THE DEPARTMENT OF ENVIRONMENTAL QUALITY

mississippi geology

Office of Geology
P. O. Box 20307
Jackson, Mississippi 39289-1307

Volume 17, Number 2
June 1996

ENGINEERING GEOLOGICAL GEOGRAPHICAL INFORMATION SYSTEM OF THE WATERWAYS EXPERIMENT STATION

William L. Murphy and Paul E. Albertson
Geotechnical Laboratory
U.S. Army Engineer Waterways Experiment Station
Vicksburg, MS 39180

ABSTRACT

Engineering geological data pertaining to the Waterways Experiment Station (WES) were compiled into digital format for incorporation into a computer-based geographical information system (GIS). Data were primarily from borings drilled at WES for groundwater resources or construction projects. Logs of borings in the central Warren County, Mississippi, area also provided geological information. Maps and geological profiles of mappable geologic units at WES were prepared from the data. The GIS will make geological and engineering data readily available to anyone planning or conducting construction, testing or groundwater resource activities in the immediate vicinity of WES.

BACKGROUND

WES is the principal research, testing, and development facility of the U.S. Army Corps of Engineers. Its complex of six laboratories, the Coastal Engineering Research Center, the Environmental Laboratory, the Geotechnical Laboratory, the Hydraulics Laboratory, the Information Technology Laboratory, and the Structures Laboratory, occupies 680 acres in Vicksburg, Mississippi. The authors, assigned to the WES Geotechnical Laboratory, were requested to compile the existing engineering geological information and enter it into a format usable by a GIS. The primary end user of the geotechnical information is the facility's Directorate of Public Works, Engineering and Construction Services Division.

The use of GIS technology for installation management in the Department of Defense is becoming more prevalent. Geological and geotechnical information of an installation is increasingly critical in an age of environmental concerns, as well as in the traditional areas of design and construction. To address these issues, GIS technology gives the manager the ability to study scenarios quickly and efficiently through the use of spatial queries and analyses that relate disparate data.

PURPOSE

The goal of the original work was to compile geological and other data into digital format for incorporation into an

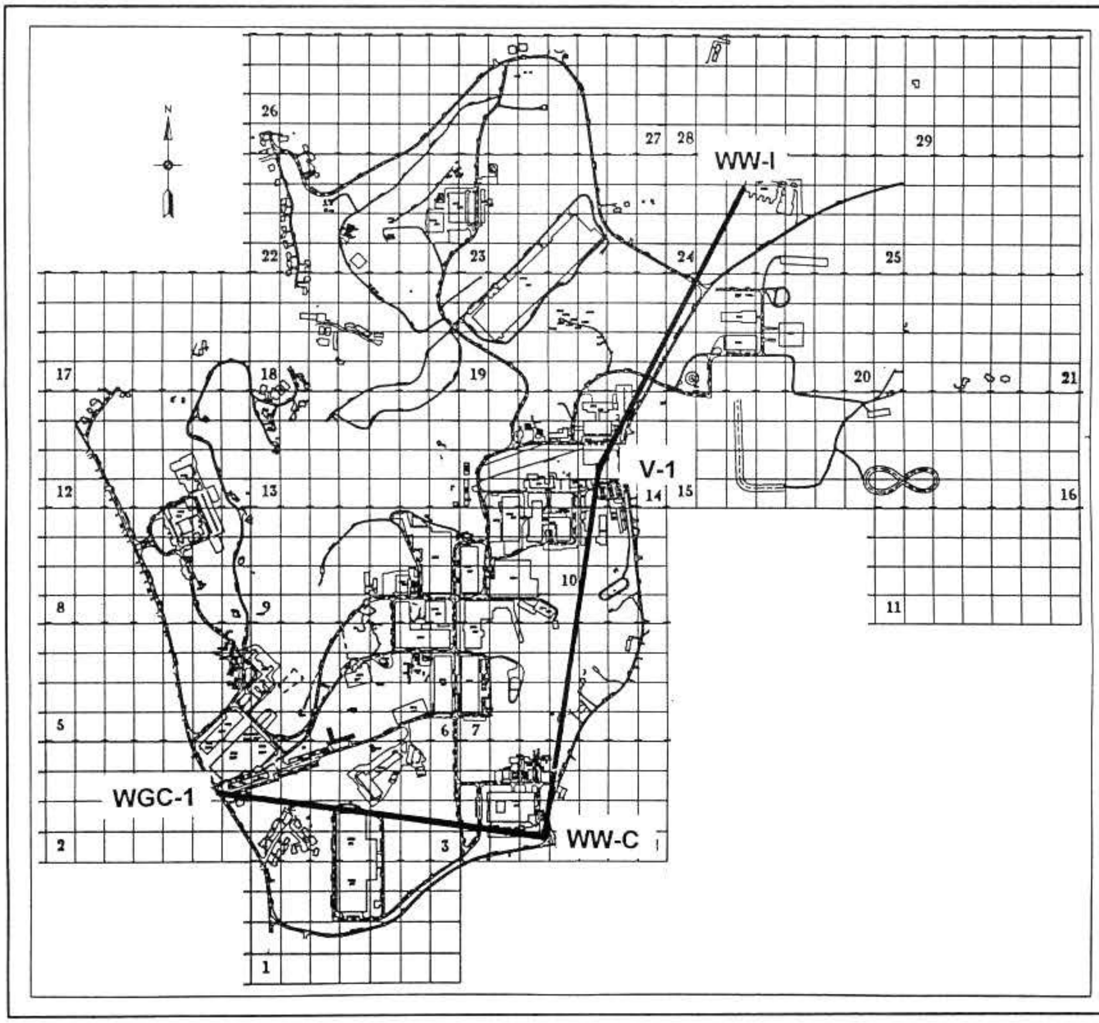


Figure 1. General plan of the Waterways Experiment Station and location of geologic profile of Figure 2.

installation management GIS. The objective of the study was to make the geotechnical information readily available to anyone planning or conducting construction or testing activities at WES, in the form of digital data and as interpreted vertical cross sections and maps of selected geological horizons. The purpose of the present paper is to share to a wider geological community the methods and results of our in-house work.

It was not the intent of the authors to reinterpret the geology of the Vicksburg or Warren County area. The authors relied heavily on existing geological literature describing the local and regional geology, supplementing it with newly acquired data from recent boring programs at and in the immediate vicinity of WES. The chief purpose of reviewing the local and regional geology was to determine whether interpretations of the geology at WES were conformable with or anomalous to the geology surrounding WES. Engineering and construction (geotechnical) characteristics of the geological materials described in this work are emphasized. However, sufficient detail of stratigraphic and structural relationships of the mapped geologic units is presented to demonstrate the variability in properties that can be expected in the vicinity of WES.

GEOTECHNICAL INFORMATION AND ANALYSIS

The authors collected, analyzed, and processed the available geological and engineering data pertaining to WES and vicinity to provide geotechnical information for a facility GIS being developed by the WES Tri-Service CADD/GIS Center. A large amount of geotechnical data for the facility and surrounding areas has accumulated from WES and county-

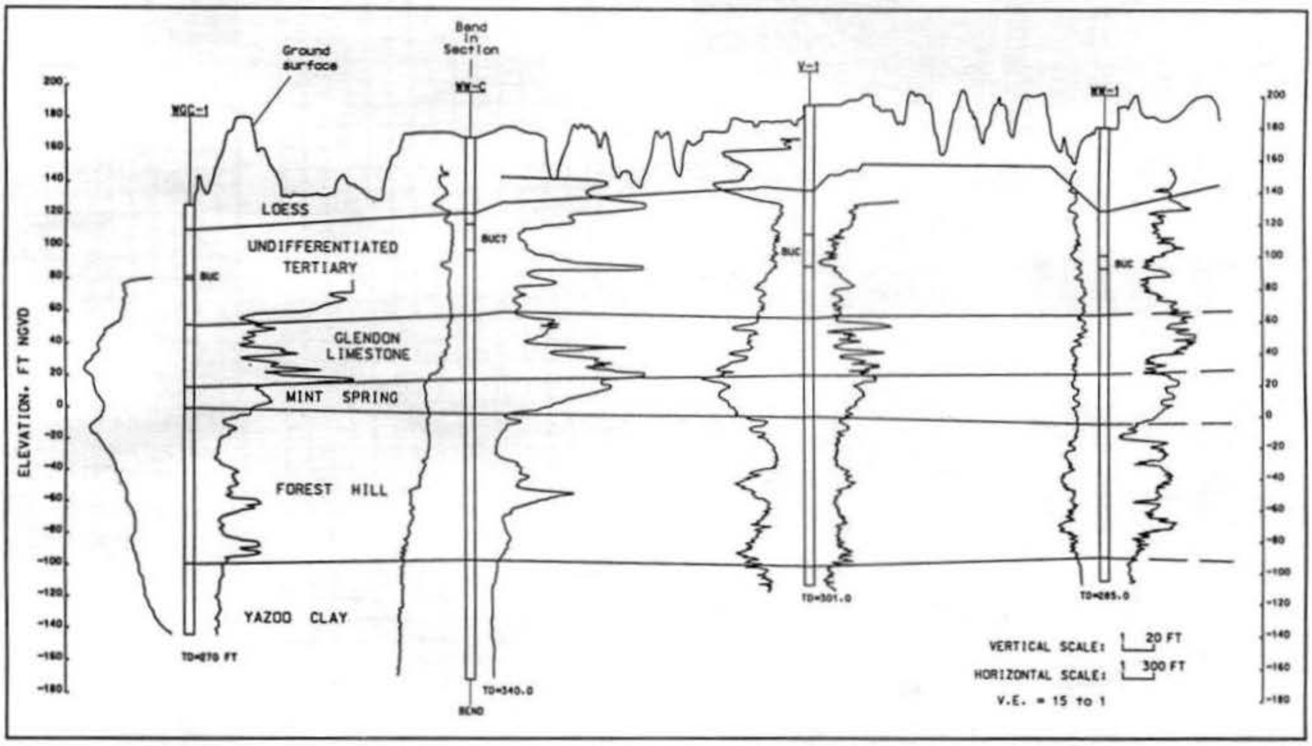


Figure 2. Vertical profile through four deep borings at WES, showing geologic units and E-logs.

wide activities but had not previously been compiled and portrayed. The authors also attempted to combine and correlate data from individual borings and other data sources into a comprehensive, three-dimensional interpretation of the surface and subsurface conditions at WES. The procedures used to accomplish this effort are applicable to any facility wishing to incorporate geology and geotechnical data into a GIS. The geological and engineering data compiled and the resulting maps and tables are site- or area-specific.

DATA COLLECTION

Data sources included foundation borings for structures on the WES installation, water and monitoring wells at WES and in the Vicksburg area of Warren County, and existing geotechnical literature. Figure 1 shows the general plan of WES and the location of the geologic profile presented in Figure 2. Figure 2 is a vertical profile through four borings at WES showing the geologic units depicted and the associated E-log signatures for each boring. A total of 92 logs of borings and wells was examined. The data set was first compiled in a spreadsheet format. The eastings (X) and northings (Y) of the borings were extracted in Mississippi State Plane coordinates (NAD 27, Mississippi West Zone) from original source maps or from survey data. Borings outside of WES for which there were no survey data were spotted on USGS topographic quadrangle base maps using available information (construction maps or section, township and range designations) and then eastings and northings extracted from the base maps. Each boring log was examined to obtain elevations of the geological contacts listed below. The geological contacts, or "picks," are based on the authors' experience and on comparison with the type section electrical resistivity/SP log (E-log), Boring J2, at Mint Spring Bayou, Vicksburg (Mississippi Geological Survey, 1964). Figure 3 shows the type section E-log, boring J2, and Figure 4 the E-log section at WES in boring V-1.

Many boring logs provided an elevation for the ground surface at the boring location. However, the elevations of top of ground for some of the borings and wells were estimated from topographic contour maps. Therefore, the elevations depicted on the geologic surface maps are presumed to be accurate to +/- 10 ft.

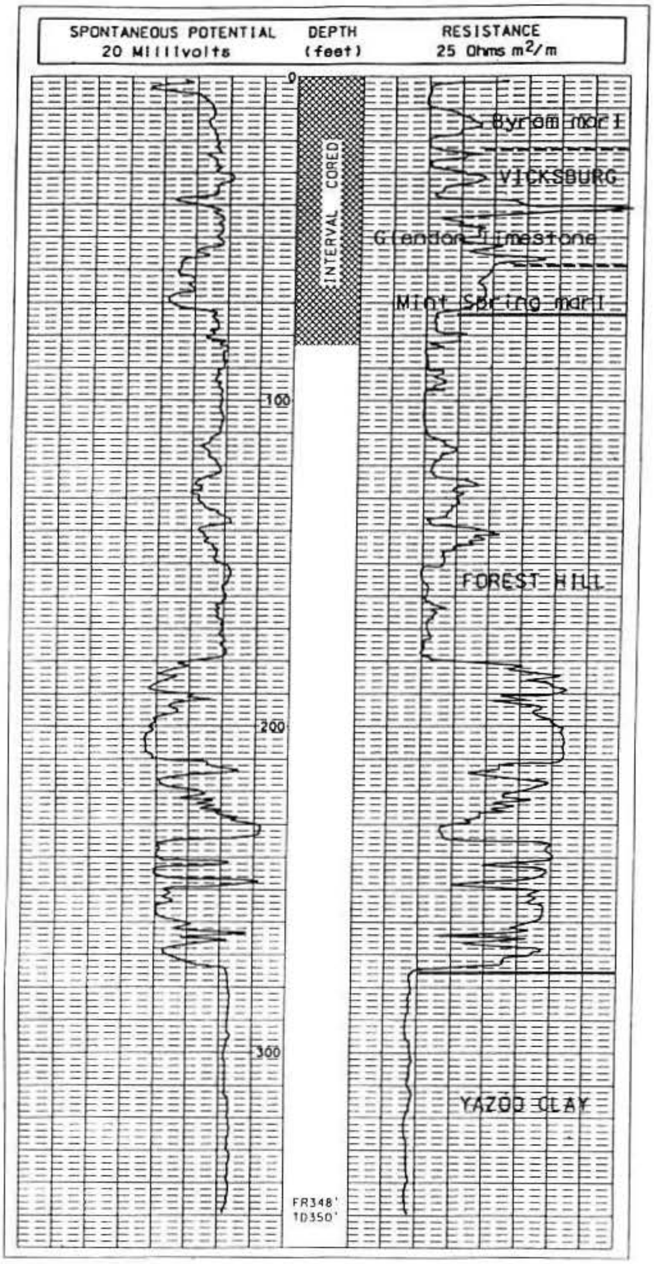


Figure 3. Electrical log (E-log) of boring J2 near type section of Vicksburg Group, Vicksburg, Mississippi. (After Mississippi Geological Survey, 1964.)

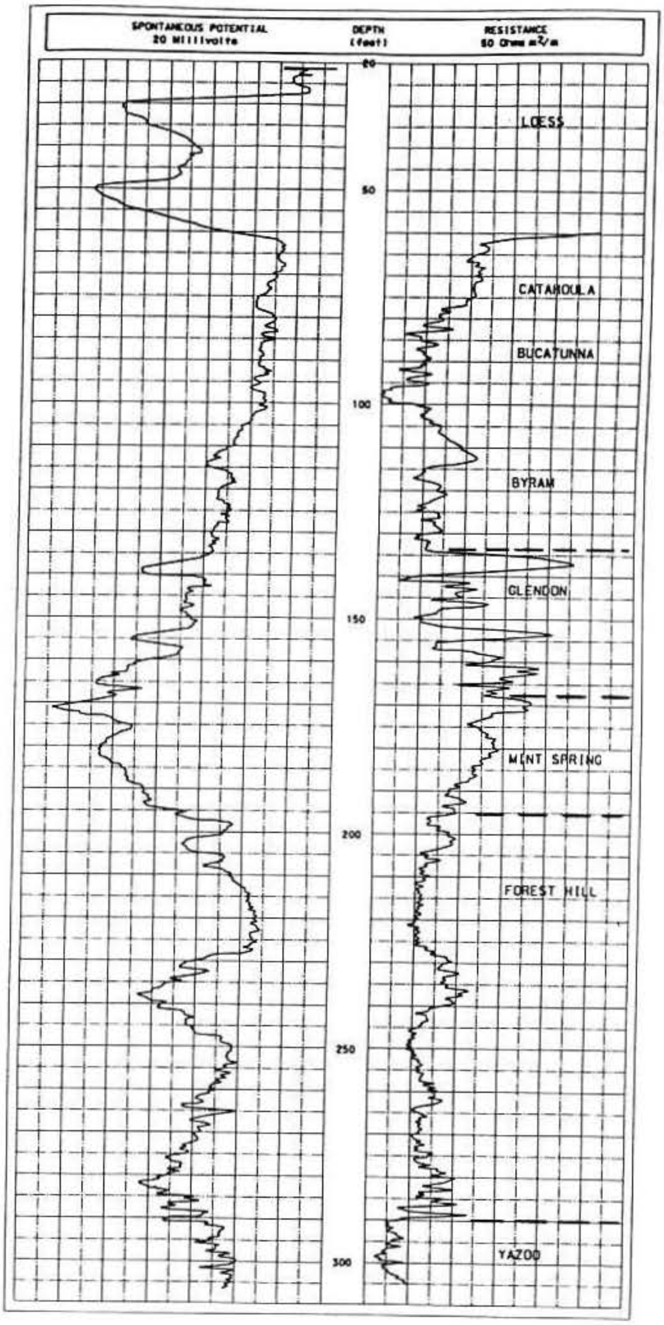


Figure 4. Electrical log (E-log) of boring V-1, WES, Vicksburg, Mississippi.

DATA PROCESSING AND ANALYSIS

After the boring, water well, and monitoring well logs were compiled and reviewed by the authors for pertinent information, geotechnical data were entered into the PC-based database, Boring Log Data Manager (BLDM). The BLDM (Nash, 1992) was used because of its ease of use and the ability to create documents in report format, graphic representations of the boring logs, and an ASCII file that would allow transfer of the data to the Intergraph program INSITU. The graphical output of selected borings is in a MicroStation DGN format file. This file can be viewed and plotted using MicroStation. INSITU is a boring data storage and retrieval program that allows the user three-dimensional (3D) capabilities in plotting and defining surfaces of contacts between soil and rock strata of interest. The INSITU software was used to

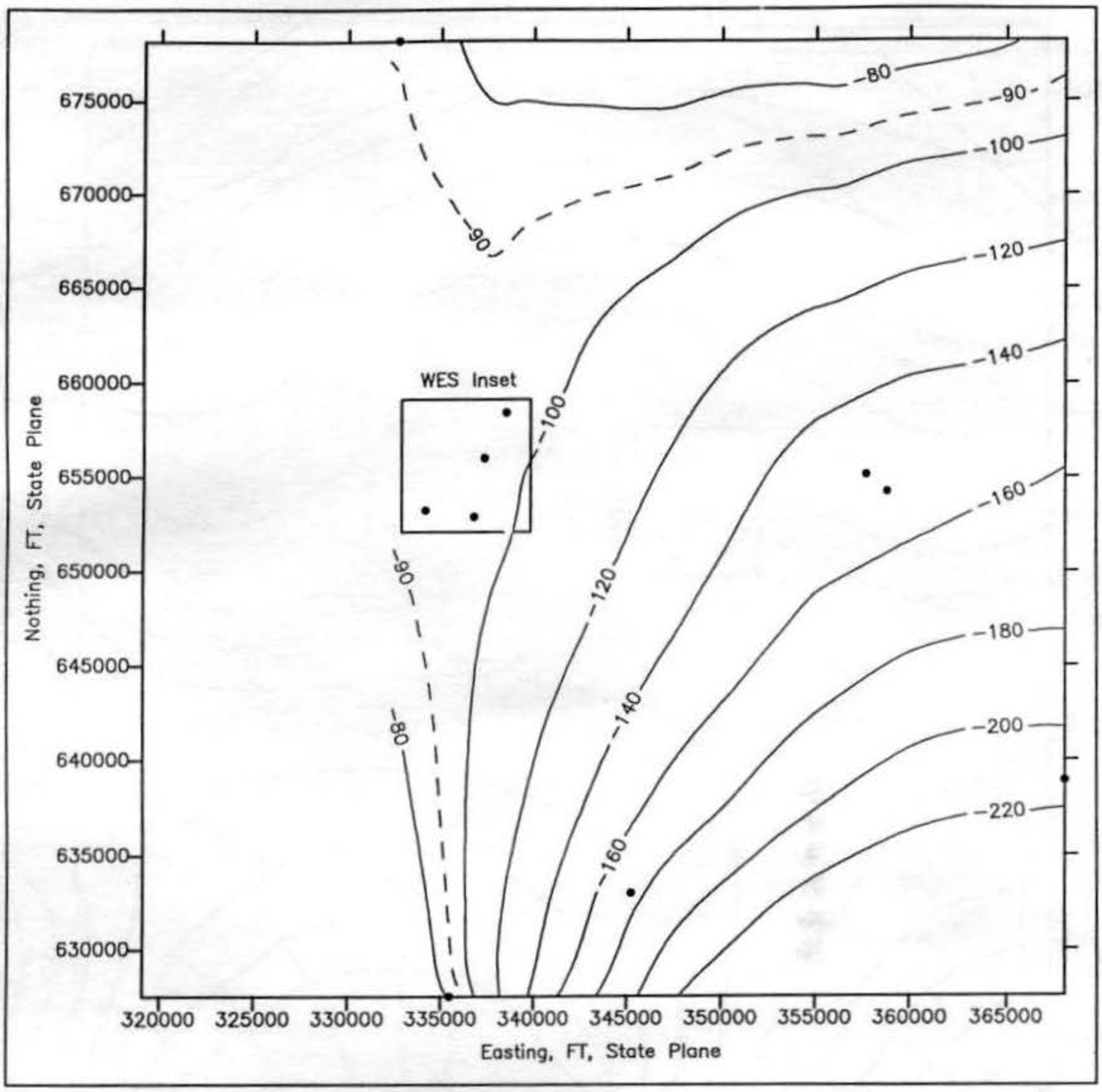


Figure 5. Surface configuration of top of Yazoo Clay in central Warren County, Mississippi.

construct five vertical cross-sections to depict the subsurface geological conditions beneath WES.

The BLDM boring data fields included the boring number or designation, a "building name" (or other site name), the location (WES or other Warren County location), the 1927 Datum State Plane eastings and northings, elevation of top-of-hole or top-of-casing, total depth, and the date the boring was completed or the well installed. Geological information fields included elevations of the tops of six selected (mappable) formations or units, the name of the uppermost sub-loess geologic unit encountered, elevation of the groundwater surface and date measured, and the aquifer designation.

The amount of boring and geological information (number of data fields) available varied greatly from boring to boring. Only 31 of the 92 boring and well logs provided usable stratigraphic information (i.e. penetrated at least one of the geological contacts). Only four borings examined provided tops of all six mappable units. Twenty-six borings provided elevations on the base of the loess soil, the uppermost mapped unit. Twelve borings were greater than 200 ft in depth, and four of those were within or very near WES.

The six mappable geologic units evaluated from the boring data, from oldest to youngest, were (1) the Eocene Yazoo Clay, (2) the Oligocene Forest Hill Formation, (3) the Oligocene Mint Spring Marl, (4) the Oligocene Glendon Limestone, (5) an undifferentiated uppermost Tertiary sequence consisting of the Miocene Catahoula Formation and upper Oligocene Formations, presumably the Bucatunna Clay and Byram Marl, and (6) the Pleistocene Vicksburg

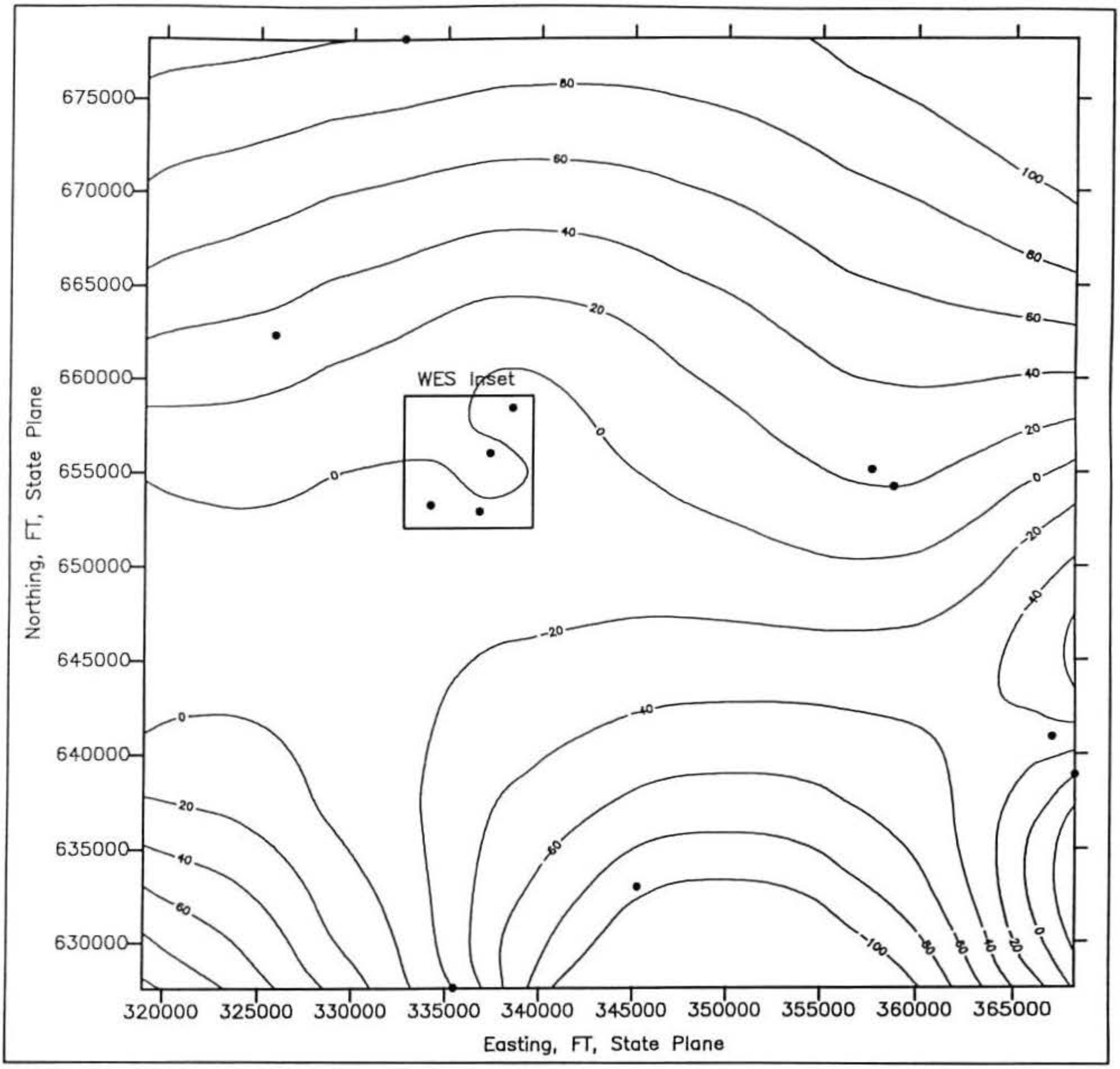


Figure 6. Surface configuration of top of Forest Hill Formation in central Warren County, Mississippi.

loess. Figures 5 through 8 show the surface configurations of the tops of units 1 through 4 in central Warren County, Mississippi, as interpreted from available boring information and using computer-generated contours. Albertson, Lee, and Harrelson (1986) interpreted a structural flexure below WES in the saddle between the Glass and Blakely structural highs. Although there are probably numerous structural distortions in the Warren County region, the apparent local structural flexures at WES (inset) in some of the maps are probably a product of a greater density of borings in the WES area than in the regional central Warren County area.

ENGINEERING GEOLOGY OF THE MAPPED UNITS

STRATIGRAPHY

The GIS provides information on the six geologic units beneath WES that are considered mappable. Figure 9 is a stratigraphic column for the upper sequence of geologic units

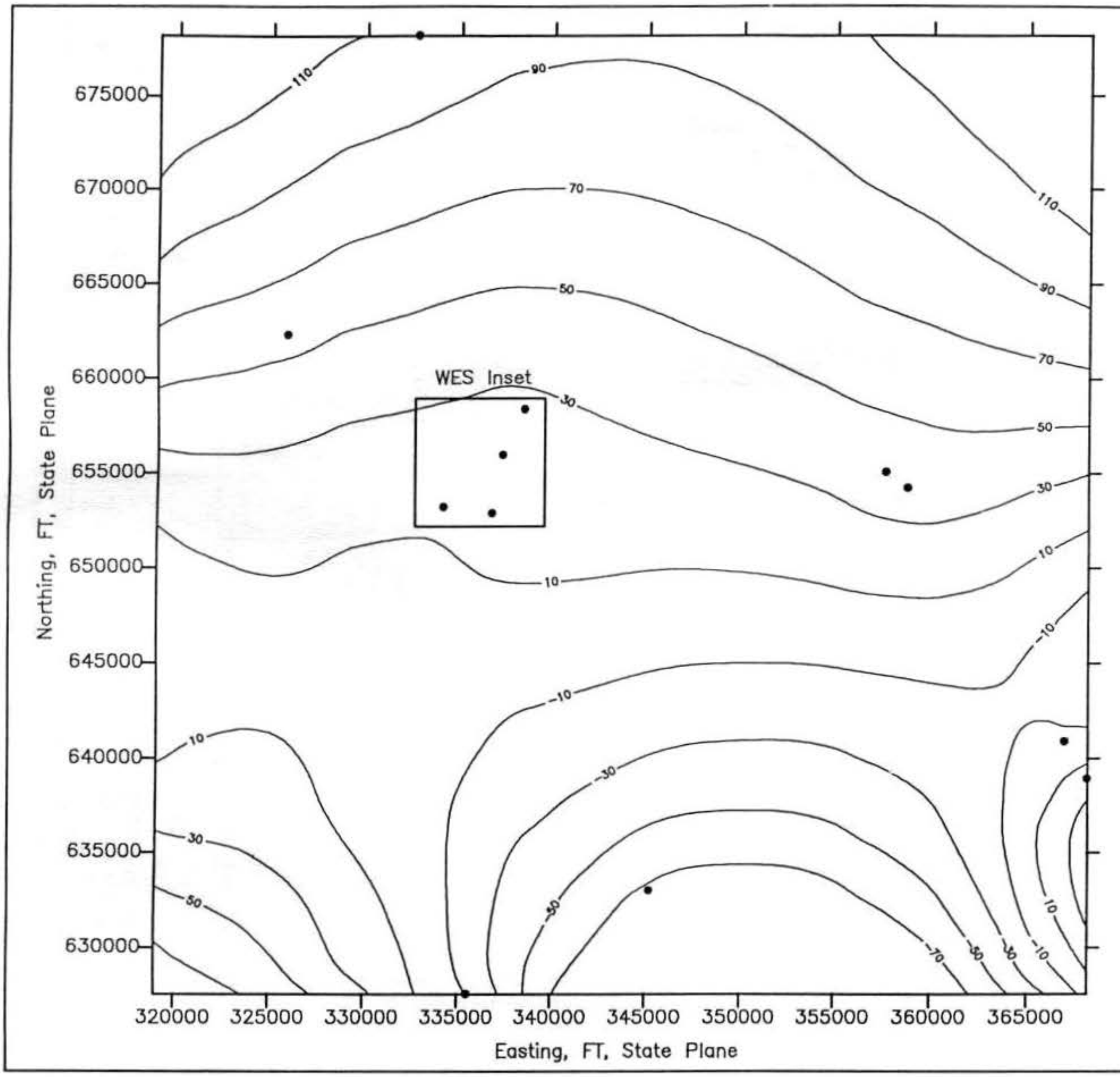


Figure 7. Surface configuration of top of Mint Spring Formation in central Warren County, Mississippi.

of Mississippi (Dockery, 1981). It shows the succession of geologic units by age, with younger units at the top. The Yazoo Clay is of Eocene age (38 to 54 million years old). It is the oldest mapped unit of this study at WES. The Forest Hill is considered Oligocene in age (23 to 38 million years old). The Bucatunna, Byram, Glendon, and Mint Spring formations form the Vicksburg Group of Oligocene age. The Glendon Limestone is distinct enough to permit mapping the formation in all the borings that penetrate it. The Catahoula Formation is generally considered of Miocene age (5 to 23 million years old). The Catahoula and the Bucatunna and Byram formations of Oligocene age are included in the undifferentiated Tertiary geologic unit at WES because they are not consistently recognized in database borings. Certain borings do differentiate the formations, but other borings lack the detail necessary to differentiate the upper Tertiary to formation level. The Citronelle Formation of Pliocene-Pleistocene age (2 to 5 million years) underlies the loess in part of Warren County but has not been reliably identified beneath WES. The youngest unit encountered at WES, other than occasional Holocene alluvium in stream valleys, is the Pleistocene aged (about 10,000 years to 2 million years old) Vicksburg loess.

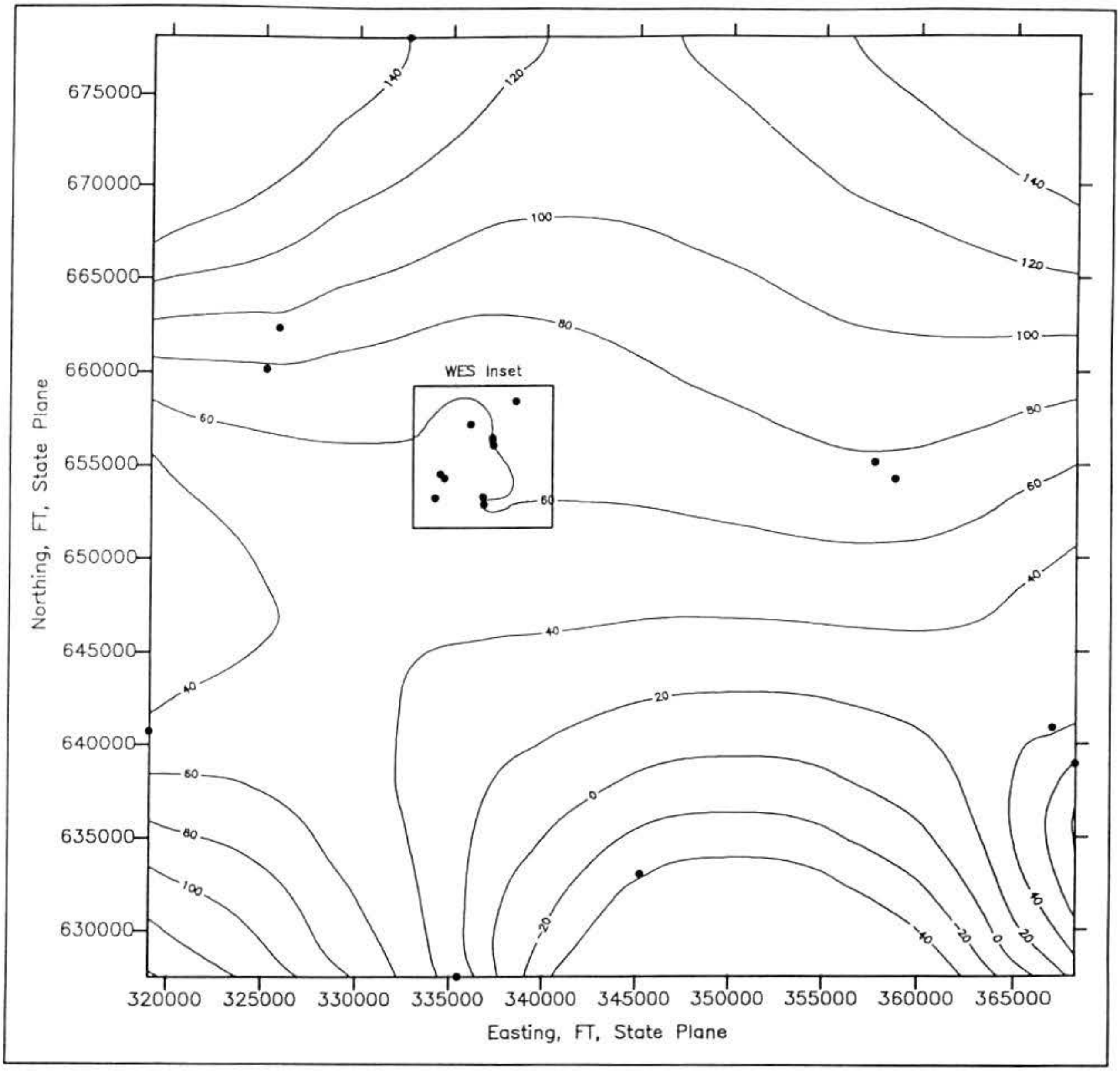


Figure 8. Surface configuration of top of Glendon Limestone in central Warren County, Mississippi.

THE YAZOO CLAY

Description and occurrence

The marine Yazoo Clay, Jackson Group, of Eocene age, is a thick (up to 500 ft) sequence of massive, calcareous, fossiliferous clays with occasional silty, lignitic zones. The Yazoo is commonly recognized in geotechnical borings as a gray, highly plastic clay (a CH in the Unified Soil Classification System). Borings at WES penetrated a maximum of about 75 ft of the Yazoo Formation. No WES borings encountered the base of the Yazoo. The top of the Yazoo Formation is a minimum of about 230 ft deep beneath WES and does not outcrop in the Vicksburg or Warren County area. The Yazoo occurs at or near the surface in a broad band from Yazoo County, through the Jackson, Mississippi, area, and then southeast to the Alabama line in Clarke and Wayne counties. The Yazoo Clay is a bentonitic material whose chief clay mineral is montmorillonite. Montmorillonites have a capacity

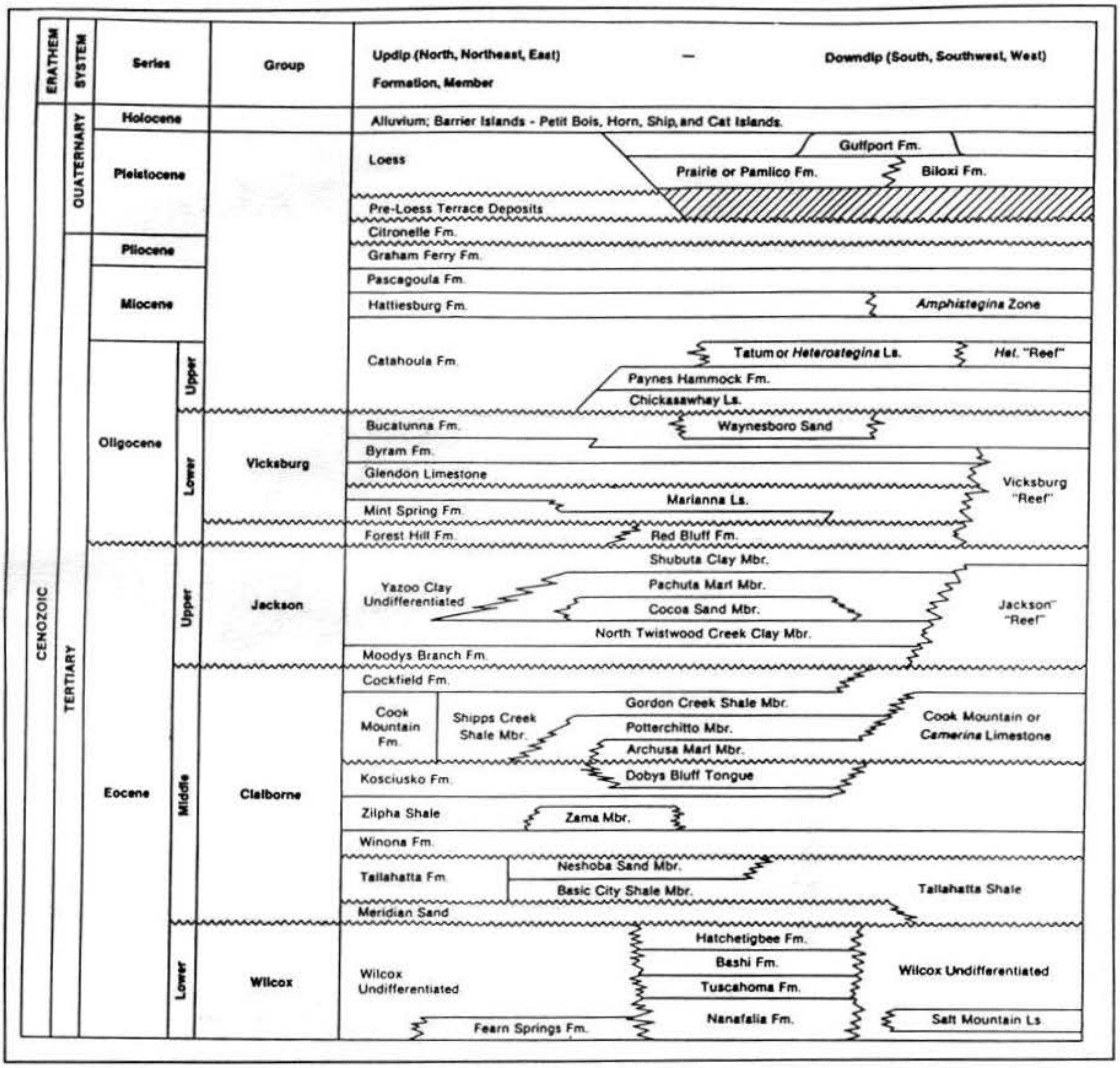


Figure 9. Partial stratigraphic column for Mississippi. (From Dockery, 1981.)

for absorbing water molecules between the clay layers and expanding to several times the original volume. Conversely, the clays can shrink in volume with desorption of the water.

Engineering and construction considerations

The Yazoo Clay is a problem material when it occurs at or near the surface where it can affect building and highway foundations. The Yazoo's shrink-swell potential makes it one of the most troublesome soils in Mississippi. The environmental geology atlas of part of Hinds County, Mississippi, prepared by Green and Bograd (1973), provided a table of strength indicators for several geologic units. The data in the table were not for specific test samples but for a suggested range of strengths based on unconfined compression and triaxial shear tests (pounds per square foot, or PSF) for cohesive soils and on standard penetration test (SPT) blows per foot for cohesionless soils. Green and Bograd stated that while the clay has respectable strength (they suggest 1500-2500 psf for weathered and 6000 psf for unweathered Yazoo Clay) it can undergo high volume change with changing moisture conditions. They report volume changes of from 100 to 225 percent and swell pressures greater than 25,000 psf. Foundations and brickwork in houses in the Jackson, Mississippi, area have been damaged by the swelling clays, and interstate highways in the central part of the state attain a "roller coaster" surface by the differential displacements of the road base and pavement by expanding or contracting clays along their routes. The Yazoo Clay is probably too deep at WES to have any effect on construction or engineering activities. The surface configuration of the Yazoo Clay is shown in Figure 5. The top of the Yazoo is significant as the base of

Figure 10. Areas of loess deposits in the United States. (From Turnbull, 1966.)

the Forest Hill aquifer. Water wells targeted to produce from the Forest Hill should be terminated in the upper 10 ft of Yazoo Clay to prevent the facility from paying unneeded drilling footage costs.

THE FOREST HILL FORMATION

Description and occurrence

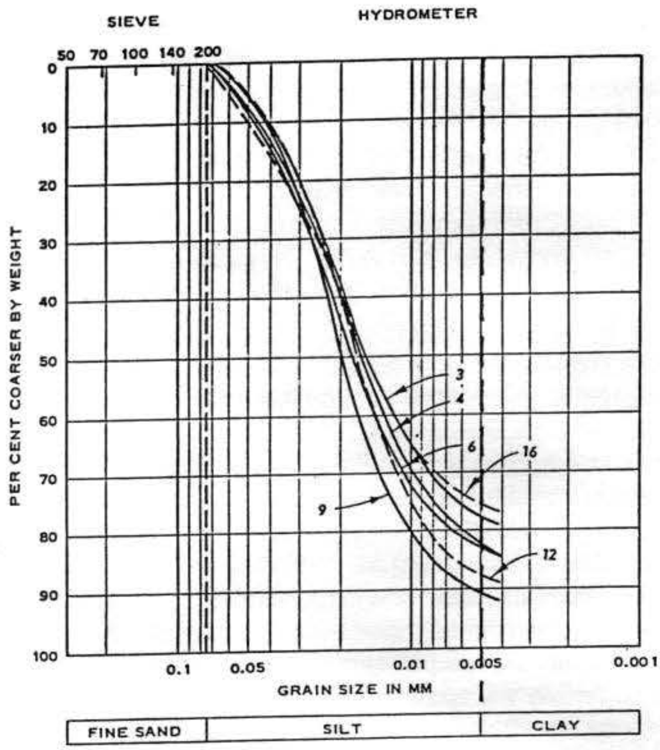
The Forest Hill Formation consists of interbedded fine-grained lignitic sands and silts and silty clays, ranging in thickness at Vicksburg from 50 to 100 ft (Mellen, 1941). Its thickness in borings at WES was 80 to 100 ft. Because of its stratigraphic position, the Forest Hill is rarely, if at all, exposed in Warren County. The Forest Hill is interpreted as a mainly terrestrial deposit based on the presence of the sands, lignites, and fossilized land plants found in it. The formation probably represents a withdrawal or regression of the Gulf of Mexico from the Mississippi Embayment between periods of marine transgression during earlier Yazoo and later Vicksburg Group times. Kolb et al. (1958) regarded the Forest Hill as probably of deltaic origin. The authors consider the formation to be of fluvial-deltaic origin because of the extensive sands present. The Mississippi Petrified Forest, a registered national landmark located at Flora, Mississippi, about 40 miles northeast of Vicksburg off State Highway 22, exhibits petrified trees deposited in streams during early Forest Hill (Oligocene) time.

The Forest Hill formation was identified in electric logging of test boring J2 (Figure 3) by the Mississippi Geological Survey (1964). In that boring, the Forest Hill was interpreted to be approximately 201 feet thick, some 100 ft thicker than it has been seen elsewhere in Warren County (for example, see E-log of boring V-1, Figure 4). The additional thickness is apparently in a thick sand interval at the base which can be interpreted as paleochannel sands cut and filled into the top of the Yazoo Clay. The surface configuration of the Forest Hill is shown in Figure 6.

Engineering and construction considerations

The only data on engineering properties of the Forest Hill Formation available to the authors was from Green and Bograd (1973). They suggested a range of SPT values of 21-74 blows per ft for Forest Hill sands and compression strengths of 4000 psf for Forest Hill clays. Those numbers are similar to their suggested strengths for the Catahoula Formation.

Wells, for example WW-I (Figure 1), were drilled to provide independent groundwater sources for the Information Technology Laboratory (ITL), WES. Boring WW-I failed to provide the required yield for the project specifications. However, the Fisher Ferry Water District of central Warren County, Mississippi, obtains its potable water from the Forest Hill. Forest Hill water is hard and contains noticeable iron.



SAMPLE	DEPTH IN FT	LOESS TYPE	GRAIN SIZE IN %		
			FINE SAND	SILT	CLAY
3	6.0-8.0	VICKSBURG LEACHED		77	23
4	9.0-11.4	VICKSBURG CALCAREOUS		82	18
6	15.0-17.4			83	17
9	24.0-26.3			90	10
12	33.0-35.4			87	13
16	52.0-54.4	BASAL TRANSITION ZONE	2	73	25

Figure 11. Grain size distribution in loess samples from Headquarters Building site, Waterways Experiment Station, Vicksburg, Mississippi. (From Krinitzsky and Turnbull, 1967).

THE MINT SPRING MARL

Description and occurrence

The Oligocene Mint Spring Formation is a uniform, massive bed of highly fossiliferous sand-marl, ranging in thickness in the Vicksburg area from about 25 to 65 ft (Mellen, 1941). The Mint Spring was about 20 to 32 ft thick in WES borings. The lower part of the Mint Spring contains rip-up clasts of the underlying Forest Hill Formation, an indication that the Mint Spring plays the role of "basal conglomerate" of the marine Vicksburg Group (Mellen, 1941). The surface configuration of the top of the Mint Spring at WES is shown in Figure 7.

Engineering and construction considerations

Green and Bograd (1973) suggested a range of strengths indicated by SPT values of 31-70 blows per ft for the Mint Spring. Mellen described the Mint Spring as "softer" and its fossils more friable than the overlying Glendon Limestone. It was also said to be more permeable and subject to weathering and oxidation by circulating groundwater than the Glendon. Accordingly, the suitability of the Mint Spring for foundation load bearing would be expected to be less than the Glendon. The Mint Spring is a regional aquifer of low yield but producing high quality water. Boring WW-C was drilled to provide unchlorinated groundwater for aquatic experiments conducted at the Environmental Laboratory at WES.

THE GLENDON LIMESTONE

Description and occurrence

Mellen (1941) described the marine Glendon Formation at Vicksburg as a crystalline, sandy, argillaceous, glauconitic, abundantly fossiliferous limestone and marl, ranging in thickness in the Vicksburg area from about 25 to 65 feet. The Glendon is 36 to 40 feet thick in borings at WES. The Glendon forms the middle portion of the Oligocene Vicksburg Group. The Glendon is exposed in road cuts north of town, along the eastern bank of the Mississippi River at Vicksburg at low water stages, and south of Vicksburg at Le Tourneau (formerly Glass), where a structural dome elevates the formation. The Glendon consists typically of 1- to 3-ft thick beds of hard limestone separated by softer intervals of clays and marls. It is usually the first "rock" encountered in borings in the WES area, although occasionally sandstone beds of the overlying Catahoula Formation refuse penetration by soil sampling devices. The top of the Glendon at WES is at an elevation of about 50 to 70 ft NGVD, representing a depth below ground surface of about 70 to 140 ft. The surface configuration of the top of the Glendon is shown in Figure 8.

Engineering and construction considerations

Few physical property or engineering test data for the Glendon Limestone were available to the authors. Green and Bograd (1973) warned that in some areas, the limestone beds are subject to solution by groundwater and may be discontinuous across a site. They recommended implementation of a boring program to ensure that adequate bearing material is available at a proposed construction site. Some of the limestone beds are relatively thin (1 to 2 ft), and any lateral thinning by weathering or solution may make them less suitable as foundations. Torrey (1975) provided water contents for four clay samples in the Glendon from undisturbed boring U-5 at the Soils and Pavements Laboratory site, WES. The water contents ranged from 26.1 to 33.3 percent with a mean of 30.3 percent.

UNDIFFERENTIATED TERTIARY UNIT

Description and occurrence

The Undifferentiated Tertiary Unit includes all of the geologic formations beneath WES younger than the Glendon Limestone but older than the loess. In the Vicksburg area these formations include the Oligocene Byram and Bucatunna Formations of the Vicksburg Group, the Miocene Catahoula Formation, and the Plio-Pleistocene Citronelle Formation, which some authors refer to as Pleistocene terrace deposits.

The Byram Marl is a mix of clayey marl and limy clay (Green and Bograd, 1973). Mellen divided the Byram into two facies: a lower portion of alternating fossiliferous beds of sand and marl, clay-marl, clay, thin beds of limestone and coquina, and occasional thin beds of bentonite and lignite; and an upper portion of nonfossiliferous, carbonaceous clays, lignitic or clayey silts, and thin beds of lignite, siltstone and fine-grained sandstone. The Byram was tentatively identified in WES borings V-1, WGC-1 and U-5 as a greenish gray clay to silty clay to clayey sand. The maximum thickness encountered was approximately 35 feet in boring U-5.

The Bucatunna Formation, the youngest member of the Vicksburg Group, is a dark gray to black clay that weathers to a characteristic chocolate brown in exposures (Green and Bograd, 1973). The Bucatunna was identified in WES borings V-1, WGC-1, and U-5 as a dark gray to brown, fat clay (CH). The greatest thickness encountered was about 25 ft in boring V-1. The Bucatunna probably varies in thickness across WES and may be absent where the overlying Catahoula has eroded and replaced it. The Bucatunna reportedly was temporarily exposed in the excavation for the centrifuge immediately north of the Geotechnical Laboratory in 1993.

The Catahoula Formation consists of gray to white sands, silts and silty clays. Some of the sands are indurated in sandstone layers (Green and Bograd, 1973). Mellen, in his geological descriptions of Warren County (1941), described the lower portion of the Catahoula as a clayey, kaolinitic sand or sandstone. The total thickness of the Catahoula in Mississippi is probably over 400 ft. Only about 30 ft of Catahoula was identified in borings at WES. The materials logged as Catahoula in test boring V-1 at WES by Albertson were primarily greenish-gray clay (CL) with sand and silt laminae.

Some of the boring logs used to reconstruct the geology beneath WES identified clays and some gravel as Pleistocene terrace materials (for example, borings U-5 at the Soil and Rock Mechanics (now Geotechnical Laboratory) Building site, WGC-1 at the Old Paint Shop site, and several borings at the Durden Creek Dam and Spillway site). The authors examined the logs, however, and believe that in most cases the strata logged as terrace deposits probably were actually Catahoula Formation. Albertson personally logged test boring V-1 in the Geotechnical Laboratory (Bldg. 3396) parking lot, located about 250 feet south of the U-5 boring site, in 1985 and confidently identified strata of equivalent depth as Catahoula. A similar determination was made by Mr. Stephen Lee, a Vicksburg District geologist, at the site of the new Information Technology Laboratory in 1987. No terrace or Citronelle strata have been identified in excavations or in natural drainage gullies within WES.

Engineering and construction considerations

Little engineering and physical property data on the undifferentiated Tertiary formations were available for WES. Green and Bograd (1973) suggested a range of 40-54 blows per foot for the Byram marl and 22-90 blows per foot for the sandy Catahoula strata. They suggested a range of 800 to 4000 psf for weathered to unweathered clayey Catahoula.

The only site-specific study at WES for the undifferentiated Tertiary was conducted for the Soils and Pavements Building site (Bldg. 3396). Torrey (1975) provided SPT blow counts and water contents for 13 samples from the Byram marl in boring SS-6 and water contents for 14 samples in undisturbed (Shelby tube) boring U-5 at the Soils and Pavements Building site, now the Geotechnical Laboratory Building (3396). Relative strengths for the Byram in boring SS-6 ranged from 12 to 46 blows per foot with a mean of 28 blows per foot (lower than those suggested by Green and Bograd, 1973). Water contents for the 13 samples of Byram marl ranged from 25.6 to 30.0 percent with a mean of 31.4 percent. Water contents for Byram marl in boring U-5 ranged from 22.1 to 54.8 percent with a mean of 30.2 percent.

THE LOESS

Description and occurrence

Loess is an eolian (windblown) deposit of predominantly silt-sized soil particles. The distribution of loess within the United States is illustrated in Figure 10. Krinitzsky and Turnbull (1967) extensively described the stratigraphy and geotechnical properties of loess deposits of the lower Mississippi River Valley, including those at Vicksburg. The following excerpt is borrowed from their abstract:

"Loess sheets in Mississippi are draped over hills in the uplands adjacent to the Mississippi River alluvial valley. The loess is thickest on the bluffs bordering the valley and thins eastward away from the bluffs. The loess sheets were developed by eolian transport from braided-stream deposits in the Mississippi River alluvial valley during late Pleistocene and early Recent time. Stratigraphically, the loess is separable into (1) the Vicksburg loess, which is leached in a thin uppermost layer but is calcareous in the remainder of the section; (2) a basal transition zone, which is weathered, generally noncalcareous, and contains a distinct buried soil horizon; and (3) a pre-Vicksburg loess, which may be calcareous and unweathered to noncalcareous and greatly weathered."

The Vicksburg loess is a unique geologic deposit consisting of 75 to 90 percent silt-sized grains (0.075 to 0.005 mm in diam.), 10 to 15 percent clay (particles less than 0.005 mm), and may or may not contain a small percentage of sand. Figure 11, a grain-size distribution diagram of loess from a boring at the WES headquarters building site, illustrates the uniformity of grain sizes typical of loess. Loess caps the hills of western Mississippi and drapes conformably over the underlying formations. The mineral composition of the Mississippi loess is dominated by quartz. The Mississippi loess sheet occurs in a band about 70 to 120 miles wide, and thins to the east. Thicknesses of loess as great as 108 feet have been measured at Vicksburg, but east of a 5 to 15 mile wide band along the bluff the loess is less than 10 ft thick (Krinitzsky and Turnbull, 1967). The maximum thickness encountered in WES borings was about 60 ft, and was over 100 ft in boring LC at Louisiana Circle, near the intersection of old U.S. Highways 61 and 80. Loess is capable of sustaining steep slopes as high as 100 ft under certain conditions (Lutton, 1969).

The Vicksburg loess is the uppermost and predominant geologic unit encountered in construction and operation activities at WES. The base of the loess at WES is quite variable in elevation, but generally between 100 and 155 ft NGVD, based on borings in the area. These elevations represent a depth below ground surface of about 5 to 65 ft. Many building foundations are sited entirely in the loess present at the facility. Therefore, a relatively large amount of geotechnical data is available for the loess. Accordingly, this report emphasizes the geological, physical, and engineering properties of the loess more than the other geologic units.

Engineering and construction considerations

<u>Physical and engineering properties</u>

Lutton (1969) and Krinitzsky and Turnbull (1967) compiled physical property test data on Vicksburg loess. Torrey (1975) provided property and test data on undisturbed Vicksburg loess samples obtained from the foundation investigation of the Geotechnical Laboratory (Building 3396), WES. The Vicksburg District, U.S. Army Corps of Engineers (1968), determined some properties and strengths of loess for the Durden Creek Dam and Spillway Modification at WES. Lutton's data were for two sites at WES and two sites from grading excavations on the U.S. Highway 61 North Bypass right-of-way in Vicksburg. Krinitzsky and Turnbull tabulated data for loess from another Waterways Experiment Station site (their table also contains data for the basal transition zone below the Vicksburg loess).

Specific gravity (G_s). The specific gravity of the Vicksburg loess samples ranged from 2.69 to 2.74. Lutton attributed the relatively high G_s (quartz has a G_s of 2.65) to suspected minor amounts of iron oxide in the loess.

Density. The density of the Vicksburg area loess, expressed as a dry unit weight (weight of soil solids per unit of volume of soil) varied from 79.4 to 96.2 pounds per cubic foot (pcf). The basal transition zone recorded dry densities as high as 104.2 pcf. The Vicksburg District (1968) determined dry densities of 86 to 104 pcf for loess in two borings for the Durden Creek Dam and Spillway Modification.

Porosity and void ratio. Porosity (ratio of volume of voids to total volume of sample) and void ratio (ratio of volume of voids to volume of solids in the sample) are related by the expression

$$n = e/(1+e)$$

where n is porosity and e is void ratio. Porosities in Lutton's samples ranged from 45 to 53 percent, with corresponding void ratios of 0.820 to 1.131. Krinitzsky and Turnbull reported that porosity in the Vicksburg loess ranged between 43 and 54 percent.

Plasticity. The plasticity of a fine-grained soil (a soil passing the No. 200 sieve, grains less than 0.074 mm in diameter) is described by its laboratory-determined Atterberg limits: liquid limit (LL), plastic limit (PL), and plasticity index (PI). The limits are water contents determined by standardized laboratory manipulations of a sample of the soil (see Department of the Army, 1970). The plasticity index is equal to the liquid limit minus the plastic limit. Liquid limits of the Vicksburg loess tested by Lutton and Krinitzsky and Turnbull ranged from 28 to 43 percent and plastic limits from 24 to 29 percent. Corresponding PIs for Krinitzsky and Turnbull ranged from 2 to 16 percent (Lutton did not report the PIs). Torrey (1975) determined indices for four loess samples from foundation boring U-5 of the Soils and Pavements Building. His values were LL, 29 to 41 percent; PL, 23 to 26 percent. Lutton reported that the ranges in limits are narrow and indicative of the uniformity of the Vicksburg loess. Vicksburg District (1968) determined limits for two borings for the Durden Creek project. Four samples in one boring showed LLs of 21 to 26 percent and PLs of 19 to 22 percent, with corresponding PIs of 3 to 4.

Water content. The natural water content, the ratio of the weight of water contained in a sample to the weight of solids in the sample, varies with conditions encountered at the sampling site. Lutton (1969) reported a range of natural water contents of 18 to 33 percent in his samples. These values corresponded to saturations (S_o) of 53 to 100 percent (degree of saturation is the ratio of the volume of water contained in a soil to the volume of voids available, expressed as a percentage). Torrey (1975) reported a range of water contents for boring U-5 at the Soils and Pavements Building site of 19 to about 32 percent, and a value of 38 percent for one sample near the base of the loess. Water contents of the loess samples from two borings of the Durden Creek project (Vicksburg District, 1968) were 20 to about 24 percent.

Strength. Undisturbed loess usually has a higher strength than remolded loess. Krinitzsky and Turnbull (1967, p. 35-38) attributed the higher undisturbed strength to the bonding of silt particles by clays and by carbonate cements. They and Lutton agreed that an internal skeleton of carbonate tubules and root tubes imparts a unique strength to the loess (see Lutton, p. 4, and Krinitzsky and Turnbull, p. 38 and 48). Wetting of the loess tends to break down the carbonate skeleton and decrease the effectiveness of the clay cements, while drying increases strengths. Remolded loess is generally not as strong as undisturbed loess even when compacted to higher densities. Krinitzsky and Turnbull concluded, from unconsolidated-undrained triaxial (UUT) shear tests on undisturbed loess, that higher strengths were generally related to lower water contents and higher dry densities. Shear strength (UUT test) values recorded by Krinitzsky and Turnbull ranged from 0.06 to 0.69 tons per square ft (tsf). Lutton's UUT data from his Sites 57 and 60 convincingly show that strength indeed increases dramatically with decreasing water contents, although some of his samples were dried below natural water contents. Torrey (1975) provided UUT results on four loess samples. Torrey described an uppermost 12 ft of loess of slightly higher strength than lower loess at the Soils and Pavements Building site (Bldg. 3396) and attributed the higher strength to overconsolidation by desiccation. Shear strength (UUT) tests in boring 3-M conducted for the Durden Creek project (Vicksburg District, 1968) yielded values of 0.6 and 1.04 tsf.

Erosion and slope stability of loess

The nature of loess cut banks is to form a near-vertical slope (Turnbull, 1966). Freshly cut, unvegetated slopes laid back at more than about 2 vertical to 1 horizontal (2v/1h) are subject to rapid erosion by moving water. Gullying occurs dramatically in loess as running water carries away the silt-sized particles, which have low cohesion when wet (Krinitzsky and Turnbull, 1967). Gullies with nearly vertical banks 20 or more feet in height with slowly retreating headwalls are common in the Vicksburg area. Piping of loess occurs when water gains access to the subsurface through rodent or other holes and exits at a free face at a lower elevation, forming large cavities ("piping wells" of Turnbull, 1966) and in some cases collapse or subsidence of the ground surface above the cavities.

Shear failure is another mechanism by which loess slopes are eroded. Krinitzsky and Turnbull noted the persistent sloughing of the loess bluffs at Natchez and Vicksburg, Mississippi, over several years by oversteepening of the high banks and loss of strength by saturation with water. A distinctive arch type of shear failure, called an alcove failure by Lutton (1969), is fairly common in the steep highway cut banks at Vicksburg. Turnbull and Lutton attributed arched failures to undercutting by erosion at the foot of the bank or saturation by ponding. Water should be kept away from the base of the cut bank, either by berms or by offset drainage ditches to prevent these types of failures. Lutton (1969) described other failure modes in the Vicksburg loess. The Mississippi Highway Department routinely cuts loess banks to a 3v/1h slope on benches 20 to 25 feet in height. The cut banks in the excavation of the U.S. Highway 61 North Bypass at Vicksburg were cut as steep as 4v/1h in the late 1960s but that practice has been discontinued.

Loess as a construction material

Krinitzsky and Turnbull (1967) briefly discussed the use of remolded (excavated and reworked) loess for construction fill. Loess can be remolded as fill for foundations, roads, and dams if proper engineering design practices are followed. Field compaction increases the density of the Vicksburg loess from an undisturbed range of 80-95 pcf to a remolded density of 100-105 pcf. Under optimum moisture conditions the remolded loess may have greater strength than the undisturbed loess, but the lowering of its permeability with densification may lead to lower strengths under high moisture conditions. Krinitzsky and Turnbull stated that proper drainage is essential in fills of remolded loess.

CONCLUSIONS AND LESSONS LEARNED

- The authors stressed the engineering characteristics of the geological units for the GIS to address the needs of the end-user, Engineering and Construction Services.

- Emphasis was placed on descriptions and discussion of the loess because it constitutes the engineering geologic unit that WES facility managers deal with most and because the loess comprises the largest data set.

• GIS provides excellent technology to store and access geological and geotechnical data.

• The quality and density of data affect the graphic depiction of physical and other parameters, and thus impacts geological interpretation.

• Investigators and end users should exercise caution when using mechanized (computer generated) analysis of geotechnical data. Geological principles must be considered to provide quality control for all interpretations.

• Facility managers should periodically update the geotechnical database to accommodate newly acquired information such as boring, sampling, and analytical data.

ACKNOWLEDGMENTS

The information presented and resulting data, unless otherwise noted, were obtained from research conducted at the Geotechnical Laboratory. Permission to publish this paper was received from the Director, U.S. Army Waterways Experiment Station. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

The authors wish to thank the following persons for their part in the study: Mr. Dale Balefoot for digitizing the cross-sections and E-logs; Mr. Terry Jobe for BLDM input and INSITU outputs; Mr. Chris Dixon for providing Information Technology Laboratory support; Mr. William Steinriede for passing the archival boring logs to Mr. Murphy; Mr. William Strohm, Jr. for initiating the boring database; Mr. Colin McAneny for access to recent landfill borings; Mr. Joseph Dunbar for locating the oldest borings at WES; Mr. Ed Adcock for providing contractor boring logs. The authors are grateful for the reviews provided by Ms. Laurel Gorman and Mr. Michael Bograd.

A general gratitude goes to the Vicksburg District for boring and geotechnical data. Last but not least the authors acknowledge the many unnamed drillers and lab technicians who provide the geotechnical information without which the geological interpretation is impossible.

REFERENCES CITED

Albertson, Paul E., Stephen L. Lee, and Danny W. Harrelson, 1986, Expanding evaluation of Vicksburg-Jackson aquifers, Warren Co., MS (abstract): Journal of the Mississippi Academy of Sciences, v. 31 Supplement, p. 37.

Department of the Army, 1970, Laboratory Soils Testing: Engineer Manual EM 1110-2-1906, 30 November, Office of the Chief of Engineers, Washington, D.C.

Dockery, David T., 1981, Stratigraphic Column of Mississippi: Mississippi Bureau of Geology, one sheet.

Green, John W., and Michael Bograd, 1973, Environmental geology of the Pocahontas, Clinton, Raymond, and Brownsville Quadrangles, Hinds County, Mississippi: Mississippi Geological Survey, Environmental Geology Series No. 1.

Kolb, C. R., P. R. Mabrey, and W. B. Steinriede, 1958, Geological investigation of the Yazoo Basin: Technical Report No. 3-480, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Krinitzsky, E. L., and W. J. Turnbull, 1967, Loess deposits of Mississippi: Special Paper Number 94, Geological Society of America.

Lutton, R. J., 1969, Fractures and failure mechanics in loess and applications to rock mechanics: Research Report S-69-1, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi, 53 p. plus plates.

Mellen, F. F., 1941, Warren County mineral resources: Mississippi Geological Survey, Bulletin 43, 140 p.

Mississippi Geological Survey, 1964, Stratigraphic test at type locality of Vicksburg: Electrical log of Boring (File No.) J2, near Mint Spring Bayou, Vicksburg, Mississippi.

Nash, Keith, 1992, User Guide for Boring Log Data Manager, Version 2.0: Instruction Report GL-92, U.S. Army Waterways Experiment Station, Vicksburg, MS.

Torrey, V. H., III, 1975, Foundation investigation for proposed Soil and Pavements Laboratory Building, Phase II Construction: Prepared for U.S. Army Engineer Waterways Experiment Station, Engineering and Construction Services Division, Vicksburg, Mississippi, December, 14 p., several plates.

Turnbull, W. J., 1966, Construction problems experienced with loess soils: Submitted for publication in the Proceedings of the 45th Annual Meeting of the Highway Research Board, Washington, D.C., 49 p.

U.S. Army Engineer District, Vicksburg, 1968, Durden Creek Basin, Warren County, Mississippi, Durden Creek Dam and Spillway Modification: Design Memorandum No. 2, Vicksburg, Mississippi, File No. V-14-14, September, 15 oversized plates.

FIRST REPORT OF THE CRETACEOUS SHARK *SQUALICORAX* FROM LOUISIANA

Gary L. Stringer
and
Marion Henry
Department of Geosciences
Northeast Louisiana University
Monroe, Louisiana

INTRODUCTION

Surface exposures older than Tertiary are extremely rare in Louisiana (Louisiana Geological Survey, 1984). The oldest surface deposits in Louisiana are Cretaceous and are confined to the flanks of salt domes in northern Louisiana. Therefore, it is not surprising that Cretaceous sharks have not been reported in the literature from Louisiana. Sharks and other selachians have been reported in the literature in the southern United States since the early 1800s (Morton, 1842; Agassiz, 1833-1844). Numerous early workers (Roemer, 1852; Gibbes, 1849; Hilgard, 1860; and Leidy, 1868, 1872, 1873) described Cretaceous shark remains from Alabama, Mississippi, and Texas, but no Cretaceous shark remains were noted from Louisiana.

Domning (1969) lists eight sharks and rays in his index of fossil vertebrates from the Cretaceous of Louisiana and Mississippi. However upon closer examination, all of the Cretaceous vertebrates reported are from Mississippi. Meyer (1974) conducted an exhaustive study of Cretaceous elasmobranchs (Albian to Maastrichtian) in the southern United States. Although the study included over 20,000 specimens of elasmobranchs from 50 localities in Texas, Arkansas, Mississippi, and Alabama, no Cretaceous shark remains were reported from Louisiana. The oldest shark remains previously reported from Louisiana are late Paleocene (Manning, 1990). The discovery of a tooth from *Squalicorax pristodontus* from Bienville Parish in northern Louisiana represents the first Cretaceous shark and the oldest selachian described from the state.

LOCATION AND STRATIGRAPHY OF COLLECTION AREA

The specimen of *Squalicorax pristodontus* was collected at the Prothro salt dome locality which is in the southeastern part of Bienville Parish, Louisiana. The Prothro locality is an old open pit mine in the NW1/4, SW1/4, Section 8, T.14N., R.6W., and is approximately 5 km northwest of the community of Saline, Bienville Parish. The specimen was found by Marion Henry, a geology graduate student at Northeast Louisiana University, in the fall of 1995 while collecting Cretaceous invertebrates from surface exposures. All of the associated invertebrates were typical Cretaceous forms such as the oyster *Exogyra* and the gastropod *Turritella*.

A varied ostracode fauna was described from the Prothro locality and the nearby Rayburns salt dome by Butler and Jones (1957). The fauna consisted of 40 species which were compared to ostracode faunas from Cretaceous formations in Arkansas. Based on the comparisons, Butler and Jones concluded that the Cretaceous exposures on the Prothro and Rayburns domes were equivalent to the Saratoga Formation of Arkansas. The Saratoga Formation has long been recognized as Upper Cretaceous (Dane, 1929) and has been correlated with the Navarro Group of Texas based on ostracodes and other invertebrates (Israelsky, 1929). Since the Navarro Group is Maastrichtian (Welton and Farish, 1993), this would indicate that the Cretaceous sediments in which the shark tooth was found are Upper Cretaceous, most likely Maastrichtian.

DESCRIPTION AND AGE OF *SQUALICORAX*

Squalicorax is a very widespread genus both in time and space. It is found from the Albian (Lower Cretaceous) to the Maastrichtian (Upper Cretaceous) in Europe, Russia, North America, South America, West Indies, North and West Africa, Near East, India, Japan, and Australia (Cappetta, 1987). According to Welton and Farish (1993), *Squalicorax* belongs to the Family Anacoracidae, and extinct family known as crow sharks. The genus has at least two lineages of development with the common lineage including *S. volgensis, S. falcatus, S. kaupi,* and *S. pristodontus*.

Squalicorax is known from numerous localities in Mississippi and Texas (Bilelo, 1969; Meyer, 1974; Emry et al., 1981; Derstler, 1988; Case, 1991; Daly, 1992; Manning and Dockery, 1992; Welton and Farish, 1993). According to Welton and Farish (1993), at least five species are known from the Cretaceous of Texas (*S. curvatus, S. falcatus, S. kaupi, S. pristodontus,* and *S.* sp.). Manning and Dockery (1992)

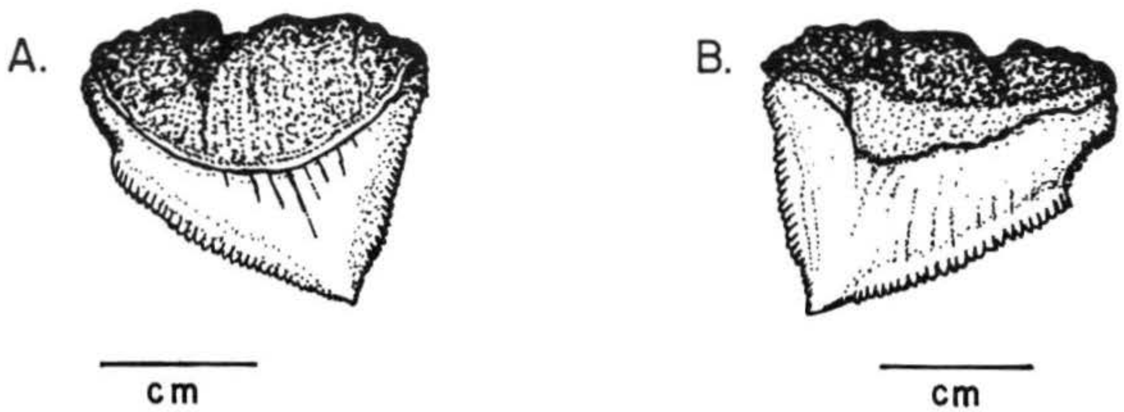


Figure 1. Lingual (A) and labial (B) views of *Squalicorax pristodontus* from southeastern Bienville Parish, Louisiana.

reported *Squalicorax kaupi*, *Squalicorax pristodontus*, and an intermediate form from Upper Cretaceous sediments in Prentiss County in northeastern Mississippi.

The teeth of *Squalicorax* may be small or large depending upon the species and may attain heights up to 3 cm. The crown or blade is triangular and tends to be straight in the anterior teeth and bent toward the rear in the lateral teeth. Generally the crown is not very thick. The apex of the cusp can be acute or obtuse, and the cutting edges are clearly serrated. The root is usually low in the primitive species and becomes high and flat in derived species. The basal edge is always notched, and basal foramina are present (Cappetta, 1987).

Squalicorax pristodontus is one of the largest species of the genus and is characterized by high teeth with very erect crowns and obtuse cusp apex (Welton and Farish, 1993). Coarse serrations are found along the margin, and there is no distinct distal blade. The root is very high and may compose over two-thirds of the tooth height in lingual view on some teeth. The root tends to be labiolingually thin with well-developed mesial and distal root lobes often present (Welton and Farish, 1993). The lingual face in strongly convex while the labial face is concave. This causes a pronounced curvature of the teeth when viewed from the side.

DESCRIPTION OF *SQUALICORAX* SPECIMEN

The specimen from the Prothro salt dome is 24 mm in width (measured across the root) and 21 mm in height (measured from the root to the tip of the blade). The root is partially eroded, but the blade is almost complete (Figure 1). The enamel is well-preserved on the blade on the lingual (Figure 1, A) and labial (Figure 1, B) views. No distinct distal blade exists, and the distal cusp edge is curved. Serrations are coarse and discernable along the entire margin of the blade with the exception of one small chip (less than 5 mm). Foramina are not distinguishable, but this is due to the eroded condition of the root.

CONCLUSIONS AND DISCUSSION

The discovery and subsequent identification of a tooth from the Cretaceous shark *Squalicorax pristodontus* at the Prothro salt dome in southeastern Bienville Parish, Louisiana, represents the oldest selachian described from the state. Prior to this account, the oldest shark remains reported in the literature from Louisiana were late Paleocene. This finding indicates a need for a closer examination of the Cretaceous sediments associated with salt domes in northern Louisiana. The potential exists for additional Cretaceous marine vertebrates through extensive surface collecting and bulk sampling.

ACKNOWLEDGMENTS

Thanks are extended to Dr. Bruce Welton of Mobil who verified the identification of the tooth and made numerous suggestions for this report, Dr. David Ward, England, who provided data and discussion on *Squalicorax pristodontus*, Dr. Judith Schiebout, Louisiana State University, Museum of Natural History, who supplied information on fossil sharks in Louisiana, and Dr. Lloyd Glawe, Northeast Louisiana University, who provided data on the Prothro and Rayburns salt domes. Thanks also to Dr. Mervin Kontrovitz, Northeast Louisiana University, Department of Geosciences, Mr. S. Q.

Breard, Applied Biostratigraphix, Inc., Houston, and Dr. David Dockery, Mississippi Office of Geology, for reviewing the manuscript.

REFERENCES CITED

Agassiz, L., 1833-1844, Recherchés sur les poisson fossiles, Part III: Neuchatel and Soleure, 1420 p .

Bilelo, A., 1969, The fossil shark genus *Squalicorax* in north-central Texas: Texas Journal of Science, v. 20, p. 339-348.

Butler, E., and D. Jones, 1957, Cretaceous Ostracoda of Prothro and Rayburns salt domes, Bienville Parish, Louisiana: Louisiana Geological Survey, Geological Bulletin 32.

Cappetta, H., 1987, Chondrichthyes II, Mesozoic and Cenozoic elasmobranchii. Handbook of Paleoichthyology, Volume 3B: Gustav Fischer Verlag, Stuttgart and New York, 193 p.

Case, G., 1991, Selachians (sharks) from the Tupelo Tongue of the Coffee Sand (Campanian, Upper Cretaceous) in northern Lee County, Mississippi: Mississippi Geology, v. 11, no. 3, p. 1-8.

Daly, E., 1992, A list, bibliography and index of the fossil vertebrates of Mississippi: Mississippi Office of Geology, Bulletin 128, 47 p.

Dane, C., 1929, Upper Cretaceous formations of southwestern Arkansas: Arkansas Geological Survey, Bulletin 1, 215 p.

Derstler, K., 1988, A rich vertebrate fossil assemblage from the upper Demopolis Formation of western Alabama and northeastern Mississippi: Journal of the Alabama Academy of Science, v. 59, no. 3, p. 144.

Domning, D. P., 1969, A list, bibliography, and index of the fossil vertebrates of Louisiana and Mississippi: Gulf Coast Association of Geological Societies, Transactions v. 19, 385-422.

Emry, R., J. Archibald, and C. Smith, 1981, A mammalian molar from the Late Cretaceous of northern Mississippi: Journal of Paleontology, v. 55, no. 5, p. 953-956.

Gibbes, R., 1949, Monograph of the fossil Squalidae of the United States: Journal of the Academy of Natural Science of Philadelphia, v. 1, part III, p. 191-206.

Hilgard, E., 1860, Report on the geology and agriculture of the State of Mississippi: E. Barksdale, Jackson, Mississippi.

Israelsky, M., 1929, Upper Cretaceous Ostracoda of Arkansas: Arkansas Geological Survey, Bulletin 2, 29 p.

Leidy, J., 1868, Notice of American species of *Ptychodus*: Proceedings of the Academy of Natural Science of Philadelphia, v. 20, p. 205-208.

Leidy, J., 1872, On some remains of Cretaceous fishes: Proceedings of the Academy of Natural Science of Philadelphia, v. 24, p. 162-163.

Leidy, J., 1873, Contributions to the extinct vertebrate fauna of the western territories: Report of the United States Geological Survey, no. 1, part 1, p. 14-358.

Louisiana Geological Survey, 1984, Geologic Map of Louisiana, scale 1:500,000.

Manning, E., 1990, The late early Miocene Sabine River: Gulf Coast Association of Geological Societies, Transactions, v. 40, p. 531-550.

Manning, E., and D. Dockery, 1992, A guide to the Frankstown vertebrate fossil locality (Upper Cretaceous), Prentiss County, Mississippi: Mississippi Office of Geology, Circular 4, 43 p.

Meyer, R., 1974, Late Cretaceous elasmobranchs from the Mississippi and east Texas embayments of the Gulf Coastal Plain: Unpublished Ph.D. dissertation, Southern Methodist University, Dallas, Texas, 418 p.

Morton, S., 1842, Description of some new species of organic remains of the Cretaceous group of the United States with a tabular view of the fossils hitherto discovered in this formation: Journal of the Academy of Natural Science of Philadelphia, series 1, v. VIII, part II, p. 207-227.

Roemer, F., 1852, Die Kreidebildungen von Texas und Ihre Organische Einschleusse: Bonn, Adolphus Marcus, 100 p.

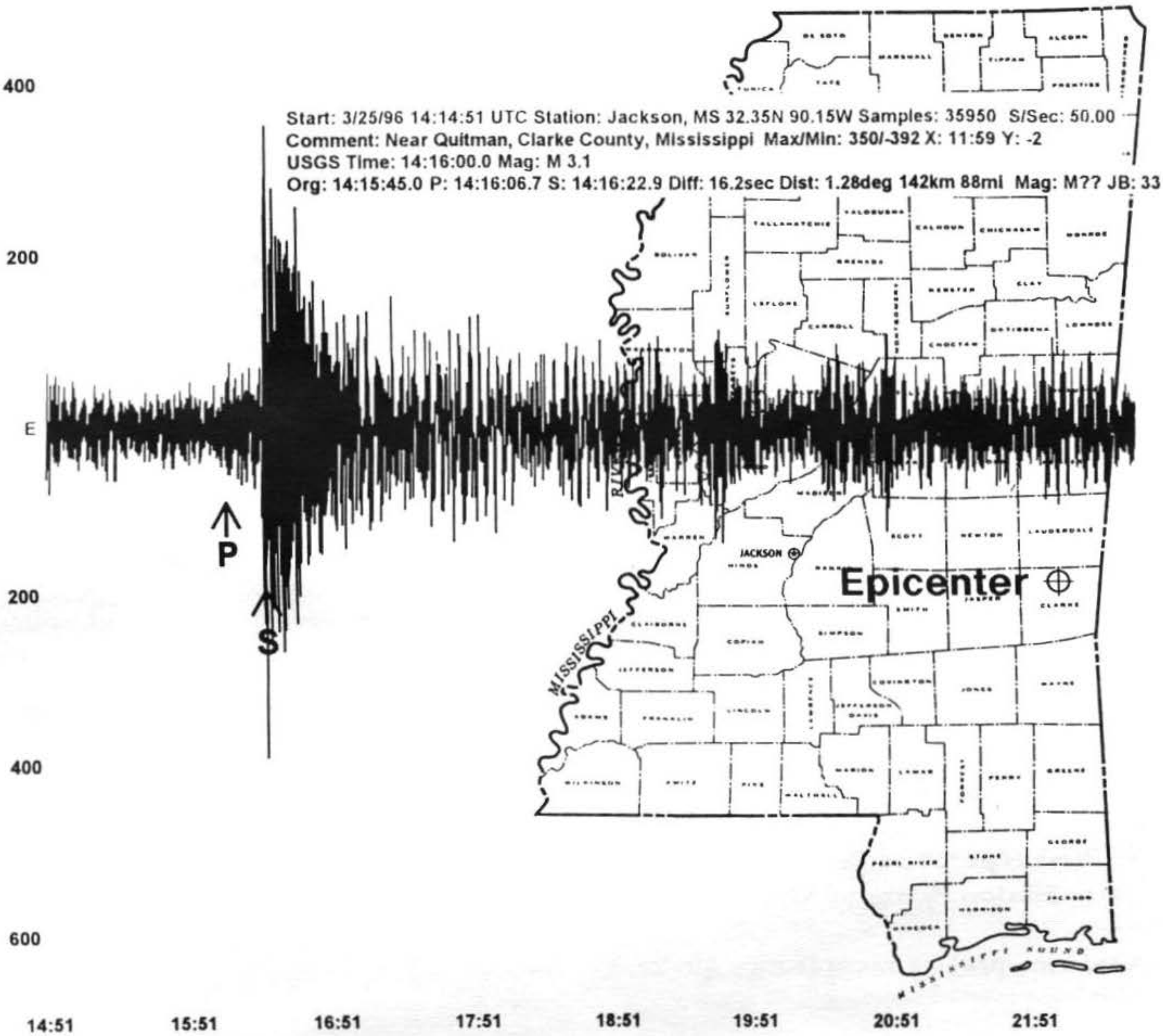
Welton, B., and R. Farish, 1993, The collector's guide to fossil sharks and rays from the Cretaceous of Texas: Before Time, Lewisville, Texas, 204 p.

NINTH GRADE SCIENCE PROJECT RECORDS RARE MISSISSIPPI QUAKE

David T. Dockery, Mississippi Office of Geology

Fortunately, Katie Underwood's 9th-grade science project, a homemade seismograph, was switched on in her family's garage in Jackson when a 3.5 magnitude earthquake struck near Quitman, Mississippi, at 8:16 a.m. Monday March 25. In fact, Katie's $70 instrument was the only one in the state known to the writer that recorded the earthquake, and it registered the same magnitude as that of an expensive, research-grade seismograph in northwestern Alabama near Pickwick Lake operated by the Center for Earthquake Research and Information at the University of Memphis.

It was noon the following day, after news reports of the earthquake, that Katie's father thought to check her instrument to see if it recorded the event. By this time, the seismograph was on display in the science fair at St. Andrew's Episcopal School. When Katie and her father entered the time of the quake on her computer, the monitor showed a prominent seismic signal. Katie's record of the Quitman earthquake, as shown below, made her an instant celebrity. Her science-fair project appeared on the local evening news and in the March 29, 1996, edition of the *Clarion-Ledger*.



MISSISSIPPI GEOLOGY
Department of Environmental Quality
Office of Geology
P. O. Box 20307
Jackson, Mississippi 39289-1307

Mississippi Geology is published quarterly in March, June, September and December by the Mississippi Department of Environmental Quality, Office of Geology. Contents include research articles pertaining to Mississippi geology, news items, reviews, and listings of recent geologic literature. Readers are urged to submit letters to the editor and research articles to be considered for publication; format specifications will be forwarded on request. For a free subscription or to submit an article, write to:

Editor, Mississippi Geology
Office of Geology
P. O. Box 20307
Jackson, MS 39289-1307

Editors: Michael B. E. Bograd and David Dockery

In this issue:

- **an engineering geological GIS of the Waterways Experiment Station, by William Murphy and Paul Albertson of WES**
- **a first report of a Cretaceous shark from Louisiana, by Gary Stringer and Marion Henry of Northeast Louisiana University**
- **science project records rare quake, by David Dockery**