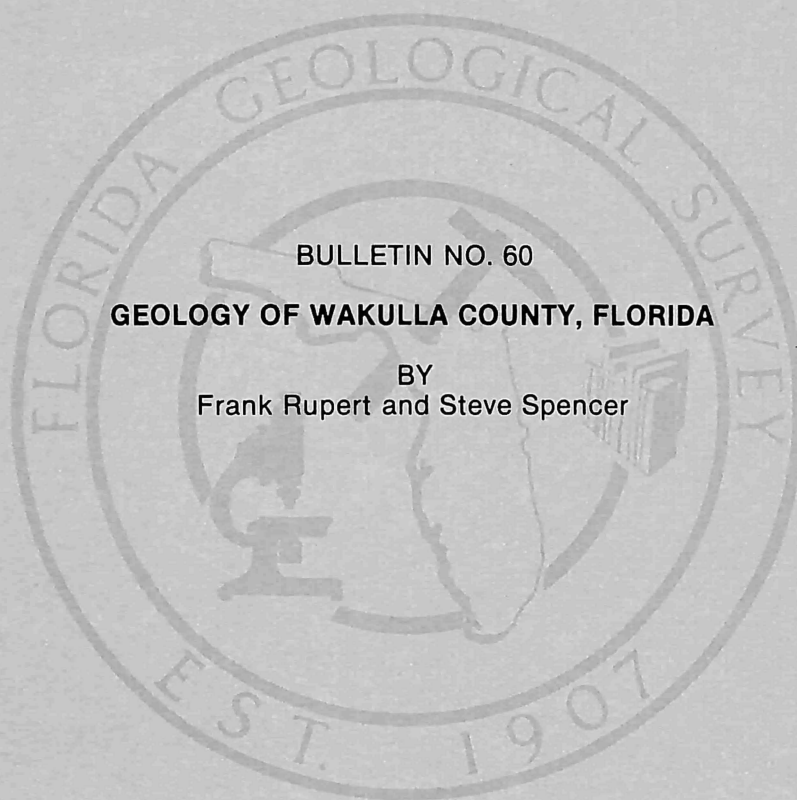


STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Tom Gardner, *Executive Director*

DIVISION OF RESOURCE MANAGEMENT
Jeremy A. Craft, *Director*

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist*



BULLETIN NO. 60
GEOLOGY OF WAKULLA COUNTY, FLORIDA
BY
Frank Rupert and Steve Spencer

Published for the
FLORIDA GEOLOGICAL SURVEY
Tallahassee
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**DEPARTMENT
OF
NATURAL RESOURCES**



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Governor

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LETTER OF TRANSMITTAL

Bureau of Geology

August 1988

Governor Bob Martinez, Chairman
Florida Department of Natural Resources
Tallahassee, Florida 32301

Dear Governor Martinez:

The Florida Geological Survey, Division of Resource Management, Department of Natural Resources, is publishing as its Bulletin No. 60, *Geology of Wakulla County, Florida*, prepared by Frank Rupert and Steve Spencer. This report fulfills a need for information on the stratigraphy of Wakulla County, which is fundamental to ground-water resource investigations and land use planning. Information on mineral resources is also presented, along with data helpful to other agencies, planners, and the citizens of Florida.

Respectfully yours,

Walter Schmidt, Ph.D.
State Geologist and Chief
Florida Geological Survey

Printed for the
Florida Geological Survey

Tallahassee
1988

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GEOLOGY OF WAKULLA COUNTY, FLORIDA

by
Frank Rupert and Steve Spencer

INTRODUCTION

PURPOSE

Florida's expected rapid population growth through the year 2000 dictates the need for an understanding of the geological parameters affecting intelligent growth planning. Previous research has provided a good geologic data-base for much of Florida, but information on many of the state's less-populous counties is lacking. Consequently, the Florida Geological Survey is currently undertaking a series of geological studies of Florida's smaller counties in an attempt to fill this information gap. The purpose of this report is to present a general overview of the geology and mineral resources of Wakulla County based on existing literature and well data on file at the Florida Geological Survey.

LOCATION AND EXTENT

Wakulla County is situated in the Big Bend area of the Florida panhandle (Figure 1). It is bounded on the west by Franklin and Liberty Counties, on the north by Leon County, on the east by Jefferson County, and on the south by the Gulf of Mexico.

Wakulla County is irregular in shape, spanning 39 miles at its widest east-west dimension and is about 23 miles north-to-south. The total area is approximately 601 square miles. Population in 1987 numbered 13,695 (Office of the Governor, 1987).

PREVIOUS INVESTIGATIONS

A number of previous authors have referred to the geology and paleontology of Wakulla County and the Big Bend area. In the early Annual Reports of the Florida Geological Survey, Sellards (1909, 1910, 1914, 1916 and 1917) included brief discussions of the history, geology, botany, physiography, mineral resources, and springs of Wakulla and adjacent counties. Sellards and Gunter (1912) discussed water supply characteristics, and Matson and Sanford (1913) reviewed the county's physiography, geology, and hydrology in their statewide report on water. The geology of the Big Bend area was included in reports by Mossom (1926), Matson and Clapp (1929), Cooke and Mossom (1929), Cooke (1945) and Puri and Vernon (1959, 1964). Campbell (1941) and Rainwater (1971) investigated the petroleum prospects of the Wakulla area, and the excellent series of articles by Applin and Applin (1944, 1947), P.L. Applin (1951) and E.R. Applin (1955) provided useful background on panhandle stratigraphy and paleontology. Major springs of Wakulla County were discussed by Ferguson et al. (1947) and Rosenau et al. (1977). Puri (1953) studied Miocene stratigraphy and paleontology of the Florida panhandle. McNeal (1944), Bridge and Berdan (1952), Vernon (1952) and Doering (1960) included Wakulla County in their stratigraphic studies, and Schmidt (1978, 1979) covered the surficial geology of Wakulla County in a pair of environmental maps. Cameron and Mory (1977) studied the geology of Bradwell Bay Wilderness in the western part of the county, and Pascale and Wagner (1982) addressed the geology and hydrology of the Ochlockonee River Valley. Schmidt (1984) described a core from southeastern Wakulla County in his report of the Apalachicola Embayment. Scott (1988, in press) reviewed the stratigraphy and extent of the Hawthorn Group sediments in the panhandle area.

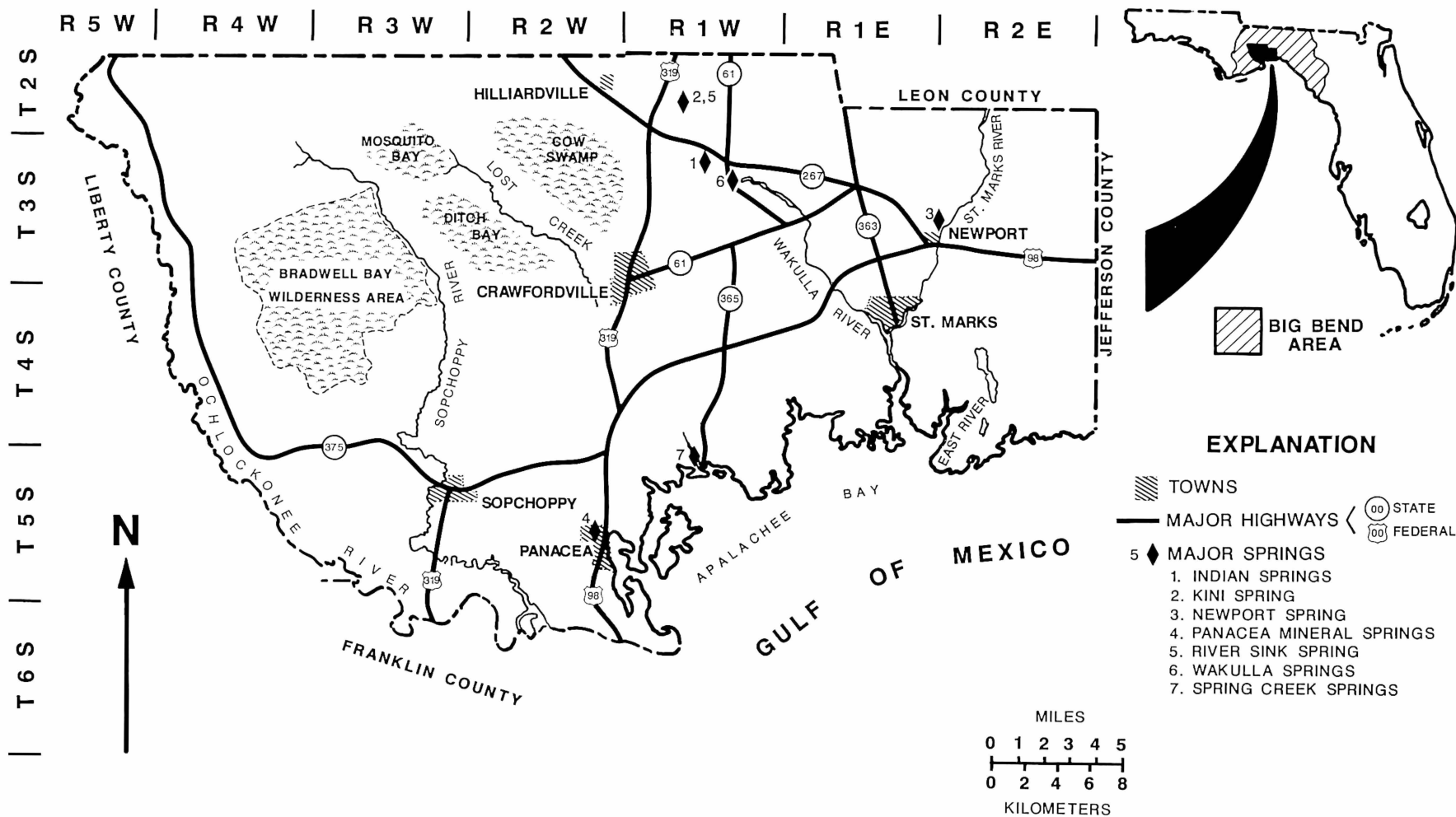


Figure 1. Map showing location of study area.

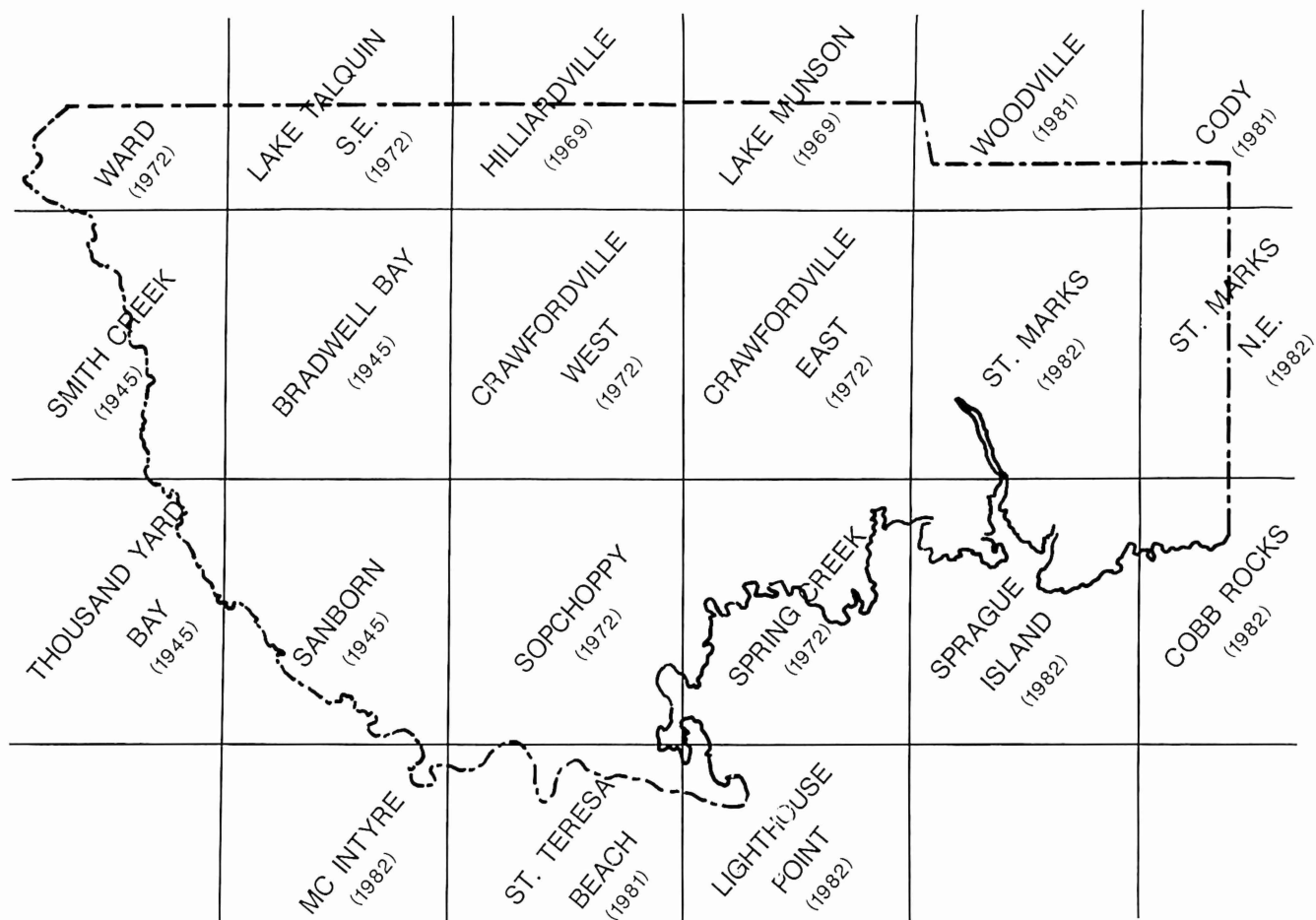


Figure 2. Index to 7.5 minute topographic quadrangle map coverage of Wakulla County.

MAPS

Elevation information and cross-section profiles were obtained from the United States Geological Survey 7.5 minute topographic quadrangle maps. Figure 2 illustrates the topographic map coverage of Wakulla County. Base maps were derived from the Florida Department of Transportation General Highway Map for Wakulla County.

WELL AND LOCALITY NUMBERING SYSTEMS

The well numbering system used in this study is that of the Florida Geological Survey well filing system. Each well is identified by a "W", a dash, and a one-to-five digit number unique to that well.

Wells and locations within the county are plotted according to the township, range, and section rectangular system. The location coordinates assigned to each well consist of five parts: the township number, the range number, the section number, and two letters representing the quarter/quarter location within the section. The basic unit of this coordinate system is the township, which is six miles square (Figure 3). Townships are numbered consecutively in tiers both north and south of the Florida Base Line, an east-west survey line passing through Tallahassee. The township rectangle is also numbered both east and west of the Principal Meridian, a north-south survey line also passing through Tallahassee. Each township square is equally divided into 36 one-square-mile pieces called sections. Sections are numbered 1 through 36 as shown on Figure 3. The sections are in turn divided into four quarters labeled a through d, and each quarter is further divided into quarters labeled a through d in a similar fashion. Figure 3 provides an example of a well located according to this system. Table 1 is a list of the wells referred to in this report, with their elevations, depths, and locations.

METRIC CONVERSION FACTORS

In order to prevent awkward duplication of parenthetical conversion of units in the text of reports, the Florida Geological Survey has adopted the practice of inserting a tabular listing of conversion factors. For readers who prefer metric units to the customary U.S. units used in this report, the following conversion factors are provided:

MULTIPLY	BY	TO OBTAIN
acres	0.4047	hectares
acres	4047.0	sq. meters
cubic yards	0.7646	cu. meters
feet	0.3048	meters
inches	2.540	centimeters
inches	0.0254	meters
miles	1.609	kilometers
sq. miles	2.590	sq. kilometers
cubic feet per second	0.646	million gallons per day

GEOLOGY

GEOMORPHOLOGY

Wakulla County lies entirely within the Gulf Coastal Lowlands physiographic province (Puri and Vernon, 1964). This province is characterized by generally flat, sandy terrain and extends from the

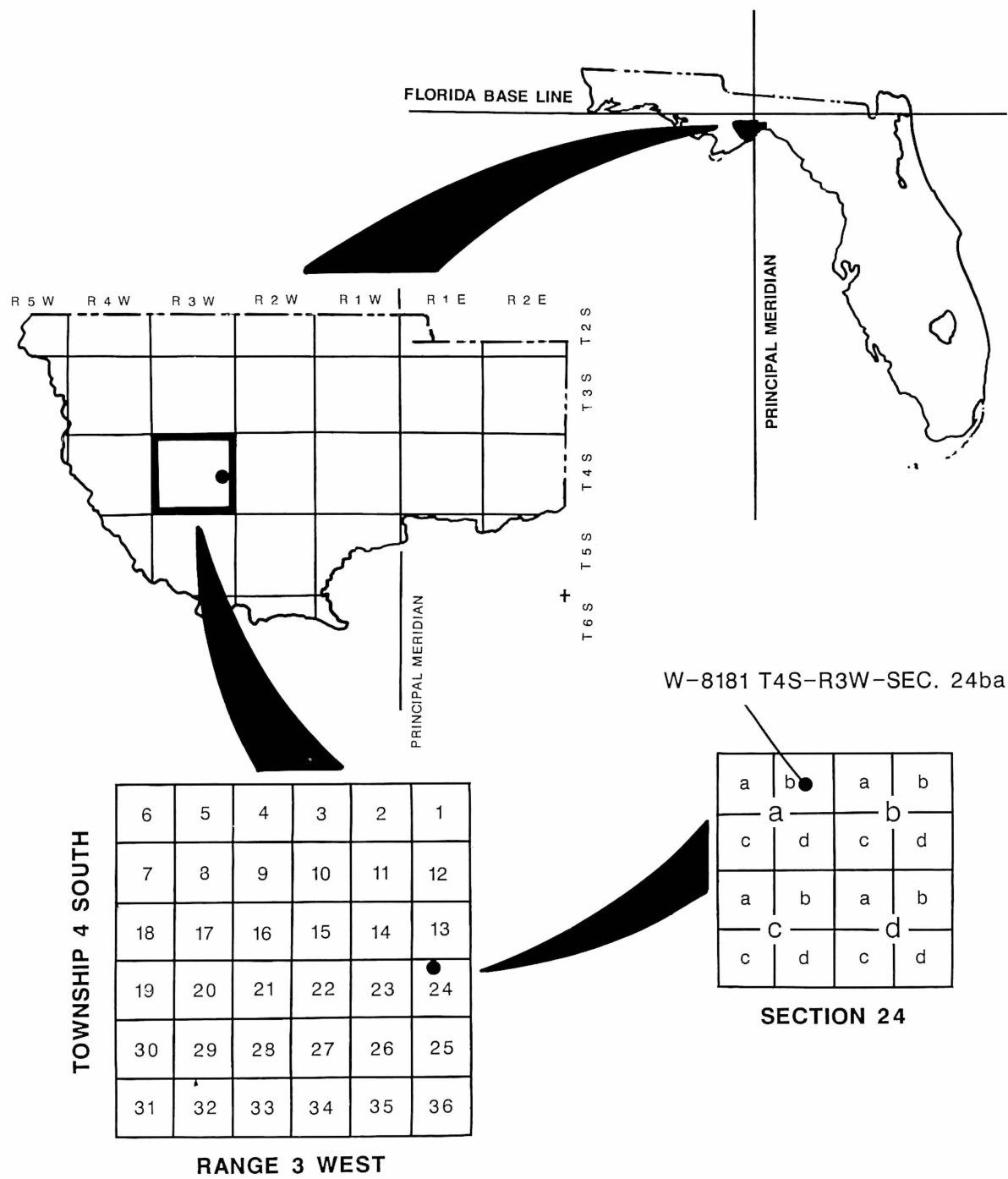


Figure 3. Well and locality numbering system.

Table 1. Wells cited in this study.

County	Well No.*	Location					Elevation (MSL)	Total Depth (feet) below surface
		T	R	Sec	¼	¼		
Wakulla	W-12	3S	1E	16	d	a	17'	2,169
Wakulla	W-440	3S	1E	14	c	d	28'	5,766
Wakulla	W-5585	4S	4W	33	c	b	22'	136
Wakulla	W-5817	3S	2W	18	d	a	63'	300
Wakulla	W-5953	4S	1E	2	b	c	13'	130
Wakulla	W-6886	5S	1W	2	d	a	9'	220
Wakulla	W-7741	4S	1W	27	c	a	14'	205
Wakulla	W-8106	3S	1W	3	a	d	10'	183
Wakulla	W-8181	4S	3W	24	b	a	14'	127
Wakulla	W-8350	3S	1E	27	b	a	12'	150
Wakulla	W-8464	5S	2W	7	a	c	25'	265
Wakulla	W-8467	4S	2E	31	b	d	12'	115
Wakulla	W-8477	6S	2W	1	c	a	7'	192
Wakulla	W-8479	5S	2W	12	a	d	26'	260
Wakulla	W-8792	4S	1W	14	c	b	5'	205
Wakulla	W-12114	2S	3W	27	d	a	85'	11,100
Wakulla	W-16020	5S	3W	28	a	d	10'	402
Wakulla	W-16053	2S	2W	27	a	b	65'	470
Franklin	W-14876	6S	4W	1	c	d	10'	182
Jefferson	W-6527	3S	3E	30	b	c	14'	50
Leon	W-6199	1S	2W	34	b	d	98'	315
Leon	W-7524	2S	2W	6	d	a	78'	211
Leon	W-13950	2S	1E	16	b	a	36'	200
Liberty	W-14996	3S	5W	31	b	a	64'	212

*Florida Geological Survey well accession numbers.

coast inland to approximately the 100 foot contour line. In the panhandle of Florida, the east-west trending Cody Scarp forms the boundary between the Gulf Coastal Lowlands and the topographically higher Tallahassee Hills to the north.

In Wakulla County, the Gulf Coastal Lowlands include the poorly-drained pine flatwoods, swamps, and river basins that extend from the Gulf north into Leon County. Surface slope averages about four feet per mile. A series of Pleistocene marine terrace zones, based on elevation, punctuate the surface of the Gulf Coastal Lowlands (see Figure 4). In addition, the Gulf Coastal Lowlands are locally divided into a series of geomorphic subzones. Figure 5 illustrates the distribution of these subzones in Wakulla County.

Marine Terraces

Superimposed upon the flat, karstic terrain of the Gulf Coastal Lowlands are minor, relict marine beach ridges, bars, spits, dune fields and low marine terraces. These terraces are step-like surfaces representing nearshore erosional plains developed between former shorelines positioned by advances and retreats of the sea during the Pleistocene. Healy (1975) recognizes five marine terraces in Wakulla County based on topographic elevation. In order of descending elevation, these shorelines are the Wicomico, the Penholoway, the Talbot, the Pamlico and the Silver Bluff (see Figure 4).

The Wicomico, Penholoway, and Talbot Terraces occur primarily as bands in the west and northwest portions of Wakulla County (Healy, 1975). The Wicomico Terrace (70-100 feet elevation) and the Penholoway Terrace (42-70 feet elevation) occur only in the northwest corner of the county. The Talbot Terrace is a two-to-three mile wide band lying between 25 and 42 feet above mean sea level (MSL). It arcs through the western half and just fringes the northern edge of eastern Wakulla County.

The Pamlico Terrace is generally well developed throughout Florida at approximately the 10 to 25 foot contour interval (Healy, 1975). In Wakulla County, the Pamlico Terrace covers much of the eastern half of the country, narrowing near Panacea and broadening again in the Ochlockonee River Valley. The terrace plain is developed on limestone and is overlain by varying thicknesses of sands and clays (Yon, 1966).

The name Silver Bluff terrace was first applied by Parker and Cooke (1944) to a wave-cut notch occurring at five feet above sea level near Miami. McNeal (1950) extended this shoreline to other areas of Florida and Georgia. In Jefferson County, Yon (1966) places the Silver Bluff shoreline at the 10 foot MSL contour line, with the terrace extending from the present coastline north to this elevation. Although this varies slightly from the eight feet generalized Silver Bluff elevation of Healy (1975), it appears to be an accurate limit in the Big Bend area. Tracing the 10 foot contour into Wakulla County shows the Silver Bluff shoreline varying from one to six miles inland, narrowing in the vicinity of Panacea. The coastal marshes border the seaward edge of this terrace. Inland towards the ancient shoreline, the flat, poorly drained terrace plain supports stands of pines and palms along with various other swamp flora (Yon, 1966). Scholl (1963) considers the Silver Bluff to be Pleistocene in age.

Woodville Karst Plain

Hendry and Sproul (1966) recognized two broad subdivisions of the Gulf Coastal Lowlands named the Woodville Karst Plain and the Apalachicola Coastal Lowlands. Figure 5 illustrates the areal extent of each major geomorphic subdivision in Wakulla County.

East of a line drawn roughly north-south through the towns of Crawfordville and Panacea, the topography is comprised of an essentially flat veneer of sand overlying karstic limestone bedrock. Elevations average less than 35 feet above MSL. Hendry and Sproul (1966) named this low plain the Woodville Karst Plain, and their terminology is adopted in this report.

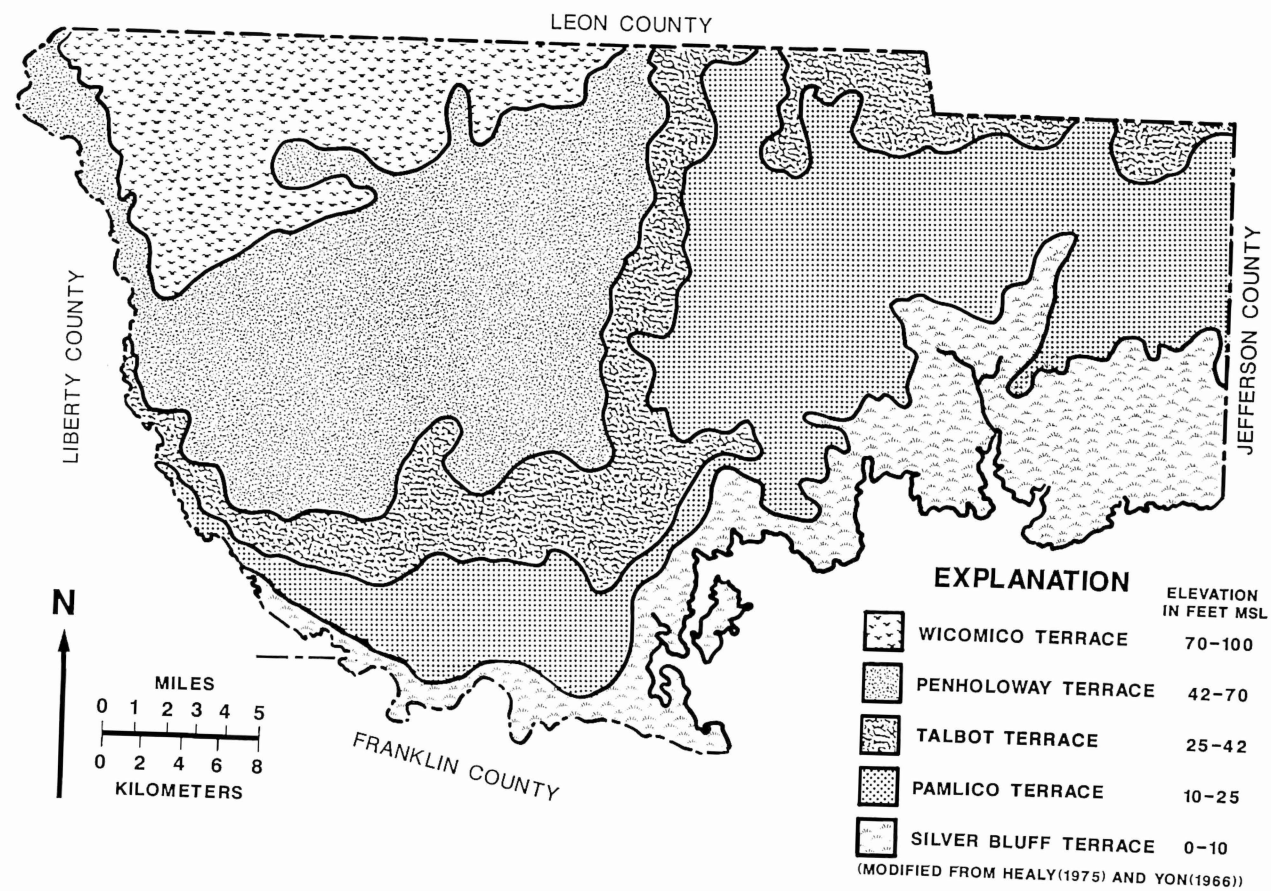


Figure 4. Marine terraces of Wakulla County (modified after Healy, 1975, and Yon, 1966).

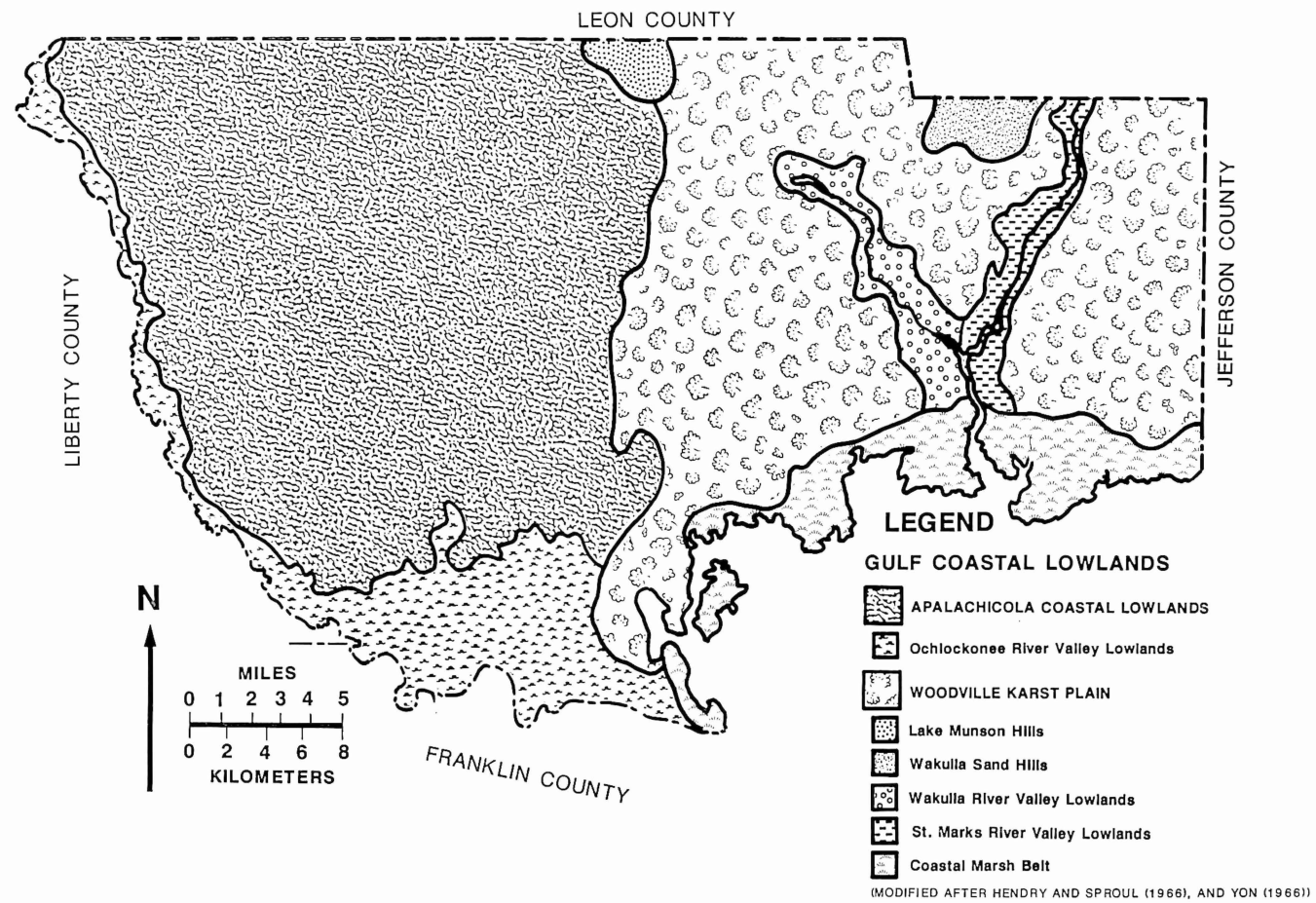


Figure 5. Geomorphic map of Wakulla County.

The Woodville Karst Plain comprises the entire eastern portion of Wakulla County. Bounded on the west by the Apalachicola Coastal Lowlands, it extends eastward into Jefferson County and north to the Cody Scarp. A surface veneer of generally less than 20 feet of quartz sand lies on the karstic St. Marks Formation and Suwannee Limestone. The result is a topography of low sand dunes and sinkholes sloping gently towards the coast. Vegetation patterns on the plain vary with the degree of drainage. High and well-drained relict sand dunes at the north edge of the plain support a flora of pines, black-jack, and turkey oak trees. In contrast, wetter areas to the south are populated largely by cypress and bay trees (Hendry and Sproul, 1966). Harper (1914) described 30 tree species, seven species of woody vines, 30 shrubs, and 109 species of herbs growing within the Woodville Karst Plain zone.

Several small geomorphic subdivisions of the Woodville Karst Plain have been named by Hendry and Sproul (1966). These are the Lake Munson Hills, the Wakulla Sand Hills, and the River Valley Lowlands. Bordering the southern edge of the karst plain is the Coastal Marsh Belt (Puri and Vernon, 1964).

The Lake Munson Hills

The Lake Munson hills are relict sand dunes and bars projecting about a mile into Wakulla County near Hilliardville. Hendry and Sproul (1966) considered these hills to be relict offshore bars related to the Wicomico sea level stand. They overlie an area of interfingering between resistant silts and clays on the west and the sands of the karst plain on the east. Hendry and Sproul (1966) theorize that the more resistant beds reduced downward percolation of water, thus reducing dissolution of the underlying limestones. Subsidence was slowed or prevented by the clays, and the Lake Munson Hills may approximate the original, pre-solution elevation of the Woodville Karst Plain.

The Wakulla Sand Hills

The Wakulla Sand Hills are a series of Pamlico shore dunes (Hendry and Sproul, 1966). Attaining approximately 50 feet elevation, these hills extend from Woodville in Leon County southeastward about two miles into Wakulla County, terminating at the Pamlico paleo-shoreline. Orientation of these barchan-type dunes suggest a paleo-wind from the northeast (Hendry and Sproul, 1966).

River Valley Lowlands

The St. Marks and Wakulla Rivers are the major streams flowing in the Woodville Karst Plain. Both have low, swampy floodplains averaging less than 10 feet in elevation, which comprise the River Valley Lowlands portion of the Woodville Karst Plain.

The St. Marks River

The headwaters of the St. Marks River are in the Tallahassee Hills area of eastern Leon County. Part of its course is through Jefferson County, and it re-enters Leon County to flow underground into a limestone sink at Natural Bridge. South of Natural Bridge, the river re-emerges as spring flow and courses southward into Wakulla County through a well-defined channel incised in limestone bedrock. Sands and silts are deposited on the low floodplain. The St. Marks River widens considerably south of the town of St. Marks and empties into Apalachee Bay near Sprague Island.

The Wakulla River

The Wakulla River originates at Wakulla Springs in the north-central portion of Wakulla County. It flows southeastward through limestone bedrock and merges with the St. Marks River below the town of St. Marks. McBride Slough forms a tributary to the Wakulla about two miles below the springhead. A topographic low traceable northward from McBride Slough to Munson Slough in Leon County, and eventually to Lake Munson, is considered by Hendry and Sproul (1966) to be a former course of the Ochlockonee River.

Coastal Marsh Belt

At the southern edge of the Woodville Karst Plain is the Coastal Marsh Belt geomorphic subzone (Puri and Vernon, 1964). This subzone represents the seaward edge of the Silver Bluff shoreline with an inland limit at approximately the five foot contour line (Yon, 1966). Sediments in this belt are mud and silt, which support a marsh flora of predominately *Juncus* and *Spartina* grasses (Clewell, 1981). The Coastal Marsh Belt extends from the Jefferson County line westward along the Wakulla County Gulf coast, eventually pinching out near Panacea. Formation of open coastal marshes is attributable to the zero-energy nature of the Big Bend coast. Sand movement is minimal, and beaches are virtually absent due to a lack of wave activity (Price, 1953; Tanner, 1960).

Apalachicola Coastal Lowlands

Hendry and Sproul (1966) proposed the name Apalachicola Coastal Lowlands for the flat sandy portion of western Leon County underlain by thick clastic deposits. This geomorphic subdivision of the Gulf Coastal Lowlands is recognizable in western Wakulla County and is hereby adopted in this report.

West of U.S. Highway 319 in Wakulla County, the near-surface sands and clays thicken towards the Ochlockonee River. While the topography remains essentially flat, elevations of almost 150 feet are attained in the northwest corner of the county.

The Apalachicola Coastal Lowlands are characterized by flat, sandy surface sediments with shallow "bays" (densely-wooded, swamp-like areas) and poorly-defined creeks. Although the water table may be close to the surface, lakes are absent. Cameron and Mory (1977) studied the Bradwell Bay Wilderness Area of the Apalachicola National Forest in western Wakulla County. They found the area to be flat terrace deposits underlain by up to 30 feet of sands, clay, peat, and muck of Pleistocene to Holocene age. These deposits overlie Miocene age limestones.

Numerous creeks drain the bays and serve as tributaries for larger streams. Because of the flat-lying topography, most creek channels are poorly defined. The three major streams flowing in the Apalachicola Coastal Lowlands are the Ochlockonee River, the Sopchoppy River, and Lost Creek. The valley of the Ochlockonee River has been described as a geomorphic subzone of the Apalachicola Coastal Lowlands named the Ochlockonee River Valley Lowlands (Hendry and Sproul, 1966).

The Ochlockonee River Valley Lowlands

The headwaters of the Ochlockonee River occur in the hills of south Georgia, from which it flows southward approximately 115 miles to Ochlockonee Bay on the Gulf coast. It forms the county boundaries between Liberty and Wakulla Counties and between Franklin and Wakulla Counties. Numerous small creeks contribute to the flow of the Ochlockonee along its course.

In extreme northwestern Wakulla County, the Ochlockonee flows along a 50-foot high bluff of sands and clays. South of this area, the river flows in a wide, swampy valley, bounded by occa-

sional bluffs. A number of cutoffs and oxbow lakes are present along its meandering course. Southwest of the town of Sanborn, surrounding elevations decrease to less than 30 feet and the river widens considerably. From this point the river assumes a much broader meander pattern to its terminus at Ochlockonee Bay.

The Sopchoppy River and Lost Creek

The Sopchoppy River originates at the confluence of several small creeks in northwest Wakulla County. It flows in a narrow, deep valley incised in sands and clays. The northern three-quarters of the river meanders through the Apalachicola National Forest. Miocene-age limestone is exposed sporadically along this course. South of the town of Sopchoppy, the river widens and assumes a more meandering course through the low, marshy area west of Panacea. A cutoff meander branch of the Sopchoppy known as Dead River connects with the Ochlockonee River here. The Sopchoppy River empties into Ochlockonee Bay at the southern edge of Wakulla County.

Lost Creek forms in southern Leon County and is fed by several small creeks as it enters Wakulla County. It flows southeastward through a narrow meandering valley, and is contributed to by creeks flowing out of Mosquito Bay, Cow Swamp, and Ditch Bay. Southwest of Crawfordville it disappears underground into a sink and does not reappear.

Sinks

The karstic surface of eastern Wakulla County is dotted with numerous sinkholes and depressions formed by dissolution, subsidence and collapse of the limestone bedrock. Most are small and unnamed. If the amount of collapse is small, a topographical depression forms which may not be wet. When the collapse is sufficiently deep to intercept the water table or an aquifer, a water-filled sinkhole forms. Cherokee Sink, centered on the northern edge of section 21, Township 3S, Range 1W, is a deep sink intersecting the water table and forming a small swimming hole. The St. Marks Formation and overlying clays are exposed around the perimeter of the sink.

Springs

Springs are waters discharged as natural leakage or overflow from an aquifer through a natural opening in the ground. Seven major springs occur in Wakulla County. They are briefly described below, using data taken from Rosenau et al. (1977).

Indian Springs

Indian Springs is a privately-owned spring located about 13 miles south of Tallahassee in section 13bc, T3S, R1W. The pool formed by the spring is approximately 150 feet by 190 feet and 30-feet deep. A run flows to the south into a swampy area. Discharge measured on October 31, 1972 was 0.11 cubic feet per second (cfs).

Kini Spring

Kini Spring is located in the Apalachicola National Forest about 12-miles south of Tallahassee in section 28ac, T2S, R1W. Its pool is approximately 120 feet by 135 feet, and varies between 10 and 24-feet deep. Discharge recorded March 21, 1972 was 176 cfs.

Newport Spring

Newport Spring is located 0.7 mile north of the town of Newport in section 24bb, T3S, R1E. The

spring pool measures 50 by 100 feet and averages four feet in depth. It is fed by an orifice at the west end of the pool, and discharges through a run to the St. Marks River, 0.3 mile to the southeast. March 2, 1972 discharge was 8.24 cfs.

Panacea Mineral Springs

Panacea Mineral Springs are located on the western side of U.S. Highway 98 in Panacea, in section 24ad, T5S, R2W. Six separate concrete-lined springs are situated in an abandoned park, and were used for recreation. Today the park is overgrown, and the springs are in a state of ruin. Total combined flow from the six springs was estimated at 0.11 cfs on March 16, 1972.

River Sink Spring

River Sink Spring is in section 28cc, T2S, R1W, about 12-miles southwest of Tallahassee. The pool measures 65 by 160 feet and is situated in a pine flatwoods. Water depth averages 30 feet. Discharge measured March 21, 1972 was 188 cfs.

Wakulla Springs

Wakulla Springs, comprised of the main spring and Sally Ward Spring, form the headwaters of the Wakulla River. It is the county's largest spring and is located 14-miles south of Tallahassee in section 11bd, T3S, R1W. The Springs were operated as a resort and attraction for years, and were purchased by the State of Florida in 1986 for use as a state park.

The main spring is in the south part of the pool. Sally Ward Spring is about 0.7-mile northwest of the main spring. A low, swampy run connects Sally Ward Spring with the main spring pool. Discharge of Wakulla Springs is measured downstream of the pool in the Wakulla River at the Highway 365 bridge. The average discharge for the 67 years prior to 1974 was 390 cfs. Wakulla Springs display the greatest known range in discharge of any Florida spring. A minimum flow of 25.2 cfs was recorded on June 18, 1931, and a maximum flow of 1,910 cfs occurred on April 11, 1973.

The Wakulla Spring pool and adjacent river bottom have yielded many fine vertebrate fossils. Large mammal bones, most likely of a mastodon or elephant, were reportedly first discovered in the spring floor sediments in the 1800's. A nearly complete mastodon skeleton recovered from Wakulla Springs in the 1890's was purportedly lost in transit when the ship carrying it up the east coast sank during a storm (Sellards, 1916).

Perhaps the best known fossil find occurred in August of 1930 when the owner of Wakulla Spring, Mr. George Christie, discovered a nearly complete skeleton of an American Mastodon (*Mastodon americanus*). The bones were scattered over an area of the bottom at the northern edge of the spring pool, in water 20 to 26-feet deep (Gunter, 1931). With the assistance of the Florida Geological Survey, the City of Tallahassee, the Floridin Company, and the Everglades Drainage District, the necessary equipment and personnel were assembled to recover the skeleton (Gunter, 1931). During the winter of 1930-1931, all skeleton pieces except some of the vertebrae, ribs and front feet were located and removed from the spring. Plaster casts of the missing bones were later obtained from the Warren Mastodon skeleton housed at the American Museum of Natural History in New York (Florida Geological Survey in-house correspondence files). Figure 6 is a photograph of the recovery effort, and Figure 7 shows the assembled skeleton. The Wakulla Spring Mastodon was originally displayed in the Florida Geological Survey Museum in the mid-1930's. Today, the skeleton is housed at the Museum of Florida History in the R. A. Gray Building in downtown Tallahassee.

In 1955, the first organized underwater exploration of Wakulla Springs was coordinated by Dr. Stanley Olsen, paleontologist with the Florida Geological Survey. Olsen and six scuba divers ex-



Figure 6. Wakulla Mastodon recovery, Wakulla Springs, Fall 1930 (from Florida Geological Survey photo archives).

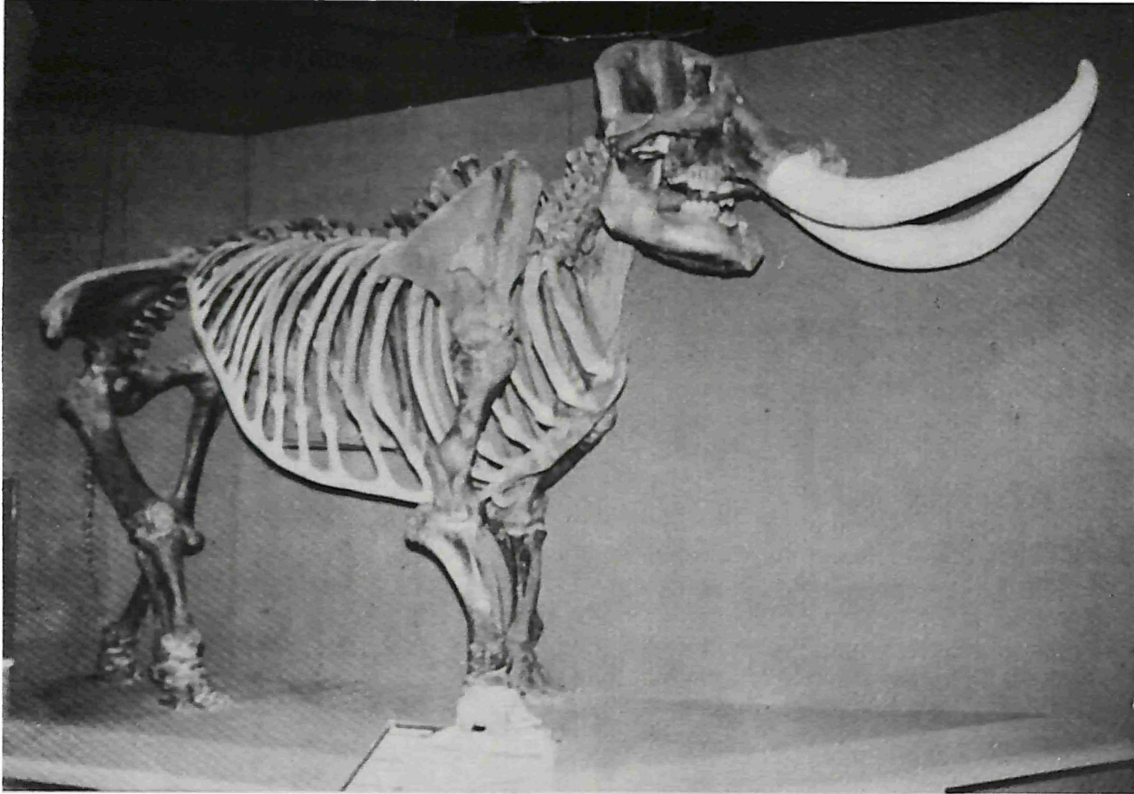


Figure 7. The Wakulla Mastodon skeleton.

explored a distance of approximately 1100 feet into the spring tube, where the cavern is over 200 feet below the surface. An interesting narrative of the diver's exploration of the spring is given in Olsen (1958). In addition to preparing a cross-sectional map of the Spring cave (see Figure 8), the diving team recovered numerous fossil bones and artifacts from within the main spring tube. Among the finds were bones of Pleistocene mastodons, sloths, and deer, as well as over 600 bone spear points manufactured by early Indians residing near the springs. Most of the vertebrate fossil material recovered by Olsen's team is now housed at the Florida State Museum in Gainesville.

The most extensive exploration of the Wakulla Spring cave system occurred over a two month period beginning in October, 1987. Working under a permit from the State of Florida, 14 divers from the United States Deep Caving Team conducted a multifaceted exploration project in the spring. Although the primary mission of this team was to map and videotape the spring conduit and test the latest technology in mixed gas rebreathing apparatus, the divers also cooperated with various state agencies in collecting scientific data.

Over two miles of submerged conduit system were mapped during the project (see Figure 9). The primary spring tunnel was found to head generally southwest from the spring entrance. Beyond the depths originally explored by Olsen (1958), the cave system increased in both complexity and size. At a distance of about 900 feet into the main cave, in a room named the Grand Junction Depot, the tunnel splits into four separate conduits. Tunnels "A" and "C" head to the south, while tunnel "B" trends eastward towards McBride Slough and tunnel "D" heads north, to within 1200 feet of a similar conduit discovered by the divers in Sally Ward Spring. The tunnels

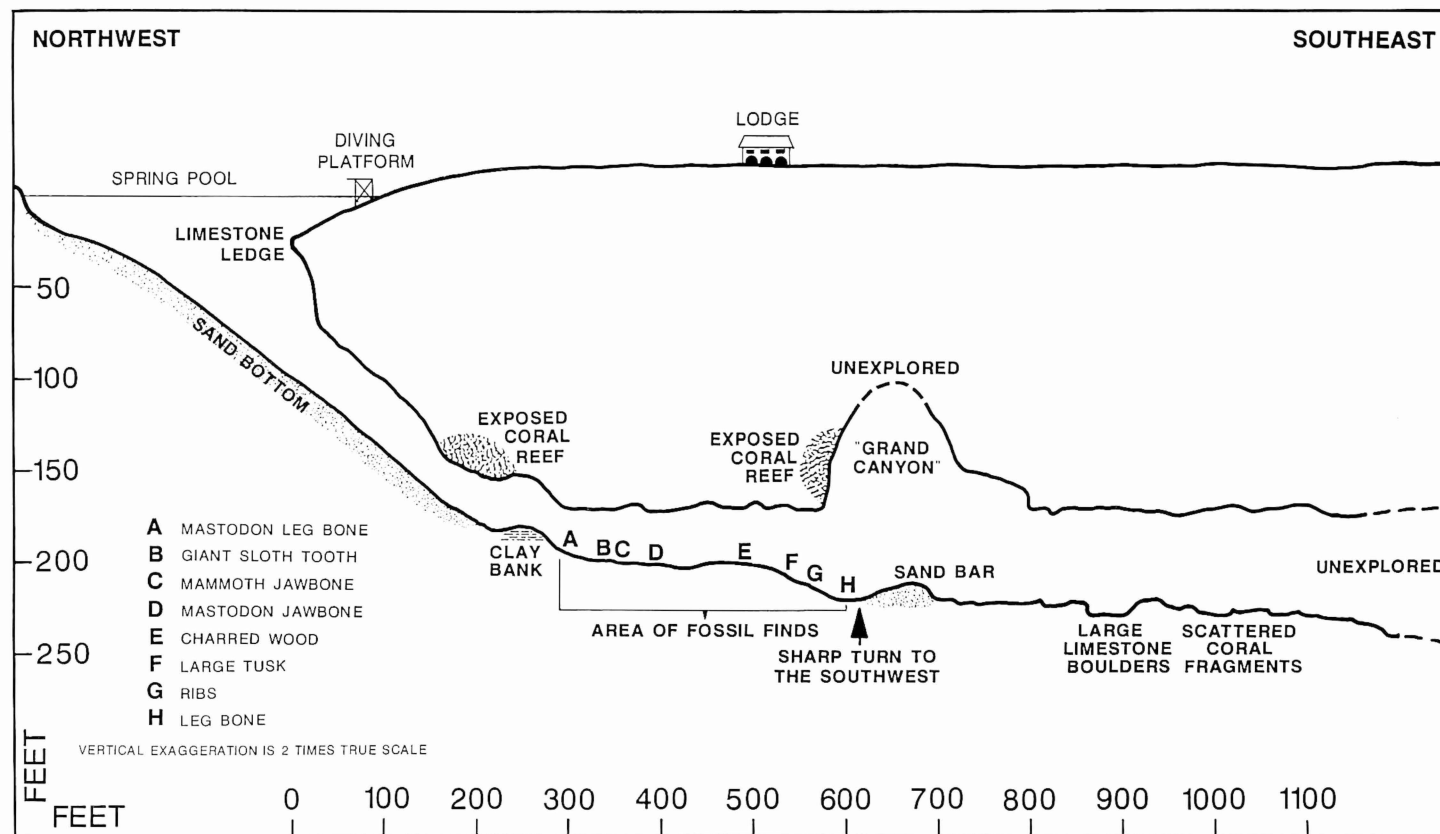


Figure 8. Cross section of the Wakulla Cave (modified from Olsen, 1958).

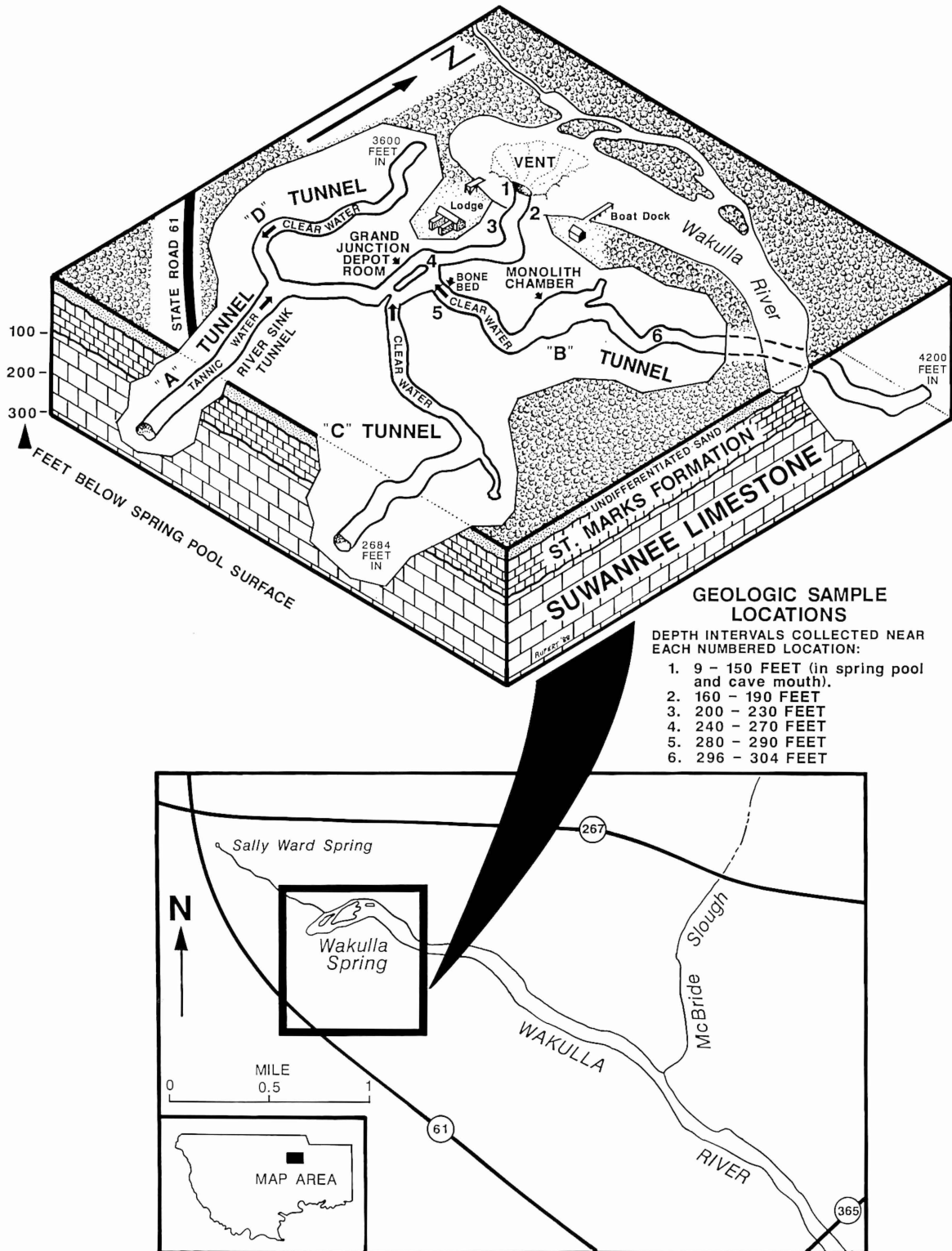


Figure 9. Block diagram of the Wakulla Springs conduit system (data from United States Deep Caving Team divers).

vary in size, but are for the most part large. Diver Wes Skiles reported that in one average size area within the primary spring tube, the dimensions of the cave were 47-feet high and 117-feet wide. Although time and visibility limitations prevented extensive exploration of all the subordinate conduits, tunnel "B" was explored to a total distance of 4500 feet in from the spring vent. The deepest depth recorded during the project, 360 feet below spring pool surface, was recorded in tunnel "B" near the 4500 feet limit.

Water flow in all the tunnels is towards the Grand Junction Depot room, and ultimately northward to the spring vent. Interestingly, this flow is generally in opposition to the local hydrologic gradient. Water quality within the conduits showed somewhat differing characteristics. Tunnels "B", "C", and "D" carried "air clear" water, while Tunnel "A" carried tannic (tea-colored) water. Input from the tannic-laden conduit frequently determined the spring's overall clarity on a daily basis. Preliminary uranium isotope counts conducted on water samples taken within the four conduits reveals that tunnels "B" and "C" carry regional groundwater, while tunnel "D" and possibly tunnel "A" have recent surface-water components (Dr. Kenneth Osmond and Milena Macesich, Florida State University, personal communication, 1988). The bulk of the data collected suggests that these conduits are just a portion of an extensive network of interconnected and possibly joint-controlled conduits underlying the Woodville Karst Plain.

Geologic samples were collected within the Wakulla Spring cave system to better understand the local stratigraphy as well as the geology of the entire conduit network. In cooperation with the Florida Geological Survey, the divers recovered seven shallow sediment cores from the cave floor and cave-wall rock samples from 28 depth intervals ranging from 9 to 304-feet below spring pool surface (approximately four feet MSL). These samples were described and are currently cataloged in the Florida Geological Survey sample repository as M-3023. The entire conduit system is developed in the Oligocene age Suwannee Limestone. Throughout most of the cave, the lithology consists of white to very pale orange, poorly indurated, recrystallized foraminiferal biocalcarenic limestone. Near the cave mouth, samples show a rind of iron oxide staining ranging from 0.5 to 1-inch thick on the exposed, weathered faces. The typical fossil fauna include the Foraminifera *Dictyoconus cookei*, *Rotalia mexicana*, *Cancris sagra*, *Operculinoides vicksburgensis*, and *Quinqueloculina* spp., molds of the mollusk *Cerithium* sp., corals, and recrystallized casts of the echinoid *Rhyncholampus gouldii*. A distinct lithologic change within the Suwannee Limestone, first noted at a depth of approximately 218 feet, is sporadically traceable along the tunnel walls into the caves as far as exploration progressed (Wes Skiles, personal communication, 1987). This lithologic change appears as a sharp color change on the video tapes taken of the conduit walls. The color change is caused by an abrupt transition from the soft biocalcarenic above the change to a harder, recrystallized dolomitic calcarenite below. This lower, harder layer floors most of the cave system below the 218-foot depth, and may have retarded further downward dissolution within the conduits. At the deepest-sampled depth of 304 feet, the lower lithology is a brown sucrosic dolomite.

The Suwannee Limestone unconformably contacts the overlying Miocene age St. Marks Formation at a depth of approximately 90 feet below water surface (see Figure 9). This contact is exposed on the face of the limestone ledge in the spring pool directly above the spring vent. The St. Marks Formation is a white to very pale orange, fossiliferous, slightly sandy calcilutitic limestone. Diver Bill Wilson reported several distinct coral and shell beds within the portion exposed in the ledge. Most of the contained fossils are recrystallized, with Foraminifera, mollusk molds, and corals dominating. Foraminifera include *Sorites* sp. and *Archaias* cf. *floridanus*. Between 20 and 40-feet deep, the lithology of the St. Marks Formation is a pale orange, generally unfossiliferous calcilutite containing some white to pale green clay stringers. The nine foot sample is abundantly mollusk-moldic. In the vicinity of Wakulla Springs, the elevation of the top of the St. Marks Formation is variable. The shallowest samples collected in the spring pool cropped out at nine feet of water depth, and locally, this formation is generally overlain by 10 to 20 feet of undifferentiated Pleistocene sand. However, boulders of St. Marks Formation "float" may be observed along the

nature trail on the park grounds.

Collection of paleontological remains was not part of the Wakulla Springs exploration project. The divers documented on videotape the extensive Pleistocene bone beds first noted by Olsen (1958) in the primary spring tunnel (see Figure 8), and also discovered a second deposit of similar bones some 1200 feet into tunnel "B", at a depth of 285 feet. The origin of these deposits is uncertain. Two hypotheses explaining the placement of these bone beds center on the 300-foot drop in sea level postulated to have occurred during Pleistocene glacial periods. Such a drop in worldwide sea level would have left the spring conduits stranded as dry caves. One theory holds that the Pleistocene mammals roamed in these dry caves, or that paleoindians carried animal carcasses into the cave. A second theory is that Wakulla Spring may have been a "shallow hole" during lower sea level, receiving the flow of an ancient stream. The water inflow, it is reasoned, may have flushed animal remains down into the cave, possibly as far as the outer bone beds noted by Olsen. However, the recent discovery of bones 1200 feet back into the caves may make the latter theory seem less plausible. Future radiometric and micropaleontologic study of the short core taken in the bone bed may help determine the true origin of these deposits.

Spring Creek Springs

Spring Creek Springs are a group of submarine springs situated in the floor of Spring Creek, in Hartsfield Survey Land Grant Sections 114 and 115, near the village of Spring Creek. The stream known as Spring Creek flows in the coastal marsh belt, and empties into Oyster Bay. Although as many as 14 different springs have been reported by local residents, eight identified outlets, most near the east bank of Spring Creek, are described by Rosenau et al. (1977). Spring Creek rise is a major vent about 20-feet offshore of the old Spring Creek Hotel. Flow from this outlet produces a prominent boil at the surface. Aggregate flow measurements downstream of the springs area show a discharge of about 2000 cfs.

STRATIGRAPHY

The known sediments underlying Wakulla County range in age from Paleozoic to Holocene. The oldest rock that crops out in the county is the Oligocene age Suwannee Limestone. Holocene terrace sands and alluvium are the youngest.

The subsurface data discussed in this report were derived from lithologic logs of water and oil well cuttings and cores (Table 1). Figure 10 is a generalized stratigraphic section for Wakulla County. Figure 11 shows the locations of a series of geologic cross-sections (Figures 12 through 16), which illustrate the shallow stratigraphy of the county. Columnar sections for the two recent cores taken in Wakulla County are illustrated in Figures 19 and 20. Most area water wells end in post-Eocene formations, and data on formations older than Oligocene were obtained from oil test well records.

Paleozoic Erathem

Relatively little is known about the deep Paleozoic rocks underlying Wakulla County. Various basement rock maps (Applin 1951; Chowns and Williams, 1983; Thomas et al., 1987; and Dallmeyer, 1987) indicate that all of Wakulla County is probably underlain by Ordovician through Devonian age sedimentary rocks. According to Barnett (1975), the Placid Oil Co. No. 1 USA Unit 27-2 (W-12114) encountered what is probably a Paleozoic shale at 12,200 feet, and a diabase sill at 12,220 feet. This is the only well drilled to date in Wakulla County to reach Paleozoic rocks.

TIME SCALE (MILLION YEARS BEFORE PRESENT)	ERATHM	SYSTEM	SERIES		UNIT			
					WEST	EAST		
0.1	CENOZOIC	QUATERNARY	HOLOCENE		UNDIFFERENTIATED SAND AND CLAY			
1.6			PLEISTOCENE					
5.2		TERTIARY	NEOGENE	PLIO-CENE	UPPER	JACKSON BLUFF FM.		
10.2					LOWER			
16.2				MIOCENE	UPPER			
25.2						MIDDLE	INTRACOASTAL FM.	
30.0							BRUCE CREEK LMST.	
36.0					HAWTHORN GROUP - TORREYA FM.			
39.4			PALEOGENE		LOWER	ST. MARKS FORMATION		
49.0								
54.0				OLIGO-CENE	UPPER			
60.2					LOWER	SUWANNEE LIMESTONE		
66.5				EOCENE	UPPER	OCALA GROUP		
					MIDDLE	AVON PARK FORMATION		
					LOWER	WILCOX GROUP UNDIFFERENTIATED		
					PALEO-CENE	UPPER	WILCOX GROUP UNDIFFERENTIATED	
		LOWER						
96.0		MESOZOIC	CRETACEOUS		UPPER		UNNAMED CHALKY LIMESTONE	
131.0				EUTAW FORMATION				
152.0				ATKINSON FORMATION				
179.0	JURASSIC		LOWER					
210.0								
231.0			UPPER	COTTON VALLEY GROUP				
240.0				HAYNESVILLE FORMATION				
250.0	LOUANN SALT							
280.0	TRIASSIC		UPPER		EAGLE MILLS FORMATION			
345.0								
395.0								
435.0	PALEOZOIC	PERMIAN						
500.0		CARBONIFEROUS						
570.0		DEVONIAN		UNDIFFERENTIATED				
		SILURIAN		UNDIFFERENTIATED				
		ORDOVICIAN		?				
		CAMBRIAN		?				
	PRE-CAMBRIAN	?						



ABSENT IN WELLS

FM. = FORMATION

LMST. = LIMESTONE

? = NOT REACHED IN WELLS

EXPLANATION

Figure 10. East-West diagrammatic stratigraphic section in Wakulla County.

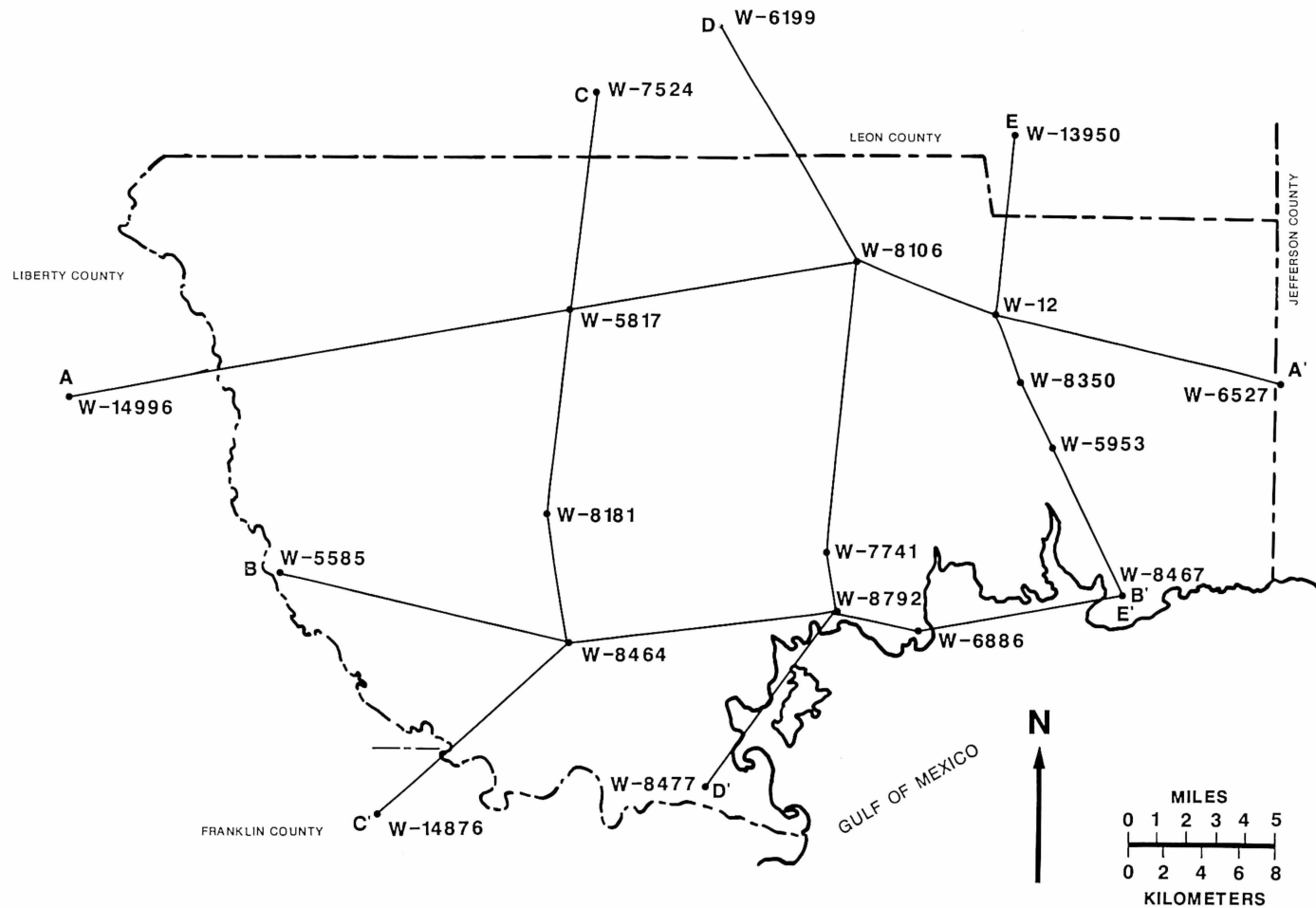


Figure 11. Geologic cross section location map.

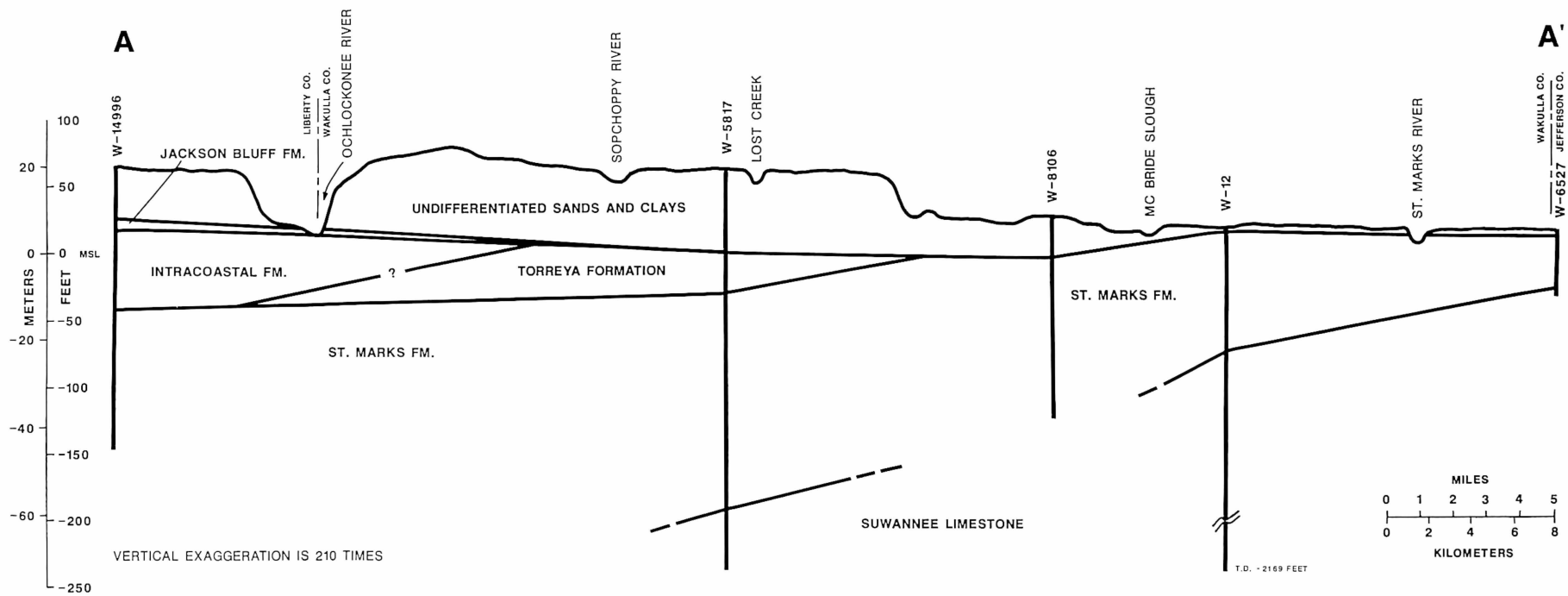


Figure 12. Geologic cross section A-A'.

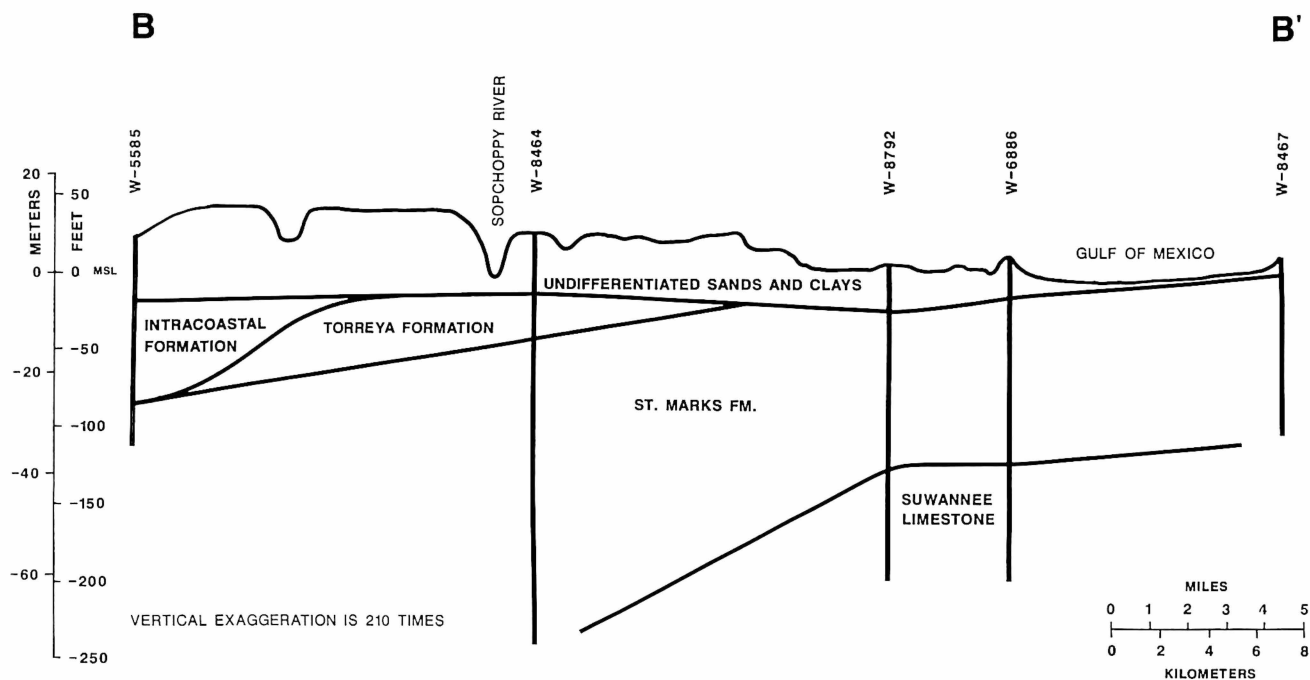


Figure 13. Geologic cross section B-B'.

Mesozoic Erathem

Two oil test wells penetrated Mesozoic sediments in Wakulla County. The Brown and Ravelin No. 1 Phillips (W-440) was drilled to a total depth of 5,766 feet, and penetrated Atkinson Formation sediments, consisting of alternating sandstones and shales, in the interval from 3,672 feet to 4,270 feet (Puri and Vernon, 1964). Eutaw Formation sandy shales were encountered at 3,482 feet, and an Upper Cretaceous, unnamed chalky limestone was penetrated at 2,715 feet. A foraminiferal assemblage consisting of *Globotruncana arca*, *G. fornicata*, and *Pseudotextularia varians* was noted at this depth by E. Applin (Fla. Geological Survey unpublished report, 1943).

The Placid No. 1 USA, Units 27-2 (W-12114) well encountered the Upper-Triassic age Eagle Mills Formation at a depth of 11,574 feet (Barnett, 1975). This well also drilled through 705 feet of Middle Jurassic age Louann Salt from 10,869 feet to 11,574 feet, and encountered the Upper Jurassic Haynesville Formation at a depth of 10,300 to 10,869 feet. The Upper Jurassic to Lower Cretaceous age Cotton Valley Group sediments were encountered from 9,230 feet to 10,300 feet, and the Upper Cretaceous age unnamed lower member of the Atkinson Formation was drilled from 4,177 feet to 4,525 feet (Applegate et al., 1978).

Cenozoic Erathem

Tertiary System

Paleocene Series

Upper Paleocene Wilcox Group Undifferentiated

A diagnostic Late Paleocene foraminiferal assemblage recognized from the Velasco Formation of Mexico was noted in several north Florida wells (Applin and Applin, 1944; Yon, 1966). The com-

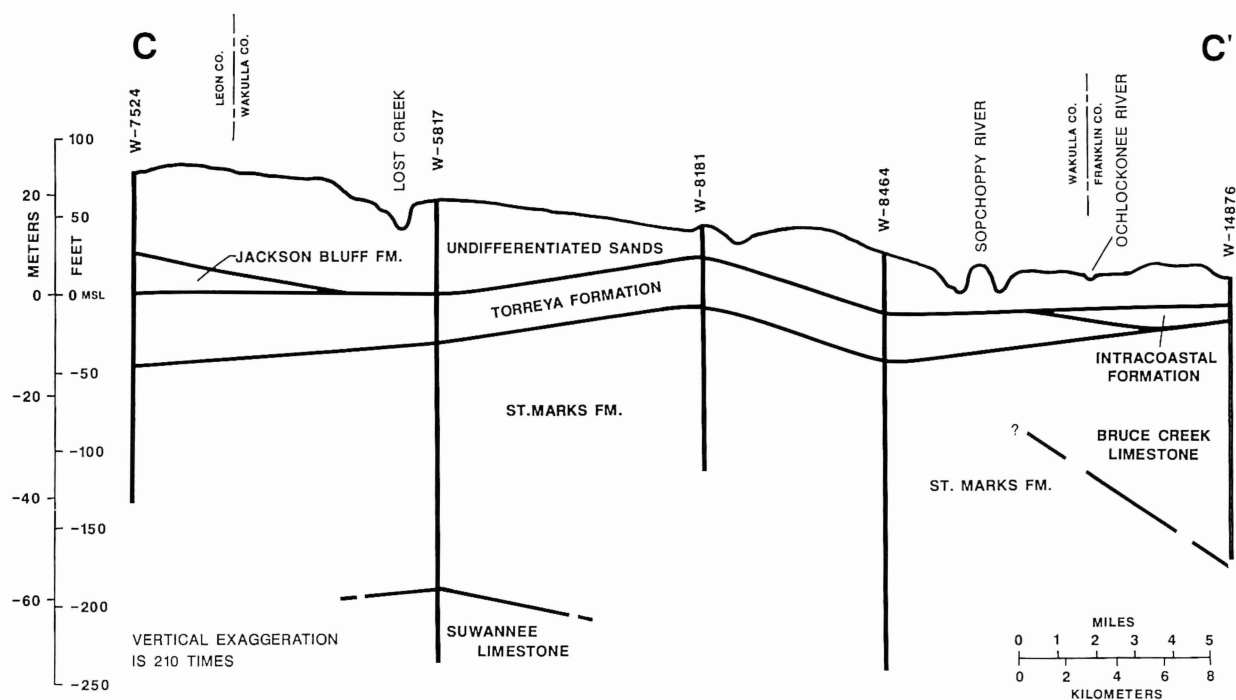


Figure 14. Geologic cross section C-C'.

mon species comprising this assemblage are *Globorotalia velascoensis*, *G. angulata*, *G. pseudo-meanardii*, *Globigerina velascoensis*, and *Eponides cf. exigua*. This fauna was noted by Applin and Applin (1944) in Wakulla County well W-440 at a depth of 2,675 - 2,715 feet in a gray, marly limestone, and was originally considered by the Applins to be a thin Midway Group bed.

Eocene Series Lower Eocene Wilcox Group Undifferentiated

Applin and Applin (1944) noted a clastic Wilcox Group section, consisting of calcareous and glauconitic sandstones and chalky, glauconitic limestones from 2,122 to 2,665 feet in well W-440. Fossils were sparse in this interval, and a lithologic correlation to nearby wells was used for age determination.

Middle Eocene Avon Park Formation

Miller (1986) grouped the lithologically similar Avon Park Limestone and Lake City Limestone of Applin and Applin (1944) into a single unit, the Avon Park Formation. The Avon Park Formation includes the Middle Eocene age carbonates occurring in Florida.

In Wakulla County, the Avon Park Formation was observed in two wells: W-12 at a depth of 1,760 to 2,169 feet (Puri and Vernon, 1964), and W-440 in the interval 920 to 2,122 feet (Applin and Applin, 1944). As represented in these wells, the Avon Park Formation is a white, cream, or brown-colored, chalky, calcitic, and fossiliferous limestone with varying amounts of gypsum, glauconite, dolomite, and chert. Foraminifera present include *Coskinolina* sp., *Dictyoconus americanus*, and *Fabularia cf. vaughani* (Applin and Applin, 1944).

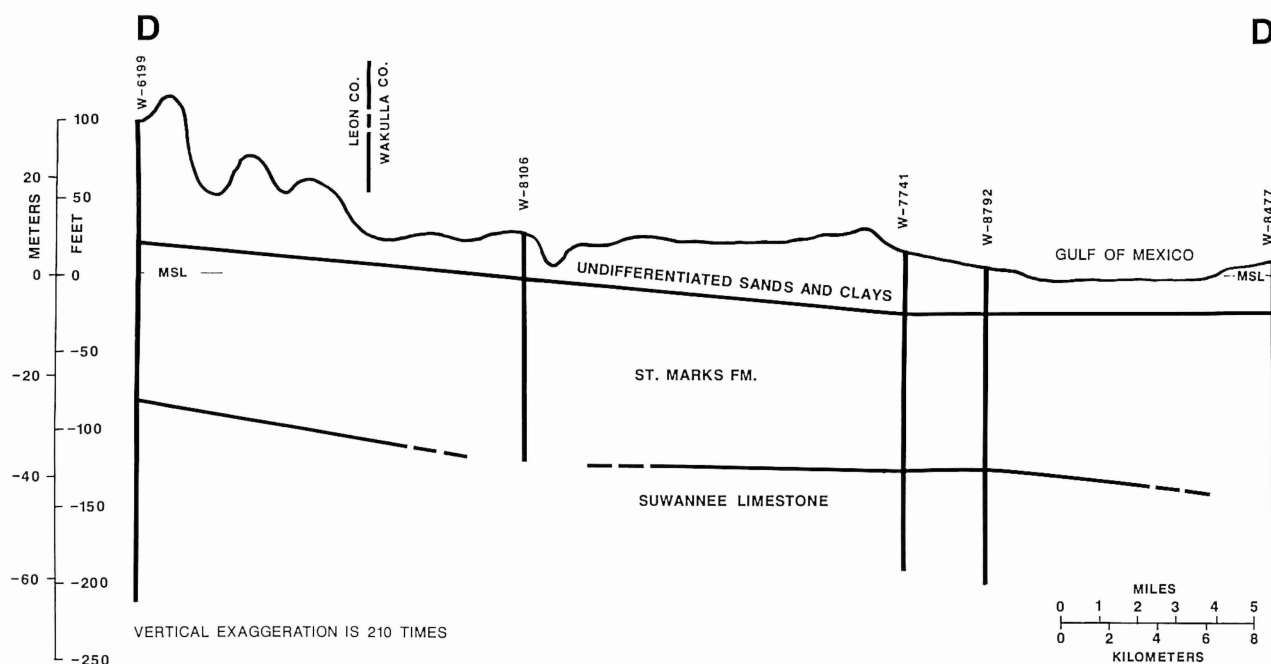


Figure 15. Geologic cross section D-D'.

Upper Eocene Ocala Group

Dall and Harris (1892) first proposed the name Ocala Limestone for calcareous sediments exposed in the vicinity of Ocala, Marion County, Florida. Since this initial usage, the term Ocala Limestone has been redefined by numerous authors. An excellent historical review is provided by Puri (1957).

The nomenclature proposed by Puri (1957) is generally used today by the Florida Geological Survey. He raised the Ocala to group rank, with three subdivisions; in ascending order, these are: the Inglis Formation, the Williston Formation, and the Crystal River Formation.

The Ocala Group is known to underlie most of Florida. Statewide, elevations range from greater than 100 feet above MSL in west-central peninsular Florida and the panhandle to over 1,200 feet below sea level in south Florida (Applin and Applin, 1944; Puri, 1957).

In Wakulla County, the Ocala Group lies below the depth attained by water wells. Two deep oil test wells penetrated what are thought to be Ocala Group sediments based on fossil content. Well W-12 encountered a light-tan limestone and brown dolomitic limestone in the depth interval 400 to 580 feet (J. Martin, Fla. Geol. Survey unpublished report, 1949). Well-440 penetrated a chalky and dolomitic limestone from 740 to 917 feet deep (Applin and Applin, 1944). A typical Late Eocene foraminiferal assemblage was present in this interval, including *Operculinoides* cf. *wilcoxi*, *Operculinoides* sp., *Lepidocyclina ocalana*, *Gypsina globula*, and *Camerina* sp. (E. Applin, Fla. Geological Survey in-house report, 1943). It was not possible to differentiate formations in either well.

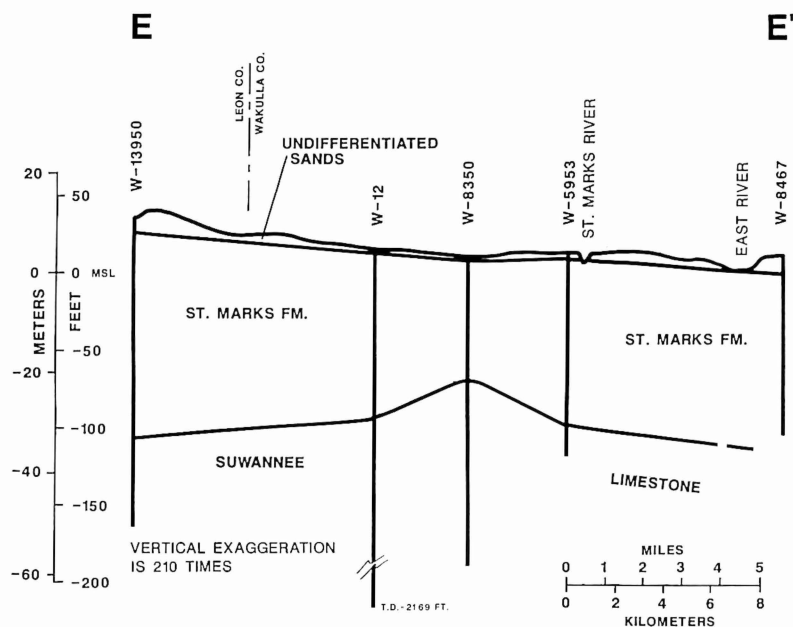


Figure 16. Geologic cross section E-E'.

Oligocene Series Lower Oligocene Suwannee Limestone

Cooke and Mansfield (1936) first proposed the name Suwannee Limestone for the fossiliferous limestones which crop out on the Suwannee River between the towns of White Springs and Ellaville. Vernon (1942) and Cooke (1945) give good nomenclatural histories for this unit, and are recommended as references.

The Suwannee Limestone crops out sporadically in southeast Wakulla County. Yon (1966) shows the Suwannee bordering the Gulf Coast and along a portion of the Wakulla-Jefferson county line. Outcrops are in the form of dolostone and silicified limestone boulders.

Seventeen water wells, two oil wells and two continuous cores have penetrated the Suwannee Limestone in Wakulla County. In well cuttings and cores, the Suwannee Limestone is generally a white to light-tan, cream, or brown recrystallized calcarenitic limestone, frequently dolomitic, and usually fossiliferous. Foraminifera are the most common fossils. A typical assemblage is comprised of *Dictyoconus cookei*, *Rotalia mexicana* var. *mecatepecensis*, *Discorinopsis gunteri*, *Coskinolina floridana*, *Asterigerina* cf. *subacuta*, and *Eponides byramensis*. The conduits of the Wakulla Spring cave system are developed in Suwannee Limestone. Rock samples taken in the Spring cave show the lithology to be a white to pale orange, recrystallized biocalcarene, composed nearly entirely of benthic Foraminifera tests. Figure 17 is a contour map showing the top of the Suwannee Limestone in Wakulla County.

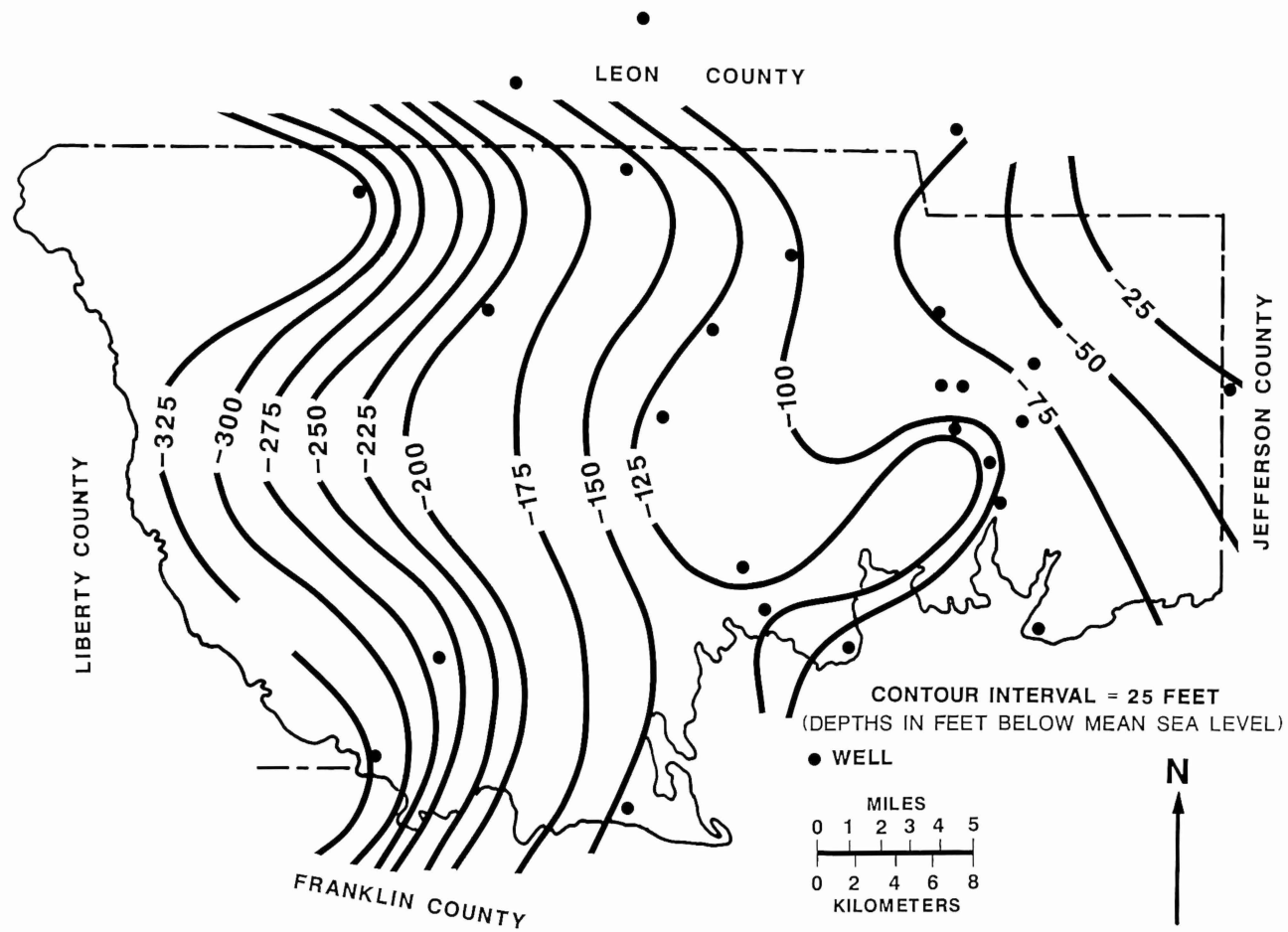


Figure 17. Structure contour map of the top of the Suwannee Limestone.

Miocene Series
Lower Miocene
St. Marks Formation

Johnson (1888) first applied the term Tampa Formation to Lower Miocene sediments cropping out in the vicinity of Tampa, Hillsborough County, Florida. Over the years, many authors have attempted to redefine and divide this unit. Vernon (1942) included all sediments lying above the Suwannee Limestone and below the Alum Bluff Group in the Tampa Formation. Puri (1953) placed all the sediments previously assigned to the Tampa Formation in the Tampa (Aquitanian) Stage, and erected two subdivisions: the St. Marks (Finch, 1823) and Chattahoochee (Langdon, 1899) facies. These facies were raised to formation status by Puri and Vernon (1964).

The Chattahoochee Formation includes the updip, generally silty and clayey facies occurring to the west of Wakulla County. The name St. Marks Formation refers to the calcareous downdip facies (Puri, 1953). The St. Marks Formation underlies nearly all of Wakulla County, and interfingers with the Chattahoochee Formation to the west and northwest. The St. Marks crops out throughout much of eastern Wakulla County, particularly along the southeast coast of the county. Many of the springs and sinks are associated with the St. Marks, and the bulk of the freshwater wells in the county draw from this formation. The type locality for the St. Marks Formation is in a sink known as the "Swirl" located about two miles south of Crawfordville. This section is on private property, and is mostly covered today. The following is the original description of the type section of the St. Marks Formation, taken from Puri and Vernon (1964).

The "Swirl"
Section 13bb, T4S, R2W

Bed Number	Age, Formation and Lithology	Thickness (Feet)
3	Pleistocene and Holocene Soil	10.0
2	Miocene Series, ST. MARKS FORMATION. Pale, argillaceous, rubbly limestone in places indurated marl, with casts of mollusks, <i>Sorites</i> sp. and rounded nodules of limestone.	6.0
1	Hard, yellowish gray, massive limestone with casts and molds of mollusks. Top 6 feet bedded. Weathers to a tan-brown color. Abundant specimens of large <i>Sorites</i> sp.	12.0
Total thickness exposed:		28.0

In Wakulla County, the St. Marks Formation is typically a pale orange to light gray, to white, calcarenitic limestone, generally very fossiliferous, well indurated, and frequently dolomitic. The Foraminifera *Sorites* sp. and *Archaias* sp. are common fossils along with numerous species of mollusks (Mansfield, 1937).

The thickness of the St. Marks Formation varies from zero in southwestern Jefferson County, where it pinches out against the Suwannee Limestone, to over 200 feet in Gulf County to the west. The lithology of the St. Marks Formation becomes indistinguishable from that of the younger

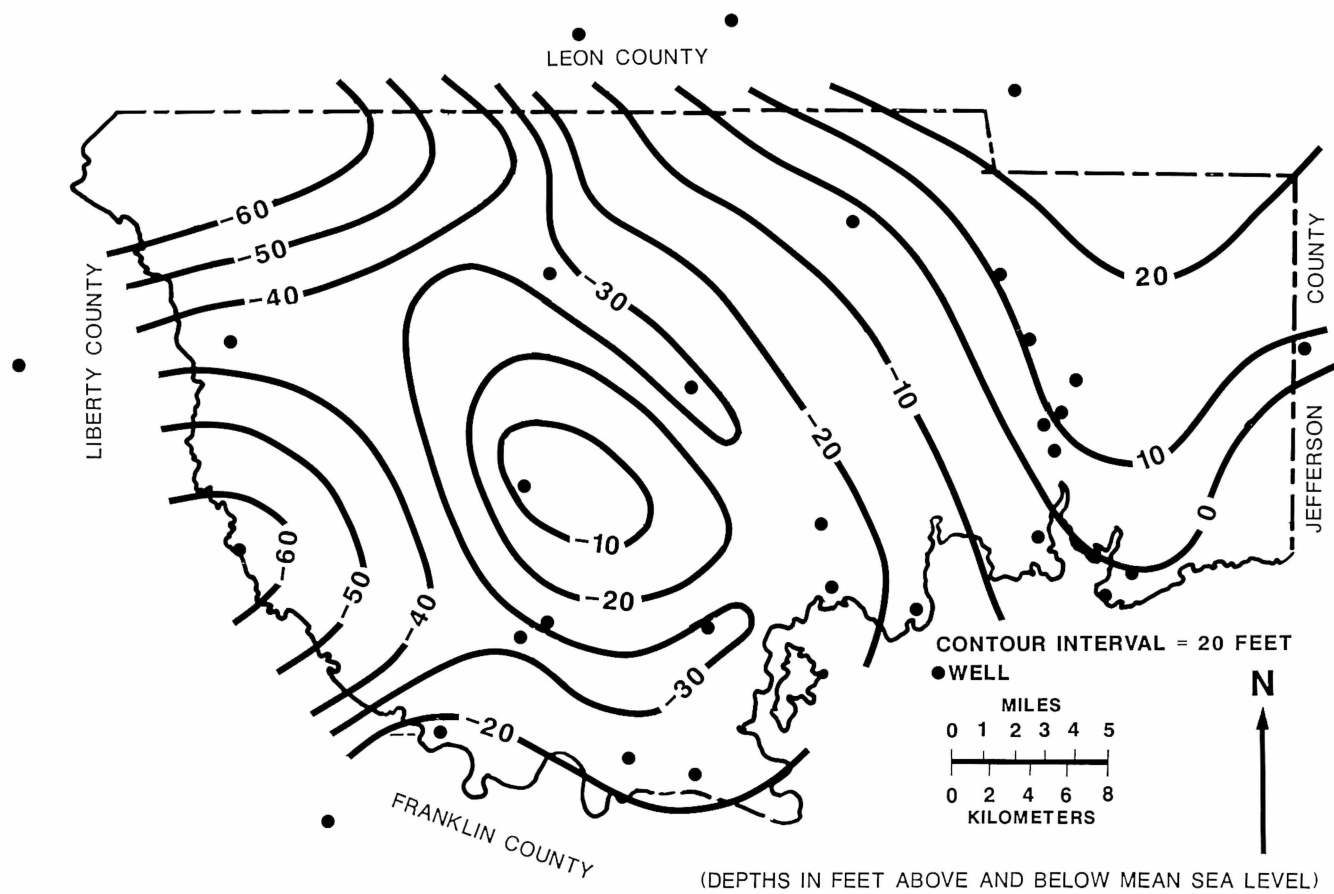


Figure 18. Structure contour map of the top of the St. Marks Formation.

Bruce Creek Limestone west of Wakulla County (Schmidt, 1984). Figure 18 is a contour map of the top of the St. Marks Formation.

Hawthorn Group

The name Hawthorn was first proposed by Dall and Harris (1892) for Middle Miocene sediments exposed near the town of Hawthorne, Alachua County, Florida. An excellent historical review of the numerous redefinitions of these sediments over the years is given by Scott (1988, in press). Huddlestun (in press) has more recently raised the Hawthorn to group status in Georgia. Scott (1988, in press) has extended the formations associated with the Hawthorn in southern Georgia into Florida, and has erected several new formations statewide.

Torrey Formation

Huddlestun and Hunter (1982) informally placed all deposits previously referred to the Hawthorn Formation in the eastern Florida panhandle into the Torrey Formation of the Hawthorn Group. Scott (1988, in press) and Huddlestun (1988, in press) formalized this designation. The type section is located at Rock Bluff, Torrey State Park, in Liberty County, Florida.

The Torrey is characteristically a clastic unit, consisting of very fine-to-medium-grained, clayey sands to sandy, silty clays, and frequently containing variable amounts of limestone, dolomite and minor amounts of phosphate pellets. Carbonate content increases in the basal portion of the unit. Huddlestun and Hunter (1982) consider the Sopchoppy Limestone of Dall and Harris (1892) to be a member of the Torrey Formation.

Although little is known of the areal extent of the Torrey Formation in Wakulla County it probably underlies much of western Wakulla County. Core W-16053 (see Figure 19), taken in the Apalachicola National Forest near Hilliardville, penetrated 23 feet of Torrey Formation sediments. The Sopchoppy Member crops out sporadically along the Sopchoppy River in western Wakulla County, and Banks and Hunter (1973) note its presence in an abandoned quarry south of Crawfordville. In a series of water well cross-sections, Pascale and Wagner (1982) indicate undifferentiated Hawthorn sediments under nearly all of western Wakulla County, pinching out in the vicinities of Crawfordville and Panacea. Further coring will be necessary to accurately delineate the extent of the Torrey in the Wakulla County area.

Middle Miocene Bruce Creek Limestone

The Bruce Creek limestone is a Middle Miocene age limestone named by Huddlestun (1976) in Walton County. Schmidt (1984) describes it from a core in easternmost Franklin County, showing its probable up-dip limit in western Wakulla County. In wells to the west of Wakulla County, the Bruce Creek is typically a white to light yellow-gray, moderately indurated, calcarenitic and quartz sandy, highly fossiliferous limestone. It is often difficult to distinguish from the St. Marks Formation. Schmidt (1984) places its easternmost limit at the eastern edge of the Apalachicola Embayment, but the extent to which it underlies Wakulla County is yet to be determined.

Intracoastal Formation

Huddlestun (1976) first described the Intracoastal Formation as a soft, sandy limestone of Pliocene age underlying the coastal area of western Florida. Schmidt and Clark (1980) later established a Middle Miocene to Late Pliocene age for this formation based on planktonic Foraminifera. Clark and Schmidt (1982) mapped the Intracoastal as far east as easternmost Franklin and Liberty Counties, and Schmidt (1984) shows its up-dip limit occurring in western-

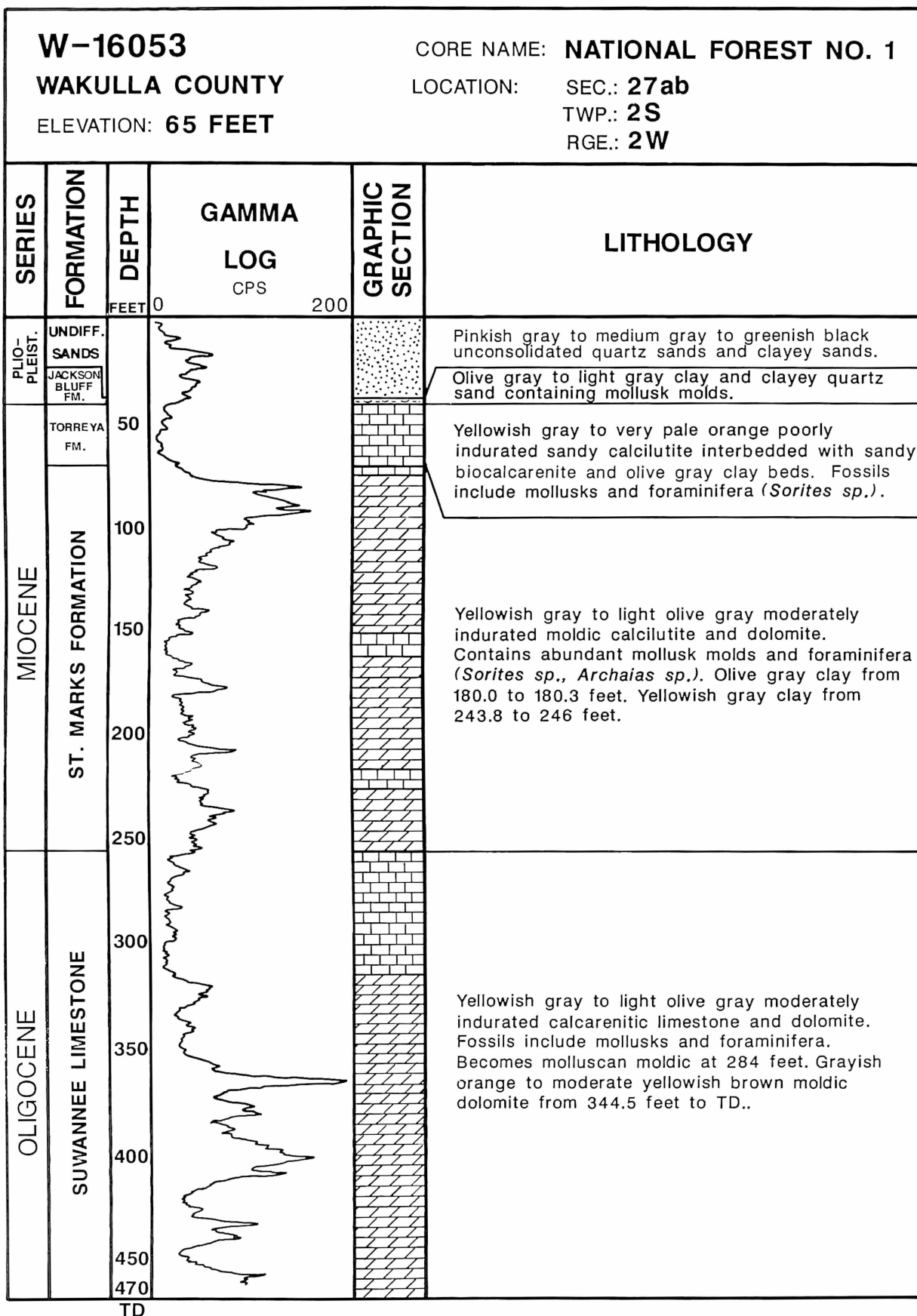


Figure 19. Columnar section, W-16053, National Forest No. 1 Core.

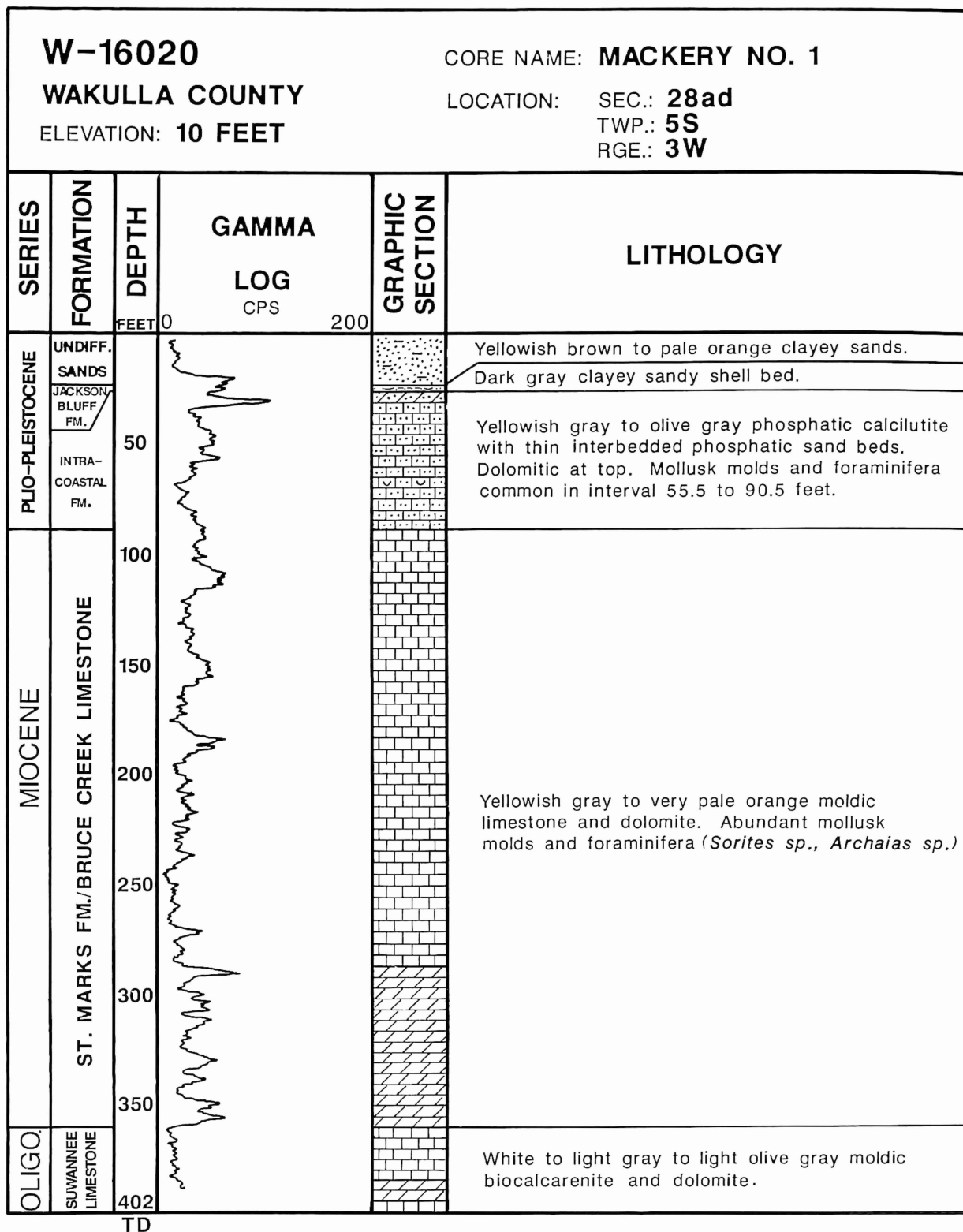


Figure 20. Columnar section, W-16020, Mackery No. 1 Core.

most Wakulla County. Throughout its areal extent, the Intracoastal is a very sandy, highly microfossiliferous, poorly-consolidated limestone; it is generally argillaceous, micritic, and phosphatic (Schmidt and Clark, 1980). Core W-16020 (see Figure 20) penetrated 64.5 feet of yellowish-gray phosphatic calcilutite and interbedded phosphatic sand beds, herein placed in the Intracoastal Formation. Further coring will be necessary to delineate its pinchout in western Wakulla County.

Pliocene Series
Upper Pliocene
Jackson Bluff Formation

Puri and Vernon (1964) combined the Upper Miocene age *Ecphora* and *Cancellaria* mollusk facies of Puri (1953) into the Jackson Bluff Formation, named after Jackson Bluff on the Ochlockonee River in western Leon County. Stratigraphically, Puri and Vernon (1964) placed the Jackson Bluff Formation above the Middle Miocene age sediments, and below the Miccosukee Formation and younger deposits. Akers (1972) reassigned the Jackson Bluff Formation to the Upper Pliocene based on planktonic Foraminifera and calcareous nannofossils.

The areal extent of the Jackson Bluff is not well defined in Wakulla County. Hendry and Sproul (1966) mapped the Jackson Bluff as extending roughly south from Lake Talquin to where State Road 267 crossed the Leon/Wakulla county line, and westward to the Ochlockonee River. More recently Cameron and Mory (1977) recorded Jackson Bluff deposits in auger samples from the western half of the Bradwell Bay Wilderness area in western Wakulla County. These samples were recovered from a depth of approximately 20 feet, and lithologically were composed of a sandy, light orange, cream, and very light gray or off-white marl. Fragments of the marine mollusk genera *Pecten* and *Cancellaria* were present in the cuttings. Core W-16020 (see Figure 20) in southwestern Wakulla County penetrated 2.2 feet of light gray mollusk-rich clayey sands, considered to represent the southernmost occurrence of Jackson Bluff recorded in Wakulla County.

Pleistocene and Holocene Series

Pleistocene and Holocene undifferentiated quartz sands, silts, and clays comprise the undifferentiated surficial sediments of Wakulla County (Schmidt, 1979). Most Pleistocene sediments are marine terrace deposits, lying unconformably on older formations.

In eastern Wakulla County, the St. Marks Formation and Suwannee Limestone are overlain by a veneer of fine, unconsolidated sands and clays, generally less than 20-feet thick. West of Crawfordville, these sediments thicken to as much as 100 feet and may lie directly on the Jackson Bluff Formation, Hawthorn Group, or St. Marks Formation. Holocene alluvial and aeolian deposits are predominantly fine quartz sand, and are difficult to differentiate from Pleistocene sediments.

STRUCTURE

The subsurface structure of Wakulla County has been influenced by several regional structural features. Figure 21 illustrates the location and orientation of these features.

Peninsular Arch

The Peninsular Arch forms the axis of peninsular Florida (Applin, 1951). It is a southeast-trending structural high in pre-Mesozoic sediments. Although no direct structural relationships are known to exist between the arch and the Tertiary sediments of Wakulla County, the downwarped western flank of the Peninsular Arch extends beneath the Big Bend area (Hendry and Sproul, 1966).

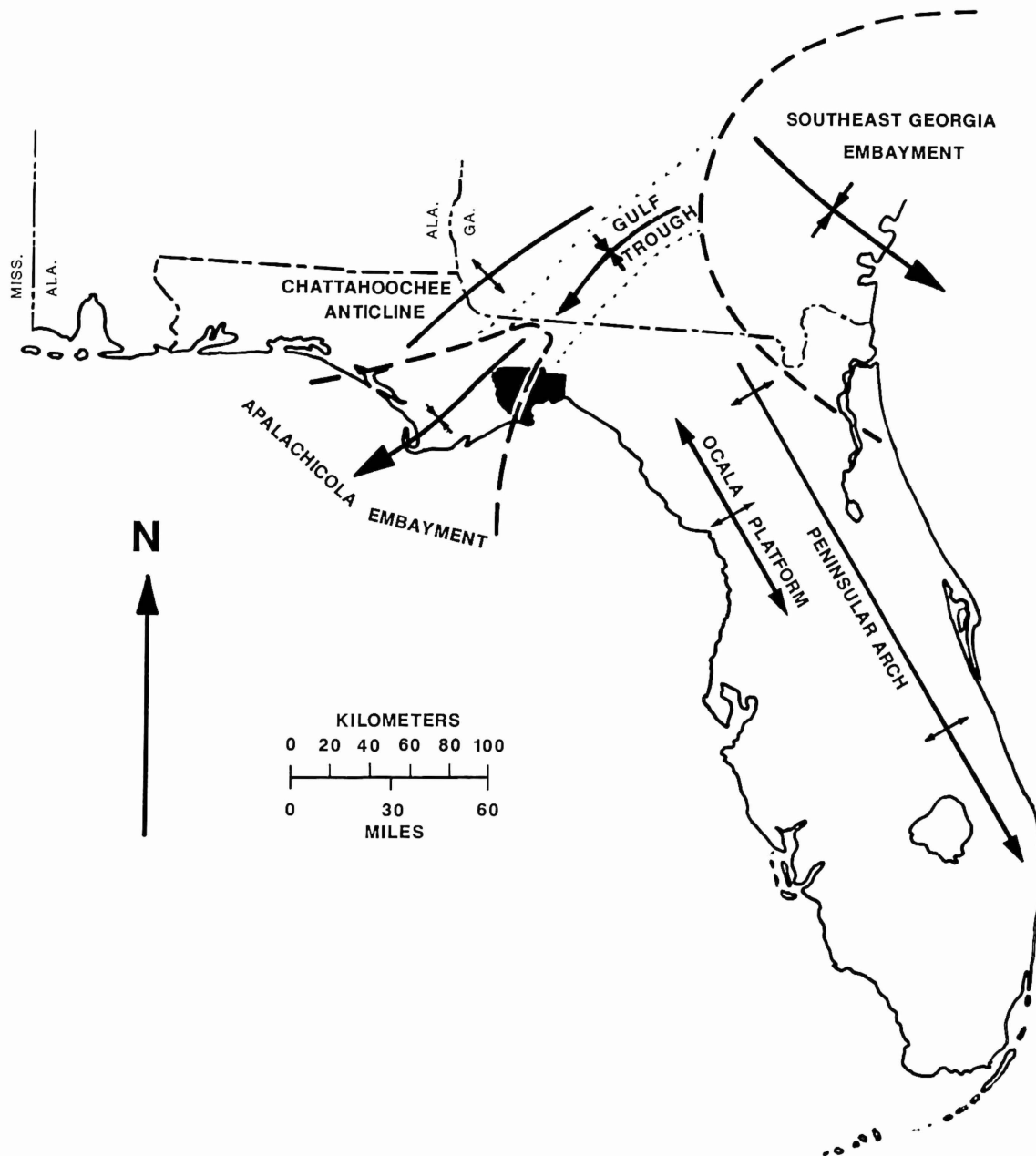


Figure 21. Principal subsurface structures of north Florida (modified from Puri and Vernon, 1964, and Schmidt, 1984).

Apalachicola Embayment

Wakulla County is situated along the eastern edge of a broad sedimentary basin known as the Apalachicola Embayment. Pressler (1947) estimated its size as approximately 30,000 square miles. Schmidt (1984) provides an excellent interpretive and nomenclatural history of this feature. Oil test wells have shown the sediment fill of the basin to be about 13,000 feet of Triassic to Holocene-age deposits, all resting on Paleozoic-age metamorphic rocks (Applegate et al., 1978; Schmidt and Clark, 1980).

Chattahoochee Anticline

North and northwest of the Apalachicola Embayment is a minor structural high called the Chattahoochee Anticline (Veach and Stephenson, 1911; Puri and Vernon, 1964). This structure is an elongate anticline trending northeast-southwest. Oligocene and Eocene rocks are exposed at the surface in the vicinity of the crest. Younger sediments pinch out or are truncated against it (Schmidt, 1984).

Gulf Trough

Wakulla County lies in a transitional area between the carbonate-evaporite facies to the southeast and the terrigenous clastic facies to the north and west. Dall and Harris (1892) proposed the existence of a channel-like area of erosion separating the continental border from the Eocene and Miocene islands of the Florida peninsula. Later authors, including Veach and Stephenson (1911), Applin and Applin (1944), Pressler (1947) and Jordan (1954) recognized a structural channel or trough, possibly a graben, in older sediments extending from southeast Georgia southwestward to the Big Bend area. Schmidt (1984) gives a good structural history of this feature. During Late Cretaceous through Oligocene time, this elongate structure connected the Southeast Georgia Embayment with the Apalachicola Embayment (Pressler, 1947). Structure maps on different stratigraphic horizons indicate the axis of the trough migrated over time. In the Late Mesozoic, the trough axis moved southeastward to the vicinity of western Taylor and Madison Counties; the direction reversed in the Early Tertiary and the trough moved northwestward to the present Gadsden/Liberty County area (Schmidt, 1984). Throughout its existence as an open connection between the embayments, the trough was an area of non-deposition. Chen (1965) believed that strong, scouring water currents in the trough formed both a lithologic and biologic facies barrier during almost the entire Paleocene through Eocene time. Although its influence as a sediment barrier apparently waned by the end of the Oligocene, wells drilled in Oligocene and younger sediments over the trough show a sediment thickening which may be related to post-Eocene downwarping in the trough (Hendry and Sproul, 1966) or simply infilling of the topographically low feature.

The Ocala Platform

The Ocala Platform (Scott, 1988 in press) is a gentle, post-Oligocene flexure in west-central peninsular Florida. This structural high has an axis parallel to that of the Peninsular Arch, but the two features are unrelated (Applin, 1951). The platform exposes the Ocala Group and Avon Park Formation near its crest; younger sediments truncate against the flanks of the structure (Applin, 1951).

GROUNDWATER

Groundwater is water that fills the pores and interstitial spaces in the rocks and sediments beneath the surface of the earth. Most of Wakulla County's groundwater is derived from precipitation within the county and in neighboring counties (Hendry and Sproul, 1966). A portion of the precipitation leaves the area by surface runoff in stream flow or by evaporation and transpiration. The remainder soaks into the ground and moves downward into the porous zone of saturation. The top of the zone of saturation is known as the water table. Once in the zone of saturation, the water moves under the influence of gravity towards discharge points such as wells, springs, or the Gulf of Mexico. Some of the water seeps into the deeper aquifer units. Water remaining in the shallow sand and clay units above the St. Marks Formation is free to rise and fall, and is referred to as unconfined water. This unconfined water comprises the surficial aquifer system, and is not

used extensively for public consumption (Pascale and Wagner, 1982). Water which becomes confined under pressure between formations of low permeability is not free to rise and fall, and is called artesian water. In Wakulla County, artesian water occurs in the Floridan aquifer system, which provides the bulk of the water for drinking and other consumptive uses.

The Floridan aquifer system

The name Floridan Aquifer was proposed by Parker et al. (1955) for the artesian aquifer including all or parts of formations from Middle Eocene age to Middle Miocene age. The Florida Geological Survey has adopted the name Floridan aquifer system for this unit (Southeastern Geological Society Ad Hoc Committee, 1986). In most of Wakulla County, the St. Marks Formation comprises the upper portion of the Floridan aquifer system. Basal Hawthorn Group limestones may comprise the intermediate confining unit in areas of western Wakulla County (Pascale and Wagner, 1982). Most public supply wells draw from the St. Marks Formation at depths ranging from 25 to 150 feet below land surface. The Suwannee Limestone, the Ocala Group, and the Avon Park Formation comprise the lower units of the Floridan aquifer system in north Florida (Pascale and Wagner, 1982).

The Floridan aquifer system is recharged by downward leakage from the surficial aquifer system, by direct recharge via lakes and sinks, and directly through porous sands. In the Big Bend area, the Floridan receives much of its direct recharge from southern Georgia, central Leon County, and northeastern Wakulla County where porous sands overlie the aquifer (Hendry and Sproul, 1966; Pascale and Wagner, 1982).

Potentiometric Surface

Water confined within an artesian aquifer is generally under a pressure greater than atmospheric, resulting in a positive static head. The height to which water rises in tightly-cased wells penetrating an artesian aquifer forms an imaginary surface called the potentiometric surface. If the land elevation of a well is below the level of the potentiometric surface, the well will flow.

Figure 22 shows the potentiometric surface contours for the upper Floridan aquifer system in Wakulla County. The potentiometric surface varies from sea level along the coast and in eastern Wakulla County to nearly 60 feet above MSL in the extreme northwest corner of the county. Regional water flow in the aquifer is generally perpendicular to the contours, in this case, to the southeast. Porous sands in northeastern Wakulla County provide high recharge to the Floridan aquifer system, while the thick sand and clay sequences in the northwestern portion of the county provide only low to moderate recharge (Stewart, 1980).

MINERAL RESOURCES

Introduction

The following discussion is intended to provide a general overview of the near-surface mineral commodities and petroleum resources of Wakulla County. Data for each mineral resource is taken primarily from recent works by Cameron and Mory (1977), Schmidt et al. (1979), and Patterson et al. (1986). A brief discussion of the future commodity potential for each mineral resource follows.

Clay

In Gadsden County, Florida, and neighboring south Georgia counties, large deposits of fuller's earth belonging to the Miocene age Hawthorn Group are presently being mined. Calver (1957)

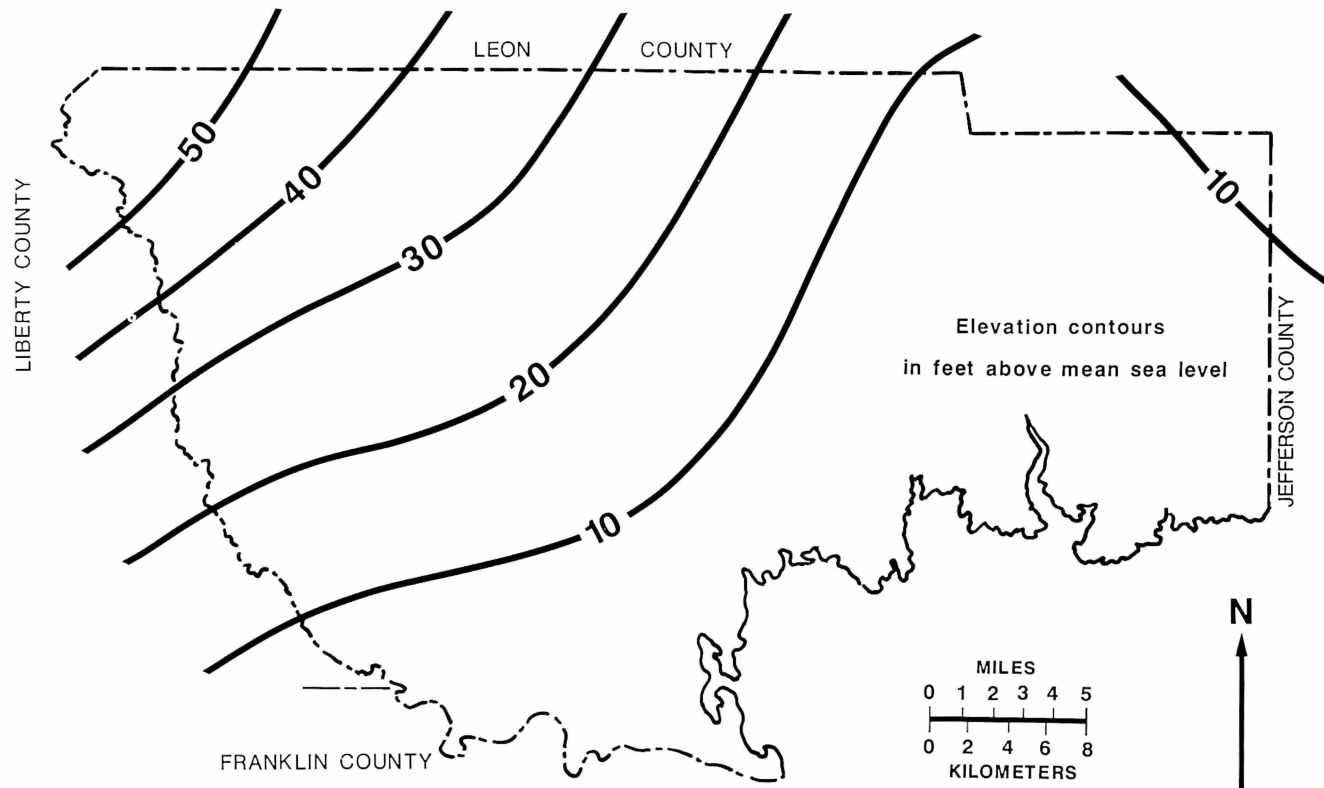


Figure 22. Potentiometric surface map of the Floridan aquifer system in Wakulla County (from Barr, 1987).

reported that palygorskite (attapulgitite) has been mined there since 1895. The fuller's earth region is approximately 30 to 40 miles northwest of Wakulla County, Florida.

Sellards (1917) states that fuller's earth is present in southwestern Leon and northwestern Wakulla Counties. Cameron and Mory (1977), in a study of the mineral resources of the Bradwell Bay region, found clays in two drill holes along the Sopchoppy River. They reported that clays from the two holes have poor absorption qualities and have little potential in brick making.

Significantly more sampling and testing would be needed if a commercial clay operation were to be considered. However, the potential for producing this high volume, low value commodity in Wakulla County is considered low due to its limited extent and lack of nearby market.

Limestone

Oligocene and Miocene age limestone (CaCO_3) is present at depths of generally less than 20 feet in eastern Wakulla County. Schmidt et al. (1979) include this limestone in the Suwannee and St. Marks Formations. West of Crawfordville, the limestone dips in a westward direction, and topographic elevations increase due to a significant thickening of siliciclastic overburden deposits. Generally, depth to limestone in western-most Wakulla County may exceed 100 feet; however, along the Sopchoppy River and Mill creek, limestone is in the near-surface sediments. Depths of limestone and its presence within the confines of the National Forest might preclude it from future mining.

Two inactive limestone quarries are present in Wakulla County. They are the Strickland Quarry (section 4, Township 3S, Range 1W) along County Highway 267 and the Taft Pit (section 12, Township 4S, Range 2W) just south of Crawfordville. The Strickland Quarry, located on a 52-acre site, produced limestone from the St. Marks Formation. The Taft Pit operated from the mid-1960's to early-1970's and encompassed approximately 20 acres. Limestones mined from both quarries were used as road base. Data on the limestone taken from the Taft Pit are not available. The former owner of the Strickland Quarry reported that the limestone was generally not well indurated and therefore it did not meet federal specifications. A calcareous clayey sand material belonging to the Torreya Formation was extracted from the Taft Pit and used for road base and road shoulders.

Limestone mining in Wakulla County was by the open pit method. This method utilized bulldozers to remove the overburden and extract the limestone. Typically, in Florida, if the limestone is indurated to the point that it is not easily removed by mechanical means, blasting is used to fracture the rock. Large trucks then transport the material to a site where processing, in the form of crushing and screening occurs. Beneficiation processes, those which upgrade the material by removing impurities and adding desirable materials to form a finished marketable product (Schmidt et al., 1979), may be required.

Sand

During the course of this study five sand samples were collected from two different localities. They were described and analyzed using the following methodology to determine the usefulness as a commodity and to better understand the geology of the deposit. Samples were repeatedly put through a riffle splitter until a 100-gram sample was obtained. The sample was treated with hydrogen peroxide to remove organic material, rotapped and weighed. Data from the sieve analyses (Table 2) represent one set of samples and not the entire deposit. However, information derived from Table 2 may aid the reader in determining the general usefulness of the particular deposit for commercial purposes.

The Florida Department of Transportation, Standard Specifications for Road and Bridge Construction (1986) gives requirements for sieve analysis in percent retained and percent passing each sieve as a guide in determining usefulness of the commodity. Data from Table 2 indicate

that some sand samples may be suitable for brick masonry, sand-asphalt hot mix, and as a sand seal coat while others are not. No tests were performed to determine if the sands in the county were suitable as glass sand.

Cameron and Mory (1977) analyzed 27 sediments samples from the Bradwell Bay Area of western Wakulla County for potential sand use. These authors determined that the sands were not suitable for mortar, masonry or use as glass sands.

Phosphate

In Wakulla County, minor amounts of phosphate are present in sediments ranging in age from Miocene to Holocene. The phosphate grains range in size from fine to very coarse and are variably colored black to tan to white. It is most probable that the phosphate in post-Miocene sediments is from reworking of older Miocene sediments. In the Bradwell Bay area Cameron and Mory (1977) report phosphate grains and phosphatized mollusk shells in post-Miocene sediments; however, the volume is insufficient and therefore, the potential for phosphate as an economic commodity is low. In a more recent study, Patterson et al. (1986) state that the Big Bend region, which includes Wakulla County, has no valuable phosphate deposits and support this conclusion by referencing phosphate exploration programs of two companies. These two companies drilled 124 bore holes in the western Wakulla County and the southern Leon County areas. Although several bore hole sites contained sediments with phosphate, the P_2O_5 contents of the richest sample was only 5.45 percent, at a depth of greater than 80 feet (Patterson et al., 1986). Current phosphate mining technology requires a minimum P_2O_5 content of 28 percent (Cathcart and Patterson, 1983). On the basis of the cited literature and from sediments observed in this study it is concluded that commercial phosphate production from Wakulla County has low potential.

Table 2. Screen Analyses of Sand in Wakulla County, Florida.

Deposits			Laboratory Test Data Screen Analysis Sieve No. and Cumulative Weight Percent Retained							
Sample No.	Location	Method of Sampling	4	8	16	30	50	100	200	Fineness Modulus *
Wa-1	Section 91, T4S, R1W	Spot	0.827	3.694	21.420	43.367	69.974	94.873	99.655	3.34
Wa-2	Section 91, T4S, R1W	Spot	---	---	0.682	6.630	22.304	86.139	99.230	2.15
Wa-3a	Section 12 T4S, R2W	Channel	---	---	2.275	23.985	64.379	89.942	99.100	2.85
Wa-3b	Section 12 T4S, R2W	Channel	---	0.612	7.757	31.351	68.003	90.212	97.458	2.95
Wa-3c	Section 12 T4S, R2W	Channel	---	0.308	4.265	22.080	57.686	85.115	97.141	2.67

* Fineness Modulus: a means of evaluating sand and gravel deposits which consists of sieving samples through a standardized set of sieves, adding the cumulative weight percentages of the individual screens, dividing by 100, and comparing the resultant fineness modulus number to various specification requirements (Bates and Jackson, 1980, p. 230).

Peat

Information cited in this section is largely compiled from United States Geological Survey Bulletin No. 1431 (Cameron and Mory, 1977) and the Florida Geological Survey Special Publication No. 27 (Bond et al., 1986). In general, peat deposits form in a wet, reducing environment when accumulation of organic materials (vegetation) exceeds the decomposition rate of that material (Bond et al., 1986). Cameron and Mory (1977) reported that the dominant vegetation types in Bradwell Bay area of Wakulla County are pine-palmetto flatwood, bay swamp, and titi swamp. They further state that bay swamps, populated largely by sweetbay (*Magnolia virginiana*), are the most favorable areas for peat accumulation. Peats and peat mosses in the bay swamps of this region may reach four feet in thickness (Cameron and Mory, 1977). Sediments immediately underlying the peat consist of organic-rich sands.

Areas adjacent to and including Wakulla County may have minor accumulations of peat. Most peat deposits in Wakulla County lie within, but are not limited to, the Apalachicola National Forest. Therefore, special problems inherent to mining in a national forest, particularly those involving environmental concerns, and the thin nature of these deposits tend to preclude them from future mining.

If peat mining is to occur in Wakulla County, it will require extensive clearing and dewatering of the site. Draglines and bulldozers would be necessary to remove the material and stockpile it for drying and shredding. The primary use for the peat would be horticultural.

Heavy Minerals

Nearly all of Florida is covered by a surface layer of sand. Heavy minerals comprise a very minor portion of the Florida sands (generally less than one percent). When concentrations of heavy minerals comprise from three to five percent of the total volume of a sand deposit, commercial mining ventures become an economic possibility. Presently in Florida, the mining of heavy minerals is restricted to the Trail Ridge and Green Cove Springs area of northeast Florida. Discussions of the northeast Florida deposits are presented by Pirkle et al. (1974, 1977).

In the Wakulla County area, Revell (1957) and Larsen (1958) compiled data from several auger sites to determine the heavy mineral potential. Data from these reports indicate there are no economic deposits of heavy minerals in the study area.

Petroleum

A total of four oil test wells have been drilled in Wakulla County to date. The maximum depth penetrated occurred in the Placid Oil No. 1 USA (W-12114, section 27da, Township 2S, Range 3W) which reached a depth of 12,242 feet below land surface before it was plugged and abandoned as a dry hole. None of the test wells encountered oil or gas. Data suggest that the potential for oil in Wakulla County is minimal due to its position updip of the Jurassic-age Smackover Formation pinchout (Applegate et al., 1978). Geophysical crews continue to perform occasional reconnaissance in the Wakulla County vicinity. The implication of such work is that interest in the Apalachicola Embayment has not totally waned during recent years.

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