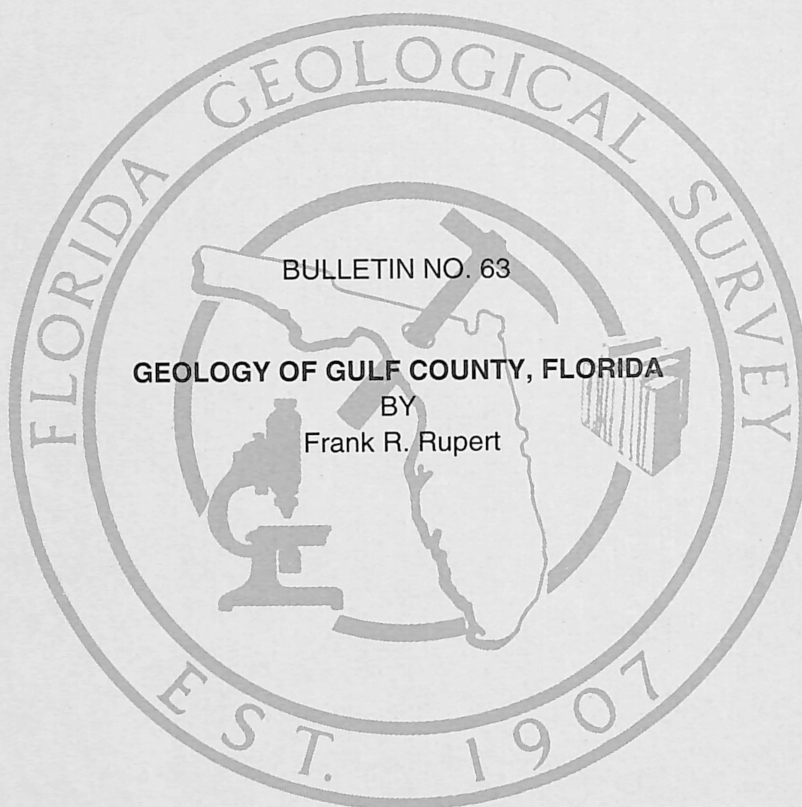


STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Tom Gardner, *Executive Director*

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

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist and Chief*



BULLETIN NO. 63
GEOLOGY OF GULF COUNTY, FLORIDA
BY
Frank R. Rupert

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



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LETTER OF TRANSMITTAL



Florida Geological Survey
1991

Governor Lawton Chiles, Chairman
Florida Department of Natural Resources
Tallahassee, Florida 32301

Dear Governor Chiles:

The Florida Geological Survey, Division of Resource Management, Department of Natural Resources, is publishing as its Bulletin No. 63, *Geology of Gulf County, Florida*, prepared by Frank R. Rupert, P.G. This report fulfills a need for information on the stratigraphy of Gulf County, which is fundamental to ground-water resource investigations and land use planning. Information on the hydrogeology and 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
1991

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GEOLOGY OF GULF COUNTY, FLORIDA

by

Frank R. Rupert, P.G. No. 149

INTRODUCTION AND 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 counties in an attempt to fill this information void. The purpose of this report is to present a general overview of the geology and mineral resources of Gulf County based on existing literature and well data on file at the Florida Geological Survey.

LOCATION AND EXTENT

Gulf County was established in 1925 from what was formerly the southern portion of Calhoun County. It is situated on the Gulf coast of the central Florida panhandle (Figure 1). Gulf County is bounded on the west by Bay County, St. Joseph Bay, and the Gulf of Mexico, on the east by Liberty and Franklin Counties, and on the south by the Gulf of Mexico. The county is irregular in shape, spanning 22 miles at its widest east-west dimension, and is approximately 38 miles north-to-south. The total area is 578 square miles. Population in 1988 was estimated to be 12,200 (Smith and Bayya, 1989).

PREVIOUS INVESTIGATIONS

A number of authors have referred to the geology, geomorphology, and paleontology of Gulf County and the adjacent Gulf coastal panhandle

area. Only those studies directly concerned with the geology of Gulf County are mentioned in the following discussion. Specific works are also referenced under the applicable sections in the text.

The earliest studies included brief discussions of the geology and geomorphology of Gulf County (then southern Calhoun County) in the early Annual Reports of the Florida Geological Survey (Sellards and Gunter, 1918; Sellards and Gunter, 1922). Martens (1928a) discussed the sand and gravel deposits of Gulf County. The same year, Martens (1928b) studied the heavy mineral sands on Cape San Blas and St. Joseph Spit. The Gulf County area was included in the statewide report on the geology of Florida by Cooke and Mossom (1929). Martens (1931) described the beaches of St. Joseph Spit in his work on the beaches of Florida. Cole (1938) examined a Gulf County oil test well as part of a biostratigraphic study, and Applin and Applin (1944) included the Gulf County area in a regional paleontologic and stratigraphic paper. In his statewide report on the geology of Florida, Cooke (1945) discussed the Pleistocene surficial sands of Gulf County. Toler and Shampine (1962) and Musgrove et al. (1965; 1968) covered western Gulf County in a series of Floridan aquifer system studies of the Econfinia Creek Basin. Stewart (1962) investigated the Recent sedimentary history of St. Joseph Bay as a graduate thesis. The Gulf County area of the panhandle was also included in the statewide summary of the geology of Florida by Puri and Vernon (1964). Chen (1965) studied three Gulf County oil wells in his regional lithostratigraphic analysis of Paleocene and Eocene rocks. Schnable and Goodell (1968) described the stratigraphy and evolution of Cape San Blas. A Bouguer Anomaly map of the western Florida panhandle, including Gulf County, was produced by Chaki and Oglesby (1972). Stapor (1973a) included samples from Gulf County in his granulometric and compositional

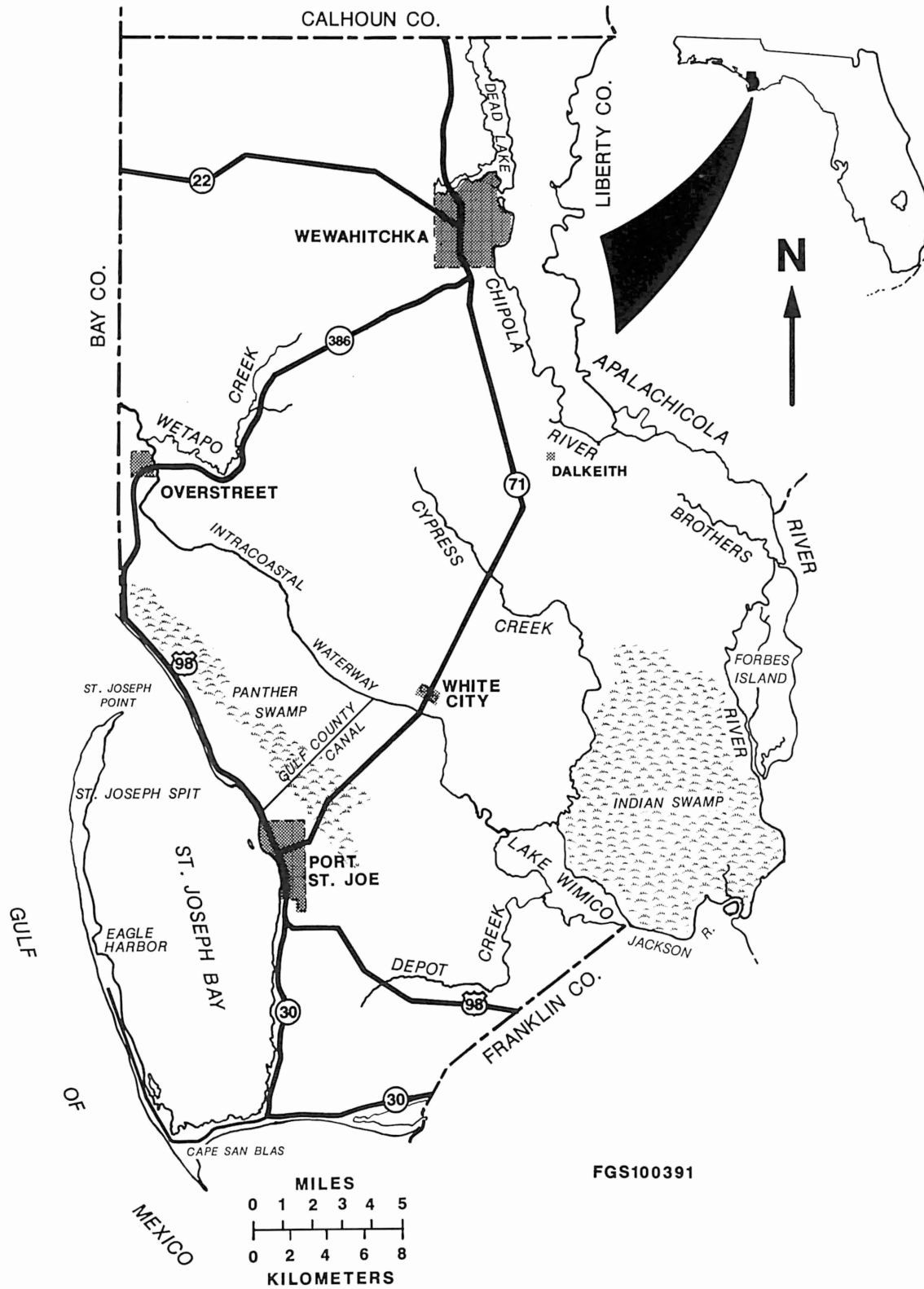


Figure 1. Gulf County location map.

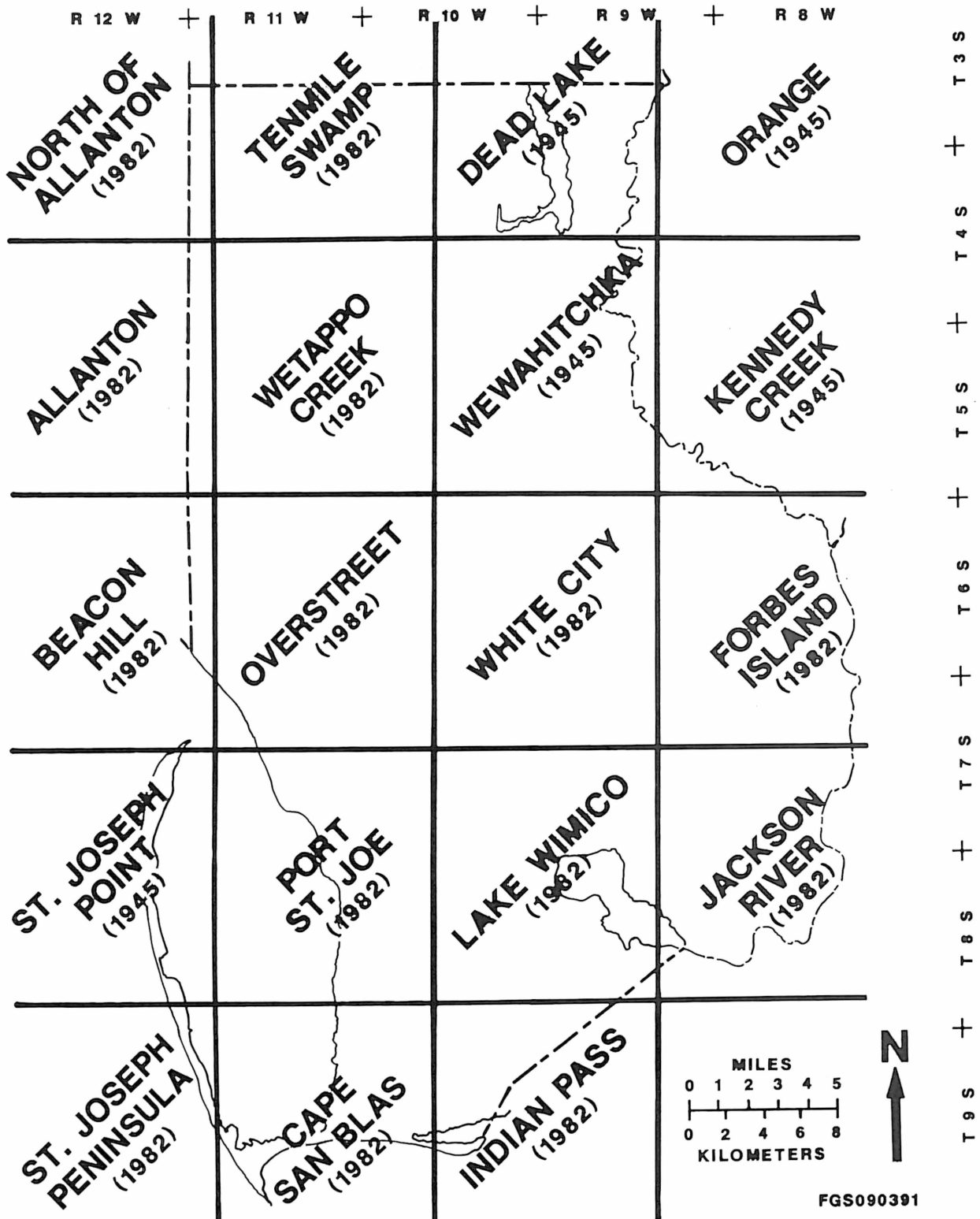


Figure 2. Index to U.S. Geological Survey 7.5 minute topographic quadrangle map coverage of Gulf County.

study of heavy minerals in the Apalachicola region. Von Drehle (1973) investigated the sedimentology and origin of the linear sand bodies in the Gulf County Canal, and Stapor (1973b) analyzed the sand budgets for St. Joseph Spit and Cape San Blas. Pascale (1975) included Gulf County on a map showing estimated freshwater aquifer yields statewide. Barnett (1975) discussed the basement rocks encountered in three deep Gulf County oil test wells. Huddlestun (1976; 1984) utilized Gulf County cores in his stratigraphic study of the central Florida panhandle. Rosenau et al. (1977) briefly discussed Dalkieth Springs in Gulf County in their report on the springs of Florida. In a report on the Jurassic oil potential in the Florida panhandle, Applegate et al. (1978) included four Gulf County oil test wells. Schmidt (1978, 1979) addressed the surficial geology of Gulf County in a pair of environmental geology maps. Barr and Pratt (1981) reported on Floridan aquifer system drawdown tests performed in northern Gulf County. As her Master's thesis, Bolling (1982) provided a comprehensive study of the Neogene stratigraphy of Gulf County. Schmidt et al. (1982) reported on the Neogene carbonates in the Florida panhandle and included a stratigraphic cross section through Gulf County. Schmidt (1984) also included five geologic cross-sections covering portions of Gulf County. Wuchang (1985) investigated the sedimentological character of beach ridges along the mainland coast of Gulf County, and Barr (1987) included Gulf County on a potentiometric surface map of the Florida panhandle.

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 Gulf County. County base maps were derived from the Florida Department of Transportation General Highway Map for Gulf County.

WELL AND LOCALITY NUMBERING SYSTEM

The well numbering system used in this study is that of the Florida Geological Survey (FGS) well filing system. Each well is identified by a "W", a dash, and a one-to-five digit accession number unique to the 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 squares are also assigned Range numbers both east and west of the Principal Meridian, a north-south 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 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

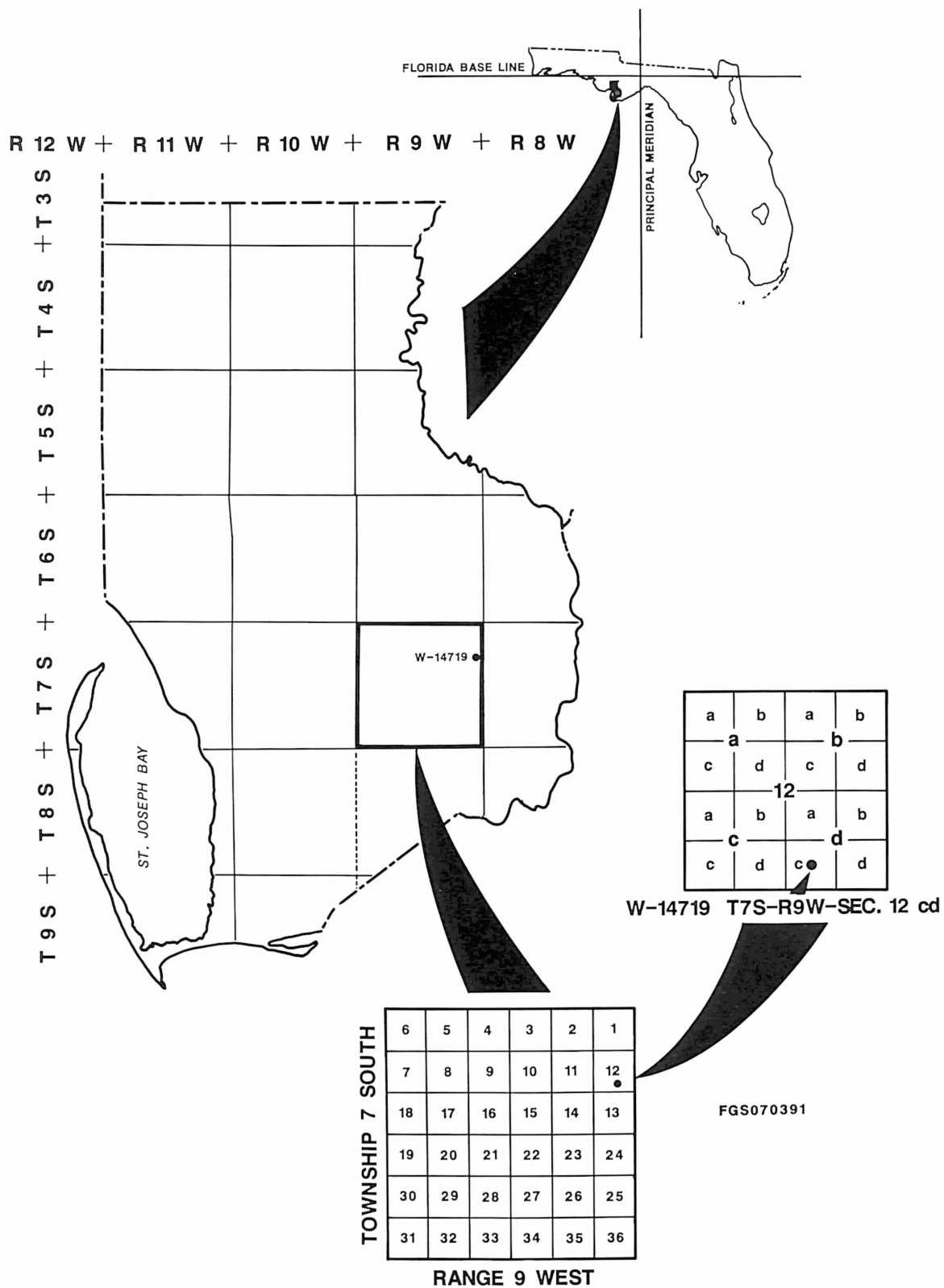


Figure 3. Well and locality numbering system.

report, the following conversion factors are provided:

MULTIPLY	BY	TO OBTAIN
feet	0.3048	meters
inches	2.540	centimeters
inches	0.0254	meters
miles	1.609	kilometers
sq. miles	2.590	sq. kilometers
tons	2.205	metric tons

GEOLOGY GEOMORPHOLOGY

Gulf County lies within the Gulf Coastal Lowlands geomorphic province (Puri and Vernon, 1964). This province is characterized by generally flat, sandy terrain and extends from the coast inland to middle Calhoun County, with its northern limit at approximately 100 feet above mean sea level (MSL). The inset map on Figure 4 shows the extent of the lowlands in the panhandle. The modern Gulf coastline consists of well-developed quartz sand beaches and spits, occasionally interrupted by marshy inlets and coves. Inland, the terrain is comprised of relict marine terrace deposits, sand dunes, ridges, bars, and river delta deposits populated largely by poorly- drained pine flatwoods and swamps.

The Apalachicola River is the largest river in Gulf County, forming the northern two-thirds of the eastern county boundary (Figure 1). Most smaller streams within the county are tributaries to the Apalachicola River. These include the Chipola, Brothers, and Jackson Rivers. The Chipola River flows southward out of Dead Lake in a meandering course through the low, swampy floodplain southeast of Wewahitchka; it empties into the Apalachicola River east of Dalkeith. The Brothers River originates in eastern Gulf County, flowing southeastward, then southward to converge with the Apalachicola River east of Indian Swamp. Forbes Island, a low swampy area dissected by numerous creeks and sloughs, is formed between the courses of the Brothers and

Apalachicola Rivers. The Jackson River meanders southeastward out of Lake Wimico, and comprises a leg of the Intercoastal Waterway between Gulf and Franklin Counties.

Marine Terraces

Superimposed on the flat terrain of the Gulf Coastal Lowlands are a series of relict marine beach ridges, bars, spits, dune fields, and low marine terraces. These terraces are step-like surfaces representing near-shore depositional plains developed during former shoreline positions of high-standing Pleistocene Epoch seas. Healy (1975) recognized four marine terrace levels in Gulf County based on topographic elevation. In order of descending elevation, these are the Penholoway, Talbot, Pamlico, and Silver Bluff terrace zones. Figure 4 shows the extent of the elevation zone assigned to each terrace in Gulf County.

The Penholoway is an east-west trending terrace lying between 42 and 70 feet above MSL elevation. It spans the northwestern edge of Gulf County in a five-mile wide band, with the easternmost end truncated by Dead Lake and the flood plain of the Apalachicola River.

The Talbot terrace lies between 25 and 42 feet above MSL. It trends eastward across north-central Gulf County in a variable 3 to 7-mile wide band, roughly paralleling the Penholoway terrace. The eastern end of the Talbot terrace, east of Wewahitchka, is truncated by the swampy floodplain of the Apalachicola River.

Lying between the 8 and 25 feet MSL elevations, the Pamlico terrace occupies much of central Gulf County and the northern portion of the Apalachicola River floodplain. Although Healy (1975) shows this terrace extending northward along the Apalachicola River into Calhoun County, fluvial erosion by the river is undoubtedly responsible for the lower elevations within the Apalachicola River Valley. The true northern extent of the Pamlico terrace is, therefore, uncertain.

Table 1. Wells and cores referenced in text and cross sections.

<u>County</u>	<u>Well number</u>	<u>Permit No.</u>	<u>Location (T R S 1/4-1/4)</u>	<u>Land surface elevation (feet MSL)</u>	<u>Total depth (feet below land surface)</u>
Gulf	W-914		6S 9W 22bb	32	8,708
	W-1098	B-4	7S 9W 10cc	21	5,796
	W-1462	40	6S 11W 3bc	24	5,025
	W-1468	48	4S 11W 25ad	35	5,069
	W-1469		5S 9W 19ad	43	5,606
	W-1470		6S 9W 21cb	33	7,255
	W-3301	194	5S 9W 33bc	30	4,955
	W-5710		4S 10W 25ba	45	578
	W-6881		7S 11W 26bc	10	500
	W-12051		8S 12W 14aa	10	567
	W-12509	746	3S 11W 30da	81	13,284
	W-12483	670	8S 10W 26ad	33	14,290
	W-12617	762	8S 10W 12ad	22	14,570
	W-12649		7S 10W 2bd	9	395
	W-12723		6S 11W 31ad	15	325
	W-13249		4S 10W 20bc	40	220
	W-13341	846	4S 10W 20dc	59	13,587
	W-14077		5S 11W 6aa	30	522
	W-14173	957	5S 9W 29aa	47	13,587
	W-14451		9S 10W 22bc	5	525
	W-14529		5S 10W 12dc	40	300
	W-14533		7S 10W 20da	18	516
	W-14704		6S 10W 7ba	15	465
	W-14719		7S 9W 12cd	10	282
	W-14746		8S 10W 28cb	5	410
	W-15808	37	9S 11W 12da	19	5,656
Bay	W-13965		3S 12W 14bc	70	450
Calhoun	W-14125		3S 10W 19bc	67	492

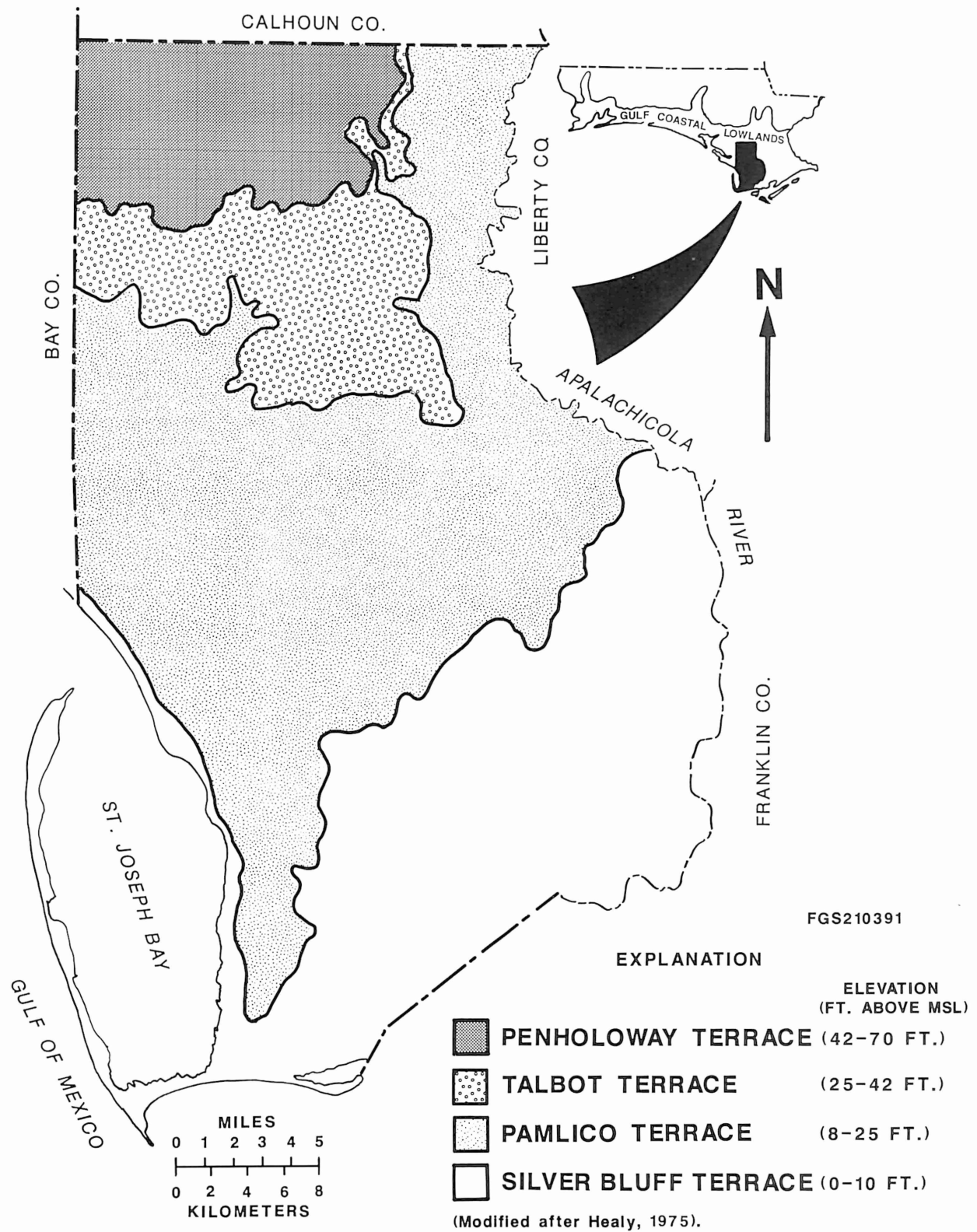


Figure 4. Marine terrace elevation zones of Gulf County.

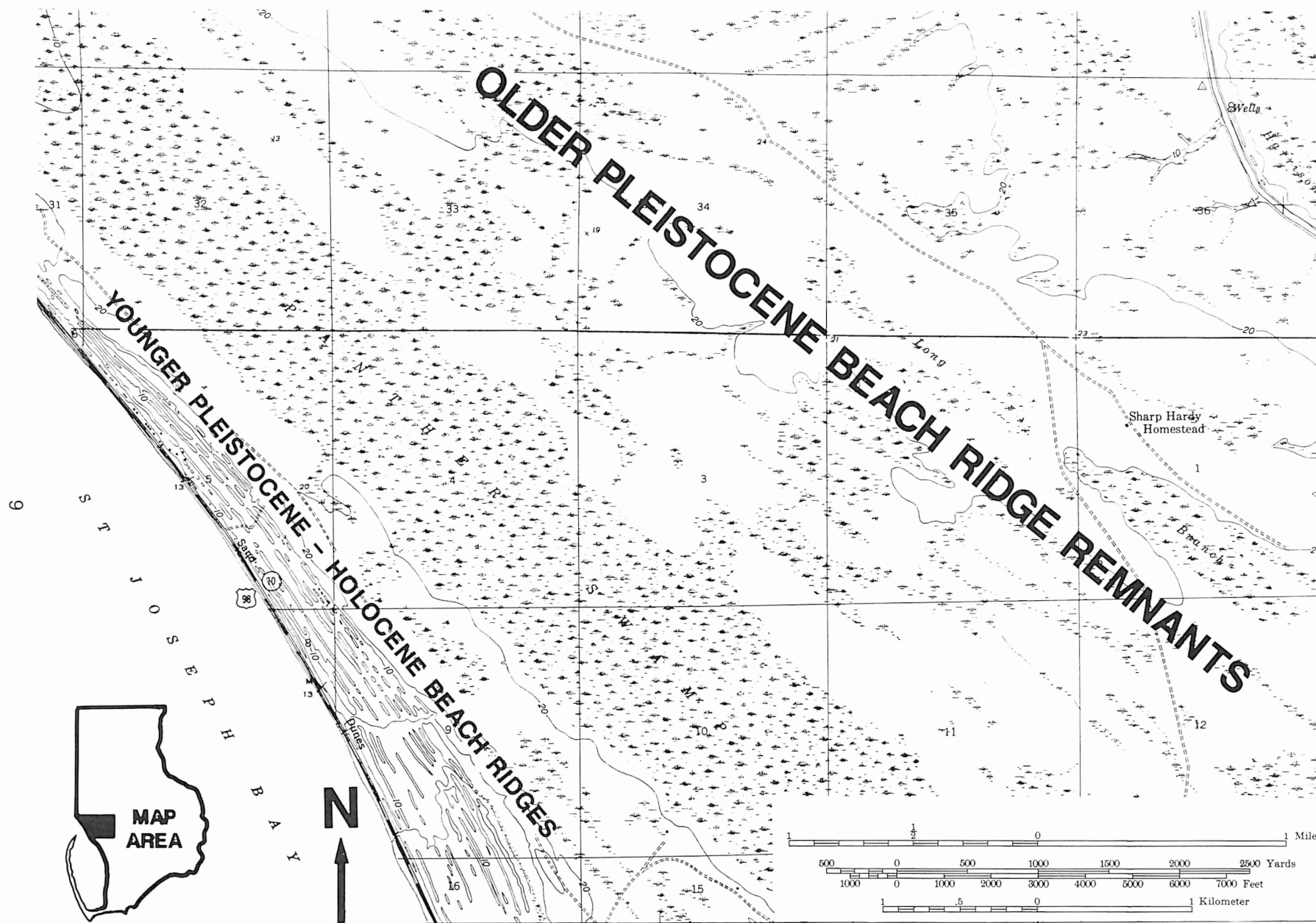


Figure 5. Portion of the Overstreet topographic quadrangle map showing relict beach ridges northeast of Port St. Joe.

FGS010391

The Silver Bluff terrace occupies the portion of Gulf County lying below approximately eight feet MSL, and extends to the modern Gulf coast. This includes St. Joseph Spit and a one-quarter mile wide strip of mainland coastline facing St. Joseph Bay, as well as most of southeastern Gulf County. A prominent escarpment separating the higher Pamlico terrace and the Silver Bluff terrace is evident near the coast just west of Panther Swamp. Relict beach ridges and dune systems, most likely associated with the Silver Bluff sea level stand, are common on St. Joseph Peninsula and throughout the southern portion of Gulf County. A distinct series of relict ridges and swales border Panther Swamp, just east and north of Port St. Joe, subparallel to the modern shore of St. Joseph Bay. Figure 5 is a portion of the Overstreet topographic quadrangle map showing various relict beach ridges northeast of Port St. Joe.

St. Joseph Bay and Spit

St. Joseph Bay is a non-estuarine lagoon formed between St. Joseph Spit and mainland Gulf County. No major streams directly contribute freshwater to the bay. North to south, St. Joseph Bay is approximately 11-miles long, and varies from three to five-miles wide. Water depths within St. Joseph Bay range from less than five feet at the southern, enclosed end, to approximately 30 feet near the northern tip of the spit. Bottom sediments are predominantly sand, with localized areas of clayey silt, silty sand, clayey sand, and gravel-sand mixtures (Stewart, 1962).

St. Joseph Spit is an elongate sand body formed by a bi-directional littoral drift system. The northern portion of the spit is supplied by a northward transporting system, and Cape San Blas is fed by a southward transporting drift system (Stapor, 1973b). St. Joseph Spit is connected to the mainland by a three-mile-long arm extending eastward from Cape San Blas. The spit bends sharply at Cape San Blas, and extends approximately 15 miles northward in a gentle convex-

seaward arc. Throughout its entire length, the width of the spit is generally less than one mile. A series of relict sand beach ridges and intervening swales trend north-northwest across the spit; between Cape San Blas and the mainland, the ridge trend is nearly east-west. These remnant ridges vary between 10 and 15 feet MSL over most of the spit. Coastal aeolian dunes, migrating over these old ridges, may approach elevations of 50 feet above MSL at the northern end of the spit (Stapor, 1973b).

A white quartz sand beach, 50 to 100-feet wide and backed by aeolian dunes (Figure 6), borders the Gulf side of the spit; a muddy sand beach of variable width fringes the bay side. The dunes on the Gulf side typically reach elevations of 30 feet above MSL. Eagle Harbor, midway along the spit, forms a natural cove on the bay side. This feature represents the remains of an ancient pass which once divided the spit into two islands (Stapor, 1973b).

While little is known of the pre-Holocene history of St. Joseph Spit, observable changes in the shape of the spit have occurred in historic times. Stapor (1973b) reviewed the shoreline changes in the spit derived from old navigation charts dating from the period 1841 to 1970. Between 1875 and 1970, the west-facing coast of the spit underwent about 33 feet per year of retreat. During this same time interval, St. Joseph Point migrated northward about a mile, and Cape San Blas moved eastward about half a mile and developed its prominent southward-jutting spit. A series of lighthouses constructed between 1847 and 1919 had to be located progressively further east on the cape as the land migrated eastward (Stapor, 1973b). The wrecked iron framework of one lighthouse constructed in 1885 now sits 1000 feet seaward of the modern Cape San Blas coast.

STRATIGRAPHY

The known sediments underlying Gulf County range in age from Paleozoic to Holocene.



Figure 6. Sand dunes on St. Joseph Spit (photo by Ken Campbell).

Florida Geological Survey

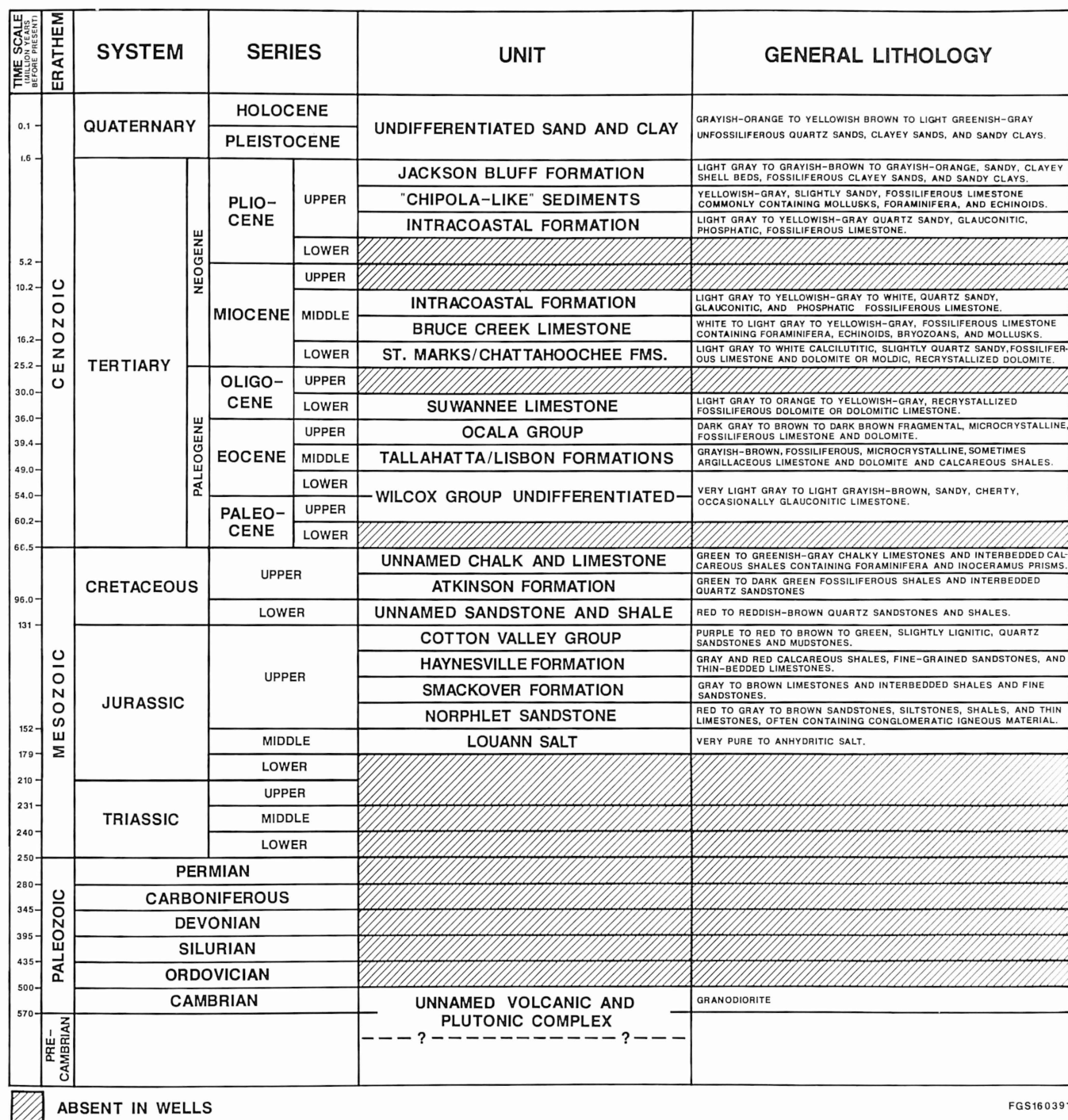


Figure 7. Generalized stratigraphic section in Gulf County (modified from Braunstein et al., 1988).

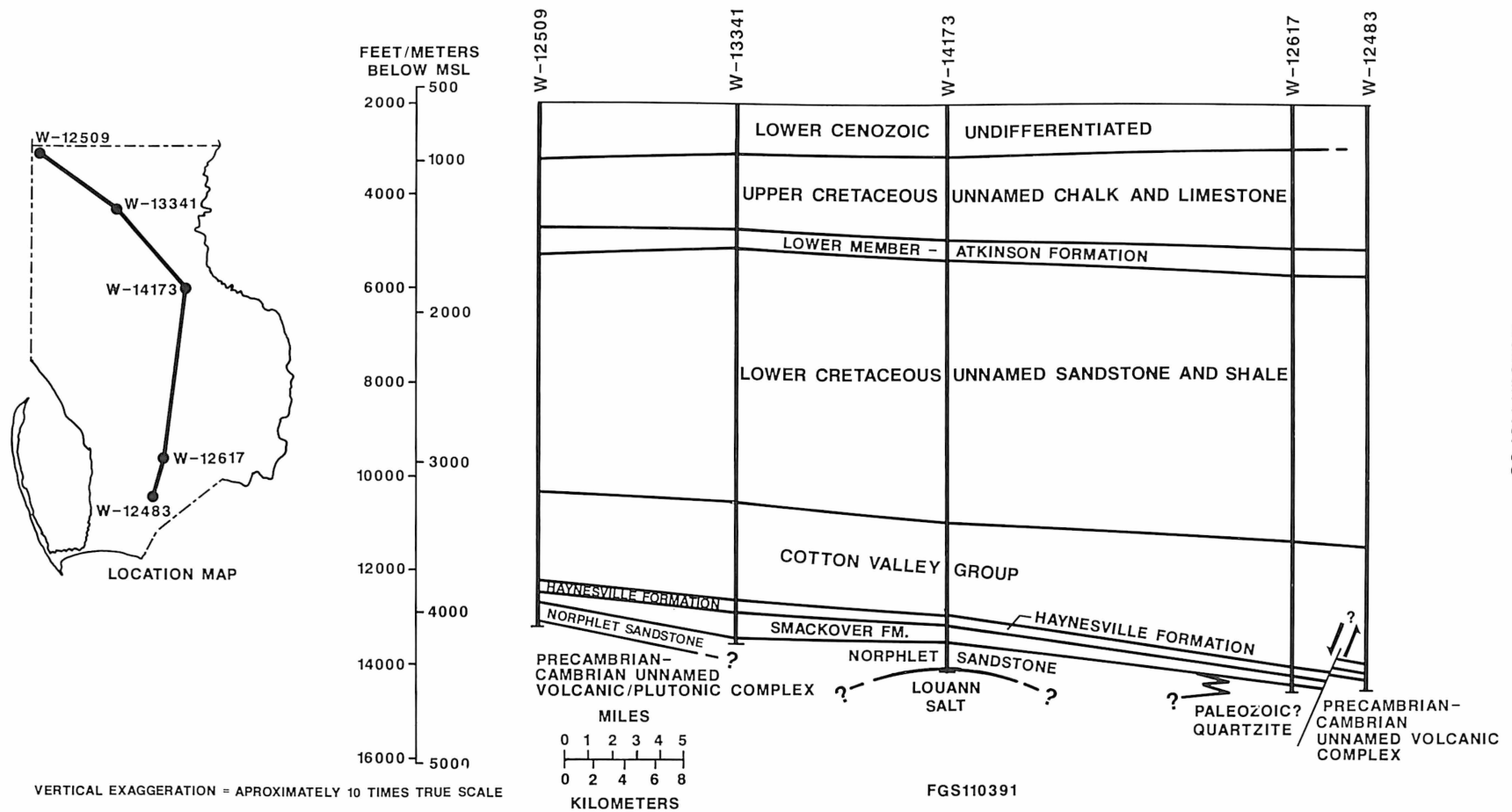


Figure 8. Paleozoic and Mesozoic geologic cross section in Gulf County.

Undifferentiated Pleistocene and Holocene marine terrace sands and alluvium are the only deposits exposed at the surface.

The subsurface data discussed in this report was derived from lithologic logs of water and oil well cuttings and cores on file at the FGS. Figure 7 is a generalized stratigraphic section for Gulf County.

Thirteen oil test wells penetrated Cretaceous or older sediments at depths in excess of 3,000 feet. Five of these wells penetrated Jurassic age section, and of this group, three wells encountered Lower Mesozoic or Upper Paleozoic basement rock at or near their respective total depths (up to -14,522 feet MSL). These wells were utilized to construct the deep stratigraphic cross-section in Figure 8.

Cuttings from water wells and FGS cores taken in Gulf County provide data on the shallow stratigraphy. Figure 9 shows the locations of a series of geologic cross sections (Figures 10 through 15) illustrating the shallow stratigraphy of the county.

Precambrian and Paleozoic Erathems Unnamed volcanic and plutonic complex

Relatively little is known about the Paleozoic rocks underlying the Florida panhandle. Prior to the advent of plate tectonics theory, the deep rocks of the Florida platform were traditionally considered part of the North American craton. Bullard et al. (1965) presented a novel model illustrating the probable pre-rift fit of the circum-Atlantic ocean continents. In this model, the area of present day Florida fitted closely with what is now the coast of northwestern Africa. A number of subsequent authors (including Wilson, 1966; Cramer 1971 and 1973; Odom and Brown, 1976; Smith, 1982; Chowns and Williams, 1983; Dallmeyer, 1987; and Opdyke et al., 1987) have suggested that the Precambrian and Paleozoic rocks underlying Florida were originally part of the African craton. This fragment of African Plate underlies both the Florida Platform and the

Bahama Platform, and remained accreted to North America when the continents rifted in mid-Mesozoic time. This theory is supported by lithologic and paleontologic similarities in the Paleozoic strata from both Florida and the Morocco-Algeria area of Africa.

Our knowledge of the Precambrian/Paleozoic rocks of Florida has been obtained from core chip and cutting samples recovered during the drilling of deep oil test wells. The Hunt Oil, International Paper Company No. 30-4 (W-12509, Permit 746) drilled 386 feet of granodiorite in the interval -12,817 to -13,203 feet MSL (Barnett, 1975). The granodiorite was K-Ar age dated at 709 +/- 25 million years old (unpublished report, Earth Resource Consultants, Inc., in: Arthur, 1988). This well is situated in the extreme northwestern corner of Gulf County, at the southern edge of what Barnett (1975) believed is the upthrown block of a faulted granitoid batholith. A limestone facies of the Jurassic Norphlet Sandstone immediately overlies the granodiorite (Applegate et al., 1978).

The Charter Exploration and Production Company, St. Joe Paper Company No. 6 (W-12617, Permit 762) encountered 65 feet of coarse quartzite, with a kaolinized weathered zone at the top, in the interval -14,477 to -14,522 feet MSL (Barnett, 1975). Applegate et al. (1978) assign this quartzite to the Paleozoic. However, Barnett (1975) believed these sediments may be either Mesozoic (Lower Triassic) or Upper Paleozoic in age. The Jurassic age Smackover Formation overlies the quartzite in this well.

The southernmost deep oil test well in Gulf County, the Charter No. 1 St. Joe Paper Company (W-12483, Permit 670), encountered 36 feet of reddish-brown dacite porphyry at a depth of -14,228 feet MSL. Barnett (1975) considered the rocks to be ash fall tuff and of Late Triassic or Early Jurassic age. Later authors (Chowns and Williams, 1983; Arthur, 1988) place the basement rocks of southern Gulf County in the Late Pre-Cambrian or Early Cambrian based on radiometric age dates obtained on similar strata in nearby wells.

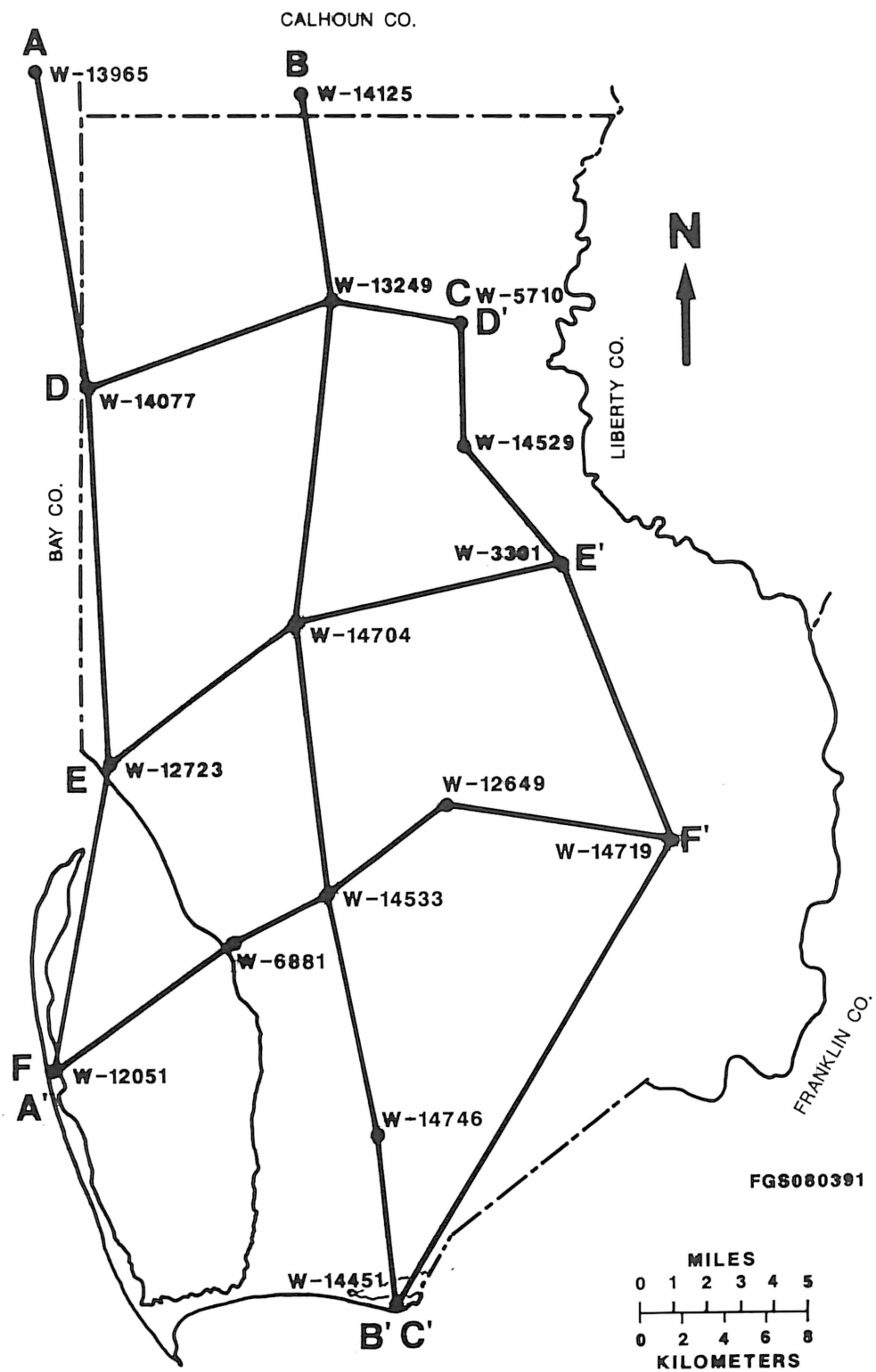


Figure 9. Cenozoic geologic cross section location map.

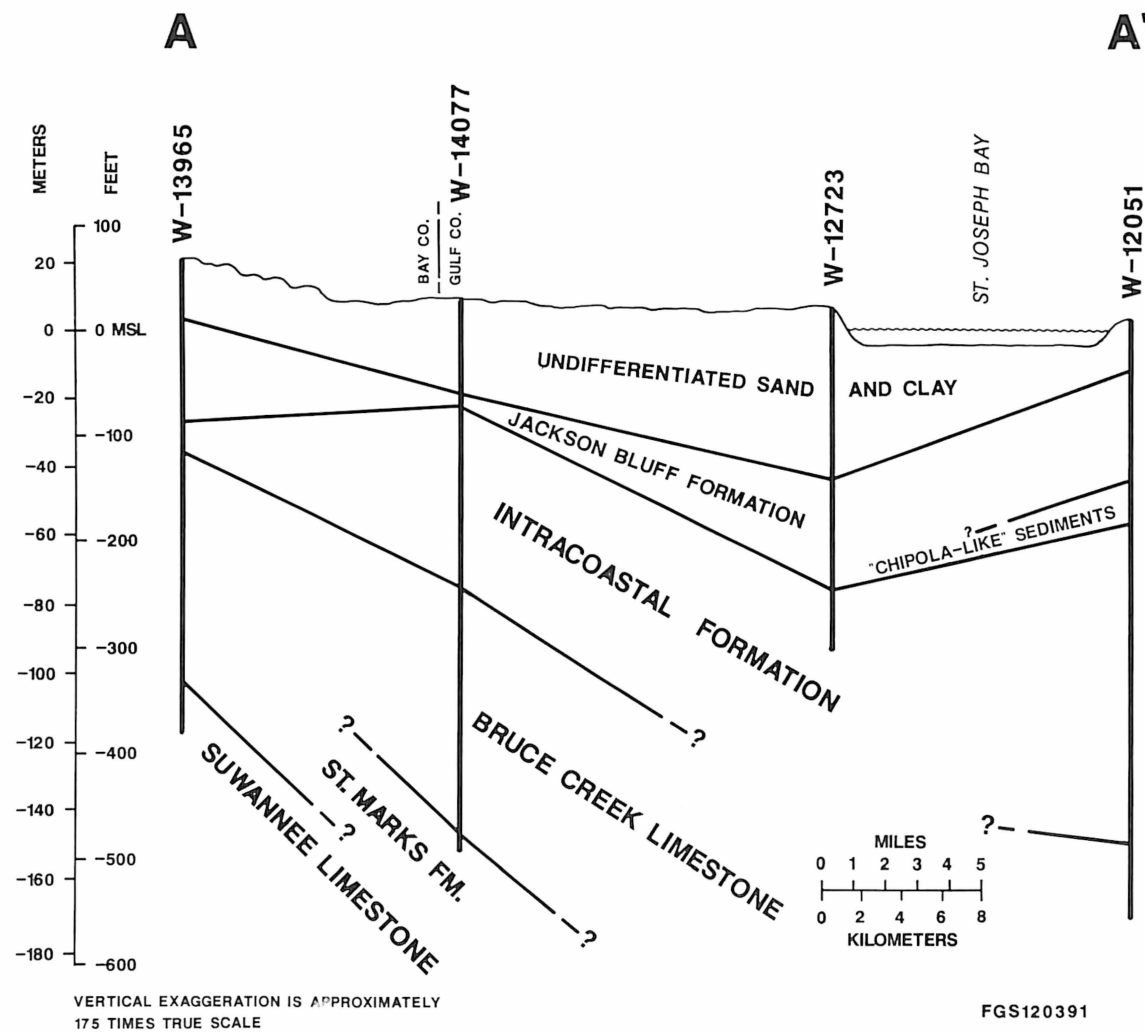


Figure 10. Geologic cross section A-A'.

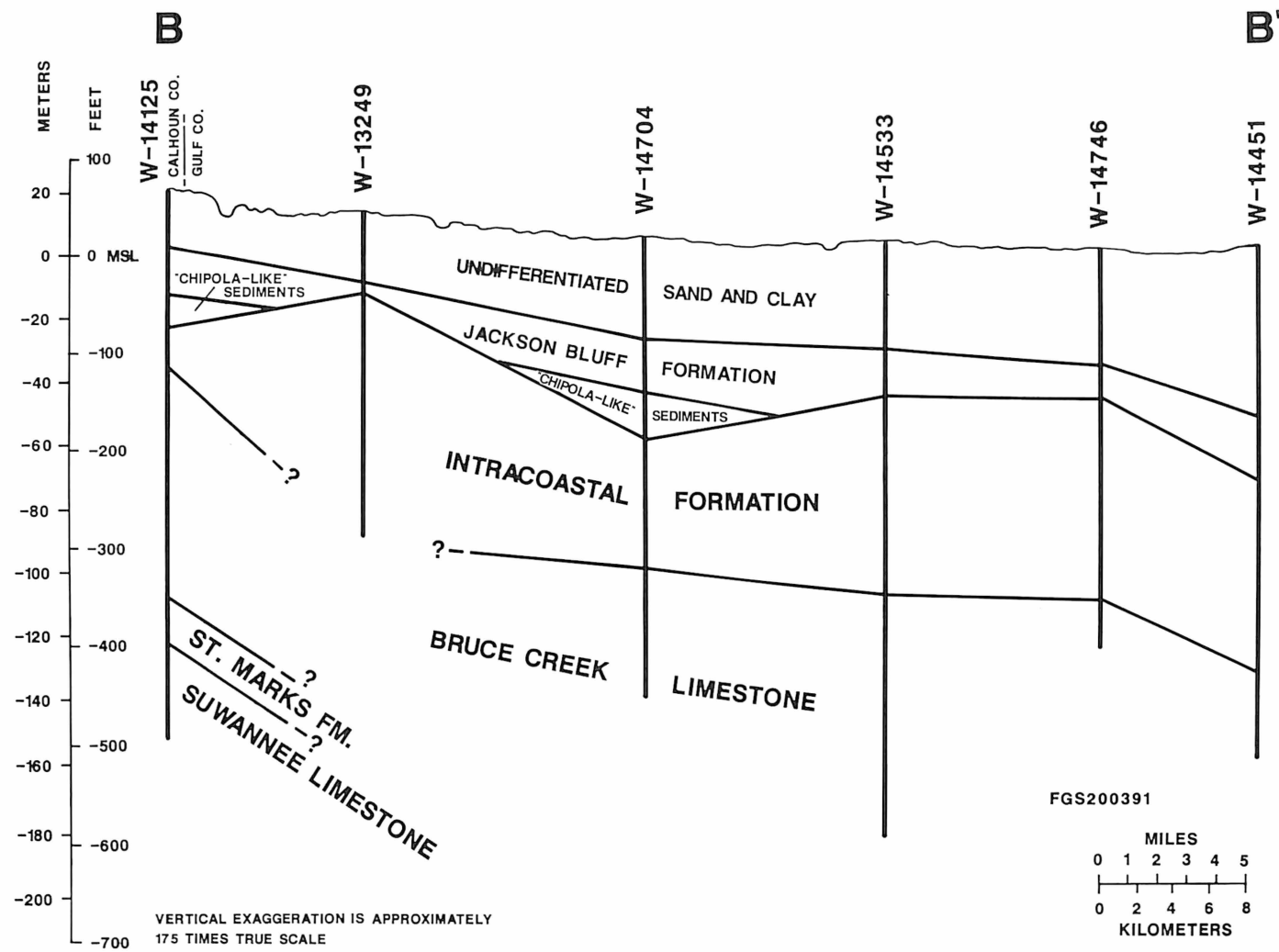


Figure 11. Geologic cross section B-B'.

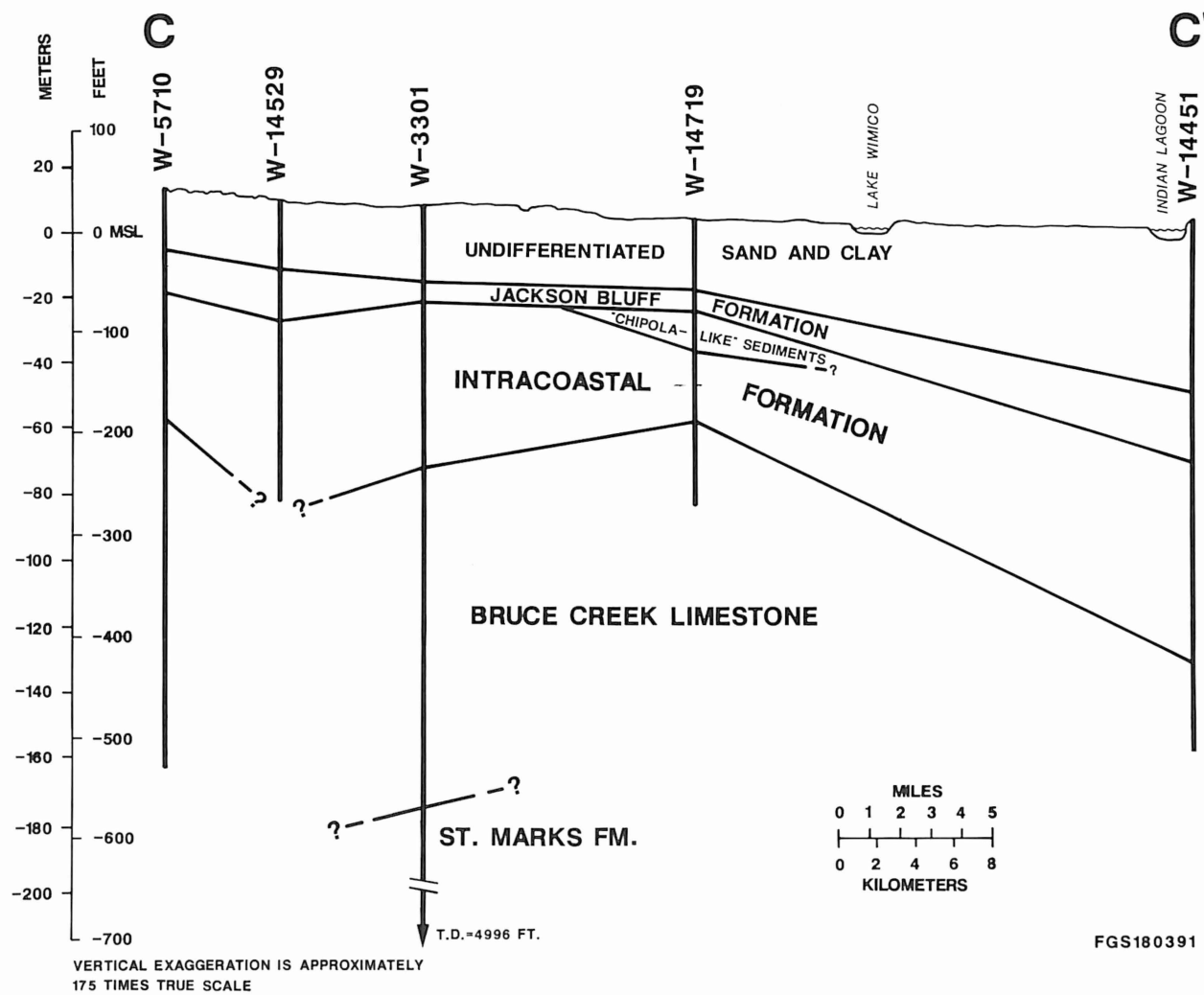


Figure 12. Geologic cross section C-C'.

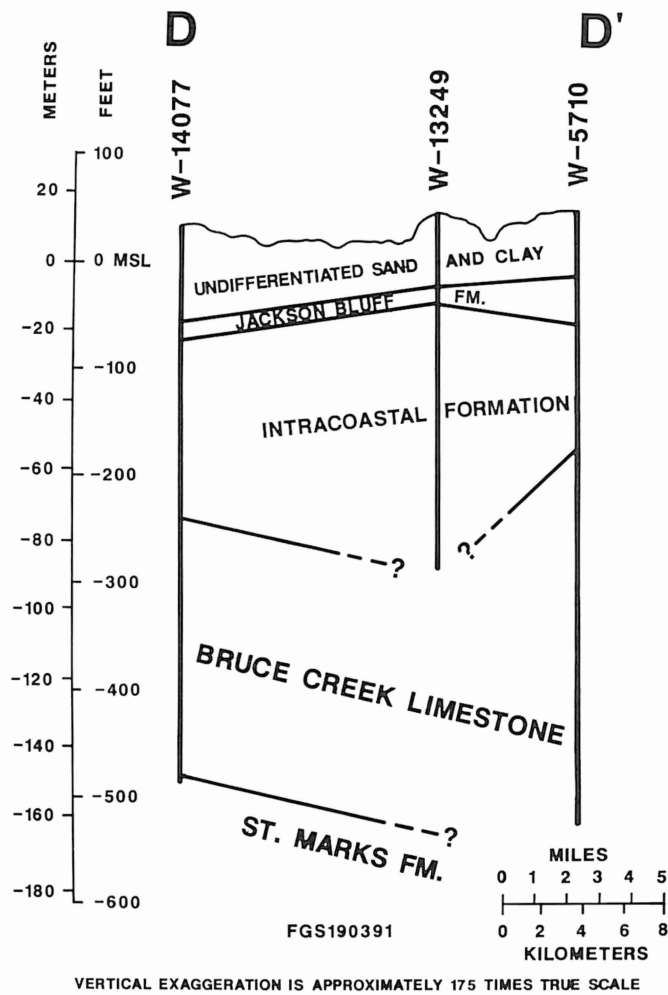


Figure 13. Geologic cross section D-D'.

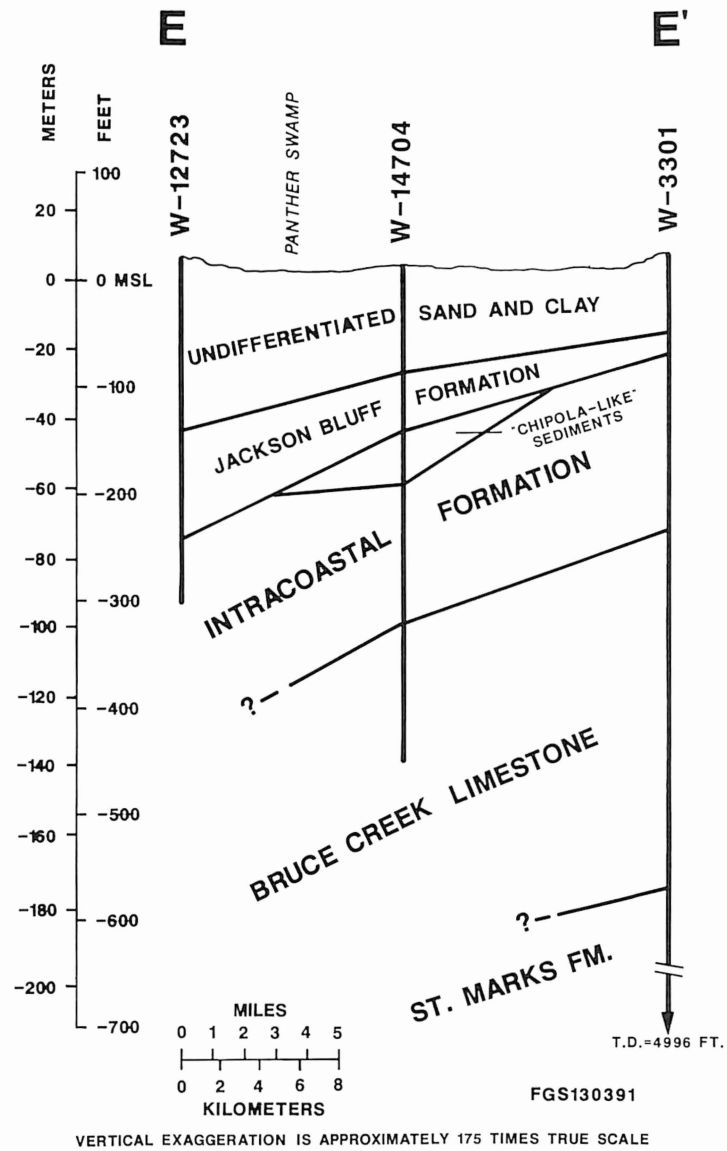


Figure 14. Geologic cross section E-E'.

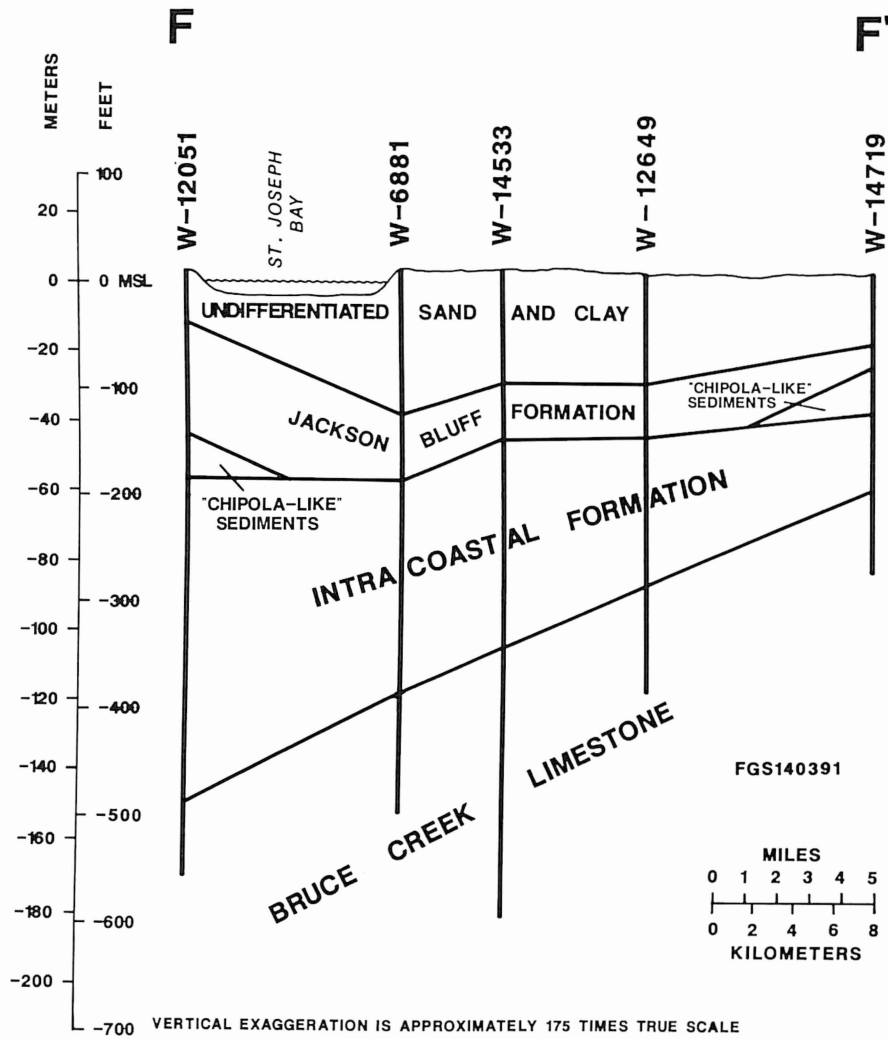


Figure 15. Geologic cross section F-F'.

Mesozoic Erathem

The Mesozoic stratigraphic section underlying Gulf County is comprised primarily of Jurassic and Cretaceous age sedimentary rocks and Late Triassic to Early Jurassic age igneous rocks. As with the deeper Paleozoic section, our knowledge of Florida's Mesozoic rocks is derived principally from deep oil well samples. Prior to the discovery of the oil-bearing Jurassic Smackover Formation and Norphlet Sandstone in the early 1970's, most Florida panhandle oil wells were terminated in Cretaceous sediments. Recent wells targeting the Norphlet and Smackover have penetrated most or all of the Mesozoic section, bottoming in Paleozoic rocks or Jurassic salt. Figure 8 illustrates the Mesozoic and older stratigraphy of Gulf County.

Middle Jurassic System Louann Salt

The oldest Mesozoic rock known in Gulf County is the Louann Salt. This unit is an evaporite deposit which formed in the great Jurassic sea that covered much of southeastern North America. The Louann Salt is characteristically a pure to anhydritic salt (halite). Halite often undergoes plastic flow in response to vertical loading by overburden sediments. This flow is frequently upward in a plume which displaces the overlying younger sediments. The numerous subsurface salt domes occurring in the northern Gulf of Mexico coastal areas were formed by upward extrusion of Louann Salt. The existence of such domes under Gulf County has, to date, not been determined. In Gulf County, only well W-14173 (Permit 957) bottomed in Louann Salt at a depth of -14,139 feet MSL.

Upper Jurassic System Norphlet Sandstone

The Norphlet Sandstone locally overlies the

unnamed volcanic and plutonic rocks and the Louann Salt. In the Jay trend of northeastern Santa Rosa County, this unit is a source of natural gas production. Its lithology consists predominantly of red to gray to brown sandstones, conglomerates, siltstones, and shales, representing paleoenvironments ranging from braided stream-deltaic to intertidal mudflat to beach shore-face (Sigsby, 1976). Three deep Gulf County oil test wells penetrated Norphlet Sandstone section. The Hunt Oil, International Paper Co. No. 30-4 (W-12509, Permit 746) drilled 267 feet of Norphlet Sandstone between -12,469 and -12,736 feet MSL. The lithology consisted of red to brown sandstones, siltstones, and shales (Applegate et al., 1978). Similarly, the Exxon Neal Lumber No. 1 (W-13341, Permit 846) bottomed out in Norphlet sediments at -13,528 feet MSL after drilling 117 feet of the unit. The thickest Norphlet section was encountered in the Mesa Petroleum St. Joe Paper No. 1 (W-14173, Permit 957), which drilled 676 feet of Norphlet between -13,463 and -14,139 feet MSL, before bottoming out in salt. Dip is generally to the southwest. Throughout Gulf County, the Norphlet Formation is unconformably overlain by the Smackover Formation.

Smackover Formation

In contrast to the siliciclastics of the underlying Norphlet Sandstone, the Smackover Formation is largely a carbonate unit comprised of marine, gray to brown limestones, containing occasional interbedded calcareous shales and fine sandstones (Applegate et al., 1978). The Smackover dips southwestward. It is an important oil-producing stratum in the Jay trend fields of northwest Florida. Oil test wells into the Smackover Formation in Gulf County have to date been unsuccessful in finding economic quantities of petroleum.

Five deep oil test wells penetrated Smackover Formation section in Gulf County (see Figure 8). Typical of these is the Charter Exploration and

Production Company No. 6 St. Joe Paper Co. well (W-12617, Permit 762), which drilled 196 feet of Smackover Formation. In this well, the lithology was composed of light to dark gray, micritic limestones, calcareous shales, and fine-grained calcareous sandstones.

While all oil tests in Gulf County have been plugged and abandoned, one well had an oil show in the Smackover section. Well W-12509 (Permit 749), the Hunt Oil International Paper No. 30-4, in extreme northwestern Gulf County, discovered non-recoverable oil locked in 163 feet of Smackover Formation section. The Smackover lithology in this well is characterized by brown, low permeability, miliolid and molluscan fossiliferous, occasionally dolomitic, tar-stained limestone and interbedded, unfossiliferous, micritic limestone (Applegate et al., 1978).

Haynesville Formation

The Upper Jurassic Haynesville Formation immediately overlies the Smackover Formation in Gulf County. Averaging approximately 300-feet thick, the Haynesville is comprised of gray and red, often calcareous shales, a few fine-grained sandstones, and thin-bedded micritic limestones (Applegate et al., 1978). Regional dip is to the southwest.

Cotton Valley Group

Overlying the Haynesville Formation is a thick sequence of varicolored lignitic mudstones and coarse sandstones known as the Cotton Valley Group. These siliciclastic sediments typically range from red to purple to brown, and sometimes green in color (Applegate et al., 1978). In Gulf County, the Cotton Valley Group varies from about 1,800 to 2,600-feet thick. It generally thickens to the southwest (basin-ward). The top of the unit varies from approximately -10,000 to -12,000 feet MSL, with a gentle southwest dip.

Cretaceous System Lower Cretaceous unnamed sandstone and shale

The Lower Cretaceous of Gulf County is represented by a thick sequence of undifferentiated reddish and reddish-brown interbedded shales and sandstones. These sediments dip and thicken towards the southwest, and range from about 4,800 to 5,600 feet thick under Gulf County. They are differentiated from the overlying Atkinson Formation sediments primarily on the basis of color (Applegate et al., 1978).

Atkinson Formation

The Upper Cretaceous Atkinson Formation is the Florida panhandle stratigraphic equivalent of the Tuscaloosa Formation of Alabama (Braunstein et al., 1988). It is generally subdivided into lower, middle, and upper members. Only the lower member is present in Gulf County. The general lithology is comprised of light-colored sands and interbedded calcareous and glauconitic sands and shales (Applegate et al., 1978). Foraminifera are the dominant fossils, including species of *Planulina*, *Valvulineria*, *Ammobaculites*, *Gumbelina*, and *Trochamina* (Florida Geological Survey unpublished well data). The thickness of the Atkinson Formation in Gulf County ranges from about 400 to 800 feet.

Upper Cretaceous unnamed chalk and limestone

The uppermost Cretaceous sediments of Gulf County are comprised of an unnamed series of white, chalky limestones and interbedded gray to light green calcareous shales. They often contain fossils of the cephalopod *Inoceramus* and both benthic and planktonic foraminifera (Florida Geological Survey unpublished well data). Well W-914 penetrated a characteristic unnamed

Upper Cretaceous section in the interval -3,196 to -4,200 feet MSL. The sediments in this well were largely chalky limestones and thin, interbedded, sometimes carbonaceous and pyritiferous shales. Abundant benthic foraminifera are present, including *Gumbelina excolata*, *Bulimina carseyi*, and *Bolivinoidea decorata*.

The top of the Upper Cretaceous is nearly flat-lying, at approximately -2,800 to -3,200 feet MSL. Thickness ranges from about 1,450 feet in northern Gulf County to about 2,150 feet in the southern part of the county. The Cretaceous sediments are unconformably overlain by Lower Cenozoic Erathem sediments.

Cenozoic Erathem

The Cenozoic Erathem sediments underlying Gulf County range in age from Late Paleocene through Holocene. Most of these deposits are comprised of marine limestones, dolomites, and shellbeds, containing varying proportions of siliciclastic sediments. The Cenozoic units dip and thicken to the southwest.

The carbonate strata, principally including the Eocene through Miocene limestones, are fresh-water-bearing units of the Floridan aquifer system. Pleistocene and Holocene undifferentiated sands and clays form a surficial veneer over all of Gulf County.

Tertiary System

Upper Paleocene and Lower Eocene Series Wilcox Group Undifferentiated

Applin (1964) placed the Paleocene sediments of the Florida panhandle into the Lower Paleocene Midway Group based on its fossil foraminifera. Subsequent reevaluations of the fossil fauna, as well as refinements in planktonic foraminiferal zonation schemes, indicate that the assemblage observed by Applin (1964) is actually Late Paleocene to Early Eocene in age

(Braunstein et al., 1988). Braunstein et al. (1988) place the Upper Paleocene and Lower Eocene strata overlying the Cretaceous of the central Florida panhandle in the Wilcox Group (Crider, 1906) undifferentiated.

Wilcox Group sediments under Gulf County are predominantly impure marine carbonates. The downdip carbonate lithology of these sediments differs significantly from the type area in Alabama, and direct lithologic correlation is difficult. Oil test wells have allowed description of the entire Wilcox sequence under the county. Well W-1468 penetrated 600 feet of Wilcox Group section in the depth interval -2,170 to -2,770 feet MSL. The lithology is comprised of interbedded very light brown to chalky white, fossiliferous limestones, argillaceous limestones, calcareous shale, and light brown, glauconitic and sandy limestones (Florida Geological Survey well file data). Foraminifera are the dominant fossils present. Similarly, well W-1470 penetrated Wilcox Group sediments between -2,362 and -2,863 feet MSL. In this well, the strata were largely light grayish-brown, cherty dolomites and glauconitic, sandy, and argillaceous limestones (FGS well file data).

Middle Eocene Series Tallahatta and Lisbon Formations

The Tallahatta Formation (Dall, 1898) and the overlying Lisbon Formation (Smith, 1907) comprise the Middle Eocene sediments of the central and western Florida panhandle. Both units were named from type areas in Alabama. These units are age equivalent to the Avon Park Formation (Miller, 1986) of northern and peninsular Florida.

Gulf County lies in a transitional area of the Florida panhandle over the axis of the Apalachicola Embayment. Here the carbonate facies of the Avon Park Formation grade laterally westward into the more sandy, glauconitic, and argillaceous limestones, sands and shales of the Tallahatta and Lisbon Formations. Consequently, the Middle Eocene sediments underlying Gulf

County may contain lithologic constituents characteristic of both eastern and western facies. Downdip towards the Gulf, all three units are calcareous (Chen, 1965). The assignment of these sediments to a specific lithologic unit is often difficult. Chen (1965), citing the difficulty of picking specific Middle Eocene formations in the central panhandle, grouped the Lisbon, Tallahatta, and Avon Park Formation sediments into the Claiborne Group undifferentiated. However, based on the siliciclastic constituents in the lithology as well as paleontological criteria, Braunstein et al. (1988) placed the Middle Eocene units under Gulf County into the Tallahatta and Lisbon Formations.

Most Gulf County oil test wells have penetrated Middle Eocene section. Two wells have been described in detail. Well W-1468 in the northeastern part of the county drilled typical Middle Eocene section in the interval -1,330 to -2,170 feet MSL. The lithology in this well is comprised of light grayish-brown, fossiliferous limestones interbedded with argillaceous limestones and dark grayish brown, calcareous shales (FGS well file data). Well W-1470, in west-central Gulf County, also penetrated Middle Eocene strata between -1,447 feet and -2,362 feet MSL. The lithology shown in this well ranges from dark grayish-brown, chalky, fossiliferous limestone to interbedded calcareous shales and argillaceous limestones (FGS well file data).

Differentiation of the Tallahatta and Lisbon Formations in Gulf County is not possible using lithologic criteria. Therefore, the two units are, in this report, grouped into Tallahatta/Lisbon Formations undifferentiated. These units are overlain by the lithologically distinct Upper Eocene Ocala Group.

Upper Eocene Series Ocala Group

Dall and Harris (1892) 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) has been used 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 of the top of the group range from greater than 100 feet above MSL in west-central peninsular Florida and the northern panhandle to over 1,200 feet below MSL in south Florida and the extreme western panhandle.

In Gulf County, the Ocala Group lies below the depth attained by most water wells. Its lithology in this area is derived from oil test well samples. The lithology shown in these wells is typically comprised of cream to light brown, porous, bioclastic, fossiliferous limestone and dolomitic limestone. Fossils are generally abundant, especially species of the large foraminifera *Lepidocyclina* and *Nummulites* and bryozoa, echinoids, mollusks, and algal fragments.

Depth to the top of the Ocala Group sediments is variable throughout Gulf County, but generally ranges from about -950 feet to -1,015 feet MSL. Based on available FGS well data, the thickness of the Ocala Group varies from approximately 350 feet under north-central Gulf County (well W-1468) to about 530 feet at the southern edge of the county (well W-15808). The Ocala Group is unconformably overlain by the Oligocene Suwannee Limestone.

Oligocene Series Suwannee Limestone

The name Suwannee Limestone was proposed by Cooke and Mansfield (1936) for the fossiliferous limestone exposed along the Suwannee River in north Florida. Vernon (1942)

and Cooke (1945) give good nomenclatural histories for this unit, and are recommended as references.

In Gulf County, the top of the Suwannee Limestone lies at depths only reached by oil test wells, ranging between -700 and -750 feet MSL. The lithology consists of white to light gray to yellowish gray, well-indurated, chalky to sucrosic, fossiliferous limestone and dolomite. Mollusks, bryozoans, and foraminifera are common fossils in the Suwannee Limestone.

The Suwannee Limestone underlies much of Florida, and is a major component of the Floridan aquifer system. It interfingers to the north with the Marianna Limestone, the only other Oligocene unit present in the central Florida panhandle. In Gulf County, the Suwannee is overlain by the Lower Miocene St. Marks and Chattahoochee Formations or by the Middle Miocene Bruce Creek Limestone.

Miocene Series

The Miocene Epoch marked a change in the depositional regime of the Florida Platform. An influx of siliciclastic sediments, reworked and deposited by high-standing Miocene seas, covered the carbonates of earlier epochs. Throughout northern and peninsular Florida, the Miocene is represented by the siliciclastic and impure carbonate sediments of the Hawthorn Group. These units are often characterized by abundant marine phosphate deposits. In the central portion of the Florida panhandle, a series of impure, fossiliferous, marine carbonate units were deposited during the Miocene. These include the Lower Miocene Chattahoochee and St. Marks Formations, and the Middle Miocene Bruce Creek Limestone and Intracoastal Formation. The carbonates typically contain quartz sand, clay and occasionally phosphate. Most of the Miocene units in the panhandle dip and thicken westward into the Gulf of Mexico Sedimentary Basin, with localized thickening in the area of the Apalachicola Embayment.

Lower Miocene Series St. Marks/Chattahoochee Formations

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 sediments previously assigned to the Tampa Formation in the Tampa (Aquitania) Stage and erected two lithologic subdivisions: the St. Marks (Finch, 1823) and Chattahoochee (Dall and Stanley-Brown, 1894; Langdon, 1889) facies. These facies were raised to formation status by Puri and Vernon (1964).

The name St. Marks Formation includes the calcareous downdip facies, which underlie portions of Wakulla and Franklin Counties to the east of Gulf County. Lithologically, the St. Marks Formation is a very pale orange to light gray to white, well-indurated, fossiliferous, sometimes quartz-sandy and dolomitic, marine calcarenitic limestone. Mollusks and foraminifera are the common fossils in this formation, with the mollusks often present as molds. It is often indistinguishable in wells from the overlying Middle Miocene Bruce Creek Limestone, particularly in the area from central Franklin County westward (Schmidt, 1984). The St. Marks occurs at the surface in eastern Wakulla County. From its surface occurrence, it dips and thickens westward into the trough of the Apalachicola Embayment, reaching a thickness of over 200 feet under the axis of the embayment.

The Chattahoochee Formation underlies portions of the northern central and western Florida panhandle, including northern Gulf County. This unit differs from the age-equivalent St. Marks Formation in being a dolomitic calcilutite or fossiliferous calcilutite. It occurs at the surface in the vicinity of Chattahoochee, Gadsden County, and dips south and westward.

Downdip in the vicinity of Gulf County, the St. Marks Formation, Chattahoochee Formation, and in some areas, the overlying Bruce Creek Limestone are frequently altered by ground water to the extent of being indistinguishable. As a result, the formations are locally difficult to differentiate, even in cores. For this reason, the St. Marks and Chattahoochee Formations are herein lumped as a single unit (St. Marks Formation) in the geologic cross-sections (Figures 10 - 15).

Middle Miocene Series Bruce Creek Limestone

The name Bruce Creek Limestone was proposed by Huddlestun (1976) for a white to light gray to yellowish-gray, quartz-sandy, often phosphatic, highly fossiliferous marine limestone underlying the south-central panhandle. Foraminifera, echinoids, bryozoans, and mollusks are the predominant fossils present. It is a wedge-shaped unit, extending from north-central Okaloosa County eastward to western Wakulla County (Schmidt, 1984). In Gulf County, the Bruce Creek Limestone dips generally to the southwest, ranging in depth from about -150 feet MSL at the northern edge of the county to about -500 feet MSL under St. Joseph Spit. A contour map of its upper surface is illustrated in Figure 16. Thickness of the unit exceeds 200 feet under Gulf County. The total thickness range is difficult to determine because many wells do not penetrate the entire sequence. In wells that are deep enough, the basal Bruce Creek lithology is frequently indistinguishable from the underlying units, and a lower contact cannot be picked (Bolling, 1982).

The Bruce Creek Limestone is overlain by the more fossiliferous and generally more calcarenitic Intracoastal Formation. In some wells in central Gulf County, a thin gray clayey dolosilt occurs at the top of the Bruce Creek, delineating the contact between the Bruce Creek and Intracoastal Formation (Bolling, 1982).

Middle Miocene - Pliocene Series Intracoastal Formation

Huddlestun (1976) first described the Intracoastal Limestone as a soft, sandy, fossiliferous limestone of Pliocene age underlying the coastal area of western Florida. Schmidt and Clark (1980) formally introduced the name Intracoastal Formation, and established a Middle Miocene to Late Pliocene age for the unit based on planktonic foraminifera. It is a wedge-shaped unit, dipping southwestward and westward, and extending from its updip pinchout in the eastern Franklin County-western Wakulla County area to the Okaloosa-Santa Rosa county line. The Intracoastal Formation underlies all of Gulf County, reaching a maximum thickness of 300 feet in the southwestern part of the county.

Lithologically, the Intracoastal Formation is a light gray to yellowish-gray, glauconitic, phosphatic, and sometimes argillaceous, highly fossiliferous marine limestone. Microfossils are very abundant. Other fossils commonly include mollusks, echinoids, bryozoans, ostracods, and shark teeth. The depth to the Intracoastal Formation typically ranges from about -50 feet MSL in northern Gulf County to more than -200 feet MSL under St. Joe Spit. A structural contour map of the top of the Intracoastal Formation is shown in Figure 17.

The Intracoastal Formation contains abundant planktonic foraminifera, which are useful sediment age indicators. Bolling (1982) conducted a biostratigraphic analysis of the Intracoastal Formation in six cores in Gulf County. Based on planktonic foraminiferal assemblages, she dated the age of the Intracoastal as Middle Miocene, *Globorotalia fohsi* Zone. The presence of *Globorotalia margaritae* in some samples near the top of the Intracoastal Formation sequence indicates that the upper portion of this unit is Late Pliocene in age (Bolling, 1982). This finding agrees with the work of Clark and Wright (1979) in neighboring Bay County. A hiatus, which probably occurred in the Late Miocene, separates the

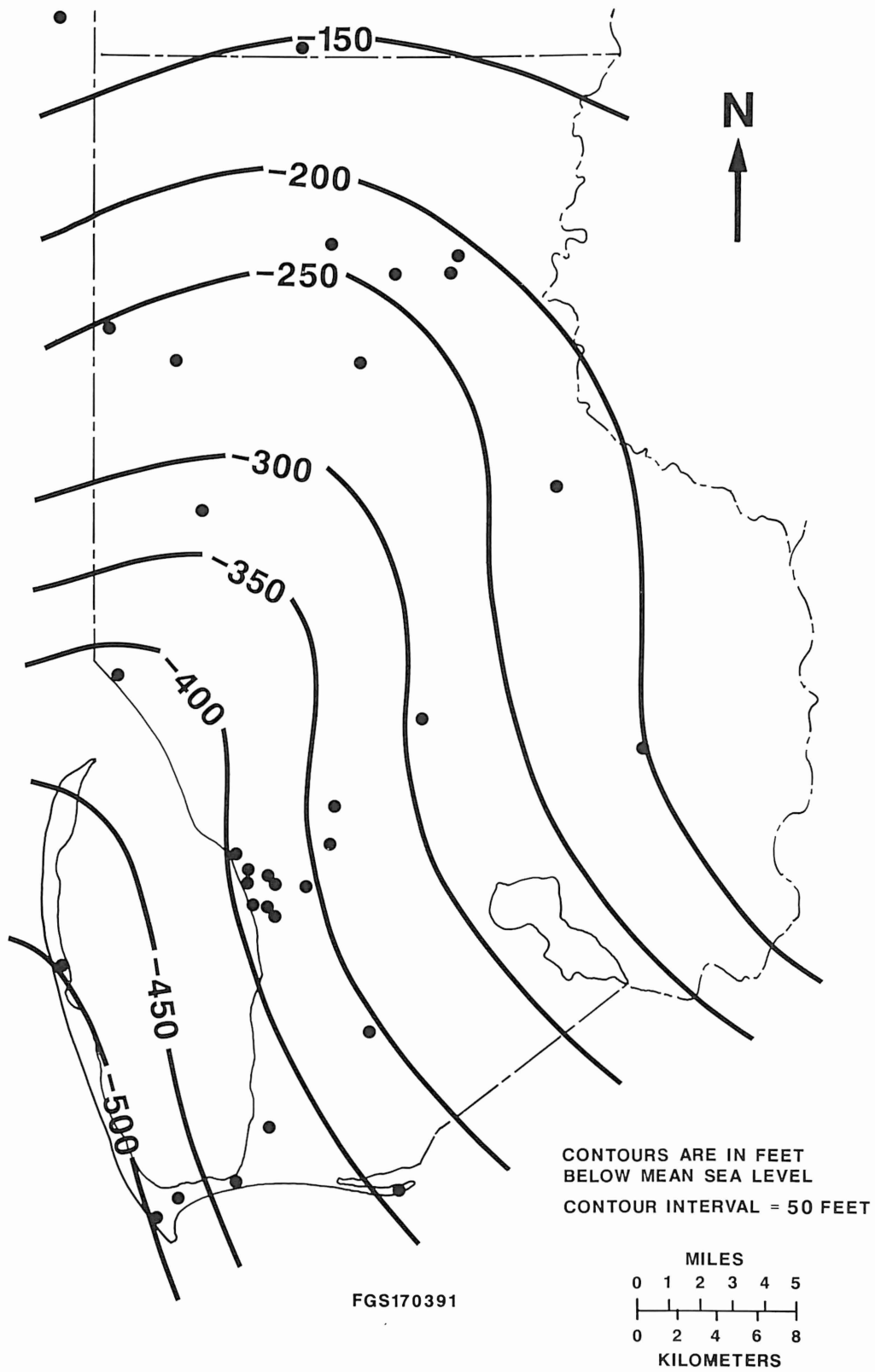


Figure 16. Structural contour map of the top of the Bruce Creek Limestone.

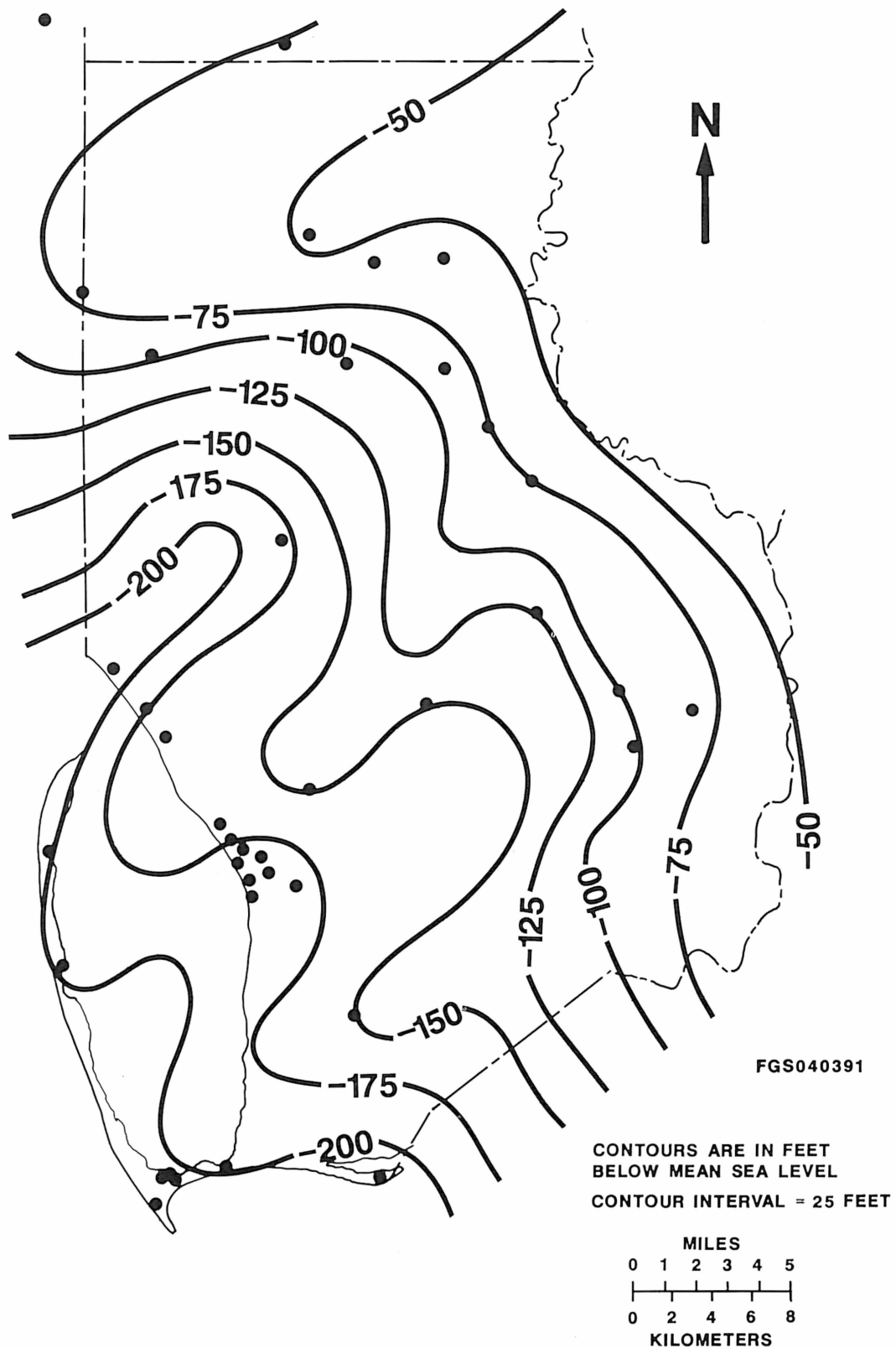


Figure 17. Structural contour map of the top of the Intracoastal Formation.

different age sections of the Intracoastal Formation. Missing section, however, is not apparent in the lithology (Bolling, 1982).

The Intracoastal Formation is unconformably overlain by the "Chipola-like" sediments, Jackson Bluff Formation, or, in a few wells, by Pleistocene-Holocene undifferentiated sediments. In local areas, the Jackson Bluff and Intracoastal Formations may be age equivalent and grade into one another (Bolling, 1982; Schmidt, 1984).

Upper Pliocene Series "Chipola-like" sediments

The sediments of the Chipola Formation have been described in outcrop areas north of Gulf County by numerous authors, including Burns (1889), Dall and Stanley-Brown (1894), Matson and Clapp (1909), Gardner (1926), Puri (1953), and Banks and Hunter (1973). Puri and Vernon (1964) redefined the unit as a formation, describing the type locality along the Chipola River near Tenmile Creek in Calhoun County. Here it is comprised of bluish-gray to yellowish brown, fossiliferous molluscan marl. It is restricted in occurrence within the east central panhandle area to the vicinity of the Apalachicola Embayment, including Bay, Calhoun, Liberty, and possibly Gulf Counties. Beds with a lithology similar to the type Chipola Formation have been traced in cores into Gulf County from the north by Schmidt (1984). Based solely on lithologic criteria, Schmidt (1984) included these "Chipola-like" sediments in the Chipola Formation. Due to insufficient core coverage and a significant age discrepancy, some uncertainty exists as to whether the beds in Gulf County with Chipola lithology are actually correlative with the type Chipola Formation to the north. Near the type area and at Alum Bluff in Liberty County, the Chipola Formation has been dated by microfossils as Late Early Miocene to Early Middle Miocene in age (Akers, 1972; Huddleston, 1976). Downdip in Gulf County, the "Chipola-like" unit is

entirely in the subsurface and has not been directly dated. However, age dates obtained from microfossils in the underlying Intracoastal Formation place this unit in the Early Late Pliocene. The "Chipola-like" sediments must therefore be younger downdip than in the type area to the north, and based on stratigraphic position, are Late Pliocene in age. For this reason, these sediments in Gulf County are herein referred to as "Chipola-like" sediments.

In general, the Chipola Formation grades downdip from the molluscan calcarenite of the type area into a yellowish-gray to light gray, quartz-sandy, fossiliferous limestone of the "Chipola-like" beds in Gulf County. It occurs sporadically in wells, possibly as erosional remnants, and does not underlie all of Gulf County. The "Chipola-like" sediments generally range from about - 80 feet MSL to -140 feet MSL in depth under Gulf County. Thickness of the unit varies from 0 to about 50 feet.

Jackson Bluff Formation

Puri and Vernon (1964) combined the Upper Miocene *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, Florida. The Jackson Bluff Formation extends in a blanket-like deposit from central Washington County eastward to central Leon County. It crops out sporadically along stream beds in the north-central panhandle.

In Gulf County, the Jackson Bluff Formation is comprised of light gray to gray, poorly consolidated clayey sands and sandy clays containing abundant mollusk shells. It underlies most of the county, dipping and thickening to the southwest. Depth to the top of the unit varies from approximately +5 feet MSL at the northern edge of the county to nearly -165 feet MSL at the southern tip near Cape San Blas (Figure 18). The thickness of the Jackson Bluff ranges from 0 feet in wells where it is missing (primarily north-central

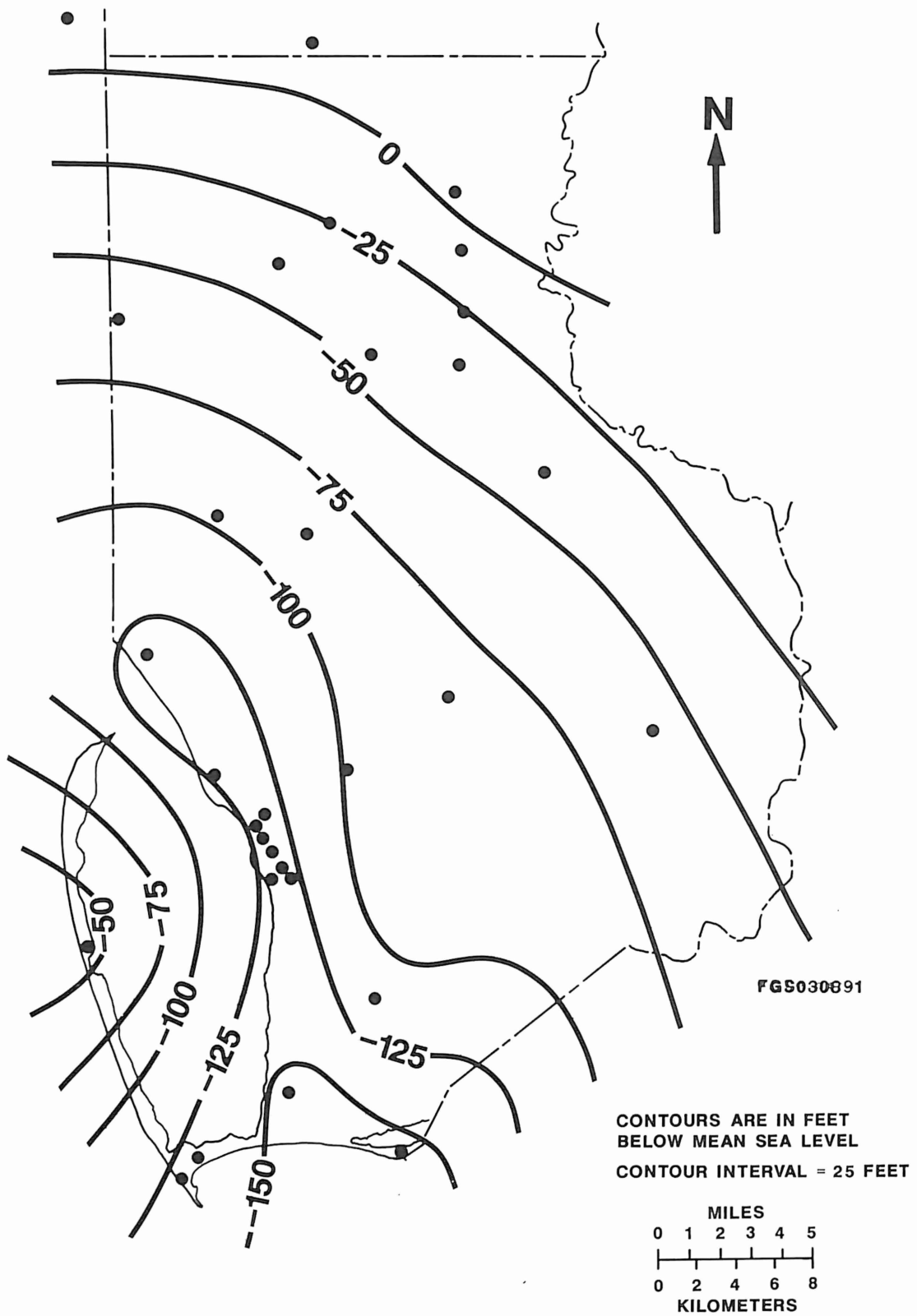


Figure 18. Structural contour map of the top of the Jackson Bluff Formation.

and eastern Gulf County) to about 150 feet along the western and southern edges of the county (Figure 18).

Based on planktonic foraminiferal assemblages (Akers, 1972; Huddlestun, 1976) and calcareous nannofossils (Akers, 1972; Akers and Koeppl, 1973) the Jackson Bluff Formation is placed in the Late Pliocene Series. Planktonic foraminifera suggest a latest Pliocene and possibly early Pleistocene age for the downdip portions of this unit (Schmidt and Clark, 1980). The Jackson Bluff Formation is overlain by the Pleistocene-Holocene undifferentiated sands and clays.

Pleistocene-Holocene Series Undifferentiated sands and clays

Much of the southern edge of the Florida panhandle is blanketed by Pleistocene to Holocene age undifferentiated sands and clays. In Gulf County, these sediments are comprised principally of white to light gray to greenish-gray to brown to pale orange sands, clayey sands, sandy clays and in southern Gulf County, massive clays. Many of the sands show cross-bedding, and the different lithologies are typically interbedded (Schmidt, 1984). Shell beds also occur locally along the coastal portion of the county. The undifferentiated sediments reach thicknesses of over 150 feet in the southern and southwestern portions of the county.

A series of undifferentiated red, limonite-rich clayey sands similar to the Citronelle Formation sediments are present along the northern edge of Gulf County. These deposits may represent reworked sediments derived from the Citronelle Formation outcrop area to the north and west of Gulf County.

The undifferentiated sands and clays forming the surficial sediments in Gulf County are predominantly marine and alluvial in origin. Relict marine features, such as stranded beach ridge systems now situated inland from the modern Gulf coast, were formed during the last sea level

highstand of the Pleistocene. Many of the Pleistocene and Holocene sediments may have been deposited at the edge of a migrating paleodelta of the ancestral Apalachicola River. In some cores, the undifferentiated sediments show graded bedding, cross-bedding, and contain well-preserved wood fragments, most likely representing deposition in a fluvial or prograding delta environment (Schmidt, 1984). The interbedded sands and clays and the massive clay units also locally contain plant remains and abundant assemblages of both freshwater and saltwater diatoms; Schmidt (1984) associated these sediments with paleo-lagoons or tidal flats adjacent to a prograding delta.

Prior to the construction of the Jim Woodruff Dam on the Apalachicola River at the Georgia-Florida state line, the river provided significant siliciclastic sediment input into the Gulf County area. Residual Late Holocene river levee and bar deposits are common along the eastern edge of Gulf County today, adjacent to the Apalachicola River and its tributaries.

STRUCTURE

The subsurface structure of Gulf County has been influenced by several regional structural features. Figure 19 illustrates the location and orientation of these features.

Apalachicola Embayment

Gulf County is situated over the axis 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 interpretative and nomenclatural history for this feature.

The Mesozoic and younger sediments underlying Gulf County are downwarped along the southwestward-plunging axis of the embayment. Oil test wells have shown the sediment fill of the basin to consist of about 13,000 feet of Triassic

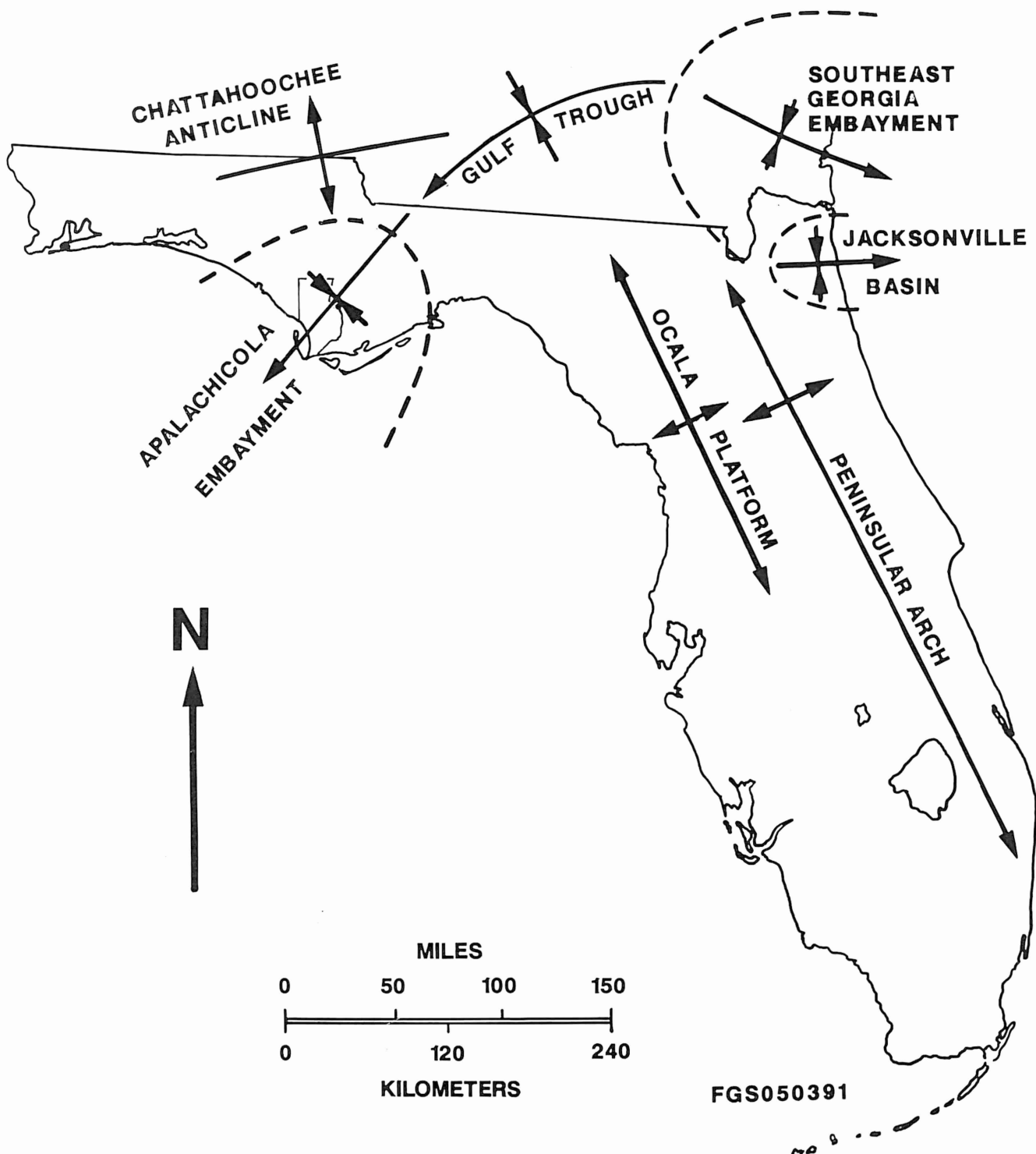


Figure 19. Principal subsurface structures of north Florida.

to Holocene age deposits, all resting on Paleozoic rocks (Applegate et al., 1978; Schmidt and Clark, 1980). Of this total sediment thickness, approximately 10,000 feet are comprised of Mesozoic rocks, and the upper 3,000 feet are Cenozoic in age (Schmidt, 1984).

The Apalachicola Embayment is a basin situated between two structural highs, the Chattahoochee Anticline to the west and the Ocala Platform (variously called the Ocala Arch or Ocala Uplift - see below) to the east. At its northern terminus, the Apalachicola Embayment narrows and extends into the Gulf Trough in southern Georgia. It opens to the south-southwest, both widening and deepening where it extends into the modern Gulf of Mexico. The southernmost extent of the embayment is not well known due to the lack of offshore well data (Schmidt, 1984).

Gulf Trough

Dall and Harris (1892) proposed the existence of a channel-like area of nondeposition 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 Mesozoic and Cenozoic sediments extending from southeast Georgia southwestward into the northern panhandle of Florida. Schmidt (1984) detailed the structural history of this feature. During Late Cretaceous through Oligocene time, this elongate structure connected the Southeast Georgia Embayment and the Apalachicola Embayment (Pressler, 1947). Structure maps drawn on different subsurface 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-to-slow 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.

Its influence as a sediment barrier apparently waned by the end of the Oligocene or earliest Miocene, at which time the depression had probably been infilled with sediments. The source of the sediment fill may have been siliciclastics eroded from the Appalachian Mountain range during a period of renewed uplift in the Early Neogene (Stuckey, 1965; Scott, 1988). The Paleogene strata in Florida, particularly those stretching from the central panhandle into the peninsula, are nearly pure carbonates, representing a carbonate bank paleoenvironment isolated from continental terrigenous sediment input. Final infilling of the Gulf Trough probably allowed, for the first time in millions of years, the influx into peninsular Florida of continentally-derived siliciclastics. These siliciclastics became common components of the Lower Miocene and younger formations in Florida.

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 with an axial surface oriented northeast-southwest. It crests in Jackson County, to the north of Gulf County, and exposes Oligocene and Eocene carbonates in the vicinity of the crest. Younger sediments pinch out or are truncated against the flanks of the anticline (Schmidt, 1984).

Ocala Platform

The Ocala Platform (Scott, 1988) is a gentle, post-Oligocene flexure in west-central peninsular Florida. Previous workers (Vernon, 1951; Puri and Vernon, 1964) have applied the name Ocala

Uplift to this feature. The mechanics and timing of formation of this structure are not well understood. It brings Eocene carbonates to the surface around its crest in Citrus and Levy Counties. Younger units, extending from the Apalachicola Embayment eastward, approach shallower depths and are ultimately truncated against the flanks of the platform.

Peninsular Arch

The Peninsular Arch forms the axis of peninsular Florida (Applin, 1951). It is a southeast-trending structural high in pre-Mesozoic sediments. As with the parallel trending but otherwise unrelated Ocala Platform, its mode of formation is poorly understood.

GROUND WATER

Ground water is water that fills the pores and interstitial spaces in the rocks and sediments beneath the surface of the earth. Most of Gulf County's ground water is derived from precipitation within the county and from neighboring counties to the north. A portion of the precipitation leaves the area by surface runoff in stream flow or by evapotranspiration. The remainder soaks into the ground and some 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, seeps, springs, or eventually the Gulf of Mexico. Some of the water seeps downward into the deeper aquifer units, providing recharge to them.

In Gulf County, three primary ground-water aquifer systems are present. These are, in order of increasing depth, the surficial aquifer system, the intermediate confining unit, and the Floridan aquifer system (Southeastern Geological Society Ad Hoc Committee, 1986). Figure 20 illustrates the aquifer nomenclature in use today.

Surficial aquifer system

Water in the shallow undifferentiated Plio-Pleistocene sand and clay sediments is not confined and the water level is free to rise and fall. This unconfined water comprises the surficial aquifer system, which is recharged through direct infiltration of rain water. The surficial aquifer is generally a thin unit, varying proportionally with the thickness of the undifferentiated sands and clays (Wagner, 1988). In general, the thickness ranges from 4 feet in eastern Gulf County to as much as 90 feet in the northwestern part of the county (Scott et al., 1991 in preparation). The surficial aquifer system surface is most likely an approximate replica of the land surface topography, and it fluctuates in elevation due to droughts or seasonal rainfall differences. Water movement within the surficial aquifer system is generally downhill, or from topographically high areas to low areas. It discharges into streams, bays and the Gulf of Mexico. A small quantity of water from the surficial aquifer system may percolate downward into the underlying intermediate aquifer system. Some form of confining layer, such as clay or clayey sand sediments, generally forms a low-permeability confining layer separating the surficial and intermediate aquifer systems. The surficial aquifer system is not used extensively for public water supplies in Gulf County.

Intermediate confining unit

The intermediate confining unit in Gulf County lies below the surficial aquifer system and is contained within the sediments of the Jackson Bluff, Chipola, and Intracoastal Formations. This unit functions primarily as a confining unit to the underlying Floridan aquifer system, but may locally contain minor aquifers, depending on the thickness and lithology of the host formations. The aquifers, where present, are comprised of sands and limestones, and generally yield small quantities of water suitable for domestic use (Wagner, 1988).

SYSTEM		SERIES	FORMATION	HYDROSTRATIGRAPHIC UNIT
QUATERNARY		HOLOCENE	UNDIFFERENTIATED SANDS AND CLAYS	SURFICIAL AQUIFER SYSTEM
		PLEISTOCENE		
TERTIARY	NEOGENE	PLIOCENE	JACKSON BLUFF FM. CHIPOLA FM. INTRACOASTAL FM.	INTERMEDIATE CONFINING UNIT
		MIOCENE	BRUCE CREEK LS. ST. MARKS/CHATTAHOOCHEE FMS.	FLORIDAN AQUIFER SYSTEM
	PALEOGENE	OLIGOCENE	SUWANNEE LS.	
		EOCENE	OCALA GROUP TALLAHATTA/LISBON FMS. WILCOX GRP. UNDIFF.	
		PALEOCENE	WILCOX GRP. UNDIFF.	SUB-FLORIDAN CONFINING UNIT
	CRETACEOUS AND OLDER		UNDIFFERENTIATED	

Figure 20. Correlation of lithostratigraphic and hydrostratigraphic units in Gulf County (modified from Southeastern Geological Society Ad Hoc Committee, 1986).

The intermediate confining unit generally conforms to the geometry of the geological formations containing it. It ranges from about 150-feet thick in northeastern Gulf County to nearly 500 feet near Cape San Blas. The top of the intermediate confining unit varies from about 10 feet MSL in northern Gulf County to approximately - 50 feet MSL at the southern edge of the county (Scott et al., 1991 in preparation). Aquifers within the intermediate confining unit are recharged primarily from lateral water influx, and from seepage from the overlying and underlying aquifers. The intermediate confining unit is not extensively used as a potable water source in Gulf County.

Floridan aquifer system

The name Floridan Aquifer was originally proposed by Parker et al. (1955) for the artesian aquifer including all or parts of formations from Middle Eocene age to Middle Miocene age. This name was formally modified to Floridan aquifer system by the Southeastern Geological Society Ad Hoc Committee (1986).

The Floridan aquifer system is the most important freshwater aquifer in Florida, underlying much of the central and eastern panhandle, and most of the peninsula of Florida. In Gulf County, it is contained within a number of Eocene through Miocene formations, including the Lisbon Formation, the Ocala Group, the Marianna and Suwannee Limestones, the St. Marks Formation, and the Bruce Creek Limestone.

The Floridan aquifer system is the thickest and most productive unit in the central panhandle, supplying the bulk of the domestic, urban and agricultural water used in Gulf County. Most wells tap the upper Floridan, where the chloride concentration of the water is 100 mg/l or less; this concentration increases to nearly 500 mg/l in the lower portion of the aquifer (Barr and Pratt, 1981). The top of the Floridan aquifer system corresponds to the top of the Bruce Creek Limestone, and in Gulf County, varies from approximately -150 MSL at the northern edge of the county to - 500 feet MSL under St. Joe

Peninsula. The aquifer thickens to the south-southwest, ranging from about 1000-feet thick at the Gulf-Calhoun County line to 2,200-feet thick in southeastern Gulf County, near Lake Wimico (Scott et al., 1991 in preparation). The Floridan aquifer system is underlain by the sub-Floridan confining unit, comprised of the Middle Eocene Tallahatta Formation and older sediments. These sediments typically contain clays, shales, and chalk which act as confining layers.

The Floridan aquifer system is confined in all areas of Gulf County. Minor recharge may occur through downward seepage from aquifer units in the overlying intermediate confining system, but most recharge occurs from water inflow from adjacent counties. Direct recharge to the Floridan aquifer system occurs in Jackson County to the north, where the porous limestones comprising the aquifer are exposed at the surface.

Potentiometric Surface

Water confined within the artesian Floridan aquifer system 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 the Floridan aquifer system 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 21 shows the potentiometric contours for the upper Floridan aquifer system in Gulf County. These contours represent the potentiometric surface relative to mean sea level. If, for example, the land surface elevation of a cased well in the Floridan aquifer system is 50 feet MSL and the water level is 20 feet below land surface, then the potentiometric surface at this location would be 30 feet above MSL. Ground water flows from a direction of high to low potentiometric surface, generally in a direction perpendicular to the potentiometric contours. In Gulf County, this direction is predominantly southward. Most water flowing through the Floridan aquifer system is discharged into the Gulf of Mexico. The elevation of the potentiomet-

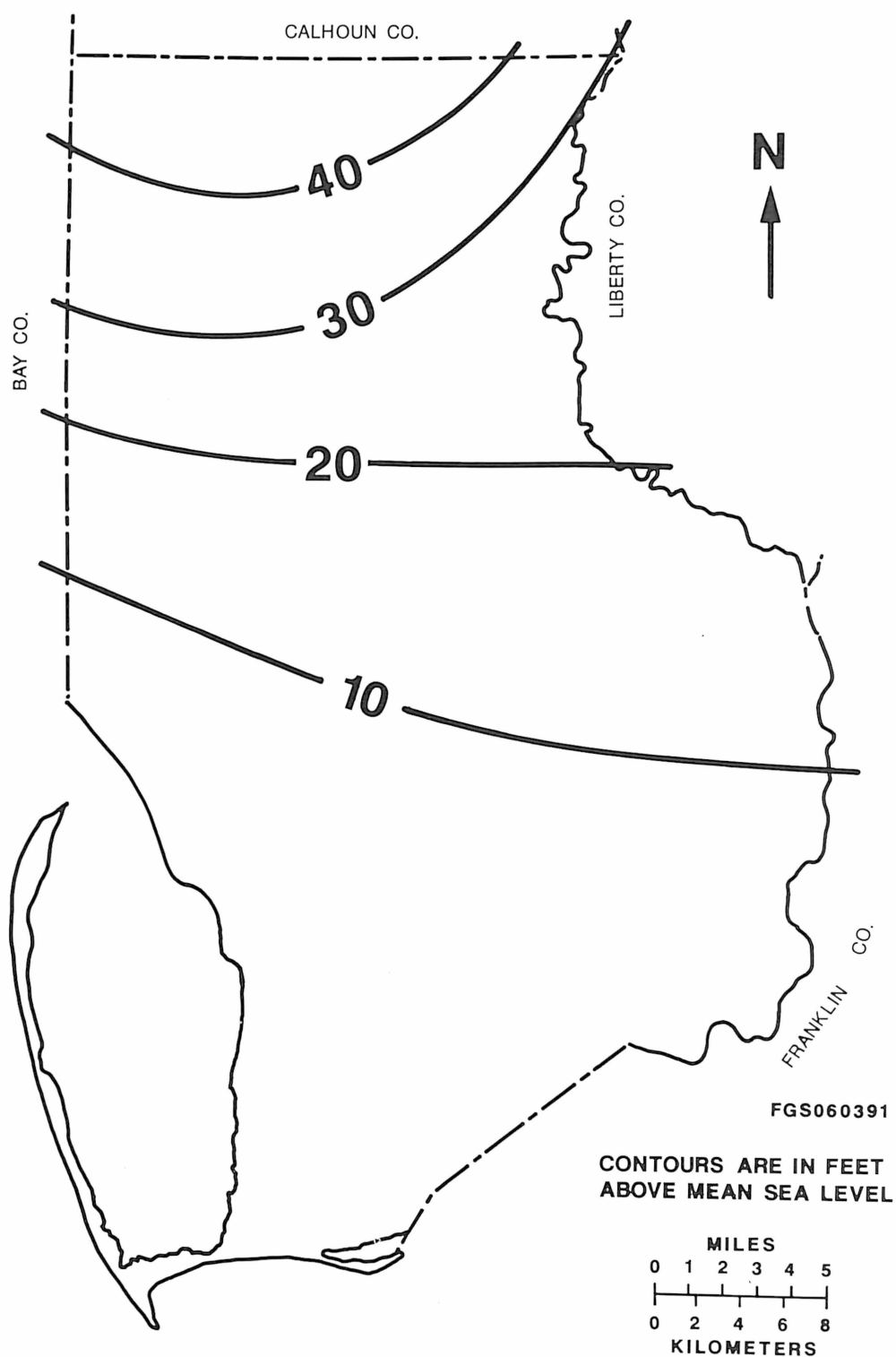


Figure 21. Potentiometric surface map of the Floridan aquifer system in Gulf County (from Barr, 1987).

ric surface of the Floridan aquifer system is highest during rainy seasons, and lowest during dry periods. It is also locally affected by wells, usually being lower adjacent to pumping wells.

Water availability within the Floridan aquifer system is currently good for all of Gulf County. The amount of water that can be withdrawn from the aquifer is largely dependent on the thickness and transmissivity of the rocks containing the aquifer. Northern Gulf County, with its higher potentiometric surface and closer proximity to the recharge areas of Jackson County, has adequate water availability from the Floridan aquifer system. In the coastal areas, the freshwater layer within the aquifer thins in a seaward direction, gradually pinching out as it laps over the wedge of saltwater which fills the aquifer rocks under the Gulf of Mexico. Less freshwater is available to pump in these areas. In some high-growth areas of Florida, such as the lower east and west coasts of the peninsula, pumping has drastically drawn down the freshwater aquifer levels causing a landward migration of the fresh-saltwater interface. In these areas many coastal wells now draw saltwater. As long as population growth and water withdrawal rates in the coastal areas of Gulf County are low, saltwater contamination of Floridan aquifer system wells near the coast should not be a problem.

MINERAL RESOURCES

The following discussion provides a general overview of the near-surface mineral commodities and petroleum resources of Gulf County. Information presented in this section was derived from mineral reports included in various Florida Geological Survey publications, data on file at the FGS, and from data supplied by the Gulf County Road Department.

Clay

Clay occurs both as discrete beds in, and as a matrix constituent of, the undifferentiated sedi-

ments covering Gulf County. Most clays represent Pliocene and Pleistocene deltaic deposits. While widespread in occurrence, many of these deposits contain significant impurities such as quartz sand. Relatively pure Holocene flood plain clays are common along the Apalachicola River, and one such deposit has been utilized for brick making in neighboring Calhoun County.

In general, specific tests on the clay resources of Gulf County are few. Three Gulf County clay samples from an area northeast of Wewahatchka were included in a joint Florida State University-U.S. Bureau of Mines study performed in 1957 (Florida Geological Survey unpublished data). These samples were tested by the U.S. Bureau of Mines for their fired properties, and the samples were retained in the Florida Geological Survey Mineral sample series (M-Series). Table 2 summarizes the location and properties of each sample.

Other clays are associated with the deeper Pliocene and Miocene units underlying Gulf County. Most are untested, and the depth of these units generally limits their economic potential.

The extent to which Gulf County's clay resources are explored and utilized will be largely dependent upon future local demand. At present, a lack of useable clay deposits and insufficient demand for clay products precludes economic development of this resource.

Limestone and Dolomite

Miocene and Pliocene limestone (CaCO_3) and dolomite ($\text{CaMg}(\text{CO}_3)_2$) are present at depth under all of Gulf County. These materials have never been mined in the county. The impure nature of most of these units, as well as the overburden thickness make economic mining of this commodity impractical. It is therefore unlikely that limestone and dolomite will ever have economic potential in Gulf County.

Basic, Incorporated, a magnesium oxide producer in Port St. Joe (see Magnesium Compounds, this section), supplied the County

Florida Geological Survey

Table 2. U.S. Bureau of Mines, Gulf County clay sample analyses

SAMPLE NO. M-2992 Common sandy clay

Location: 3S 9W sec. 30bb
 Dry color: red-gray
 Water of plasticity: 37%
 Dry volume shrinkage: 7%
 General plasticity: good, slightly sandy and fatty

Fired Properties	<i>Cone Temperature (°F)</i>					
	<u>1800</u>	<u>2000</u>	<u>2100</u>	<u>2200</u>	<u>2300</u>	<u>2400</u>
Color:	buff	buff	red-brown	red-brown	red-brown	dark brown
Volume shrinkage (% dry volume):	10.0	11.0	14.5	15.0	15.0	15.5
% absorption:	19.6	20.5	13.6	12.2	11.6	10.9

Hardness: Steel hard at 2100°F

SAMPLE NO. M-2993 Common clay

Location: 3S 9W sec. 29cc
 Dry color: buff gray
 Dry volume shrinkage: 90%
 General plasticity: fair, slightly sandy and fatty

Fired Properties	<i>Cone Temperature (°F)</i>					
	<u>1800</u>	<u>2000</u>	<u>2100</u>	<u>2200</u>	<u>2300</u>	<u>2400</u>
Color:	buff	buff	red-brown	red-brown	red-brown	dark brown
Volume shrinkage (% dry volume):	11.0	11.0	14.0	17.5	17.5	17.5
% absorption:	21.6	19.6	19.6	9.9	8.8	6.4

Hardness: Steel hard at 2200°F

Table 2, continued:**SAMPLE NO. M-2994** Sandy common clay

Location: 4S 9W sec. 4cd
 Dry color: red gray
 Water of plasticity: 30%
 Dry volume shrinkage: 6%
 General plasticity: sandy, short working, no drying defects.

Fired Properties:

Cone Temperature (°F)

	<u>1800</u>	<u>2000</u>	<u>2100</u>	<u>2200</u>	<u>2300</u>	<u>2400</u>
Color:	buff	buff	buff	buff	brown	brown
Volume shrinkage						
(%dry volume):	9.0	9.0	10.0	14.0	15.0	15.0
% absorption:	30.5	21.6	16.5	15.2	10.5	10.1

Hardness: Very hard at 2,400°F

with dolomite residues (called “grits”) from their separation process (Mr. Bill Merchant, Basic, Inc., personal communication). This material was used extensively as road base in Gulf County in the 1960’s and 1970’s. The source of the dolomite was originally from Alabama and Ohio, and is not a local commodity.

Sand and Gravel

Quartz sand (SiO_2) is a common component of the undifferentiated Pliocene through Holocene age surficial sediments in Gulf County. It is also the primary constituent of the nearshore continental shelf deposits (Arthur et al., 1986). Localized gravel deposits are also present in portions of the undifferentiated sediments in northern Gulf County. Much of this sand, with the exception of the marine coastal and aeolian deposits, occurs interbedded with clays. The beach and dune sand is generally of too fine a grain size for practical industrial use (Martens, 1928a).

Surficial sand from private borrow pits in the county is used “as is” for local fill projects. There are currently no industrial or local governmental users of sand in Gulf County. As with the other commodities, future development of this resource will depend primarily on local demand.

Heavy Minerals

Heavy minerals are comprised of sand-sized grains of a number of different mineral types, including ilmenite, zircon, rutile, staurolite, monazite, tourmaline, and others. They are typically associated with marine sand deposits, and are often concentrated by wave action along coastal beaches. Martens (1928b) noted the presence of thin layers of heavy-mineral concentrates along the dune front between Cape San Blas and the northern tip of St. Joe Spit. Table 3 shows the mineralogical analysis of a sample taken by Martens about one mile northwest of the southern tip of Cape San Blas.

Table 3: Mineralogical analysis of heavy concentrate sands from St. Joe Spit, Gulf County (modified from Martens, 1928b).

Original sample composition:

68.2% Quartz and feldspar

31.8% Heavy minerals

Percentage of other minerals corrected to 100% after deducting quartz and feldspar (280 grains counted):

Ilmenite	55.4
Zircon	15.7
Rutile	7.5
Monazite	1.4
Staurolite	3.9
Epidote	1.1
Disthene (Kyanite)	11.5
Sillimanite	0.06
Tourmaline	1.8
Hornblende	0.7
Leucoxene	0.4
Spinel	0.4

While similar in composition to the mineable deposits of northeast Florida, the Gulf County heavy-mineral deposits are not wide enough or thick enough to be commercial grade (Martens, 1928b).

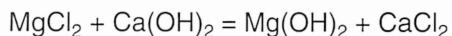
Stapor (1973a) included several heavy-mineral samples from both the western edge of St. Joseph Spit and from St. Joseph Bay in his granulometric study of mineral dispersal. He concluded that the beach face heavy-mineral concentrations were deposited during periods of high wave energy, such as storm surges.

Analyses of continental shelf sediments offshore of Gulf County show generally similar heavy-mineral assemblages and proportions. Arthur et al. (1986) studied samples taken along three offshore transects south and west of Gulf County. These authors observed a suite of heavy-minerals comprised of leucoxene, rutile, sphene, kyanite, tourmaline, staurolite, zircon, epidote, sillimanite, and amphibole (hornblende).

The offshore deposits are most likely from the same source as the beach deposits, having been carried into the area from the crystalline belt of the southern Appalachian Piedmont by the Apalachicola River (Arthur et al., 1986).

Magnesium compounds

Basic, Incorporated (P.O. Box 160, Port St. Joe, FL, 32456) is the sole producer of magnesium compounds in Florida. This company utilizes a mixture of imported calcined dolomite and seawater from St. Joseph Bay to produce magnesium oxide and magnesium hydroxide (Mr. Bill Merchant, Basic, Inc., personal communication). The calcined (treated by heating to high temperature) dolomite is shipped in by rail from Alabama and Ohio. Approximately one-half of the total compound product is present in the calcined dolomite as magnesium oxide (MgO) when it arrives at the plant. The seawater process produces the other half of the total product in the form of magnesium hydroxide ($\text{Mg}(\text{OH})_2$) precipitate. As the seawater and dolomite are mixed, the magnesium chloride in seawater reacts with the calcium hydroxide from the calcined dolomite, producing magnesium hydroxide and calcium chloride. This reaction is summarized in the following equation:



Approximately 16 pounds of magnesium compound is produced for each 1,000 gallons of seawater used. The magnesium hydroxide slurry is filtered to remove water, and the precipitate is then fired in a rotary kiln. Current production from the Basic, Incorporated plant at Port St. Joe is proprietary, but is likely in excess of 10,000 tons per year. Magnesium oxide is used in the production of chemicals, insulation, pulp and paper, rayon, fertilizers, medicines, rubber, building materials, and in refractory processes. Magnesium hydroxide is used in water purification processes, pharmaceuticals, and in sugar refining.

The magnesium reserves in seawater are unlimited. Aside from the costs of importing the calcined dolomite, worldwide demand and foreign competition determine the economics of production. Countries such as China can produce inexpensive, government subsidized magnesium in the form of periclase (Bill Merchant, personal communication). Therefore, the future of magnesium production in Gulf County is tied strongly to world market conditions as well as international trade agreements.

Petroleum

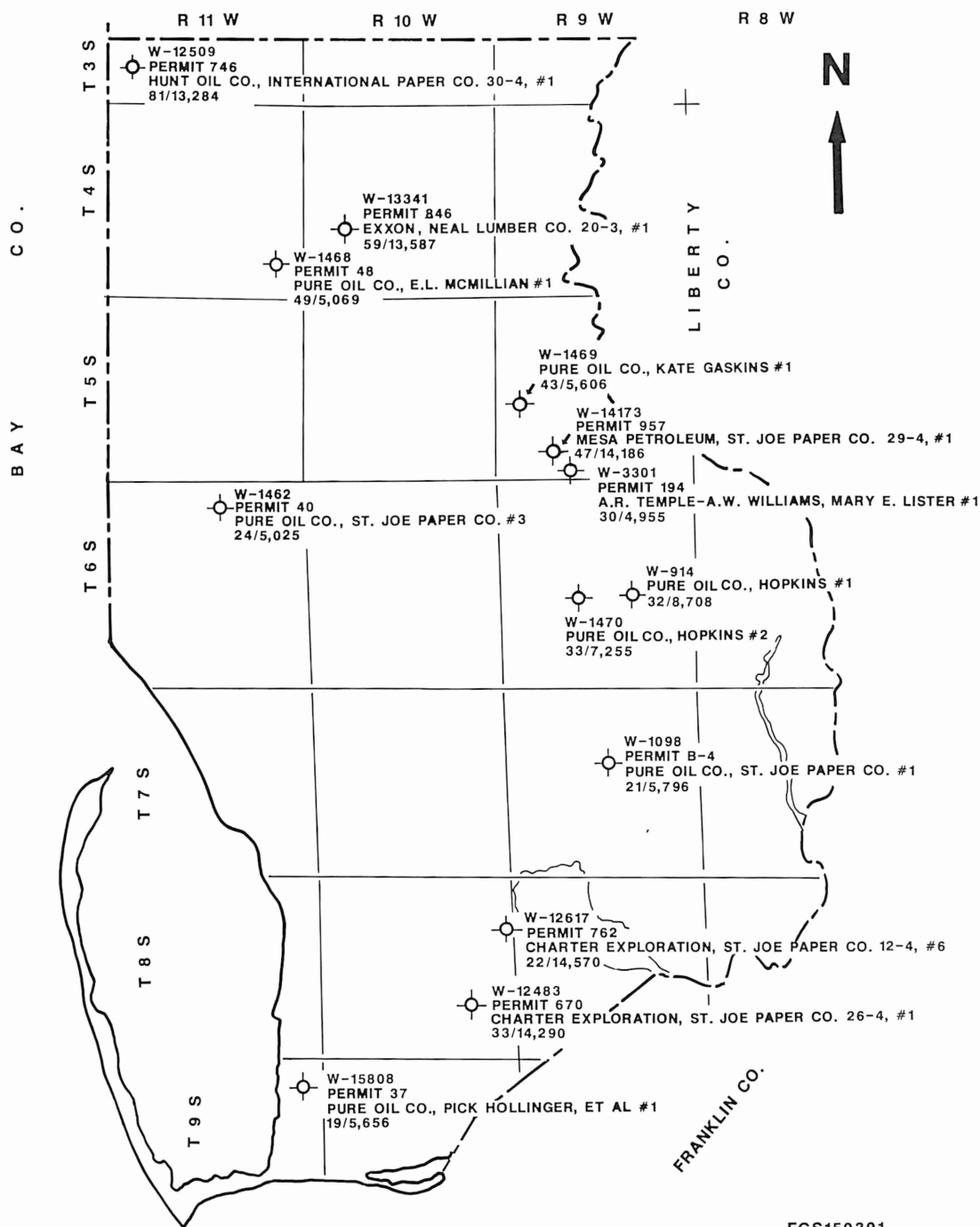
To date, thirteen oil exploration wells have been drilled in Gulf County (see Figure 22). While one had a minor petroleum show, all were plugged and abandoned as dry holes shortly after drilling.

The oldest oil wells in the county date to the mid-1940's and early 1950's. These wells targeted Cretaceous sediments, probably in an attempt to locate a southeastern extension of the productive Tuscaloosa trend of southwestern Alabama. None of the earliest wells exceeded 9,000 feet in depth, and all were dry holes.

After the discovery in 1970 of oil in the Jurassic Smackover Formation and Norphlet Sandstone in the Jay Field, Santa Rosa County, a renewed exploration program was extended by several companies into the Apalachicola Embayment area of Gulf County. The Smackover Formation is present in the westernmost panhandle, and is absent in all of the central panhandle except the Apalachicola Embayment area (Applegate et al., 1978). In the early-to-mid-1970's, Charter Exploration, Exxon, Hunt Oil, and Mesa Petroleum drilled a series of wells trending northwest-southeast through Gulf County. These wells tested the central panhandle portion of the Jurassic Smackover Formation and Norphlet Sandstone units, stopping at depths ranging from 13,284 to 14,570 feet below land surface. Of these wells, only the Hunt Oil Company's International Paper Co. 30-4 (Permit 746) in

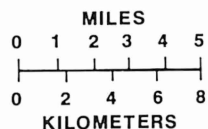
Florida Geological Survey

CALHOUN CO.



FGS150391

EXPLANATION



FGS ACCESSION NO.
FLORIDA PERMIT NUMBER
OPERATOR, WELL NAME
KELLY BUSHING ELEVATION/TOTAL DEPTH BELOW KELLY BUSHING

Figure 22. Map showing locations of oil test wells in Gulf County.

northwestern Gulf County contained oil. The oil was contained in a dense, impermeable section of Smackover Formation limestone and in an underlying calcareous sandstone, with low permeabilities and porosity (Applegate et al., 1978). Due to the low permeability and porosity of the host rock, the oil was non-recoverable and the well was plugged and abandoned in 1974.

The Smackover Formation and Norphlet Sandstone still offer potential as petroleum

sources in Gulf County. Faulting within the Smackover Formation as well as stratigraphic pinchouts along the flanks of the igneous intrusive bodies on which the Smackover sediments were deposited may provide traps for economic accumulations of oil (Applegate et al., 1978). As rising petroleum prices and dwindling supplies revitalize the oil industry, the Gulf County area may be an area of increased exploration activity.

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