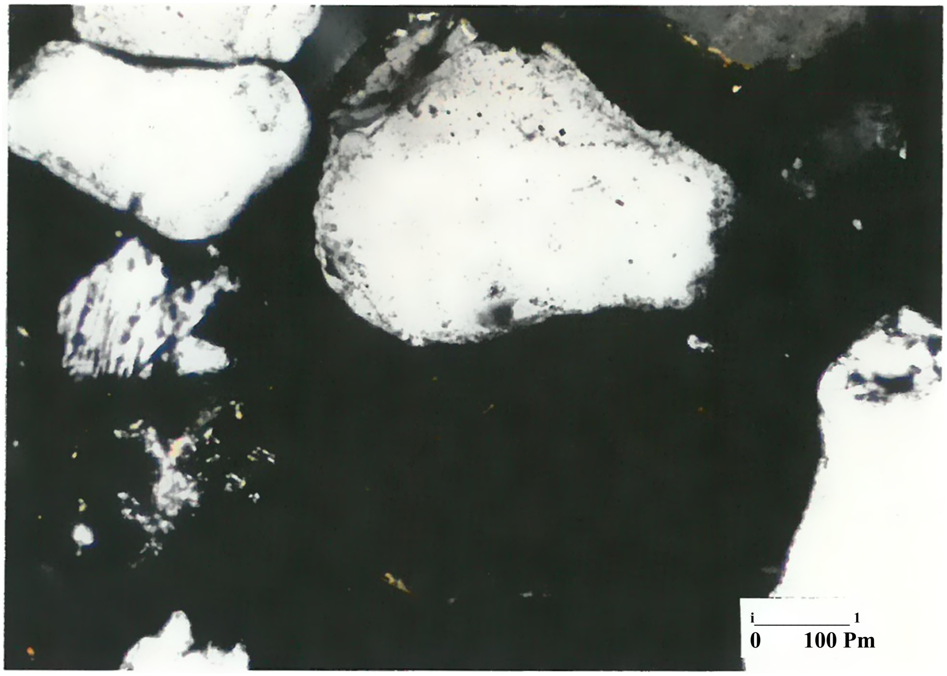


Figure 11. Same as previous photo after a very slight rotation of the microscope stage (crossed polarizers).

crystalline undulóse to strongly undulóse grains are single quartz grains in which the extinction shadow sweeps smoothly across the grain, but a large rotation of the stage (greater than five degrees) is required between the time one part of the grain is extinguished to the time another part is extinguished (Figure 11). Semicomposite grains (Figure 12) are made up of two or more subcrystals with very close optical orientation, but there is a distinct break between individual subcrystals, and the extinction shadow does not sweep smoothly across the grain. Composite grains (Figure 13) are made up of two or more subcrystals with widely differing optical orientation. These subindividuals have normal boundaries and straight to slightly undulóse extinction. Composite metamorphic grains (Figure 14) are made up of two or more subcrystals with strongly undulóse extinction and may or may not have crenulated boundaries.

The presence of inclusions may be a valuable identification tool in regard to classifying quartz types; however, inclusions were not present in any significant quantity. In general, most of the quartz grains exhibited few vacuoles (gas or liquid inclusions) with little else present. A few minor exceptions were noted, those being quartz grains with abundant vacuoles and some with abundant microlites, specifically, unknown needle-shaped mineral inclusions.

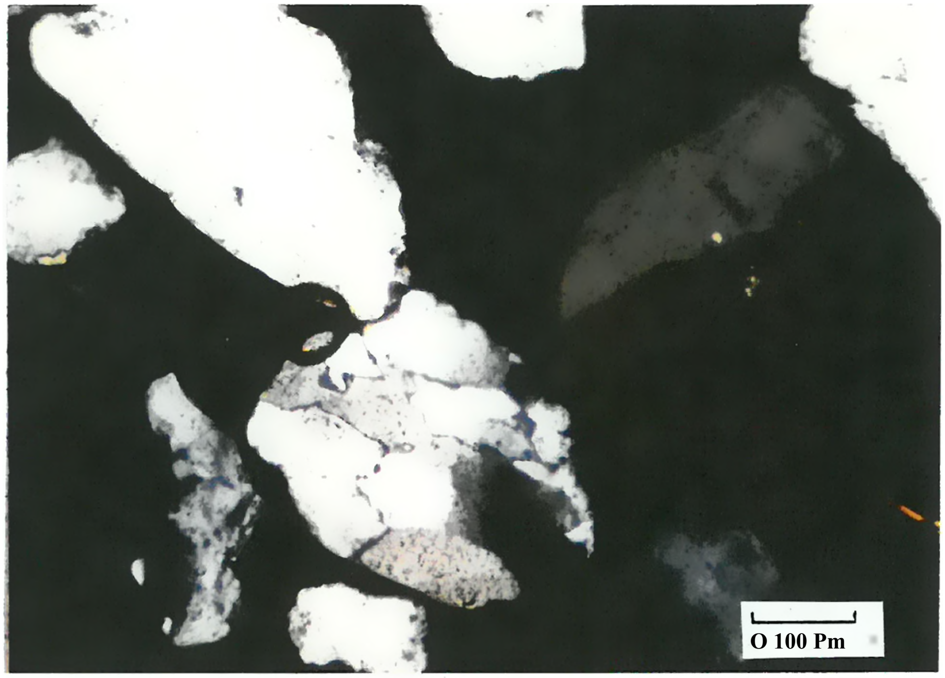


Figure 12. Photomicrograph of semicomposite quartz from sample number 103CG. Grain to the far right is semicomposite and the grain in the center is composite metamorphic quartz (crossed polarizers).

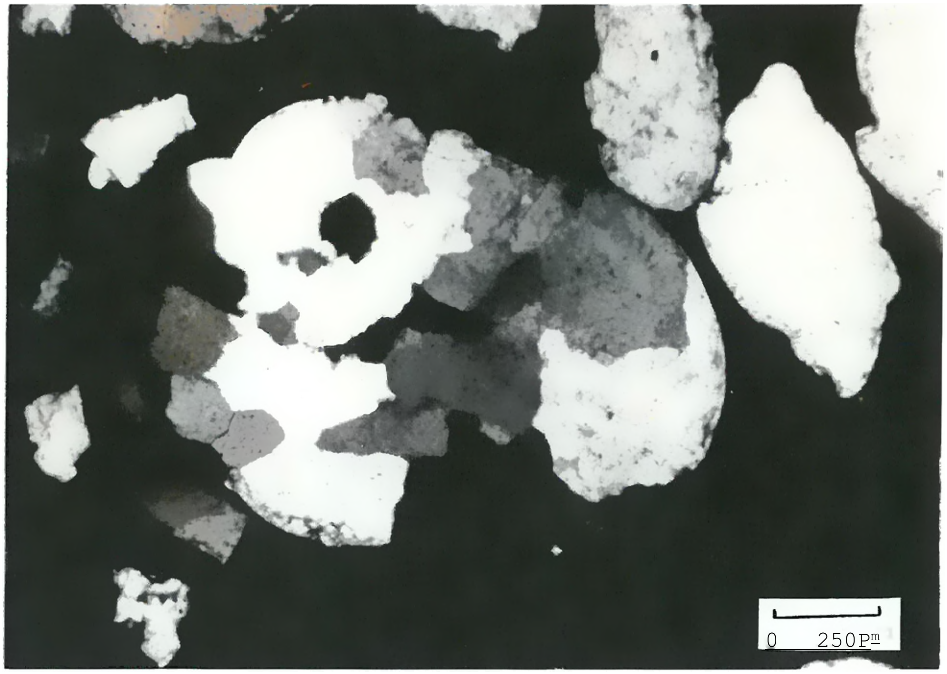


Figure 13. Photomicrograph of composite quartz from sample number 120AG (crossed polarizers).

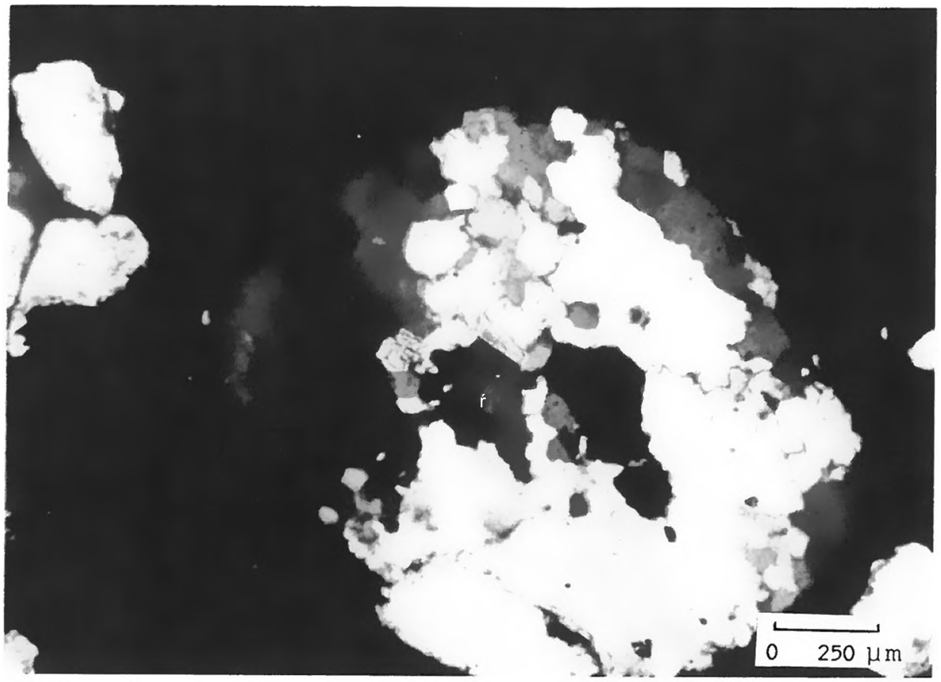


Figure 14. Photomicrograph of composite metamorphic quartz from sample number 105TG. Notice the mica inclusions (crossed polarizers) .

Quartz is the abundant light mineral in the sand size class in each clastic sedimentary unit. From all samples analyzed, quartz averages 92.4% of the non-clay, light mineral fraction. Monocrystalline grains with undulóse to strongly undulóse extinction are the most common variety with monocrystalline straight to slightly undulóse extinction types second in abundance. Metamorphic quartz, and to some extent vein quartz, represented by semicomposite, composite, and composite metamorphic types, are the least abundant quartz types; however, they do make up a considerable portion of the sand-size light mineral fraction, averaging 15.1%.

Very few generalities regarding the use of quartz types to distinguish the different clastic sedimentary units can be made (Table 6). Perhaps the most important distinguishing characteristic of the Hattiesburg lutite is a greater ratio of monocrystalline straight to slightly undulóse extinction types versus monocrystalline undulóse to strongly undulóse extinction varieties. Likewise, the Citronelle sediments and the Hattiesburg lutite contain a slightly greater percentage of metamorphic and vein quartz types than the other clastic sedimentary units.

The potassium feldspars, orthoclase, microcline, and twinned and untwinned plagioclase are present in small amounts; sanidine is not present. Microcline (Figure 15) is easily recognizable from its typical grid twinning, as are the plagioclase varieties that are twinned (Figure 16). The feldspars are sometimes distinguishable from quartz by detection of their cleavage (Figure 17). Feldspar grains often show alteration by leaching; this is most clearly visible under plain polarized light (Figure 18), and by outlining cleavage planes, assists discrimination of mineral types.

The feldspars are a relatively minor constituent (2.2%) of the non-clay, light mineral fraction. Feldspar grains occur slightly more frequently in the alluvial deposits than in others. Orthoclase is the most common feldspar type.

Table 6

Average Light Mineral Percentages by Point Count of the Sand-Size Fraction

	Quartz					Feldspar					Rock Fragments			
Clastic Sedimentary Unit	SMxl	UMxl	SCmp	Cmp	CmpM	Or	San	Mel	UP1	TP1	Chert	Other SRF's	MRF	VRF
Hattiesburg Fm. (lutite)	40.2	35.1	4.7	7.5	5.5	0.6	-	0.5	0.1	1.1	3.1	0.3	0.3	0.9
Sands and gravels associated w/ the Hattiesburg Fm.	35.6	44.1	4.0	4.5	4.5	0.9	-	0.4	0.4	0.6	3.6	0.5	0. 6	0.2
Citronelle Fm.	29.8	43.1	6.8	6.9	3.9	1.3	-	0.3	0.4	0.3	4.2	1.2	1.3	0.4
Sub-terrace Depos its	33.1	46. 8	5.7	5.3	3.9	1.0	-	0.1	0.2	0.4	3.0	0. 3	0.1	-
Alluvium	36.3	42.4	4.2	3.7	4.3	1.1	-	0.3	0.6	0.8	4.2	1.0	0.3	0.6
Average of all samples	35.0	42.3	5.1	5.6	4.4	1.0	-	0.3	0.3	0.6	3.6	0.7	0.5	0.4

NOTE : SMxl = Monocrystalline straight to slightly undulóse
UMxl = Monocrystalline undulóse to strongly undulóse
SCmp = Semicomposite
Cmp = Composite
CmpM = Composite metamorphic
Or = Orthoclase
San = Sanidine

Mcl = Microcline
UPI = Untwinned plagioclase
TP1 = Twinned plagioclase
SRF = Sedimentary rock fragment
MRF = Metamorphic rock fragment
VRF = Volcanic rock fragment

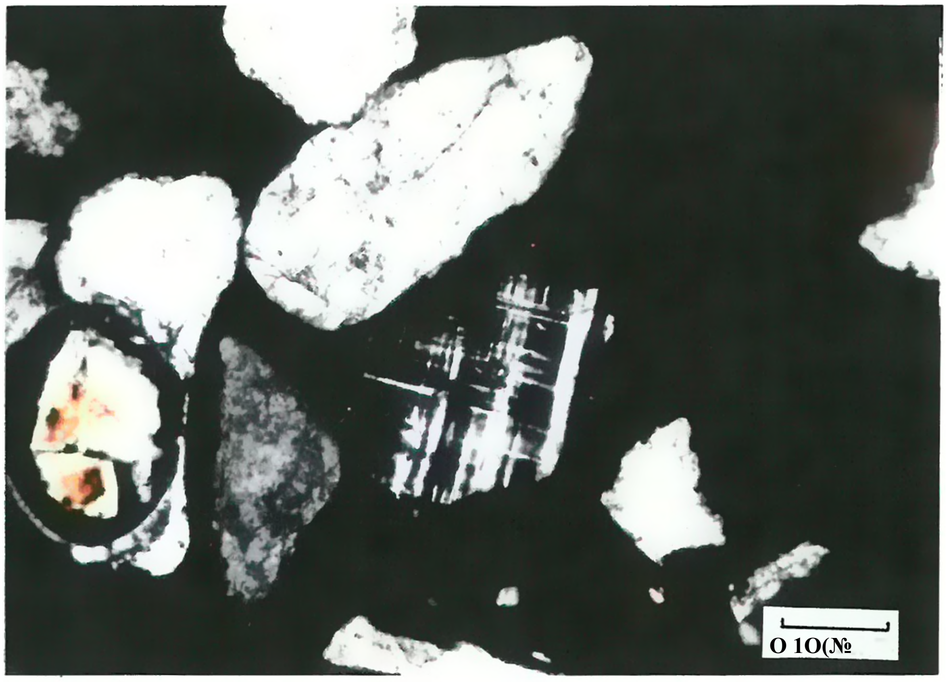


Figure 15. Photomicrograph of microcline (grain in center) from sample number 115TS (crossed polarizers).

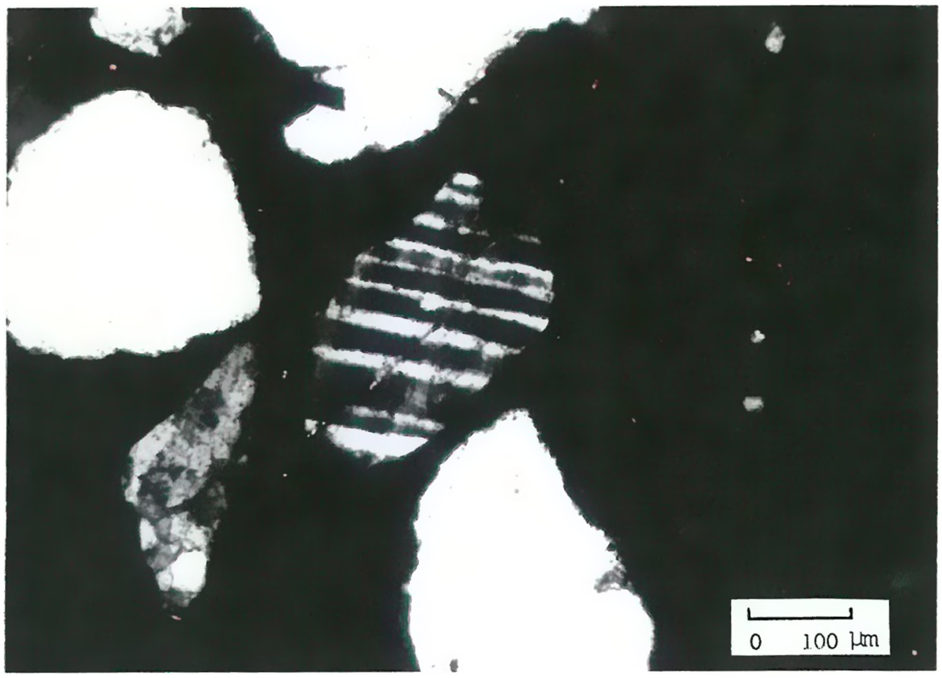


Figure 16. Photomicrograph of twinned plagioclase (grain in center) from sample number 115TS (crossed polarizers).

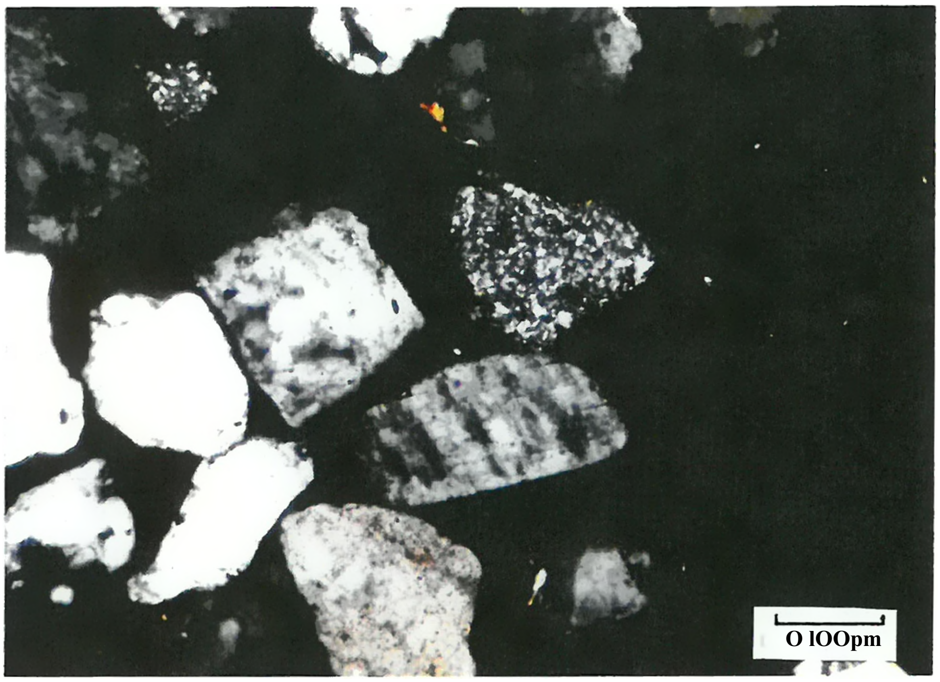


Figure 17. Photomicrograph of orthoclase (grain in center below chert grain) from sample number 111HS. Noticeable cleavage occurs parallel to the long axis (crossed polarizers).

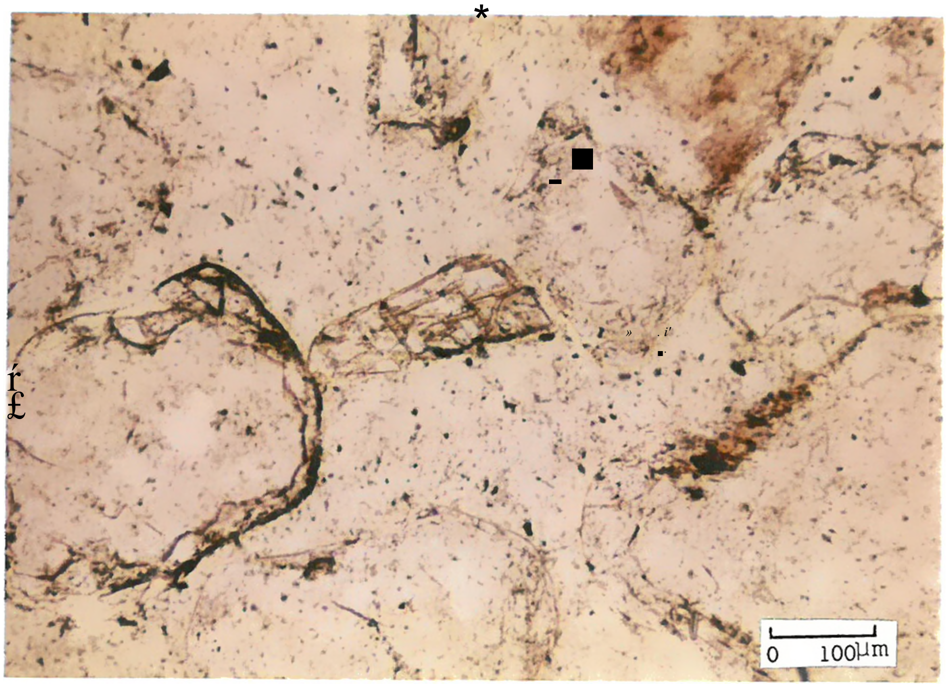


Figure 18. Photomicrograph of feldspar (grain in center) from sample number 101CS. The grain shows the affects of leaching concentrated along cleavage plains (plane-polarized).

Rock fragments are classified as either chert, other sedimentary rock fragments, metamorphic rock fragments, or volcanic rock fragments. This classification system is similar to Folk's system (1974, p. 127); however, in this study, chert and other sedimentary rock fragments have been tabulated separately, whereas in Folk's system of classification, both would have been combined under the general heading of sedimentary rock fragments. Chert is recognized by its uniform microcrystalline quartz (Figure 19); however, some chert that is not finely crystalline (Figure 20) resembles composite quartz grains with a fine crystalline texture. Other sedimentary rock fragments include grains that contain generally fine-grained constituents and quartz (Figure 21). Metamorphic rock fragments typically have elongate or stretched quartz crystals (Figure 22) and muscovite crystals. It is very difficult at times to distinguish metamorphic rock fragments from composite metamorphic quartz grains. In general, the individual subcrystals within metamorphic rock fragments are more highly stretched than the individual subcrystals within composite metamorphic quartz grains. In addition, the finer-grained metamorphic rock fragments (slates, phyllites, and schists) show a distinct foliation not seen in composite metamorphic quartz types. Volcanic rock fragments are distinguished as fine-grained particles containing small laths of plagioclase in a very fine crystalline matrix (Figure 23).

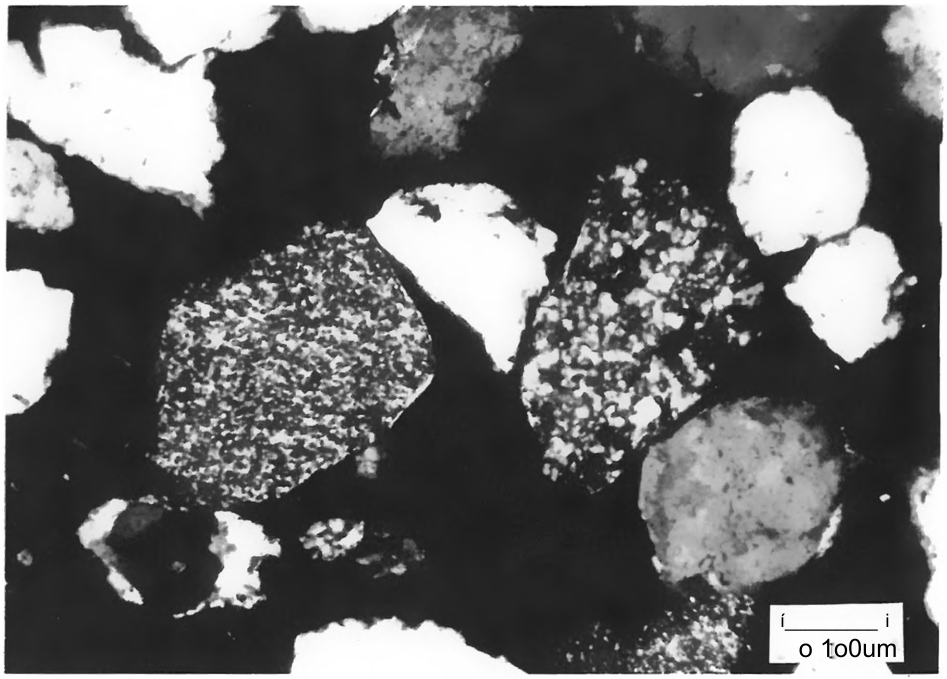


Figure 19. Photomicrograph of fine crystalline chert (grain to the left) from sample number 118AG. Chert grain to the right is more coarsely crystalline (crossed polarizers).

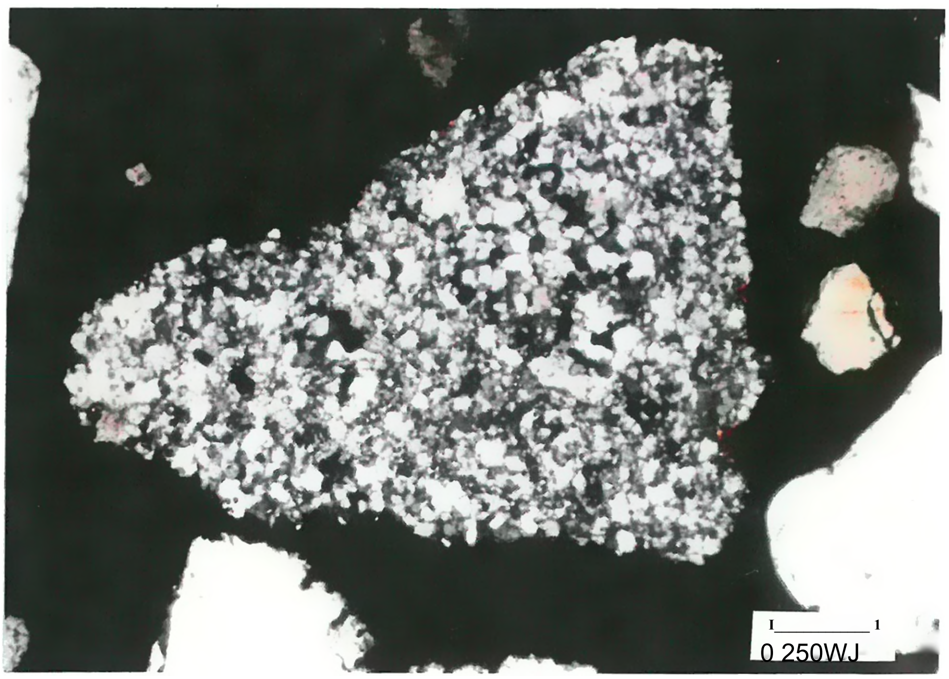


Figure 20. Photomicrograph of coarse crystalline chert which resembles composite quartz from sample number 116TG (crossed polarizers).

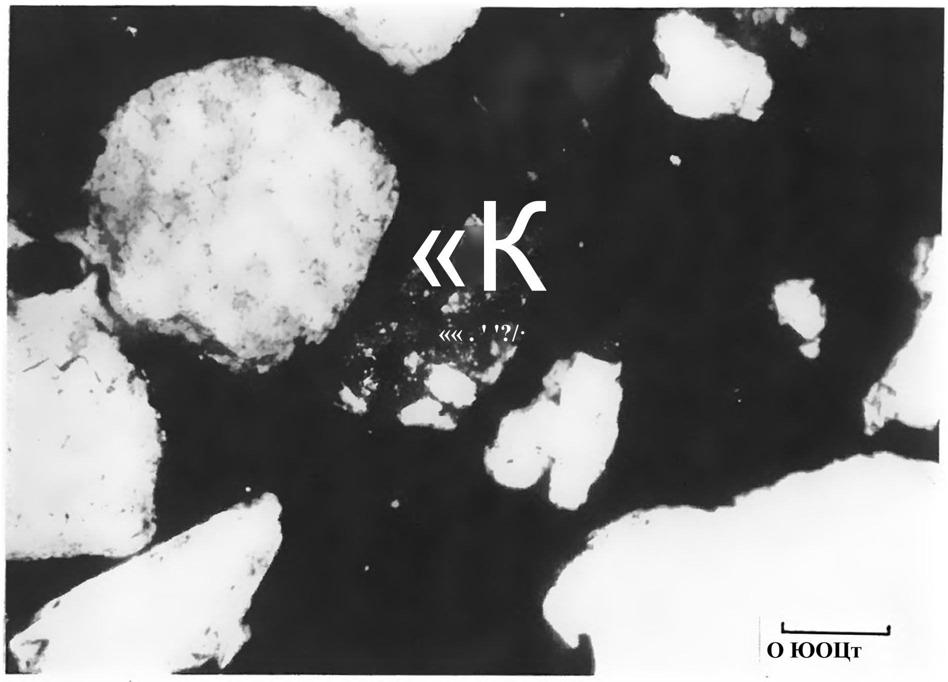


Figure 21. Photomicrograph of an "other sedimentary rock fragment" (grain in center) from sample number 101CS (crossed polarizers).

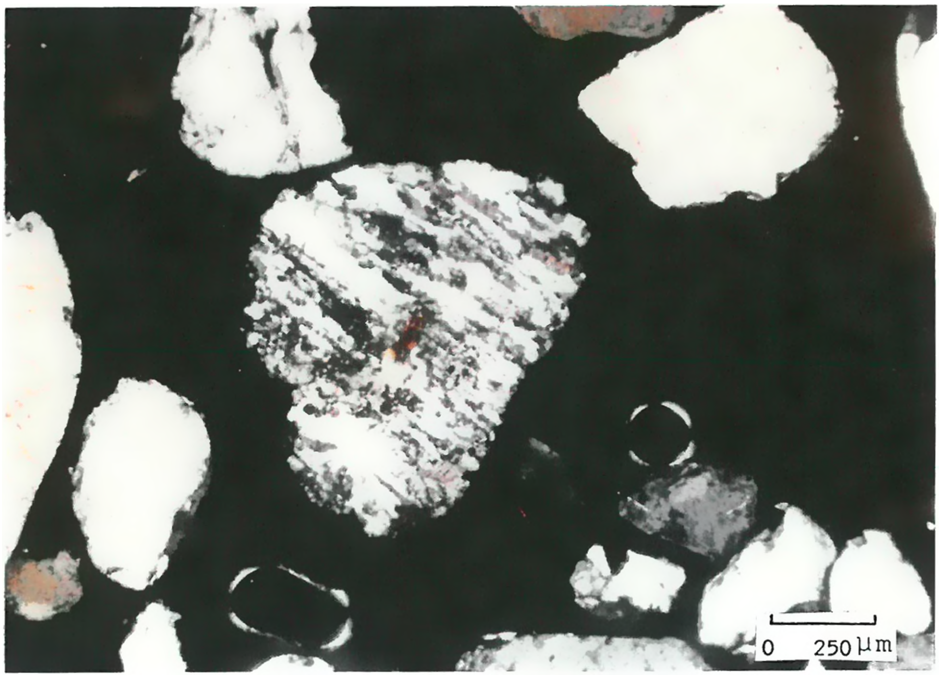


Figure 22. Photomicrograph of a metamorphic rock fragment (grain in center) from sample number 116TG (crossed polarizers).

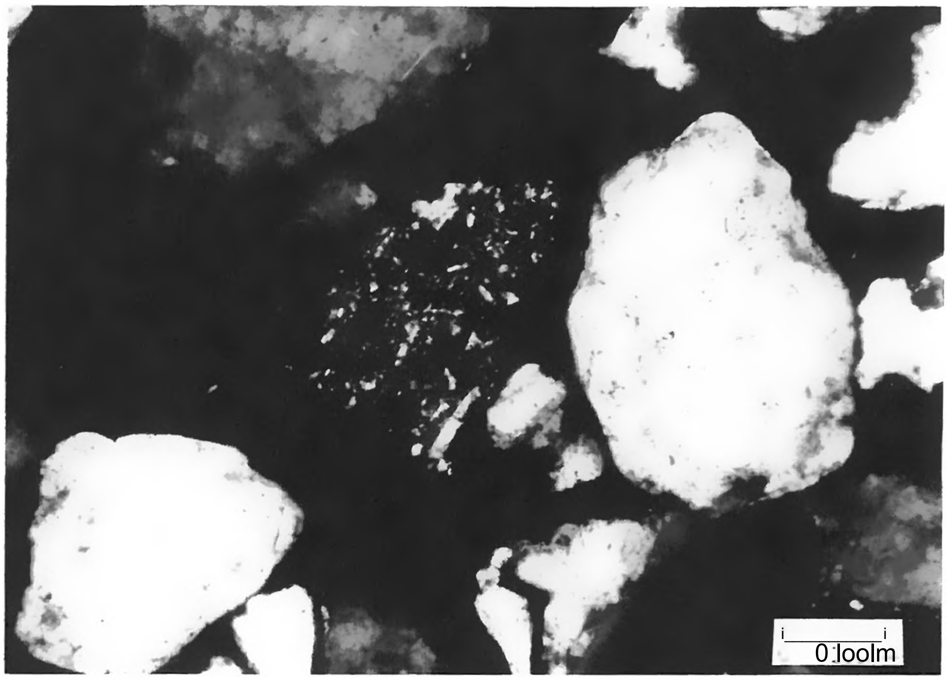


Figure 23. Photomicrograph of a volcanic rock fragment (grain in center) from sample number 119AS (crossed polarizers).

From all sand-size samples analyzed, rock fragments average 5.2% of the non-clay, light mineral fraction with chert by far the most common type. Other sedimentary rock fragments, metamorphic rock fragments, and volcanic rock fragments are present in minor amounts. The Citronelle sediments contain the greatest percentage of rock fragments with sub-terrace sediments containing the least.

All but one sample containing at least 75% sand, regardless of unit designation, plot in the sublitharenite to quartzarenite range (Figure 24). One Hattiesburg sample plots as a subarkose. The sediments here sampled

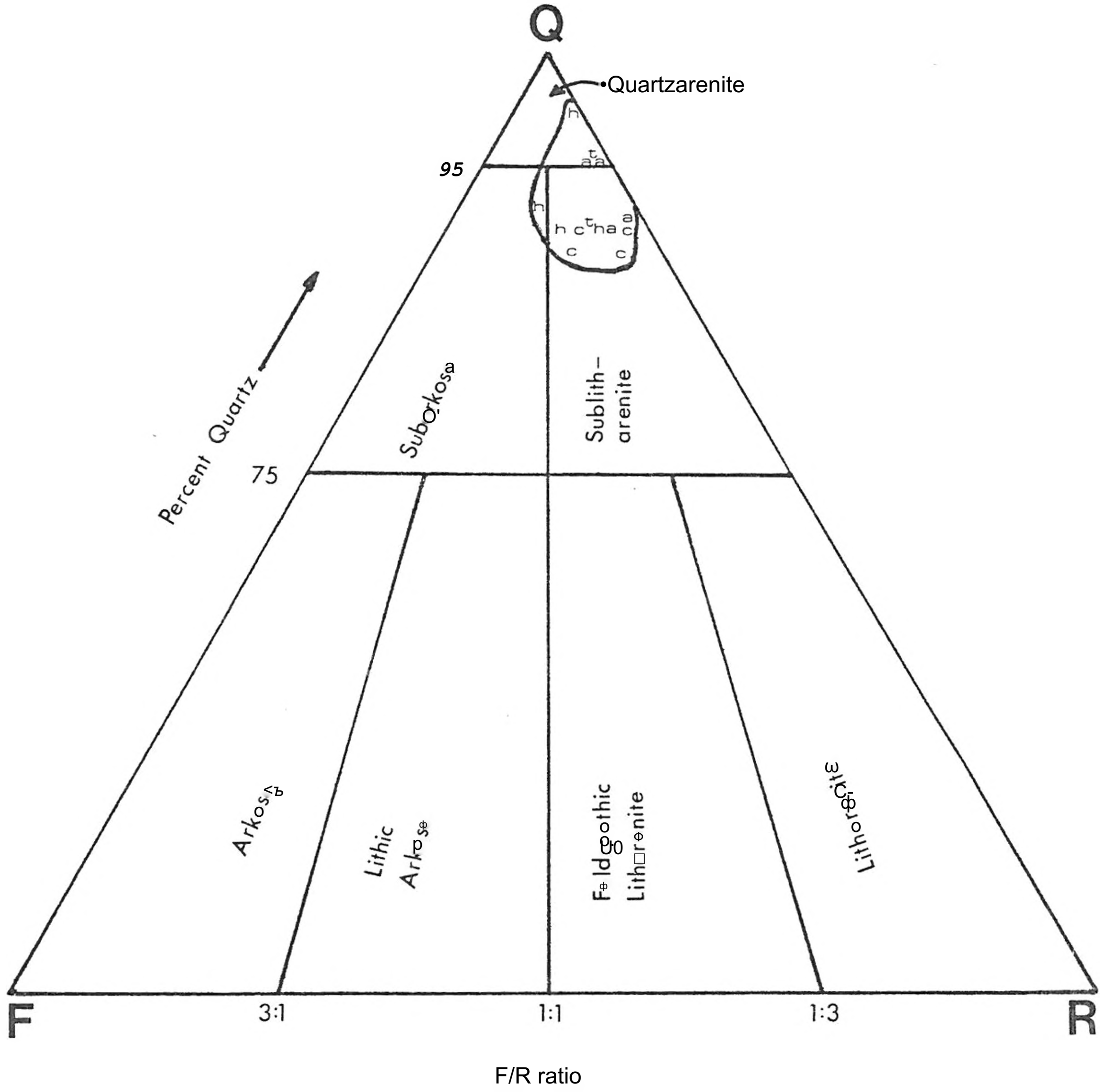


Figure 24. Sandstone classification for all samples containing at least 75% sand. This classification scheme is from Folk (1974, p. 127): c = Citronelle, h = Hattiesburg, t = Samples from deposits underlying terraces, a = Alluvium.

and analyzed contain predominantly quartz, very little feldspar, and a higher chert-nonchert rock fragment ratio and can therefore be regarded as mineralogically mature.

Gravels

In general, all gravel samples consist mainly of quartz, chert, and tripoli (tripoli is a very porous, light-weight, siliceous aggregate composed essentially of finely disintegrated chert) (Table 7). For classification purposes, all varieties of chert have been included together; however, an assortment of colors exists. The most common colors are intermediate shades of gray to light brown with rare black and red (jasper) varieties present. Much smaller amounts of silicified mudstone, silicified clayey sandstone, silicified oolitic limestone, silicified fossiliferous limestone, and silicified fossils are also present. The fossils commonly encountered are corals, brachiopods, bryozoans, and crinoid stems.

Pebbles (between -2 and -6 0) are the dominant gravel clasts and they average 35.1% of the total sample for all samples analyzed. Chert is the most common lithologic type present among the pebbles. Granules (-1 to -2 0) average only 10.2% of the total sample for all samples analyzed with quartz being by far the most dominant lithologic type. The quartz is always much better rounded than the coarser chert even in the pebble size fractions.

Table 7

Average Gravel Percentages by Size Class

Clastic Sedimentary Unit	N	Gravel Size	% of Total Sample (by weight)	Gravel Lithologies			
				Quartz	Chert	Tripoli	*Others
Sands and gravels associated w/ the Hattiesburg Fm.	2	Pebble	22.6	31.7	49.1	13.5	5.7
		Granule	7.3	68.2	21.9	6.5	3.4
Citronelle Fm.	5	Pebble	50.6	30.8	31.2	26.2	11.7
		Granule	12.7	59.9	22.3	12.4	5.2
Sub-terrace Deposits	3	Pebble	28.9	31.2	38.0	19.9	10.7
		Granule	7.3	76.2	14.5	5.3	3.8
Alluvium	4	Pebble	38.1	30.5	48.3	12.0	9.2
		Granule	13.3	64.5	26.6	4.1	4.8

NOTE: N = number of samples

*includes silicified oolitic limestone, silicified fossiliferous limestone, silicified mudstone, silicified clayey sandstone, and silicified fossils

No striking discriminations regarding gravel lithology for any of the clastic sedimentary units can be made with the possible exception that the alluvial samples and the gravels associated with the Hattiesburg Formation contain more chert and less tripoli than do the Citronelle and terrace samples.

Heavy Minerals

The post-Catahoula sediments within the study area are characterized by a non-opaque, heavy mineral suite that contains primarily kyanite, staurolite, zircon, tourmaline, rutile, and minor amounts of sillimanite (Figure 25 and 26). This heavy mineral suite corresponds to Goldstein's (1942, p. 81) metamorphic assemblage of heavy minerals from the Eastern Gulf Province.

The number of samples analyzed from each unit and the number of grains counted with the corresponding size grade are tabulated in Appendix G.

The characterizations made below include examinations of similar size grades with the exception of the Hattiesburg lutite. The very fine grain size of this material made it impossible to obtain the identical size fraction used in the analysis of the coarser sediments; however, there is an overlap in size among the sediments examined. In this section, the percentages of the heavy minerals in the Hattiesburg lutite are included in the overall examination for descriptive purposes.

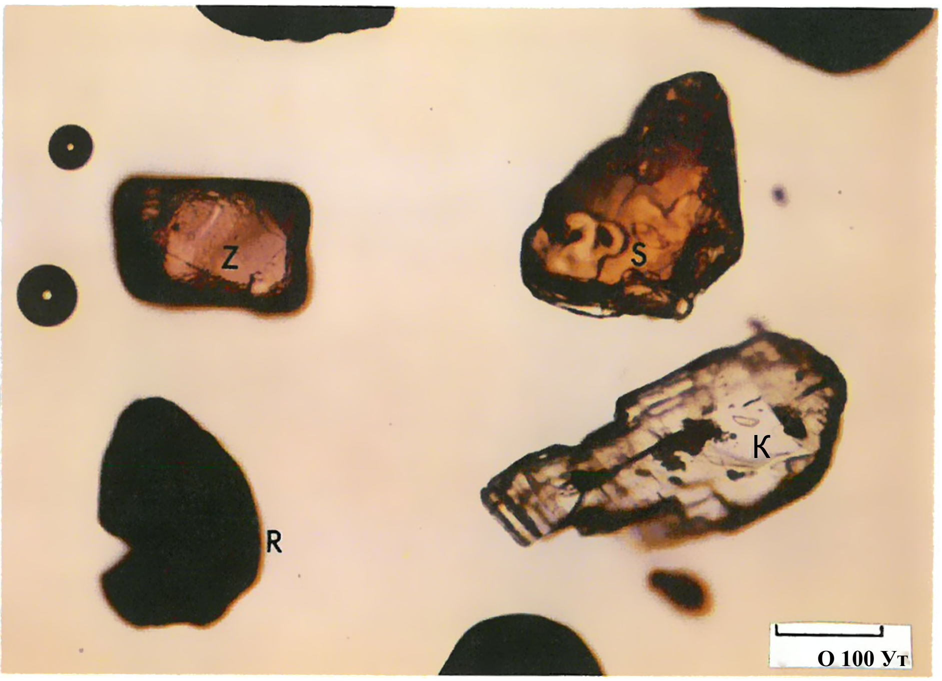


Figure 25. Photomicrograph of the common heavy minerals from sample number 103CG: K = kyanite, S = staurolite, Z = zircon, R = rutile (plane-polarized).

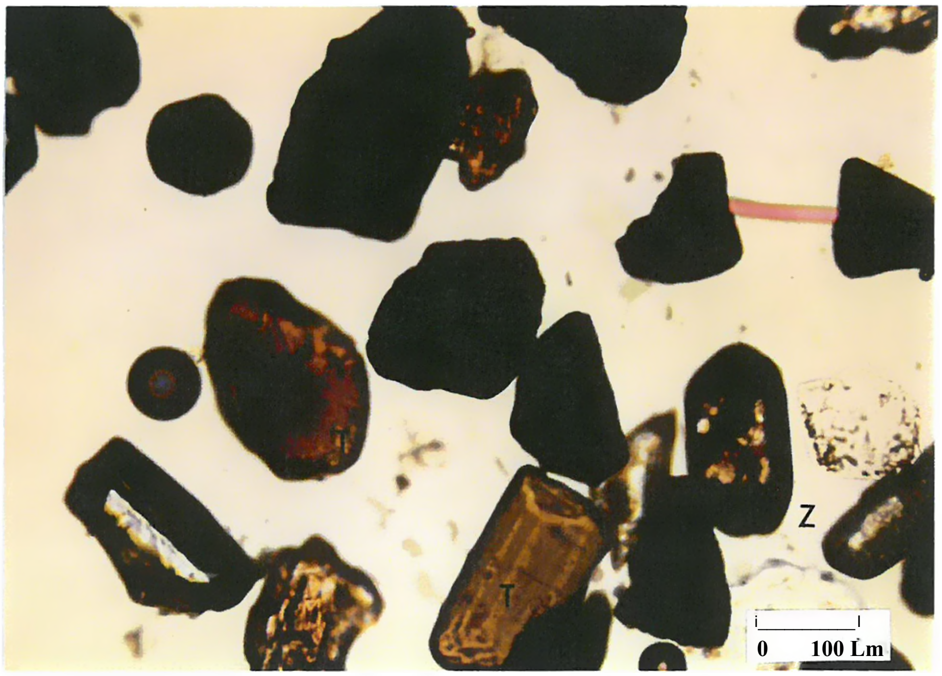


Figure 26. Photomicrograph of the common heavy minerals from sample number 117ÄS: T = tourmaline, Z = zircon (between two grains). The dark grains are opaques or aggregates of clay and silt (plane-polarized).

The total average heavy mineral content shows nearly subequal amounts of the non-opaque "heavies", kyanite, staurolite, zircon, and tourmaline (Table 8). Rutile is the least abundant ultra-stable heavy mineral. Although kyanite and staurolite are common, they are considered to be only moderately stable and usually rather soft heavy minerals (Folk, 1974, p. 96). The opaque heavy minerals, which include ilmenite, magnetite, hematite, pyrite, and leucoxene, average approximately 40% of the heavy mineral content for all samples analyzed.

In general, the Hattiesburg lutite is characterized by an abundance of zircon and tourmaline with much lower percentages of kyanite and staurolite. This is also the only distinct unit to contain a greater amount of white opaques than black opaques. Tourmaline is also the most abundant heavy mineral in the sands and gravels associated with the Hattiesburg Formation, and zircon is the least abundant of the most common "heavies" in these sediments. The Citronelle Formation is characterized by approximately subequal amounts of the four most common non-opaque heavy minerals (kyanite, staurolite, zircon, and tourmaline). The deposits beneath terraces are characterized by the dominance of kyanite and zircon in addition to containing the greatest percentage of rutile. Zircon is the most common non-opaque heavy mineral in the alluvial materials.

Table 8

Average Heavy Mineral Percentages by Point Count

Clastic Sedimentary Unit	Kyanite	Staurolite	Zircon	Tourmaline	Rutile	Sillimanite	*Black Opaques	*White Opaques	**Others
Hattiesburg Fm. (lutite)	6.2	5.4	14.7	18.6	5.1	0.7	20.2	27 . 6	1.5
Sands and gravels associated w/ the Hattiesburg Fm.	13.1	11.5	8.8	17.2	3.8	1.1	25.5	18.0	0.9
Citronelle Fm.	13.1	14.7	13.6	13.0	4.2	0.8	22.9	16.5	1.2
Sub-terrace Deposits	15.6	8.8	16.6	12.4	7.1	0.4	23.0	15.2	0.7
Alluvium	11.5	8.6	17.9	11.7	5. 9	0.4	24.2	19.4	0.4
Average of all samples	11.9	9.8	14.3	14.6	5.2	0.7	23.2	19.3	0.9

*Black and white opaques include ilmenite, magnetite, hematite, pyrite, and leucoxene

**Includes unknowns, pyroxenes, amphiboles, garnet, epidote, and sphene

Among the heavy minerals a commonly used estimator of mineralogical maturity is the ZTR index, the percentage of the non-opaque suite that is composed of zircon, tourmaline, and rutile (the ultra-stable group) (Blatt, Middleton, and Murray, 1972, p. 301). The ZTR index is independent of the maturity index based on feldspars and it is applicable to sandstones that contain very little feldspar (Carver, 1971, p. 427). Additionally, the ZTR index can be used as a means of describing and comparing sedimentary units. For example, each unit has an average ZTR index of at least 50, with the Hattiesburg lutite and the alluvial materials having the highest ZTR index and the Citronelle Formation having the lowest ZTR index (Table 9).

Table 9

Average ZTR Index For Each Clastic Sedimentary Unit

Clastic Sedimentary Unit	Average ZTR Index
Hattiesburg Fm. (lutite)	75.7
Sands and gravels associated w/ the Hattiesburg Fm.	53.7
Citronelle Fm.	51.8
Sub-terrace Deposits	59.3
Alluvium	63.4

The anomalous values that exist between the Hattiesburg lutite and the coarser clastic materials may be a function of source rock lithology or weathering in the source area. The most acceptable conclusion, however, relates directly to the size of the sediments. Hubert (1971, p. 63) states that even closely spaced samples of varying grain size yield markedly different heavy mineral assemblages because heavy minerals are deposited with light minerals of equivalent hydraulic size. Usually the heavy minerals average 0.5 to 1.0 0 size less than the light minerals deposited with them. Therefore, it seems logical to assume that this selective sorting mechanism may have concentrated the other non-opaque heavy minerals (specifically, kyanite and staurolite) within the coarser sediments.

STATISTICAL ANALYSIS

In the previous section a generalized summary of the mineralogy of the clastic Neogene sedimentary units was presented. This generalized summary was based upon averages taken from the various mineral suites for each sample in all units. These sample averages are from populations that exhibit a wide numerical range of mineral percentages and are therefore, to some extent, misleading for classification purposes. For instance, based solely on the fact that a particular unknown sample may contain roughly 6% kyanite in the heavy mineral assemblage, can om assume that it belongs to the Hattiesburg lutite where kyanite averages 6.2%? On the basis of only one mineral and the wide range of variability among percentages of individual minerals in samples from each sedimentary unit, it would be impossible to make this conclusion. An excellent example of this is zircon which averages 13.6% of the heavy mineral assemblage from all Citronelle samples. Although the average is 13.6%, there is a wide range of variability among the percentages of zircon throughout the Citronelle samples ranging 1.4 to 33.2% (standard deviation of 7.8).

Complicating the situation further is the close similarity in mineral suites within the various clastic sedimentary units. The lack of diversity in mineral suites coupled with the wide range of variability for a particular mineral type in a specific clastic sedimentary unit makes the task of sample classification very difficult.

The multivariate statistical technique of discriminant analysis has been employed to assist in the identification and classification of the specific clastic sedimentary units. The basic functions of discriminant analysis are those of interpreting group differences and classifying cases (samples) into groups. Discriminant analysis allows one to study the differences between two or more groups of objects with respect to several variables simultaneously (Kiecka, 1980, p. 7). In the present study the groups of objects are the clastic sedimentary units and the discriminating variables are percentages of specific mineral types present in the samples. Differences among the variables are detected in their relative percentages by deriving mathematical equations called discriminant functions which combine the discriminating variables in a way that will allow one to identify the group which a case most closely resembles (Kiecka, 1980, p. 9). Isphording (1976, p. 328) has successfully used the discriminant analysis procedure to differentiate Citronelle sediments from those of the

Miocene in south Alabama and west Florida, both in outcrop and in well sections.

The mineralogy of the sediments within the study area, which includes the clay minerals, non-clay light minerals, heavy minerals, and gravels,enables one to choose among many discriminating variables. Due to the large number of possible discriminating variables and the absence or relatively low percentages of some of them, the decision was made to use only 17 in order to reduce the number of misclassifications. The variables chosen were: all of the heavy minerals, all of the clay minerals, the five quartz types, and chert.

The SPSS computer package (Kiecka, 1970, pp. 437-467) was utilized in completing all of the discriminant analysis computations. As an additional means of eliminating unnecessary variables, a stepwise procedure to select the most useful discriminating variables was chosen. The stepwise procedure and specifics regarding discriminant analysis are discussed in detail in Appendix H. The stepwise procedure will list the rank order of the unique discriminating power carried by each of the selected variables using the F-to-remove (partial multivariate F) statistic. The variable with the largest F-to-remove statistic makes the greatest contribution to the overall discrimination, the variable with the second largest F-to-remove statistic is the second most important, and so forth (Kiecka, 1980, pp. 57-58). The black opaque heavy mineral percentage is the most powerful of the 17 discriminating variables used (Table 10). This table lists the rank order of the 11 most powerful variables and their corresponding F-to-remove values; the remaining six variables are not listed because they are either too weak or redundant.

Table 10

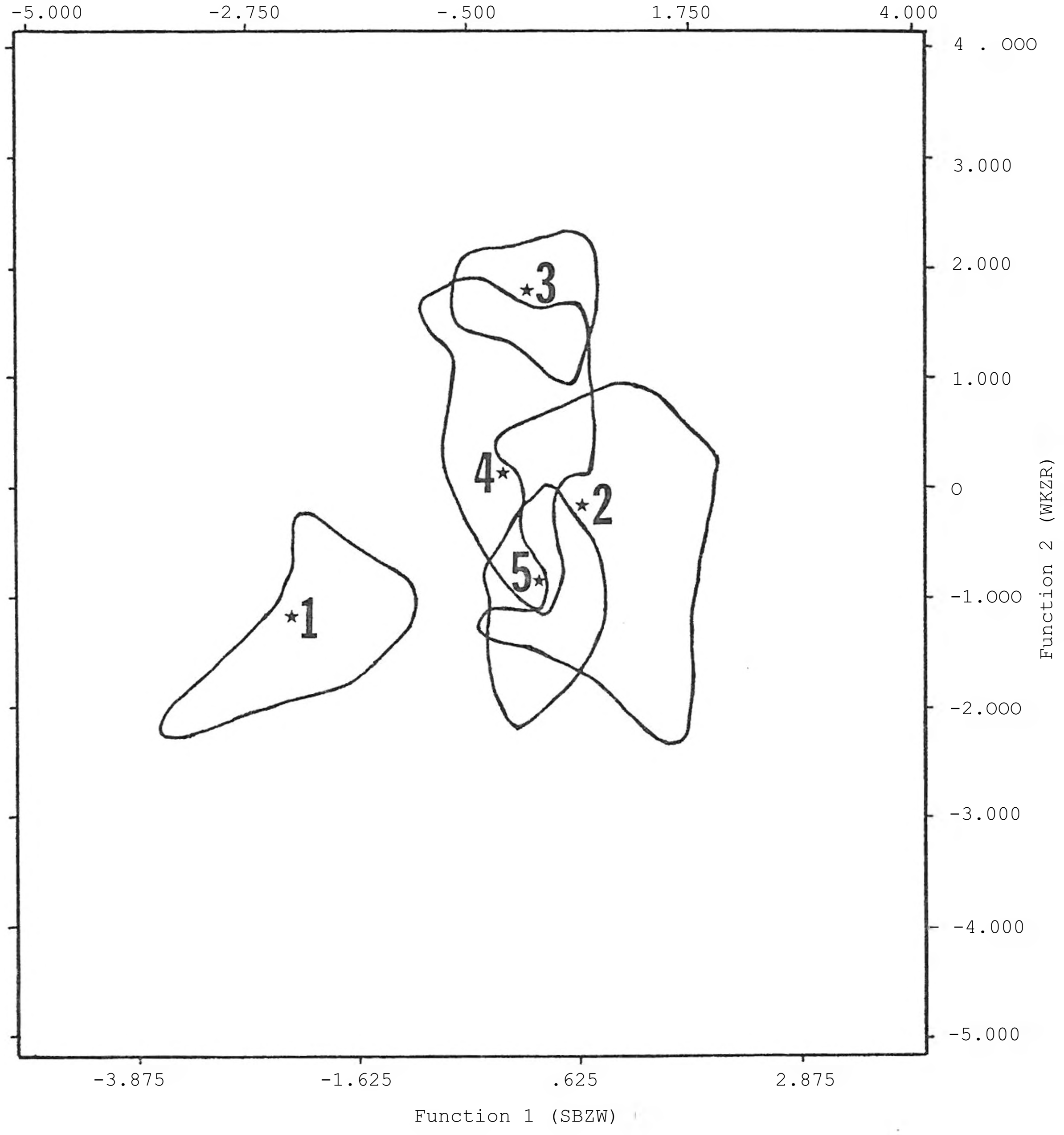
Rank Order of the Most Powerful
Discriminating Variables

Discriminating Variable	Rank Order	F-to-remove
Black opaques, hm	1	6.61
Composite quartz grains (Cmp)	2	5.02
Smectite	3	4.87
Staurolite, hm	4	3.88
Semicomposite quartz grains (SCmp)	5	3.31
White opaques, hm	6	3.21
Rutile, hm	7	2.95
Tourmaline, hm	8	2.84
Kyanite, hm	9	2.51
Monocrystalline undulóse to strongly undulóse quartz grains (UMxl)	10	1.75
Zircon, hm	11	1.22

NOTE: hm = heavy mineral

Representation of the most powerful discriminating variables for each clastic sedimentary unit (group) is shown graphically in Figure 27. The Mahalanobis squared distance between closest groups method for the stepwise procedure was chosen (Kiecka, 1980, p. 55). This particular method seeks to maximize the Mahalonobis distance between the two closest groups and tends to force all the groups to be separated (Kiecka, 1980, p. 55).

Figure 27 is a two-function plot of group centroids within their respective group areas. Two-function plots are extremely useful because, in this case, the first two functions are the most important. "SBZW" and "WKZR" are names given to the respective functions based on the most important discriminating variables for each function. For instance, function 1 is given the name "SBZW" because staurolite, the black opaques, zircon, and the white opaques are, in that order, the most important variables for that function. Similarly, the name "WKZR" is given to function 2 because the most important variables, in descending order, are the white opaques, kyanite, zircon, and rutile. Details regarding the importance of each function and the importance of the discriminating variables are given in Appendix H. Group centroids represent the mean discriminant scores for each group on the respective functions. The centroids summarize the group locations in the (reduced) space defined by the discriminant functions (Kiecka, 1970,



NOTE: Group 1 = Hattiesburg Formation (lutite)
Group 2 =Citronelle Formation
Group 3 =Sub-terrace Deposits
Group 4 =Alluvium
Group 5 =Unknown

* denotes group centroid

Figure 27. Two-function plot of group centroids within group areas. The discriminant score for function 1 (SBZW) plots horizontally and the discriminant score for function 2 (WKZR) plots vertically.

pp. 440-442). Because large numbers of cases (samples) sometimes produce a blur, it was decided to plot only group centroids shown within the total group areas.

In Figure 27 each number next to a specific group centroid corresponds to a particular clastic sedimentary unit (group). Group 1 is the Hattiesburg Formation (lutite), group 2 is the Citronelle Formation, group 3 is deposits from beneath terraces, groups 4 is alluvial deposits, and group 5 is labeled as "unknown." The sediments belonging to the unknowns of group 5 are the sands and gravels associated with the Hattiesburg Formation; however, exactly to which unit they belong is very questionable. This graphic presentation shows that the greatest amount of separation exists between the Hattiesburg lutite, the Citronelle Formation, and the deposits from beneath terraces (groups 1, 2, and 3_Z respectively). The greatest amount of overlap occurs between the Citronelle sediments, the alluvial materials, and the sands and gravels associated with the Hattiesburg Formation (groups 2, 4, and 5, respectively). There is also some overlap between the underlying terraces and the alluvium.

Although there is a great deal of similarity between all of the clastic sedimentary units except for the Hattiesburg lutite, it may be possible to classify a given sample to a reasonable degree of certainty if the sample does not plot between the triangular group centroids 2-4-5. Any sample that plots within this area could be either Citronelle, alluvium, or sands and gravels associated with the Hattiesburg Formation.

To classify an unknown sample, the discriminant scores of the first two functions are determined by taking the original value (percentage) for a sample on each variable and multiplying it by the unstandardized coefficient for that variable; we then add these products along with the constant term. Table 11 shows the unstandardized discriminant coefficients and constants for the first two most important functions. The sum of the individual contributions gives the discriminant scores which are coordinates in the subspace defined by the discriminant functions. The discriminant score for function 1 (SBZW) plots along the horizontal axis and the discriminant score for function 2 (WKZR) plots along the vertical axis. By plotting unknown samples in this manner, it may be possible to define questionable sediments within the Neogene of southern Mississippi.

Further examination of Figure 27 shows a clearly distinct separation of group centroids despite overlap by the majority of the clastic sedimentary units. Therefore, the statistical technique of discriminant analysis indicates that the groups are significantly different. Table 12 shows the predicted group membership for all samples. The data provided in this table are derived

Table 11

Unstandardized Discriminant
Coefficients and Constants

Discriminating Variable	Function 1	Function 2
Kyanite	.13921	.20060
Staurolite	.26065	.02910
Zircon	.13243	.10627
Tourmaline	.13197	.05381
Rutile	.19813	.34589
Black opaques	.19117	.11151
White opaques	.13197	.15070
Monocrystalline undulóse to strongly undulóse quartz grains	.03277	.04174
Semicomposite quartz grains	.10055	-.09560
Composite quartz grains	-.01369	-.03665
Smectite	-.02615	.01237
Constant	-17.87100	-13.22370

Table 12

Predicted Group Membership for All Samples

Actual Group (Clastic Sedimentary Unit)	N	Predicted Group Membership				
		Hattiesburg (1)	Citronelle (2)	Sub-terrace Depos its (3)	Alluvium (4)	Unknown (5)
Hattiesburg (1)	6	6 100.0%	0 -	0 -	0 -	0 -
Citronelle (2)	20	0 -	16 80.0%	0 -	2 10.0%	2 10.0%
Sub-terrace Depos its (3)	7	0 -	0 -	6 85.7%	1 14.3%	0 -
Alluvium (4)	13	0 -	1 7.7%	1 7.7%	10 76.9%	1 7.7%
Unknown (5)	10	0 -	1 10.0%	0 -	1 10.0%	8 80.0%

NOTE: N = number of samples

directly from the discriminant analysis printout and list the actual group along with the predicted group. The Hattiesburg lutite was correctly classified with all samples falling within that actual group. The majority of all samples from the other groups were also correctly classified. Eighty percent of the Citronelle sediments fell into that group with 10% predicted to belong to the alluvium group and 10% predicted to belong to the unknown group. The deposits from beneath terraces have 85.7% classified correctly and 14.3% (only one sample, however) predicted to belong to the alluvium group. The alluvial materials have 76.9% (ten samples) classified correctly and one sample predicted to belong to the Citronelle group, one to the terrace deposits, and one to the unknown group. What is most interesting about these data is the correct classification of 80% to the unknown group. As discussed previously, the unknown group consists of the sands and gravels associated with the Hattiesburg Formation. Ten percent of this group fell within the actual Citronelle group and 10% fell within the alluvial group. It seems, therefore, that it is logical to assume that these sediments associated with the Hattiesburg Formation, for the most part, are rather unique and deserve the local distinction given to them in this study.

PROVENANCE AND WEATHERING

The mineralogical composition of the clastic Neogene sediments within the study area reflects the source rocks (or sediments) from which these materials were derived. Weathering of the source rocks expresses some indication of past climatic conditions in the source area as well.

Clastic sediments basically consist of the materials left after chemical breakdown and disintegration of some preexisting rock. The washed residues have been subjected to sorting action with resultant fractionation into several size grades that differ not only in size of the grain but also in mineralogical and chemical composition. The finest grades are largely decomposition products -- the clay minerals; the coarser grades are undecomposed residues derived from the parent or source rock (Pettijohn, 1975, p. 484).

The clastic Neogene sediments of southern Mississippi were deposited largely in a fluviatile environment (May, 1980, p. 64). Grim (1958, p. 248) states that there is little further alteration of the clay minerals in the fluviatile environment; therefore, the clay mineral suites are largely inherited from the source materials. Post-depositional alteration of the feldspars within the sediments of the study area (illustrated in a previous section by grains that show the effects of leaching, Figure 18) has certainly contributed to the clay minerals present; however, to what extent is unknown.

Of the clay minerals identified in this study, kaolinite and the oxides and hydroxides of iron and aluminum form in warm, humid climates that favor leaching and the removal of metal cations. Illite, chlorite, and vermiculite form in more temperate, arid climates that favor the accumulation of metal cations. Smectite also forms where metal cations are accumulating; however, it cannot be said that its formation is typical of any climate since it has been reported from both extremes. The most characteristic feature of smectite is that it usually results from the devitrification of volcanic glass. May (1980, p. 77) reports a higher percentage of montmorillonite (a member of the smectite group) than kaolinite in the clays from below the water table in the Mendenhall area; however, this situation can be explained geochemically due to the fact that sediments below the water table tend to accumulate metal cations and sediments above the water table are leached of metal cations.

X-ray diffraction data on clays in the samples studied indicate ubiquitous kaolinite. Illite is a major constituent of the clay mineral suite; however, peak areas

(001 reflections) of kaolinite relative to illite are much greater. Sediments from beneath terraces, as well as the alluvium, contain, in addition to kaolinite and illite, smectite which is most likely inherited directly from the smectite-rich Hattiesburg lutite.

If these clay mineral suites are inherited rather than authigenic, then it would seem that the source materials of these sediments were derived from areas with different climates. The dominance of kaolinite indicates source material that was undergoing weathering in a warm and humid climate. The presence of illite and vermiculite (?) in these sediments signifies a secondary source material that was being weathered under more temperate and arid climatic conditions. Alternatively, a second school of thought stresses a source material that was being weathered in a fluctuating climatic regime ranging between the two previously stated.

Post-depositional alterations of the Neogene clastics within the study area are likewise indicative of a warm, moist climate. Oxidation and hydrolysis of these sediments are an example of <u>in situ</u> chemical weathering whereby iron oxides and hydroxides are being produced by the alteration of ferromagnesian minerals. These iron oxides and hydroxides were identified in the clay and silt size fractions in all the clastic sedimentary units except the alluvial materials. Grains coated with iron (Figure 28) were also noted in thin sections from the various units.

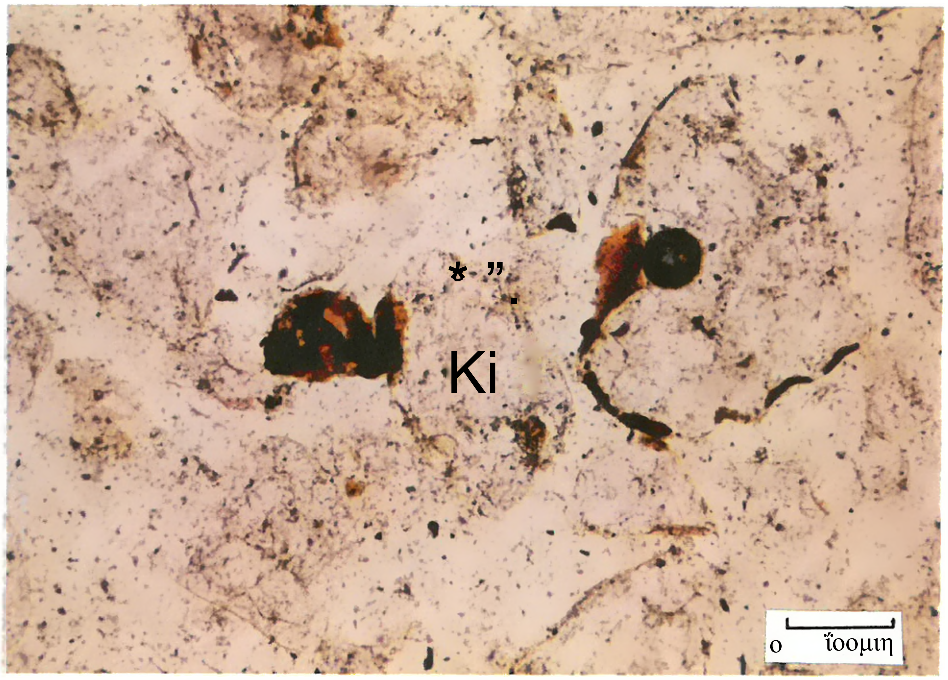


Figure 28. Photomicrograph of quartz grains coated with an iron precipitate from sample number 101CSF (plane polarized) .

The iron precipitates consisted mainly of hematite, goethite, and lepidocrocite. Ironstone concretions obtained from the Citronelle Formation (location 101C) were also composed of geothite.

Although no aluminum oxides and hydroxides were identified in any of the clastic sedimentary units, gibbsite has been reported in terrace sands near Fort Walton, Florida. These sediments consist of a "quartz-gibbsite rock devoid of kaolinite" whose origin has been attributed to either (1) deposition of gibbsite in a sandstone from solutions that obtained the alumina by leaching from a gibbsite zone above or (2) development of gibbsite by intense leaching of clastic sediments on a Tertiary terrace during which fine quartz sand, probably aeolian, was added (Clarke and Keller, 1984, p. 154). Isphording (1983, pp. 7 6-77) also reports the development of iron oxides and gibbsite within the Citronelle Formation of western Mississippi and southern Alabama. Isphording regards the formation of gibbsite as resulting from the breakdown of kaolinitic clays to gibbsite by the action of acid groundwaters. The presence of gibbsite in the areas of close proximity to this study indicates a warm, moist climate that was rather intense at some time during the Tertiary. Isphording (1970, p. 342) has suggested that the late Tertiary was a time of warm moist climates throughout the eastern United States. The abundance of kaolinite within the Neogene sediments in this study also indicates the weathering of source materials not associated with the changing climatic conditions of the Pleistocene. It is, therefore, assumable that these sediments may be older than previously stated.

The coarser clastic sediments in the study area yield a distinctive guide to the nature of the source materials. The heavy minerals that characterize these Neogene sediments are dominated by the non-opaque heavy minerals, kyanite, staurolite, zircon, and tourmaline. The variation of heavy minerals in a sediment is a function of several factors and usually the aim of the petrographer is to eliminate all factors except one -- the lithology of the source area (provenance) at a given time and place (Folk, 1974, p. 96). It has been assumed that differential physical stability during transport, differential chemical stability to weathering, and intrastratal solution have not significantly affected the heavy mineral assemblage due to the rather large percentage of the less stable (physically and chemically) heavy minerals, kyanite and staurolite. Rosen (1969, p. 1558) has determined from heavy mineral studies on the Citronelle Formation from southwestern Mississippi to the Florida Panhandle and on the Louisiana terrace deposits that physical sorting of mineral species having differing specific gravity and size distributions is not of critical importance because the mineral suite present does not change. Similarly, the heavy mineral suites in this study are the same for each sedimentary unit and, as mentioned previously, correspond to Goldstein's (1942, p. 81) metamorphic assemblage of heavy minerals from the Eastern Gulf Province. Tourmaline and zircon are the backbone of many heavy mineral suites because they are very hard and inert and can survive many reworkings. The presence of the moderately stable heavies, kyanite and staurolite, is highly diagnostic of a metamorphic source (Folk, 1974, p. 96). Further evidence for a metamorphic source is the relatively common composite quartz and composite metamorphic quartz grains (Folk, 1974, p. 76). Blatt (1982, p. 155) believes that polycrystalline (composite quartz and composite metamorphic quartz) grains are less stable than monocrystalline or unit varieties because of their internal discontinuity surfaces (crystal boundaries). If this is true, then it would seem that even minor amounts of these quartz types are indicative of a metamorphic source.

Goldstein further states that the heavy mineral assemblage from the Eastern Gulf Province is derived largely from the southern Appalachian region (Figure 29), either directly from the metamorphic rocks of the bed-rock complex or from surficial deposits of Pleistocene (?) age. Rosen (1969, p. 1557) collected sand samples along a traverse from Centerville, Alabama, southward to Marion, Alabama; stratigraphic units sampled include the Tuscaloosa Formation, the McShan Formation, the Eutaw Formation, and the Tombigbee Sand. The heavy minerals present in all of the samples are quite similar and belong to the East Gulf Province metamorphic assemblage as well. These clastics, therefore, could be the source of younger sediments to the southwest. The presence of detrital chert in the clastic Neogene sediments within the study area is another indicator of an older sedimentary source (Folk, 1974, p. 80). Well-rounded quartz grains are present and form a

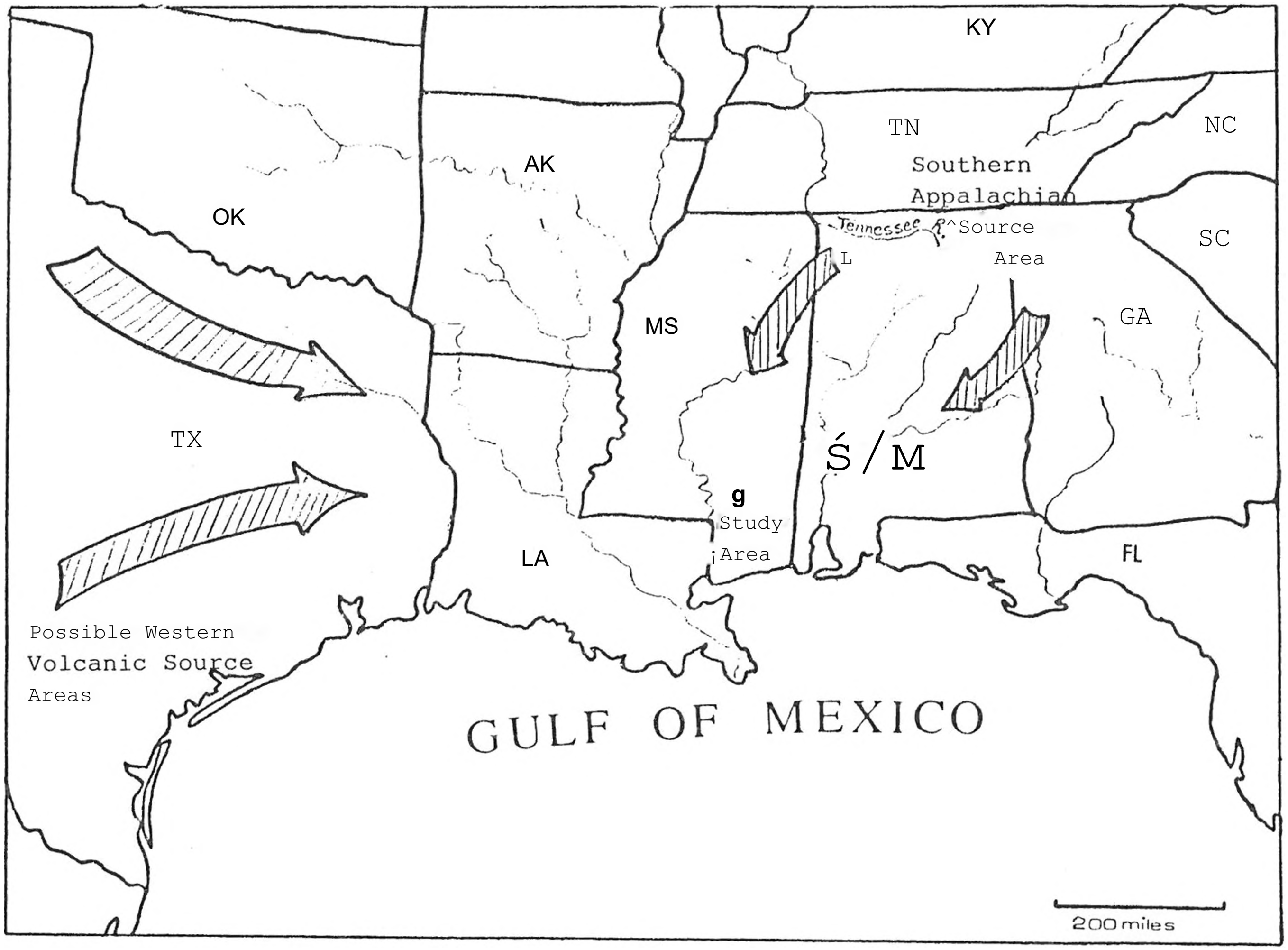


Figure 29. Location of probable source areas for the Neogene sedimentary units in the study area shown (adapted from Isphording, 1977, p. 312).

relatively large percentage of the post-Miocene clastics. Reworked overgrowths on these grains are good indicators of older sedimentary sources (Folk, 1974, p. 72); however, only a few of these were noted.

The Miocene sediments (Hattiesburg lutite) in the study area were derived from at least two sources. These sediments contain, in addition to the aforementioned heavy mineral suite, an abundance of smectite in the clay fraction. The dominance of smectite in these sediments indicates a volcanic source (Figure 29) that supplied pyroclastic materials which were reworked by fluvial processes, buried, and consequently altered. Millot (1970, p. 47) says that the alteration of the pyroclastic materials (ash and tuff) is rapid and strong because they are permeable and glassy. These characteristics account for the lack of pyroclastic materials in thin-section.

Lindemann and McBride (1976, p. 2166) and various other investigators have indicated that Tertiary volcanism in west Texas, northern Mexico, and New Mexico is the source of sands in south and central Texas. Scheldt and Ward (1977, p. 370) and Isphording (1977, p. 308) suggest the possibility of other volcanic sources for sediments closer in proximity to this study.

The greatest single mineralogic difference that exists among the Neogene sedimentary units in the study area is the presence of smectite in the Hattiesburg lutite. Assuming that post-depositional alterations have not completely altered the clay minerals in the overlying coarser sediments, this difference clearly indicates that these sediments are distinctively younger than the fine-grained Hattiesburg lutite.

ECONOMIC AND ENGINEERING APPLICATIONS

The sand, gravel, and clay deposits comprising the Neogene of southern Mississippi are economically important. Approximately a half dozen companies in the Hattiesburg area are actively producing sand and gravel from the alluvium of the Leaf and Bouie rivers and from upland and slopeland deposits of the Citronelle Formation. Production of alluvial sands and gravels from the Leaf and Bouie rivers is concentrated to the north and to the east of Hattiesburg, whereas Citronelle sand and gravel production is centered principally to the west and southwest. The sands and gravels are primarily used as fine and coarse aggregate in the production of portland cement concrete and as fill materials at construction sites. Sand is also used for masonry purposes (Foster and McCutcheon, 1941, p. 31). Currently (1984), companies in the Hattiesburg area such as the American Sand and Gravel Company are selling sand used in the making of concrete for $2.50 per ton and finer-grained masonry sand for $3.00 per ton. Small size washed gravel (3/8 inch or -3.25 ϕ, and smaller) is sold for $4.95 per ton and oversized washed gravel (larger than 3/8 inch or -3.25 ϕ) sells for $5.95 per ton (K. Courtney, American Sand and Gravel Company, Hattiesburg, Mississippi, 1984, personal communication). Companies such as the Hover Gravel Company sell sand and gravel as fill for $3.00 per ton for sand and finer-grained sediments only and $4.00 per ton for a combination of sand and gravel (J. Mooney, Hover Gravel Company, Hattiesburg, Mississippi, 1984, personal communication). The total sand and gravel produced in southern Mississippi is not known; however, production exceeds a billion tons per year in the United States (Jensen and Bateman, 1979, p. 511).

As discussed in an earlier section, the Citronelle gravels contain the greatest percentage of gravel by weight and the alluvial materials contain the second greatest percentage of gravel by weight. The coarsest and most abundant lithologic type is chert. Quartz, the second most abundant lithologic type, is much better rounded and finer in grain size. These factors are emphasized again here in an effort to show how the coarse aggregates may be deleterious. Because chert is angular, pitted, etched, and has some porosity, it takes more cement to fill the void spaces in the production of portland cement concrete. However, since the angularity and porosity make the bond between the chert gravel and cement stronger, it is economically more beneficial to utilize this type of material (R.E. Turner, Mississippi Highway Department - Sixth District, Hattiesburg, Mississippi, 1984, personal communication). One of the disadvantages of using chert as the coarse aggregate in the production of portland cement concrete is that it is expensive to crush when the aggregate is larger than the size specified. Furthermore, chert gravel is not desirable in the manufacture of asphalt because the heating of the semisolid mixture tends to drive the pore water from chert to its surface creating a film of water between the aggregate and the semisolid mixture. The bonding of chert clasts is, therefore, very weak and insufficient in the production of asphalt (R. E. Turner, Mississippi Highway Department - Sixth District, Hattiesburg, Mississippi, 1984, personal communication).

The dominant product from the economic clay deposits of Mississippi is common brick. No commercial deposits of refractory clay (kaolin and fire clay) are now mined in the state. This is not to say that these deposits do not exist; it only means that the quantity is too small or the overburden too large to make their extraction profitable (J. Granger, A. P. Green Products Company, Jackson, Mississippi, 1984, personal communication). The Hattiesburg Brick Works produced brick from clay of the Hattiesburg Formation and possibly adjacent alluvium (Foster and McCutcheon, 1941, p. 31). However, its plant has been inoperative since the latter part of 1979 and for a few years prior to closing it obtained its raw materials from the Lux, Mississippi, area (N. Langston, Hattiesburg

Brick Works, Inc., Hattiesburg, Mississippi, 1984, personal communication). Brick manufacturers currently obtain the clay used in the making of their products for $0.25 to $1.00 per cubic yard if they are not able to produce the clay themselves (P. Schneider, St. Joe Brick Company, Slidell, Louisiana, 1984, personal communication).

The clay minerals (dominantly smectite) of the Hattiesburg Formation (lutite) have many possible economic applications. Grim and Guven (1978, p. 161) state that the wide range of applications of bentonite (term used here for any clay which is composed predominantly of a smectite clay mineral and whose physical properties reflect the smectite component) in science and technology is related to the structural, chemical, and morphological properties of smectite particles in these clays. Some uses of smectite-rich sediments follow: ceramics; drilling fluids; catalysts (in petroleum refining); decolorization of various mineral, vegetable, and animal oils; adhesives; animal bedding; cement, mortar, and aggregates; clarification of wines, cider, beer, water, etc.; floor absorbents; food; greases; ink; medicines, pharmaceuticals, and cosmetics; paint; pesticides; and water impedance. The fact that the Hattiesburg lutite contains an appreciable amount of silt inhibits its use in the manufacture of common brick and drilling fluid. Grim (1962, p. 129) indicates that a high concentration of non-clay material in the silt-size range may cause difficulties by reducing the green and fired strength of brick. Similarly, Grim (1962, p. 283) states that sediments with more than very small amounts of non-clay minerals, particularly in silt and sand sizes, are not suitable for drilling muds because such materials dilute the desired properties and are abrasive on pumps and other drilling equipment.

Another important characteristic of the Hattiesburg lutite is the tendency of the smectite to shrink and swell by absorbing water between the individual silicate layers (Grim, 1962, p. 251). Smectitic clays pose hazards in construction. The United States Department of Agriculture Soil Survey of Forrest County, Mississippi, describes "severe" soil limitation on shallow excavations, dwellings with and without basements, small commercial buildings, and local roads and streets for the soil types associated with the Hattiesburg Formation. These soil types include the Faulker-Susquehanna-Urban series and the Freestone-Susquehanna-Prentiss series. The severe limitations indicate that one or more soil properties or site features are so unfavorable or difficult to overcome that a major increase in construction effort, special design, or intensive maintenance is required. These limitations generally do not include materials below five or six feet. In each case (shallow excavations, dwellings without basements, etc.) the dominant factor influencing the severe limitation was the shrink-swell characteristic (United States Department of Agriculture, 1975, pp. 25-26, 69-72). Denehie (1975, pp. 62-63) states that the smectite clay mineral is especially deceptive in that it has a higher shear strength in its natural state than other clay types, but this can quickly be altered by excavations or construction starts. Emplacement of concrete with the corresponding excess of calcium ions can cause a reaction in smectites that will reduce the shear strength by at least one-half. Denehie further indicates that in areas where the overlying sediments (whether they are Citronelle, terrace, or sands and gravels associated with the Hattiesburg Formation) are five feet or less, there should be some type of soil stabilization program in effect. Areas which have at least ten feet of sediments above the smectitic clay zone are relatively safe for family type dwellings using a mat or raft to transfer the structural load evenly. However, commercial structures of two stories or more should have footings emplaced to help disperse the load. Areas with more than 20 feet of non-clay sediments overlying a smectitic clay interval are safe for almost any type of structure (Denehie, 1975, pp. 62-63) .

SUMMARY AND CONCLUSIONS

The measurements and descriptions presented in this study will assist in resolving the problems of post-Oligocene stratigraphy of southern Mississippi.

The post-Catahoula sedimentary units within the study area are, from oldest to youngest, the Hattiesburg Formation, the Citronelle Formation, deposits beneath terraces, and alluvium. Samples of a coarse clastic unit associated with the Hattiesburg Formation of uncertain age were also examined.

Percentages and mean grain size of gravel are the best textural indicators of sedimentary unit designation. Gravels belonging to the Citronelle Formation are, on the average, the coarsest and contain the highest gravel percentage by weight. Alluvial gravels are second in both categories, and gravels associated with the Hattiesburg Formation and gravel units beneath terraces contain the least amount of gravel and are the finest in size. Although sand lithologies from the various clastic sedimentary units are quite similar, some textural generalities can be distinguished. Sands associated with the sediments overlying the Hattiesburg lutite contain, on the average, more matrix (percentage of fines) than the other sedimentary units; Citronelle sands have the highest kurtosis (peakedness of the normal probability curve) values; sands beneath terraces are the coarsest; and alluvial sands are the best sorted.

The clastic Neogene sedimentary units within the study area are mineralogically similar. Although these sediments are for the most part texturally immature, they contain primarily quartz with minor amounts of rock fragments and feldspars in the sand-size light mineral fraction and are, therefore, mineralogically mature. The most striking mineralogical differences are those that exist between the Hattiesburg lutite and the overlying coarser sediments. The Hattiesburg lutite, on the average, contains a higher ZTR heavy mineral ratio and a greater percentage of monocrystalline quartz with straight to slightly undulóse extinction (as opposed to undulóse to strongly undulóse varieties). Perhaps the single most important mineralogical difference is the predominance of smectite in the Hattiesburg lutite and its near absence in the overlying sediments.

The statistical technique of discriminant analysis provides a solution for separating and classifying these mineralogically similar materials on the basis of differing percentages of discriminating variables (minerals). The most discriminating variables are the heavy minerals, quartz types, and smectite. Furthermore, the heavy minerals make the greatest contributions to the first two discriminant functions. These discriminant functions define the subspace from which the coordinates of the discriminant scores plot. Because of the wide separation between the Hattiesburg lutite and the overlying sediments and the significant separation of group centroids associated with the overlying sediments, it may be possible to classify unknown samples by plotting the discriminant scores on each of the two discriminant functions.

The mineralogical similarities that exist between the Neogene sediments in the study area indicate similar source materials; however, the Hattiesburg lutite has at least two different sources. The abundant presence of smectite suggests that pyroclastic materials from volcanic sources were wind deposited and later altered. The second source is believed to be the same as the source of the sediments overlying the Hattiesburg lutite indicated by Goldstein’s Eastern Gulf Province heavy mineral suite. This suite is dominated by the non-opaque heavies -- kyanite, staurolite, zircon, and tourmaline -- and is attributed to a southern Appalachian provenance. Further evidence indicates that the sediments overlying the Hattiesburg lutite may be reworked from older sedimentary terranes to the northeast.

The clay minerals present in the Neogene sediments within the study area suggest the possibility of separate source areas representing differing climatic conditions or possibly one source with an in-between climatic regime. Isphording (1970, p. 342) has stated that the late Tertiary was a time of warm moist climates throughout the eastern United States. He cites the presence of kaolinitic clays, gibbsite, lepidocrocite, and goethite in the clay fraction of Miocene and Pliocene sedimentary units in New Jersey as indicating that the climate was markedly different from present conditions in this region. The abundance of kaolinite in the Neogene sediments within this study area also indicates that the primary source material was being weathered in a warm moist climate. The kaolinite-rich sediments (specifically those overlying the Hattiesburg lutite) may, therefore, be slightly older than previously cited, reflecting the weathering of source materials in the warm moist climates of the Miocene and Pliocene epochs.

The mineralogic data compiled in this study suggest a distinct age difference between the Hattiesburg lutite and those overlying coarse clastic sediments. Because there is no evidence for the presence of smectite in sediments overlying the Hattiesburg lutite and because little evidence exists in the study area for the interfingering of the Hattiesburg lutite with the

Citronelle Formation, it is probable that the overlying sediments are significantly younger than the underlying Hattiesburg lutite. Examination of an interfingering, regressive sequence of clastic sediments in a limited area should show, to some extent, similar minerals due to deposition at the same approximate geologic time; however, smectite, the Hattiesburg lutite's key mineralogic signature, is not present in the overlying sediments. Assuming that post-depositional alterations have not completely altered the clay minerals in the overlying sediments, it seems likely that these sediments are of a significantly different age and they may not represent interfingering, cyclic, regressive deposits.

Similar petrologic examinations of subsurface materials coupled with electric log studies are needed for adequate descriptions of three-dimensional stratigraphic relationships. Detailed textural and mineralogical properties identified in subsurface samples may provide much needed additional information on stratigraphy, depositional environment, and provenance; such descriptions may also aid in correlating these sediments and help in comparing surficial versus subsurface geochemical alterations. By comparing post-depositional alterations that occur on surficial sediments to those that occur in the subsurface, it may be possible to determine if smectite is present in the subsurface sediments that overlie the Hattiesburg lutite. This may help to accurately prove (or disprove) the age and stratigraphic relations discussed above.

APPENDIX A

LOCATION OF SAMPLED OUTCROPS

Citronelle Formation

(1) The southwest corner of the Hover gravel pit in northeastern Lamar County: SW/4 of NE/4 of Section 9, T4N, R14W, elevation 350-360 feet.

Description of Section (top to bottom) (Figure A-1)

- 6 to 10 feet of weathered, brownish-yellow, fine-grained sand (sample number 101CSF)
- 3 to 4 feet of reddish-brown, sandy gravel (sample number 101CG)
- 2 feet of red sand with very little gravel (sample number 101CS)
- 2 to 3 feet of extensive gravel at the bottom of the face
- A reddish-purple clay was sampled on the northeast side of the gravel pit; it stratigraphically underlies the lower gravel from the southwest face of the pit and was 1 to 1.5 feet thick with very thin lenses of sand (sample number 101CCL)

(2) A quarry face on the road leading to an abandoned gravel pit in eastern Lamar County: NE/4 of SW/4 of Section 36, T4N, R14W, elevation 300-310 feet.

Figure A-1. Citronelle Formation exposed in the Hover gravel pit (sample location 101C). Person in the picture is approximately six feet tall.

Description of Section (top to bottom)

- 1 to 3 feet of weathered, reddish-brown, fine-grained sand (sample number 102CSF)
- 3 to 4 feet of red gravel
- 2 to 3 feet of red gravel
- 2 to 3 feet of reddish-brown sand with a small amount of gravel (sample number 102CS)
- 2 feet of yellowish-white to red, sandy gravel at the bottom of the face (sample number 102CG)
- A purple to white clay was sampled adjacent to the quarry face in previously excavated materials (sample number 102CCL). The stratigraphic relationship of this

material to the other sediments is unknown; however, a similar material was noted on the west side of the gravel pit at a lower stratigraphic position relative to the other sediments.

(3) The southeast side of an abandoned gravel pit in northeastern Lamar County: SW/4 of NE/4 of Section 5, T4N, R14W, elevation 350-360 feet.

Description Section (top to bottom)

- 4 to 5 feet of weathered, brownish-gray, fine-grained sand (sample number 103CSF)
- bottom 6 feet consisting of interbedded layers of red to yellow, sandy gravels, and reddish-brown sand (sample numbers 103G and 103CS)
- clay material was sampled in this lower section in the form of a grayish-brown clayball (sample number 103CCL)

(4) The south side of Monroe Road in extreme northern Forrest County: NE/4 of NE/4 of Section 5, T5N, R13W, elevation 250 feet.

Description of Section (top to bottom)

- 5 to 6 feet of reddish-brown, sandy gravel (sample number 104CG)
- 1 foot of yellow to light brown, fine-grained sand (sample number 104CSF)
- 5 feet of red sand (sample number 104CS)
- 4 to 5 inches of mottled, reddish-purple to white, silty clay (sample number 104CCL)

Hattiesburg Formation

(1) The east side of Westover Road just north of Highway 98 in northeastern Lamar County: SE/4 of NW/4 of Section 12, T4N, R14W, elevation 250-260 feet.

Description of Section (top to bottom)

- 3 to 4 feet of yellowish-brown sand (sample number 107HSF); R. L. Bowen (1984, personal communication) regards this upper sand unit as being "probably Citronelle"
- 11 to 13 feet of reddish-gray, silty clay (lutite) (sample number 107HCL)

(2) Roadcut section (Campbell Scenic Drive) west of (behind) the Holiday Inn off U.S. Highway 49 in Hattiesburg, northwestern Forrest County: NE/4 of SW/4 of Section 31, T5N, R13W, elevation 200-230 feet.

Description of Section (top to bottom) (Figure A-2)

- 2 to 3 feet of yellowish-brown sand (sample number 109HSF); the precise identification of this upper sand unit is questionable, but it is most likely modern alluvium or Citronelle
- 12 to 13 feet of greenish-gray lutite (sample number 109HCL)
- bottom 10 feet consisting of reddish-green to gray lutite
- hard, calcareous material was noted and sampled at this locality, most abundantly near the bottom of the section; however, it occurred in smaller proportions throughout the rest of the section

Figure A-2. Hattiesburg Formation exposed behind the Holiday Inn off U.S. Highway 49 (sample location 109H). Person in the picture is approximately six feet tall.

(3) The northeast side of the outcrop formed by the intersection of the road leading to the Hattiesburg Municipal Airport from U.S. Highway 49 (John Meri Tatum Industrial Drive) and the road extending north past Morris Hill Church in central Forrest County: SE/4 of NW/4 of Section 35, T4N, R13W, elevation 180 feet.

Description of Section (top to bottom)

- 2 to 3 feet of yellowish-brown, fine-grained sand (sample number 110HSF1); the precise identification of this upper sand unit is questionable, but it is most likely modern alluvium
- 3 feet of reddish-gray lutite (sample number 110HCL)

-1.5 feet of white to red sand; it contains fine-grained material, but sand is coarser than above sampled sand (sample number 110HSF2)

- bottom few inches consists of reddish-gray lutite

(4) The northeast corner of the Hattiesburg Driving Range (southwest corner of claypit) just off U.S. Highway 49 in Hattiesburg, northwestern Forrest County: SW/4 of SW/4 of Section 32, T5N, R13W, elevation 190-220 feet.

<u>Description of Section</u> (top to bottom)

- 2.5 to 3 feet of yellowish-brown, mildly cross-bedded, medium sand (sample number 111HS); the precise identification of this upper sand unit is questionable, but it is most likely Citronelle
- weathered, 0.5 inch thick, ironstone layer separating sand and lutite
- 6 to 7 feet of greenish-gray lutite (sample number 111HCL)
- 3.5 to 4 feet of what appears to be a more uniform, finer-grained, grayish-white clay (sample number 111HVFCL)
- bottom consists of 8 to 10 feet of the greenish-gray lutite similar to the lutite in the upper part of the section

(5) The southeast side of Byron Street alongside the railroad tracks just to the southwest of the Cloverleaf Mall in Hattiesburg, northwestern Forrest County: the extreme southeast corner of SE/4 of Section 17, T4N, R13W, elevation 210 feet.

Description of Section (top to bottom)

- 2.5 to 3 feet of yellowish-brown sand with a small amount of gravel (sample number 112HS); the precise identification of this upper sand and gravel unit is questionable, but it is possibly modern alluvium
- 6 to 8 inches of sandy gravel of the same color (sample number 112HG)
- bottom consists of sandy material similar to that in the top of the section

(6) The east side of U.S. Highway 49 approximately 1/4 mile north of the intersection of U.S. Highway 98, central Forrest County: N/2 of SW/4 of Section 2, T3N, R13W, elevation 230-240 feet.

Description of Section (top to bottom)

Exposed near to U.S. Highway 49, there is a cut face composed of red to brown sands and gravels. This cut face extends for a distance of approximately 100 yards to the east where light colored silts and clays lie on top of the sands and gravels.

- 2 to 3 feet of reddish-gray lutite (sample number 113HCL)
- just below the lutite (not exposed in most places) is a gravel layer on the order of 2 to 4 inches in thickness that is partially cemented by ironstone (sample number 113HG)
- 1 foot of reddish-brown, medium sand underlying the gravel (sample number 113HS)

(7) The southeast corner (alongside Gordons Creek) of the intersection of 40th Avenue South and Lincoln Road

in Hattiesburg, northwestern Forrest County: SW/4 of SW/4 of Section 18, T4N, R13W, elevation 230-240 feet.

Description of Section (top to bottom) (Figure A-3)

- 4 to 5 feet of fining upward, tan to brown (reddish-brown at the top) sand (sample number 114HS); the precise identification of this upper sand unit is questionable, but it is probably modern alluvium
- 5 to 6 feet of reddish-gray lutite exposed at the bottom (sample number 114HCL)

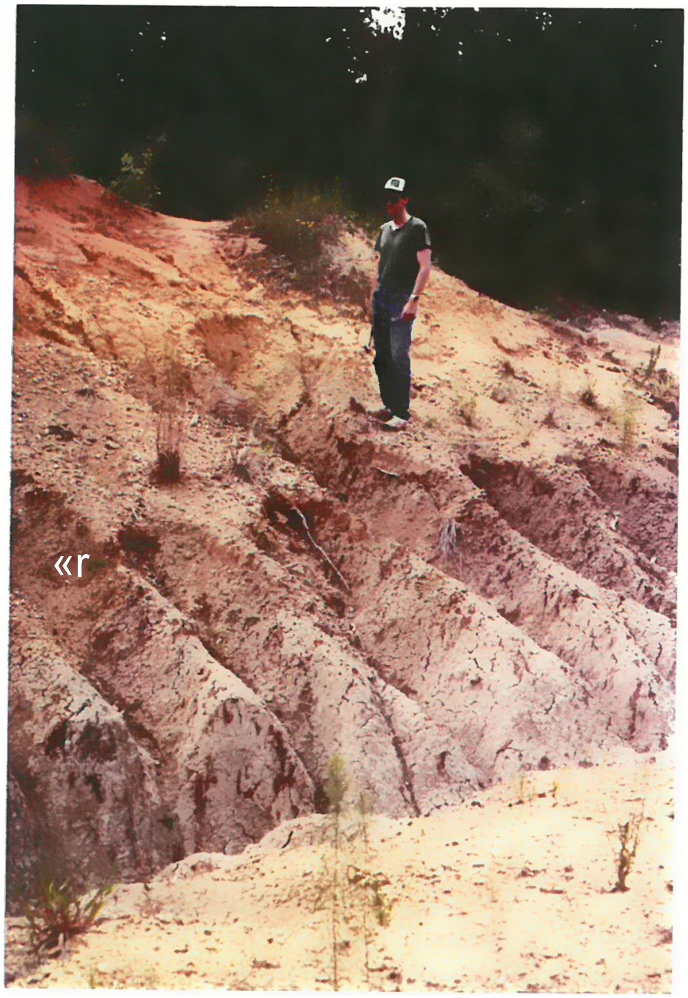


Figure A-3. Hattiesburg lutite overlain by sand and gravel of uncertain age (sample location 114H). Person in the picture is approximately six feet tall.

Deposits Underlying Terrace Surfaces

(1) The east side of U.S. Highway 11 just south of Eastabuchie in northern Forrest County: SW/4 of SW/4 of Section 2, T5N, R13W, elevation 165-170 feet.

Description of Section (top to bottom)

Section outcrops between highway and railroad tracks.

- 2 feet of light brown, sandy gravel (also contains some fine-grained material) (sample number 105TG)
- 2 feet of tan to brown, medium sand (sample number 105TS)

(2) The northeast face of an abandoned gravel pit across the street (Hillcrest Loop) from the Petal Baseball Park in northern Forrest County: SW/4 of NE/4 of Section 1, T4N, R13W, elevation 180-190 feet.

Description of Section (top to bottom)

This sample location was designated with the letter "U" (for unknown) at the time of sampling, for it had not been determined to exactly what group it belonged. R. L. Bowen indicated (personal communication, May 1984) that these sediments are Citronelle.

- 2 to 3 feet of yellowish-brown, weathered gravel (sample number 106UG)
- 6 to 7 feet of reddish-brown, fine-grained sand (sample number 106USF)
- 3 to 7 inches of reddish-purple to white clay (sample number 106UCL)
- bottom 2 to 2.5 feet consists of tan to brown, mildly cross-bedded, medium sand (sample number 106US)

(3) The northwest side of the Lowery sand and gravel pit just north of Glendale in northern Forrest County: SE/4 of NW/4 of Section 22, T5N, R13W, elevation 150-155 feet.

Description of Section (top to bottom) (Figure A-4)

- 6 to 8 inches of gravel
- 1 to 1.5 feet of reddish-brown, fine-grained sand (sample number 115TSF)
- 0.5 to 1 foot of dull brown, sandy gravel (sample number 115TG)
- bottom 0.5 to 1 foot consists of tan to dull brown, medium sand (sample number 115TS)

Figure A-4. Sand and gravel units beneath terrace surface in the Lowery sand and gravel pit (sample location 115T).

(4) Terrace face on the northwest side of the Hattiesburg Sand and Gravel Company pit southeast of Hattiesburg in northern Forrest County: SE/4 of NE/4 of Section 25, T4N, R13W, elevation 130-140 feet.

Description of Section (top to bottom)

- 3.5 to 4 feet of tan to brown sand (sample number 116TS)
- bottom 1 to 1.5 feet consists of sandy gravel of the same color (sample number 116TG)

Alluvium

(1) The west side of the Leaf River just north of the Highway 42 bridge in Hattiesburg, northern Forrest County: SE/4 of NE/4 of Section 3, T4N, R13W, elevation 140 feet.

Description of Section (top to bottom)

- 6 to 7 feet of light gray to yellow clay (sample number 117ACL)
- below the clay and exposed in a small channel a few yards closer to the river are 1.5 to 2 feet of tan to brown, medium sand (sample number 117AS)
- still closer to the river in the same small channel and below the sand are light colored, clean gravels (sample number 117AG)

(2) The north side of the Bouie River in the American Sand and Gravel pits south of Glendale in northwestern Forrest County: S/2 of NE/4 of Section 33, T5N, R13W, elevation 140-150 feet.

Description of Section (top to bottom)

- 2 feet of gravel
- 5 feet of light gray to brown clay with interbedded lenses of light gray to buff, medium sand (sample number's 118ACL and 118AS)
- 4 feet of light brown gravel at the bottom of the section (sample number 118AG)

(3) The east side of the Leaf River at the Bush Sand and Gravel Company pits west of Old River Road, south of Carterville, in northern Forrest County: SE/4 of NW/4 of Section 19, T4N, R12W, elevation 130 feet.

Description of Section (top to bottom) (Figure A-5)

- 1.5 to 2 feet of grayish-red, clayey silt (sample number 119ACL)
- 6 to 7 inches of reddish-brown, fine-grained sand (sample number 119ASF)
- 1 to 1.5 feet of white to buff, medium sand (sample number 119AS)
- bottom 4 feet consists of white to buff, sandy gravel (sample number 119AG)

(4) The east side of the Leaf River just north of the bridge near Eastabuchie in southern Jones County: NW/4 of SE/4 of Section 33, T6N, R13W, elevation 150-160 feet.

Description of Section (top to bottom)

- 3 feet of white to buff sand (sample number 120AS)

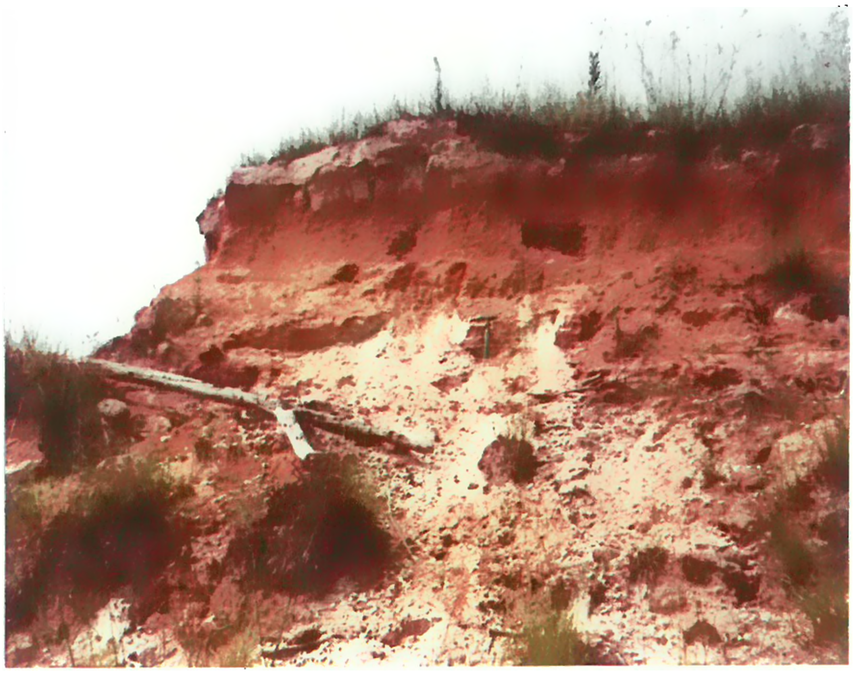


Figure A-5. Alluvial sediments adjacent to the Leaf River in the Bush Sand and Gravel Company pits (sample location 119A).

-4.5 feet of tan to brown, fine-grained sand; this sand is more fine-grained than the sands above and below (sample number 120ASF)

- 4 feet of white to buff sand

- bottom 5 to 6 feet consists of light colored, clean, sandy gravel (sample number 120AG)

APPENDIX B

GRAIN SIZE ANALYSIS PROCEDURES AND SEDIMENT SIZE STATISTICAL DATA

Grain Size Analysis Procedures

The loose sediment was split to obtain approximately 500 to 1000 grams of material when working with gravel, 200 to 400 grams when working with sand, and 50 to 200 grams when working with the finer material. Each sample was then sieved using standard sieves and a Ro-tap. Analysis of sand and gravel was made at 0.5 0 intervals from 4.0 0 to -4.0 ϕ and 0.6 0 intervals from -4.0 0 to -5.85 ϕ. Subsequent analysis of silt and clay was made later using the ASTM Standard D 422-51 hydrometer technique for all samples with a 5% or greater mud fraction.

Cumulative-frequency curves were plotted for each sample to obtain the necessary values for calculating the standard statistical parameters (see Table B-2).

Sediment Size Statistical Data

List of Tables:

Table B-1

Gravel-Sand-Silt/Clay Percentages for Selected Samples

Sample	Gravel	Sand	Silt/Clay
101CG	64 .3	32.0	*3.6
101CS	5.0	93.1	*1.9
101CSF	0.1	40.6	41.6/17.7
101CCL	0	36.8	39.7/23.5
102CG	57.9	37.6	*4.5
102CS	2.1	85.4	12.6/1.7
102CSF	6.0	57.6	31.7/4.7
102CCL	0	8.2	52.8/38.9
103CG	67.2	29.1	*3.7
103CS	8.6	84.6	6.4/0.3
103CSF	0.5	35.5	46.5/17.5
103CCL	2.3	32.4	50.3/14.9
104CG	62.1	27.3	9.7/0.8
104CS	0	80.7	17.3/2.0
104CSF	0	46.9	36.8/16.3
104CCL	0	17.3	57.6/25.0
105TG	21.0	59.8	16.9/2.3
105TS	9.1	88.9	*2.0
106UG	65.2	26.3	8.2/0.3
106US	0.1	95.9	*4.0
106USF	0	43.6	39.0/17.4
106UCL	0	2.7	61.4/35.9
107HSF	0.5	77.5	19.8/2.1
107HCL	0	15.5	53.5/31.0
109HSF	0	73.0	22.3/4.7
109HCL	0	9.9	61.3/28.8
110HSF1	0.4	56.1	35.6/7.9
110HSF2	0.3	32.0	47.1/20.6
110HCL	0	6.8	63.2/30.0
111HS	0	93.4	6.4/0.2
111HCL	0	0.3	52.5/47.2
111HVFCL	0	10.1	74.5/15.3

Table B-1 (Continued)

Sample	Gravel	Sand	Silt/Clay
112HG	28.8	44.5	21.6/5.1
112HS	2.6	57.1	32.6/7.6
113HG	30.9	42.8	22.6/3.7
113HS	0.2	86.9	11.8/1.1
113HCL	0	15.1	50.0/34.8
114HS	0.9	77.5	18.0/3.5
114HCL	0	5.1	56.3/38.6
115TG	44.2	47.6	7.8/0.4
115TS	6.3	86.5	6.8/0.3
115TSF	0.5	44.6	42.6/12.2
116TG	43.5	42.4	13.0/1.1
116TS	3.0	68.0	25.3/3.7
117AG	58.7	37.7	*3.5
117AS	3.7	94.4	*1.8
117ACL	0	1.4	76.1/22.5
118AG	72.3	24 .5	*3.2
118AS	1.3	81.7	15.0/2.0
118ACL	0.3	37.2	47.9/14.6
119AG	31.5	67.2	*1.3
119AS	0.7	97.3	*2.0
119ASF	0	71.9	23.5/4.5
119ACL	0	16.0	56.2/27.8
120AG	42.9	56.9	*0.2
120AS	0	98.1	*1.9
120ASF	0	63.4	33 .3/3.3

*silt and clay undifferentiated

Table B-2

Statistical Grain Size Parameters for
Selected Samples (after Folk, 1974)

Sample	Modality	Median(0)	Graphic Mean(0)	Standard Deviation(0)	Simple Sorting	Graphic Skewness	Graphic Kurtosis
101CG	Bimodal *-4.00 ϕ	-2.70	-1.75	2.53	3.61	+ .50	0.57
101CS	Unimodal *1.50 ϕ	1.48	1.52	0.80	1.91	- .09	2.56
101CSF	Bimodal *5.27 ϕ	4.35	5.04	3.35	5.72	+ .41	1.79
101CL	Bimodal *4.37 ϕ	4.18	5.56	3.54	5.75	+ .61	1.11
102CG	Bimodal *-3.50 ϕ	-2.20	-1.40	2.60	3.80	+ .40	0.61
102CS	Bimodal *2.00 ϕ	1.52	1.49	1.26	2.32	+ .04	1.43
102CSF	Bimodal *4.85 ϕ	2.70	2.84	2.20	4.38	+ .10	1.31
102CCL	Unimodal *4.82 ϕ	5.80	7.24	3.41	5.19	+ .58	0.81
103CG	Bimodal *-4.00 ϕ	-3.35	-1.94	2.71	3.84	+ .65	0.56
103CS	Bimodal *2.50 ϕ	2.28	2.24	1.54	3.90	-.31	3.76
103CSF	Bimodal *5.44 ϕ	4.54	5.00	3.55	6.26	+ .33	1.63
103CCL	Bimodal *4.90 ϕ	4.37	4.56	3.38	6.61	+ .28	1.89

Table B -2 (Continued)

Sample	Modality	Mediani 0)	Graphie Mean(0)	Standard Deviation(0)	Simple Sorting	Graphie Skewness	Graphie Kurtosis
104CG	Polymodal *-4.00 ϕ	-2.30	-1.40	3.01	4.58	+.42	0.72
104CS	Bimodal *3.00 ϕ	2.83	3.16	0.72	1.09	+.60	2.55
104CSF	Bimodal *5.13 ϕ	4.14	5.03	3.01	5.68	+.63	2.40
104CCL	Unimodal *4.93 ϕ	4.76	6.38	3.22	5.18	+.67	1.24
105TG	Bimodal *1.50 ϕ	1.40	0.98	3.01	4.46	-.24	1.35
105TS	Unimodal *1.50 ϕ	1.10	0.99	1.21	2.37	-.26	1.65
106UG	Polymodal *-3.50 ϕ	-2.19	-1.20	2.65	4.05	+.54	0.68
106US	Unimodal *2.00 ϕ	2.04	2.08	0.48	0.95	+.31	1.50
106USF	Bimodal *4.89 ϕ	4.18	4.62	3.21	5.73	+.39	1.42
106UCL	Unimodal *5.03 ϕ	5.89	7.27	3.00	4.51	+.63	0.76
107HSF	Bimodal *2.00 ϕ	2.08	2.56	1.23	1.83	+.46	0.99
107HCL	Bimodal *4.95 ϕ	4.87	6.75	3.30	4.84	+.73	0.73
109HSF	Bimodal *2.50 ϕ	2.67	3.03	1.15	2.04	+.54	0.95

Table B-2 (Continued)

Sample	Modality	Median(0)	Graphie Mean(0)	Standard Deviation(0)	Simple Sorting	Graphie Skewness	Graphie Kurtosis
109HCL	Bimodal *5.06 φ	5.41	6.44	2.57	4.04	+ .56	0.89
110HSF1	Bimodal *4.76 φ	3.56	3.34	2.30	5.38	+ .17	2.24
110HSF2	Bimodal *5.32 φ	4.63	5.77	3.37	5.54	+ .50	1.63
110HCL	Bimodal *5.26 φ	5.91	7.11	3.03	4.70	+ .54	0.99
111HS	Bimodal *2.50 φ	2.33	2.38	0.58	1.14	+ .35	1.77
111HCL	Polymodal *7.08 φ	7.70	8.17	2.17	3.25	+ .26	0.80
111HVFCL	Unimodal *5.07 φ	4.97	5.53	1.87	3.33	+ .56	1.40
112HG	Polymodal *4.95 φ	1.53	0.78	3.99	6.57	- .14	0.87
112HS	Bimodal *4.91 φ	2.75	2.98	2.64	5.84	+ .40	1.70
113HG	Polymodal *4.76 φ	2.10	1.17	3.06	4.28	-.34	0.56
113HS	Bimodal *1.75 φ	1.63	1.79	0.73	1.56	+ .59	2.42
113HCL	Bimodal *5.09 φ	5.33	7.11	3.61	5.38	+ .64	0.77
114HS	Bimodal *2.25 φ	2.32	2.71	1.14	1.71	+ .40	0.98

Table B-2 (Continued)

Sample	Modality	Median(0)	Graphie Mean(0)	Standard Deviation(0)	Simple Sorting	Graphic Skewness	Graphic Kurtosis
114HCL	Bimodal *5.14 ϕ	6.21	7.17	2.78	4.07	+.46	0.74
115TG	Polymodal *-4.00 ϕ	0.36	-0.46	2.91	4.37	-.26	0.43
115TS	Bimodal *2.00 ϕ	1.60	1.54	1.36	2.76	-.09	1.85
115TSF	Bimodal *5.00 ϕ	4.13	4.22	2.72	4.97	+.23	1.56
116TG	Polymodal *-3.50 ϕ	0.38	0.06	3.04	4.25	-.10	0.67
116TS	Bimodal *4.86 ϕ	2.65	2.76	1.66	2.85	+.11	0.91
117AG	Bimodal *-2.50 ϕ	-1.92	-0.96	2.43	3.42	+.49	0.57
117AS	Unimodal *2.00 ϕ	1.62	1.61	0.72	1.50	-.12	1.83
117ACL	Bimodal *5.48 ϕ	6.28	6.87	2.20	3.93	+.54	1.66
118AG	Bimodal *-4.00 ϕ	-3.46	-2.01	2.67	3.78	+.69	0.78
118AS	Bimodal *1.50 ϕ	1.66	2.24	1.38	2.08	+.47	1.31
118ACL	Bimodal *4.97 ϕ	4.36	4.55	2.76	4.74	+.25	1.53
119AG	Unimodal *1.50 ϕ	0.33	-0.09	1.93	3.00	-.28	0.79

Table B-2 (Continued)

Sample	Modality	Mediani 0)	Graphic Meant 0)	Standard Deviat ion(/)	Simple Sorting	Graphic Skewness	Graphic Kurtosis
119AS	Unimodal *2.00 ϕ	1.98	2.07	0.61	1.05	+ .17	1.04
119ASF	Bimodal *2.00 ϕ	2.70	2.92	1.38	2.39	+ .34	0.90
119ACL	Unimodal *5.69 ϕ	6.10	6.74	3.05	5.03	+ . 24	1.15
120AG	Bimodal *1.25 ϕ	0.07	-0.82	2.25	3.27	- .51	0.62
120AS	Unimodal *2.25 ϕ	2.14	2.21	0.44	0.76	+ . 32	1.11
120ASF	Bimodal *4.72 ϕ	3.46	3.44	1.07	1.88	+ .06	1.01

*primary mode

APPENDIX C

X-RAY DIFFRACTION PROCEDURES

The mineralogy of the clay, silt, and, to some extent, heavy mineral fractions was determined by x-ray diffraction.

Representative samples were dispersed in distilled water and allowed to settle the appropriate length of time (usually 2 hours and 10 minutes) for the clay size analysis. The suspended clay particles were siphoned out of the beakers and put on a glass slide to dry so as to insure proper orientation of the clay minerals. This orientation of the c-axes normal to the slide is also normal to the x-ray sample holder, thus providing an enhanced 001 diffraction making the clay mineral identification possible. In addition to the regular oriented slides each sample was glycolated by placing it in a desiccator containing ethylene glycol for one day. This provided sufficient time for the expansion of any smectite clay minerals present.

Heating was also necessary in the identification of the clay minerals. Expandable material such as montmorillonite was heated to 300° C to dry off any interlayer water thus reducing its original 001 reflection. Heating to 700° C using ceramic tiles was necessary for distinguishing chlorite from vermiculite.

Components within the silt size fraction were also identified by x-ray diffraction. Sediment caught in the pan after sieving was saved along with the dried portion of mud saved from the original pipette. This fine-grained material was sprinkled on double sticky tape placed on a slide and x-rayed. Selected heavy mineral samples were crushed and x-rayed in the same manner.

The setting used on the GE XRD-6 Diffractometer was as follows :

Radiation	Cu Ka
Scanning speed	2° 2θ per minute
Slit openings	1° beam slit
Filter	Nickel
Voltage	45KV
Milliamperes	19
Time constant	2.5
Range	2.5k
Amplitude gain	4

APPENDIX D

CLAY MINERALOGY

List of Tables :

Table D-1

Major Clay Minerals Present

NOTE: X = Positively identified, SV = Smectite-Vermiculite, IV = Illite-Vermiculite

Sample No.	Smectite	Vermiculite (?)	Illite	Kaolinite	Random Mixed Layer
101CG		X*	X*	X	
101CS			X*	X	
101CSF				X	SV
101CCL			X	X	
102CG				X	
102CS				X	
102CSF		X		X*	
102CCL			X	X	
103CG			X*	X	
103CS			X	X	
103CSF			X*	X	SV
103CCL		X	X*	X	
104CG				X*	
104CS			X	X	
104CSF		X*	X	X	
104CCL			X	X	
105TG	X		X	X	
105TS				X	SV

Table D-1 (Continued)

Sample No.	Smectite	Vermiculite	(?)	Illite	Kaolinite	Random Mixed Layer
106UG		X			X*	
106US				X*	X	
106USF				X	X	
106UCL				X	X	
107HSF		X		X*	X	
107HCL	X			X	X	
109HSF				X*	X	SV
109HCL	X			X	X	
110HSF1	X*			X	X	
110HSF2				X	X	SV
110HCL		X		X*	X	
111HS		X*		X	X*	
111HCL	X			X	X	
111HVFCL	X			X	X	
112HG		X			X	
112HS				X*	X	IV

Table D-1 (Continued)

Sample No.	Smectite	Vermiculite (?)	Illite	Kaolinite	Random Mixed Layer
113HG	X*		X	X	
113HS		X	X*	X*	
113HCL	X		X	X	
114HS		X	X*	X	
114HCL	X		X	X	
115TG	X*		X	X	
115TS	X*		X	X	SV
115TSF	X*		X	X	
116TG	X*		X	X	
116TS			X*	X	
117AG			X	X	
117AS	X*		X	X	
117ACL	X		X	X	
118AG	X*		X	X	
118AS	X		X	X	
118ACL	X		X	X	

Table D-1 (Continued)

Sample No.	Smectite	Vermiculite (?)	Illite	Kaolinite	Random Mixed Layer
119AG			X	X	SV*
119AS	X*		X	X	
119ASF	X		X*	X	
119ACL	X		X*	X	
120AG	X*		X*	X	
120AS	X*		X	X	
120ASF	X		X*	X	

*poorly crystallized

Table D-2

Peak Area Ratio of Major Clay Minerals to Illite

NOTE: SV = Smectite-Vermiculite

Sample No.	Smectite	Vermiculite(?)	Kaolinite	Random Mixed Layer
101CG		2.0	15.0	
101CS			33.8	
101CSF				
101CCL			1.8	
102CG				
102CS				
102CSF				
102CCL			6.0	
103CG			8.0	
103CS			2.9	
103CSF			6.2	SV 5.3
103CCL		46.6	50.0	
104CG				
104CS			9.7	
104CSF		0.7	15.3	
104CCL			3.8	
105TG	65.0		40.3	
105TS				
106UG				
106US			8.1	
106USF			1.8	
106UCL			8.3	
107HSF		19.1	10.1	
107HCL	33.3		4.9	
109HSF			16.7	SV 8.5
109HCL	8.7		0.7	
110HSF1	2.1		5.7	
110HSF2			2.7	SV 2.5
110HCL		1.6	4 .5	
111HS		0.5	3.6	
111HCL	14.3		2.8	
111HVFCL	27.9		5.2	

Table D-2 (Continued)

Sample No.	Smectite	Vermiculite(?)	Kaolinite	Random Mixed Layer
112HG				
112HS			2.8	SV 3.3
113HG	1.1		2.0	
113HS		20.0	10.0	
113HCL	14.4		3.0	
114HS		4.1	10.7	
114HCL	20.0		2.7	
115TG	1.8		5.7	
115TS	1.5		4.7	
115TSF	1.0		3.2	
116TG	4.1		3.6	
116TS			6.3	SV 9.3
117AG			2.5	
117AS	1.9		1.3	
117ACL	6.0		5.3	
118AG	1.2		1.9	
118AS	17.5		9.2	
118ACL	4.5		2.6	
119AG			5.0	SV 2.8
119AS	2.9		3.2	
119ASF	10.3		6.1	
119ACL	7.7		4.7	
120AG	3.5		5.7	
120AS	1.9		1.5	
120ASF	21.6		8.1	

APPENDIX E

MINERALOGY OF THE SILT SIZE SEDIMENTS

List of Tables :

Table E-1

Major Minerals Present in the Silt Size Fraction

X = Positively identified

Sample No.	Quartz	Feldspar (undiff.)	Fe oxides, hydroxides	Mica
101CG	X			
101CS	X	X	X	
101CSF	X			
101CCL	X			X*
102CG	X			
102CS	X		X*	
102CSF	X			X*
102CCL	X		X*	
103CG	X	X*		
103CS	X	X*		X*
103CSF	X			
103CCL	X			
104CG	X			
104CS	X	X		
104CSF	X			
104CCL	X			X*
105TG	X		X*	
105TS	X	X		
106UG	X			
106US	X	X		X*
106USF	X			X*
106UCL	X			X
107HSF	X		X*	
107HCL	X			X*
109HSF	X			
109HCL	X	X	X	X*
110HSF1	X			X*
110HSF2	X			X*
110HCL	X			X*

Table E-l (Continued)

Sample No.	Quartz	Feldspar (undiff.)	Fe oxides, hydroxides	Mica
111HS	X	X		
111HCL	X			X
111HVFCL	X	X		X
112HG	X			
112HS	X			X*
113HG	X			X*
113HS	X	X	X*	X*
113HCL	X	X		X*
114HS	X		X*	X*
114HCL	X		X	X*
115TG	X	X*		
115TS	X	X	X	
115TSF	X	X	X*	X*
116TG	X	X		X*
116TS	X	X		X*
117AG	X	X		
117AS	X	X		X
117ACL	X	X		
118AG	X	X		
118AS	X	X		
118AC	X	X		X*
119AG	X			
119AS	X	X*		
119ASF	X	X*		X*
119ACL	X	X		X*
120AG	X	X*		X*
120AS	X	X		X*
120ASF	X	X*		X*

*present in minor amounts

APPENDIX F

PETROGRAPHIC ANALYSIS PROCEDURES

The mineralogy of the light and heavy mineral sand fractions was determined by petrographic microscope. Gravel types were determined by examination with the binocular microscope.

Thin sections were made of 45 samples by placing the loose sediments into small cup molds and adding a casting resin and hardener. The thin sections were made by a commercial establishment (Western Petrographic). Grain mounts were made of the remaining samples due to their fine grain size and small volume. A statistical count of the light mineral grains was obtained using the petrographic microscope. Approximately 200 to 250 grains were counted per slide.

The gravels, which had been saved from the sieve analysis, were broken and examined with the binocular microscope. A statistical count was made for both pebble and granule gravel fractions.

Sediment samples were sieved to obtain the 2.0 to 3.5 ***i)*** size for the heavy mineral analysis. This size was used for the coarser material; however, smaller sizes were utilized for the finer grained materials. After the sediments had been soaked in 20% HCl, the heavy minerals were separated from the light minerals using the heavy liquid Bromoform. The cleaned and dried "heavies" were then permanently mounted on petrographic slides. Here, also, a statistical count was made using the petrographic microscope. Approximately 300 to 400 grains per slide were counted.

APPENDIX G

POINT COUNT DATA

List of Tables:

Table G-1

Light Mineral Percentages

NOTE: SMxl = Monocrystalline straight to slightly undulóse
UMxl = Monocrystalline undulóse to strongly undulóse
SCmp = Semicomposite
Cmp = Composite
CmpM = Composite metamorphic
Or = Orthoclase

San = Sanidine
Mcl = Microcline
UP1 = Untwinned plagioclase
TP1 = Twinned Plagioclase
SRF = Sedimentary rock fragment
MRF = Metamorphic rock fragment
VRF = Volcanic rock fragment

	Quartz					Feldspar					Rock Fragments			
Sample No.	SMxl	UMxl	SCmp	Cmp	CmpM	Or	San	Mcl	UP1	TP1	Chert	Other SRF's	MRF	VRF
101CG	33.3	38.4	9.7	5.5	0.5	3.2	-	0.5	1.4	-	4.2	1.8	1.4	-
101CS	27.3	40.1	7.5	11.8	1.6	1.6	-	1.1	1.6	0.5	5.3	-	1.6	-
101CSF	34.1	44.1	6.5	5.2	1.3	1.7	-	0.4	0.9	0.4	2.2	0.9	1.7	0.4
101CCL	25.9	41.8	4.3	8.2	4.7	1.7	-	1.3	0.4	0.4	3.0	2.2	4.3	1.7
102CG	39.5	30.9	5.4	8.1	7.2	1.3	-	-	-	-	4.0	0.9	0.9	1.8
102CS	39.8	37.9	4.8	6.3	3.9	2.9	-	-	-	-	3.9	-	0.5	-
102CSF	32.4	50.9	4.3	4.3	2.8	1.9	-	-	1.4	-	-	0.5	1.4	-
102CCL	31.3	41.5	7.1	3.3	3.3	1.4	0.5	0.5	-	-	6.1	1.4	2.4	1.4
103CG	23.5	50.7	10.1	4.6	3.2	-	-	-	-	0.5	3.7	1.8	1.8	-
103CS	26.4	45.8	7.0	5.3	3.5	0.4	-	0.4	-	1.8	3.5	1.8	2.6	1.3
103CSF	25.8	50.7	7.2	7.6	2.9	-	-	-	0.5	-	3.8	0.9	0.5	-
103CCL	25.8	46.1	4.6	8.3	5.1	1.4	-	-	-	0.9	5.5	1.8	0.5	-

Table G-1 (Continued)

			Quartz					Feldspar				Rock Fragments		
Sample No.	SMxl	UMxl	SCmp	Cmp	CmpM	Or	San	Mcl	UP1	TP1	Chert	Other SRF's	MRF	VRF
104CG	26.9	50.0	5.3	8.2	4.3	0.5	-	-	0.5	-	3.8	-	0.5	-
104CS	23.5	53.9	5.4	6.3	1.0	2.0	-	-	-	-	3.4	2.4	1.9	-
104CSF	19.5	46.0	10.2	10.7	4.6	0.9	-	-	-	0.5	5.6	0.9	0.9	-
104CCL	41.0	34.1	5.6	9.3	0.6	1.8	-	-	-	-	4.3	1.8	1.2	-
105TG	20.8	51.2	13.7	7.6	1.9	1.4	-	-	-	-	1.9	0.5	0.9	-
105TS	28.4	45.1	9.8	12.2	0.5	-	-	-	0. 5	-	2.9	0.5	-	-
106UG	26.2	37.4	9.2	9.7	6. 3	0.9	-	-	0.4	-	8.2	0.9	0.5	-
106US	24.7	41.4	10.9	4.3	8.1	1.9	-	0.9	0.5	0.9	3.8	1.0	0.6	0.9
106USF	35.4	43.8	4.2	2.8	4.7	1.4	-	-	0.5	-	4.7	0.9	0.9	0.5
106UCL	32.9	37.1	5.7	6.8	7.8	-	0.5	0.5	-	-	5.2	2.6	0.5	-
107HSF	30.6	48.8	5.0	5.9	2.7	1.8	-	0.4	0.4	0.9	2.7	-	0.4	-
107HCL	49.7	29.8	2.6	8.6	2.0	2.0	-	-	-	0.7	4.0	-	0.6	-
109HSF	25.7	45.9	4 . 3	6.0	6.4	1.7	-	1.3	0.8	1.3	6.0	-	-	0.4
109HCL	35.7	32.1	5.3	10.1	5.9	-	-	-	-	1.2	6.5	-	0.6	2.4
110HSF1	25.1	50.7	6.9	4.2	4.2	0.9	-	-	-	0.4	6.5	0.5	0.4	-
110HSF2	26.7	54.7	6.7	7.6	1.9	0.5	-	-	-	-	1.4	-	0.5	-
110HCL	32.7	49.1	6.5	7.0	2.3	-	-	-	-	-	2.3	-	-	-
111HS	28.9	48.6	6.4	2.7	4.1	1.4	-	0.4	0.4	0.9	2.7	0.9	1.8	0.4
111VFCL	34.3	39.5	5.6	7.7	5.1	0.5	-	1.0	0.5	3.1	1.5	-	-	1.0
112HG	49.7	35.5	1.5	3.9	6.9	-	-	-	1.0	-	1.5	-	-	-
112HS	55.1	35.7	1.4	2.9	1.9	-	-	-	-	-	1.9	1.0	-	-

Table G-1 (Continued)

	Quartz					Feldspar					Rock Fragments			
Sample No.	SMxl	UMxl	SCmp	Cmp	CmpM	Or	San	Mcl	UP1	TP1	Chert	Other SRF's	MRF	VRF
113HG	31.0	35.4	3.5	4.4	9.3	0.9	-	0.4	0.9	1.7	9.3	1.3	1.7	-
113HS	41.1	35.8	3.3	3.7	7.0	1.2	-	1.6	0.4	0.8	2.9	1.2	0.8	-
113HCL	43.2	30.2	4.2	5.6	9.7	-	-	0.5	-	1.4	2.3	1.4	0.5	0.9
114HS	41.7	50.0	1.4	3.2	0.9	0.9	-	-	-	-	1.4	-	0.5	-
114HCL	45.4	30.1	4.1	6.1	8.2	1.0	-	1.5	-	-	2.0	0.5	-	1.0
115TG	36.6	45.4	4.4	1.9	5.4	1.9	-	-	-	0.5	3.9	-	-	-
115TS	35.5	43.9	1.9	3.3	7.0	1.4	-	0.9	-	0.9	4.7	0.5	-	-
115TSF	28.4	53.5	5.7	3.3	5.2	0.5	-	-	0.5	0.9	1.9	-	-	-
116TG	39.3	44.3	2.5	7.5	3.0	-	-	-	0.5	-	3.0	-	-	-
116TS	42.6	44.0	1.9	1.4	4.3	1.9	-	-	-	0.5	2.9	0.5	-	-
117AG	29.3	33.0	5.1	6.0	7.9	3.2	-	0.9	-	1.9	8.8	2.3	1.4	-
117AS	49.5	36.3	4.4	2.9	2.0	0.5	-	-	0.5	-	2.9	0.5	0.5	-
117ACL	45.6	37.9	1.6	4.4	4.9	0.5	-	1.1	-	2.2	1.6	-	-	-
118AG	25.4	44.1	3.0	2.1	5.1	1.7	-	0.4	2.1	0.8	5.9	6.3	0.4	2.5
118AS	45.7	41.4	2.8	2.4	3.3	-	-	-	0.9	0.5	1.9	0.5	-	0.5
118ACL	35.7	47.1	4.3	3.8	1.9	1.4	-	-	-	-	4.3	0.5	-	0.9
119AG	33.3	33.3	5.6	6.8	9.0	-	-	-	1.7	-	10.2	-	-	-
119AS	39.4	43.3	4.3	2.9	3.8	0.5	-	-	-	0.5	4.8	-	-	0.5
119ASF	36.2	45.2	7.2	2.7	4.5	0.4	-	0.4	-	0.9	0.4	0.9	0.4	0.4
119ACL	51.2	28.6	3.6	6.5	2.9	1.2	-	-	2.4	0.6	2.4	-	-	0.6

Table G-1 (Continued)

		Quartz						Feldspar				Rock Fragments		
Sample No.	SMxl	UMxl	SCmp	Cmp	Cmp M	Or	San	Mcl	UP1	TP1	Chert	Other SRF's	MR F	VRF
120AG	25.7	58.2	5.3	1.4	4.8	0.5	-	-	-	-	3.9	-	-	-
120AS	29.8	52.4	2.9	3.8	1.9	1.4	-	-	-	1.0	3.8	0.5	0.5	1.9
120ASF	25.4	50.9	4.5	3.1	4.0	2.7	-	0.9	0.4	1.8	3.1	1.3	0.9	0.9

Table G-2

Number of Light Mineral Samples Analyzed and the Average Number of Grains Counted from Each Sedimentary Unit

Clastic Sedimentary Unit	N	Number of Grains Counted	
		Range	Mean
Hattiesburg Fm.	6	151-215	190
Sands and gravels associated w/ the Hattiesburg Fm.	10	203-243	219
Citronelle Fm.	20	161-232	210
Sub-terrace Deposits	7	201-214	208
Alluvium	13	168-236	205

NOTE: N = number of samples

Table G-3

Gravel Percentages by Size Class

			Gravel Lithology							
Sample No.	Gravel Size	% of Total Sample	Quartz	Chert	Tripoli	*Fossiliferous Limestone	*Oolitie Limestone	*Mudstone	*Clayey Sandstone	*Fossils
101CG	Pebble	54.1	25.3	45.3	10.2	3.5	2.1	6.3	6.3	0.7
101CG	Granule	10.2	51.0	35.0	6.3	0.8	-	1.3	4.6	0.8
102CG	Pebble	47.8	14.0	31.8	43.0	2.0	4.0	3.3	2.5	-
102CG	Granule	10.1	33.6	33.6	26.1	-	2.9	-	2.9	0.8
103CG	Pebble	60.5	17.4	58.6	7.8	0.9	6.5	5.2	3.0	0.4
103CG	Granule	6.7	53.9	35.3	5.5	-	1.1	1.4	2.6	-
104CG	Pebble	47.8	56.8	3.8	33.3	0.3	1.4	1.7	2.0	0.7
104CG	Granule	14.3	73.2	2.0	18.6	-	2.0	0.8	2.5	0.8
105TG	Pebble	16.2	34.9	43.4	12.3	0.9	1.9	2.8	3.8	-
105TG	Granule	4.8	77.6	14.4	4.9	0.3	1.8	0.3	0.6	-
106UG	Pebble	43.1	40.7	16.7	36.9	-	1.4	1.6	1.9	0.8
106UG	Granule	22.1	88.0	5.5	5.5	-	0.2	-	0.7	-
112HG	Pebble	23.0	31.8	34.9	26.4	2.3	3.0	1.6	-	-
112HG	Granule	5.8	73.7	9.5	11.0	1.1	1.6	0.5	2.1	0.5

Table G-3 (Continued)

Sample No.	Gravel Size	% of Total Sample	Gravel Lithology							
			Quartz	Chert	Tripoli	*Fossiliferous Limestone	*Oolitic Limestone	♦Mudstone	*Clayey Sandstone	*Fossils
113HG	Pebble	22.2	31.7	63.4	0.6	—	1.9	1.8	0.6	-
113HG	Granule	8.7	62.6	34.2	1.9	-	0.3	-	0.9	-
115TG	Pebble	38.0	30.1	44.9	10.7	1.5	3.4	5.7	3.1	0.4
115TG	Granule	6.2	70.4	19.1	6.5	0.6	1.5	0.9	0.9	-
116TG	Pebble	32.6	28.5	25.8	36.7	1.6	2.3	3.5	1.2	0.4
116TG	Granule	10.9	80.7	10.1	4.5	0.4	2.3	0.9	0.9	0.2
117AG	Pebble	38.9	20.0	61.1	10.0	1.1	4.3	1.4	0.7	1.4
117AG	Granule	19.8	52.0	36.9	4.0	0.3	2.9	2.1	0.3	1.3
118AG	Pebble	65.8	30.6	51.4	8.3	0.8	1.7	3.9	2.6	0.4
118AG	Granule	6.5	59.1	34.2	3.7	0.5	0.3	1.3	0.8	-
119AG	Pebble	14.1	32.2	40.7	18.6	1.5	3.5	2.0	1.0	0.5
119AG	Granule	17.4	71.1	18.6	5.5	0.7	1.5	1.1	1.1	0.4
120AG	Pebble	33.5	39.1	40.0	11.1	2.2	2.7	3.6	1.3	—
120AG	Granule	9.4	75.8	16.6	3.0	0.5	1.4	1.8	0.7	0.2

*silicified

Table C-4

Heavy Mineral Percentages

Sample No.	Kyanite	Staurolite	Zircon	Tourmaline	Rutile	Sillimanite	*Black Opaques	*White Opaques	**Others
101CG	13.2	18.8	18.1	6.6	9.1	0.3	24.4	6.6	2.9
101CS	25.0	20.3	9.0	5.3	4.6	3.3	19.3	11.6	1.6
101CSF	16.1	17.8	19.6	4.5	2.7	-	31.2	8.0	-
101CCL	13.4	30.6	14.6	12.1	1.9	1.3	14.6	7.6	3.9
102CG	16.7	19.9	8.5	7.6	4.1	0.9	21.7	19.6	1.0
102CS	25.5	21.7	7.2	13.2	5.3	1.2	17.6	7.2	1.1
102CSF	14.2	15.6	10.4	14.5	6.4	-	24.6	12.7	1.6
102CCL	4.9	6.2	16.1	13.8	3.6	-	29.5	25.2	0.7
103CG	10.9	14.4	14.7	11.5	3.9	0.2	24.9	18.5	1.0
103CS	12.2	16.3	7.2	17.9	3.4	0.7	21.0	19.2	2.1
103CSF	4.8	8.8	19.8	15.2	5.7	0.4	28.0	16.1	1.2
103CCL	9.1	10.2	23.3	13.0	3.0	1.1	29.4	9.7	1.2
104CG	9.4	10.2	33.2	11.0	5.6	0.3	23.4	6.7	0.2
104CS	12.2	13.6	1.4	19.7	0.9	0.5	11.3	39.2	1.2
104CSF	5.5	10.8	4.5	28.2	2.9	1.6	11.3	34.5	0.7
104CCL	6.4	8.8	22.0	15.2	10.6	0.8	24.3	11.6	0.3
105TG	16.1	8.9	17.9	7.7	9.8	0.3	25.1	11.0	3.2
105TS	14.2	10.1	13.1	13.7	7.1	-	17.7	23.8	0.3
106UG	17.5	12.6	8.8	13.6	2.4	0.7	27.3	16.3	0.8
106US	17.1	11.9	3.6	15.1	2.7	1.0	20.7	26.8	1.1
106USF	14.5	10.1	16.2	9.6	1.3	0.3	31.2	15.7	1.1

Table G-4 (Continued)

Sample No.	Kyanite	Staurolite	Zircon	Tourmaline	Rutile	Sillimanite	*Black. Opaques	*White Opaques	**Others
107HSF	7.7	10.0	21.1	9.7	4.5	0.2	27.9	18.8	0.1
107HCL	8.8	8.8	6.0	21.6	2.4	0.4	16.4	35.6	-
109HSF	15.9	14.2	4.8	19.8	2.5	2.3	18.4	22.1	—
109HCL	5.8	3.6	4.4	29.6	3.3	0.4	20.1	31.0	1.8
110HSF1	14.7	16.2	0.4	25.9	1.2	2.7	12.4	24.3	2.2
110HSF2	6.8	8.5	5.6	17.3	2.0	1.2	35.5	22.2	0.9
111HS	19.7	15.8	3.0	18.5	2.5	0.5	16.3	22.5	1.2
111HVFCL	4.3	5.7	10.8	10.8	7.2	1.4	30.9	26.6	2.3
112HG	17.7	13.5	3.9	15.2	7.3	0.3	27.3	12.7	2.1
112HS	11.4	10.1	6.6	19.7	5.8	0.7	29.3	15.7	0.7
113HG	2.9	5.6	27.7	8.1	5.4	1.1	36.3	12.2	0.7
113HS	19.1	12.0	4.9	18.5	4.1	1.1	23.2	16.3	0.8
113HCL	6.0	3.7	37.6	12.3	7.3	0.7	13.5	17.0	1.9
114HS	14.8	9.2	10.3	19.3	2.6	1.3	28.5	13.7	0.3
115TG	17.8	10.9	14.6	14.9	6.3	0.3	21.8	13.4	—
115TS	16.1	7.8	15.0	12.8	5.3	0.6	27.3	14.8	0.3
115SF	19.4	8.8	10.3	12.1	6.5	0.3	24.8	17.3	0.5
116TG	13.7	8.4	25.4	11.8	8.9	0.5	21.2	10.1	—
116TS	12.2	6.7	20.2	13.9	5.7	-	22.3	18.3	0.7

Table G-4 (Continued)

Sample No.	Kyanite	Staurolite	Zircon	Tourmaline	Rutile	Sillimanite	* Black Opaques	* White Opaques*	* **Others
117AG	7.5	8.2	16.5	11.3	3.7	0.2	33.1	19.5	-
117AS	11.9	10.0	14.2	14.4	4.6	-	28.9	16.0	-
118AG	7.5	6.3	19.0	11.1	8.6	0.7	28.7	16.7	1.4
118AS	15.4	8.4	19.9	11.7	4.7	-	18.2	21.3	0.4
118ACL	5.9	7.7	22.5	9.4	8.3	0.5	19.3	25.1	1.3
119AG	11.4	8.3	25.2	9.1	4.8	0.5	26.0	14.6	0.1
119AS	12.0	6.9	20.0	11.1	5.1	0.7	21.1	22.9	0.2
119ASF	14.7	10.5	7.2	17.4	6.7	0.5	17.7	24.7	0.6
119ACL	11.5	10.7	22.4	10.1	8.8	0.5	20.8	15.2	-
120AG	16.1	7.1	26.3	8.8	4.8	-	26. 6	9. 3	1.0
120AS	12.6	11.9	10.7	10.4	4.2	0.5	28.0	21.0	0.1
120ASF	11.1	7.9	10.4	15.1	6.2	0.5	22.5	26.3	-

*Black and white opaques include ilmenite, magnetite, hematite, pyrite, and leucoxene

**Others include unknowns, pyroxenes, amphiboles, garnet, epidote, and sphene

Table G-5

Number of Heavy Mineral Samples Analyzed
and the Average Number of Grains Counted
with the Corresponding Size Grades
from Each Sedimentary Unit

Clastic Sedimentary Unit	N	No. of Grains Counted		Size Grade
		Range	Mean	
Hattiesburg Fm.	4	139-399	265	3.0-4 .0 0
Sands and gravels associated w/ the Hattiesburg Fm.	10	248-443	365	2.0-3.5 0
Citronelle Fm.	19	112-589	353	2.0-3.5 0
				(clays):2.5-3.5 0
Sub-terrace Deposits	7	335-475	384	2.0-3.5 0
Alluvium	12	353-450	398	2.0-3.5 0

NOTE : N = number of samples

APPENDIX H

THE STEPWISE PROCEDURE IN DISCRIMINANT ANALYSIS

A stepwise procedure was utilized in the application of discriminant analysis computations. A forward stepwise procedure begins by selecting the individual variable which provides the greatest univariate discrimination. The variable which contributed to the best pair is selected. The procedure continues to combine the first two with each of the remaining variables to form triplets. The best triplet determines the third variable to be entered. This procedure of selecting variables on the basis of the one which adds the most discrimination to those already selected continues until all possible variables have been selected or the remaining variables do not contribute a sufficient increment.

When variables which alone appear to be good discriminators are added to other variables, it is possible for them to become useless. The forward selection procedure involves each step starting with a review of the variables previously selected. If any of these variables no longer make a sufficient contribution to the discrimination, it is cast out, although it remains eligible for reselection at a future step. The removal of previously selected variables is usually the result of shared discriminating information with other variables selected on intervening steps. At the time it was selected, this variable may have made a unique contribution. However, variables selected on subsequent steps may combine with one another or with variables selected earlier to duplicate the contribution of this variable. The variable is then redundant and a candidate for removal. This stepwise procedure is a logical and efficient way to seek the best combination, but it cannot guarantee that the end product is indeed superior to all others (Kiecka, 1980, p. 53).

The Mahalanobis squared distance between closest groups method for the stepwise procedure was chosen. This discrimination procedure picks the variable which generates the greatest separation for the pair of groups which are closest at that step. This will tend to force all the groups to be separated (Kiecka, 1980, p. 55).

A two-function plot of group centroids within their respective group areas shows any separation that exists between the groups (clastic sedimentary units). In discriminant analysis, a function is defined as a unique (orthogonal) dimension describing the location of that group relative to the others. The maximum number of discriminant functions to be derived is either one less than the number of groups or equal to the number of discriminating variables, whichever is smaller (Kiecka, 1970, p. 442). Since there are 17 discriminating variables and five groups, the maximum number of discriminant functions is four. Two-function plots are extremely useful because, in this case, the first two functions are the most important. The last two functions are relatively insignificant and do not contribute much theoretical or practical importance. Two measures (provided by the SPSS DISCRIMINANT subprogram) for judging the importance of discriminant functions are the eigenvalue and the relative percentage of the eigenvalue associated with the function. The function with the largest eigenvalue is the most powerful discriminator, while the function with the smallest eigenvalue is the weakest. The first two functions together (Table H-1) contain 83.4% (eigenvalue of 4.1765) of the total discriminating power in the system of equations.

Table H-1

Eigenvalues and Relative Percentages for Each Discriminant Function

Discriminant Function	Eigenvalue	Relative Percentage
1	2.7150	54.25
2	1.4615	29.21
3	0.4786	9.56
4	0.3492	6.98

The importance of the first two functions is based on these numbers since there is no specific rule stating how large (or how small) the eigenvalue and relative percentage must be before the function is of interest to us (Kiecka, 1980, p. 36). The relative contribution of a particular variable to either of the first two functions can be analysed by using the standardized discriminant function coefficients (Table H-2).

Table H-2

Standardized Discriminant Function Coefficients

Discriminating Variable	Function 1	Function 2
Kyanite	0.70421	1.01474
Staurolite	1.29238	0.14430
Zircon	1.07680	0.86408
Tourmaline	0.67850	0.27666
Rutile	0.44605	0.77873
Black opaques	1.10183	0.64270
White opaques	0.95587	1.09158
Monocrystalline undulóse to strongly undulóse quartz grains	0.24234	0.30866
Semicomposite quartz grains	0.25986	-0.24707
Composite quartz grains	-0.03646	-0.09764
Smectite	-0.28739	0.13590

When the sign is ignored, each coefficient represents the relative contribution of its associated variable to that function. The sign merely denotes whether the variable is making a positive or negative contribution (Kiecka, 1970, p. 443). Thus, the heavy minerals, staurolite, the black opaques, and zircon make the greatest contribution to the first function, while the white opaques, kyanite, and zircon make the greatest contribution to the second function. Since these coefficients identify the dominant characteristics on a particular function, they can be used to "name" that function (Kiecka, 1970, p. 443). For instance, the heavy minerals are the most important variables for the first two functions; however, the combination of heavy minerals that are the most important on each function differs. Staurolite, the black opaques, zircon, and the white opaques are, in that order, the most important variables on function 1; therefore, the name "SBZW" is given to that function. The most important variables on function 2, in descending order, are the white opaques, kyanite, zircon, and rutile; consequently, the name "WKZR" is given to that function.

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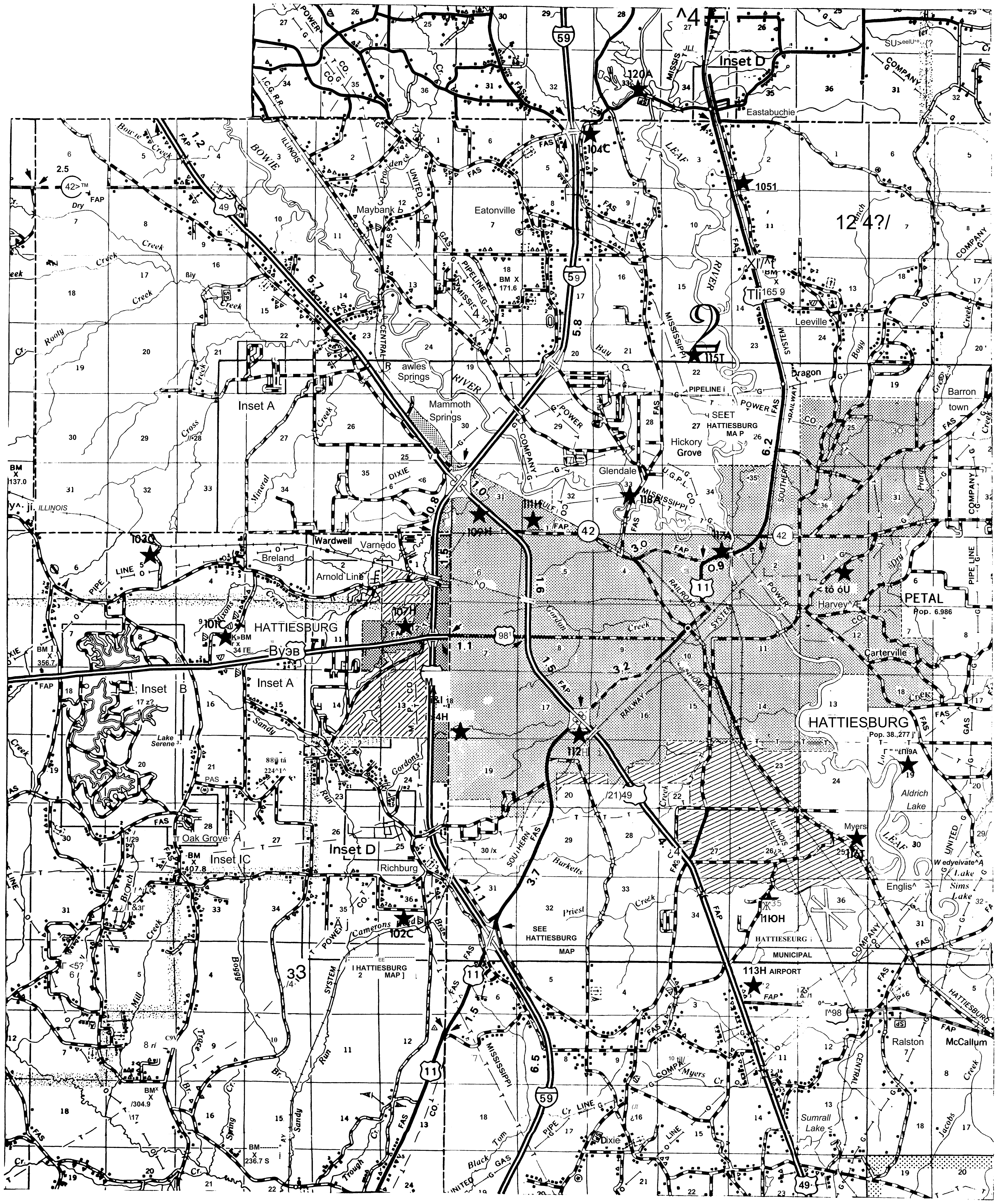

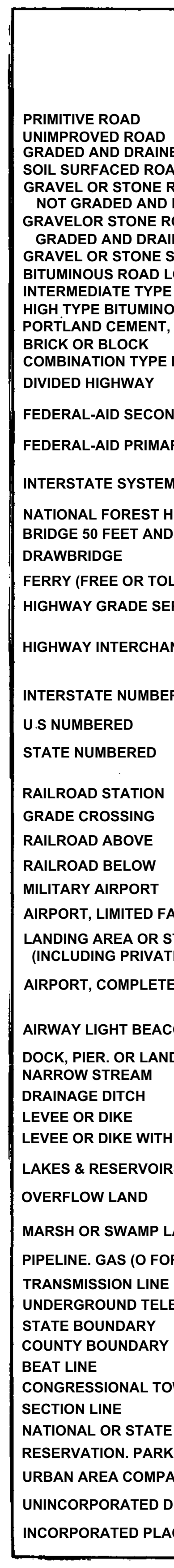

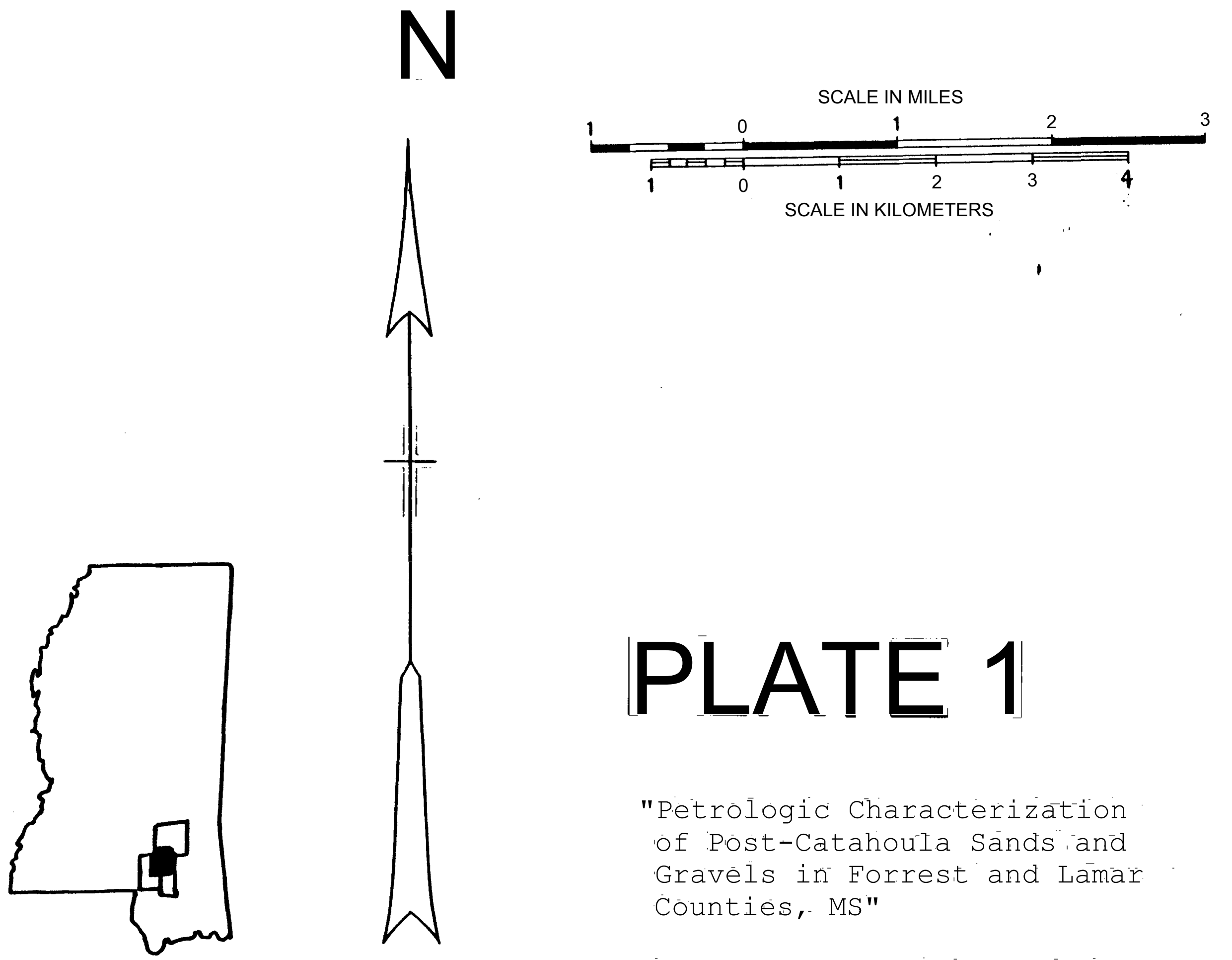

SAMPLE LOCATION MAP

PLATE 1

"Petrologic Characterization of Post-Catahoula Sands and Gravels in Forrest and Lamar Counties, MS"

by Darral W. Kirby - 1984

★ Sample Locations