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A GEOLOGICAL OVERVIEW OF FLORIDA

By

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Introduction

The State of Florida lies principally on the Florida Platform. The western panhandle of Florida occurs in the Gulf Coastal Plain to the northwest of the Florida Platform. This subdivision is recognized on the basis of sediment type and depositional history. The Florida Platform extends into the northeastern Gulf of Mexico from the southern edge of the North American continent. The platform extends nearly four hundred miles north to south and nearly four hundred miles in its broadest width west to east as measured between the three hundred foot isobaths. More than one-half of the Florida Platform lies under water leaving a narrow peninsula of land extending to the south from the North American mainland.

A thick sequence of primarily carbonate rocks capped by a thin, siliciclastic sediment-rich sequence forms the Florida Platform. These sediments range in age from mid-Mesozoic (200 million years ago [mya]) to Recent. Florida's aquifer systems developed in the Cenozoic sediments ranging from latest Paleocene (55 mya) to Late Pleistocene (<100,000 years ago) in age (Figure 1). The deposition of these sediments was strongly influenced by fluctuations of sea level and subsequent subaerial exposure. Carbonate sediment deposition dominated the Florida Platform until the end of the Oligocene Epoch (24 mya). The resulting Cenozoic carbonate sediment accumulation ranges from nearly two thousand

feet thick in northern Florida to more than five thousand feet in the southern part of the state. These carbonate sediments form the Floridan aquifer system, one of the world's most prolific aquifer systems, regional intra-aquifer confining units and the sub-Floridan confining unit. The sediments suprajacent to the Floridan aquifer system include quartz sands, silts, and clays (siliciclastics) with varying admixtures of carbonates as discrete beds and sediment matrix. Deposition of these sediments occurred from the Miocene (24 mya) to the Recent. The Neogene (24 mya to 1.6 mya) and Quaternary (1.6 mya to the present) sediments form the intermediate aquifer system and/or confining unit and the surficial aquifer system (Figure 1).

Geologic History

Florida's basement rocks, those rocks older than Early Jurassic (>200 mya), are a fragment of the African Plate which remained attached to the North American Plate when the continents separated in the mid-Mesozoic. This fragment of the African Plate provided the base for the development of a carbonate platform which included the Bahama Platform and the Florida Platform (Smith, 1982). The Florida Straits separated the Bahama Platform from the Florida Platform by the beginning of the Late Cretaceous (approximately 100 mya) (Sheridan et al., 1981). Carbonate sediments dominated the depositional environments from the mid-Mesozoic (approximately 145 mya) in southern and central Florida and from the earliest Cenozoic (approximately 62 mya) in northern and the eastern panhandle Florida. Carbonate sedimentation

SYSTEM	SERIES	PANHANDLE FLORIDA LITHOSTRATIGRAPHIC UNIT	PANHANDLE FLORIDA HYDROSTRATIGRAPHIC UNIT	NORTH FLORIDA LITHOSTRATIGRAPHIC UNIT	NORTH FLORIDA HYDROSTRATIGRAPHIC UNIT	SOUTH FLORIDA LITHOSTRATIGRAPHIC UNIT	SOUTH FLORIDA HYDROSTRATIGRAPHIC UNIT
QUARTERNARY	HOLOCENE	UNDIFFERENTIATED PLEISTOCENE-HOLOCENE SEDIMENTS	SURFICIAL AQUIFER SYSTEM	UNDIFFERENTIATED PLEISTOCENE-HOLOCENE SEDIMENTS	SURFICIAL AQUIFER SYSTEM	UNDIFFERENTIATED PLEISTOCENE-HOLOCENE SEDIMENTS	SURFICIAL AQUIFER SYSTEM
	PLEISTOCENE						
TERTIARY	PLIOCENE	CITRONELLE FORMATION MICCOSUKEE FORMATION COARSE CLASTICS		MICCOSUKEE FORMATION CYPRESSHEAD FORMATION NASHUA FORMATION		MIAMI LIMESTONE KEY LARGO LIMESTONE ANASTASIA FORMATION FORT THOMPSON FORMATION CALOOSAHATCHEE FORMATION TAMIAMI FORMATION	
	MIOCENE	ALUM BLUFF GROUP PENSACOLA CLAY INTRACOASTAL FORMATION HAWTHORN GROUP BRUCE CREEK LIMESTONE ST.MARKS FORMATION CHATTAHOOCHEE FORMATION	INTERMEDIATE CONFINING UNIT	HAWTHORN GROUP STATENVILLE FORMATION COOSAWHATCHIE FM. MARKSHEAD FORMATION PENNY FARMS FORMATION ST MARKS FORMATION	INTERMEDIATE AQUIFER SYSTEM OR CONFINING UNIT	HAWTHORN GROUP PEACE RIVER FORMATION BONE VALLEY MEMBER ARCADIA FORMATION TAMPA- NOCATEE MEMBERS	INTERMEDIATE AQUIFER SYSTEM OR CONFINING UNIT
	OLIGOCENE	CHICKASAWHAY LIMESTONE SUWANNEE LIMESTONE MARIANNA LIMESTONE BUCATUNNA CLAY	FLORIDAN AQUIFER SYSTEM	SUWANNEE LIMESTONE	FLORIDAN AQUIFER SYSTEM	SUWANNEE LIMESTONE	FLORIDAN AQUIFER SYSTEM
	EOCENE	OCALA LIMESTONE CLAIBORNE GROUP UNDIFFERENTIATED SEDIMENTS	BUB-FLORIDAN CONFINING UNIT	OCALA LIMESTONE AVON PARK FORMATION OLDSMAR FORMATION		OCALA LIMESTONE AVON PARK FORMATION OLDSMAR FORMATION	
	PALEOCENE	UNDIFFERENTIATED PALEOCENE ROCKS		CEDAR KEYS FORMATION	SUB-FLORIDAN CONFINING UNIT	CEDAR KEYS FORMATION	SUB-FLORIDAN CONFINING UNIT
CRETACEOUS AND OLDER		UNDIFFERENTIATED		UNDIFFERENTIATED		UNDIFFERENTIATED	

Figure 1. Hydrostratigraphic Nomenclature (modified from Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986)

predominated in the Paleogene (67 to 24 mya) throughout most of Florida. Evaporite sediments, gypsum, anhydrite and some halite (salt), developed periodically due to the restriction of circulation in the carbonate depositional environments. The evaporites are most common in the Mesozoic and the Paleogene carbonates at and below the base of the Floridan aquifer system, where they help form the impermeable sub-Floridan confining unit. During the early part of the Cenozoic, the Paleogene, the siliciclastic sediment supply from the north, the Appalachian Mountains, was limited. The mountains had eroded to a low level through millions of years of erosion. The minor amount of sediment reaching the marine environment was washed away from the Florida Platform by currents in the Gulf Trough (Suwannee Straits) (Figure 2). This effectively protected the carbonate depositional environments of the platform from the influx of the siliciclastic sediments. As a result, the carbonates of the Paleogene section are very pure, with extremely limited quantities of siliciclastic sediments. In the central and western panhandle areas, which are part of the Gulf Coastal Plain, siliciclastic deposition continued well into the Paleogene. Significant carbonate deposition did not begin in this area until the Late Eocene (40 mya). During the later Eocene, as the influx of siliciclastics declined dramatically, carbonate depositional environments developed to the north and west of the limits of the Florida Platform. Carbonate deposition was continuous in the central panhandle and intermittent in the western panhandle through the Late Oligocene (approximately 28 mya).

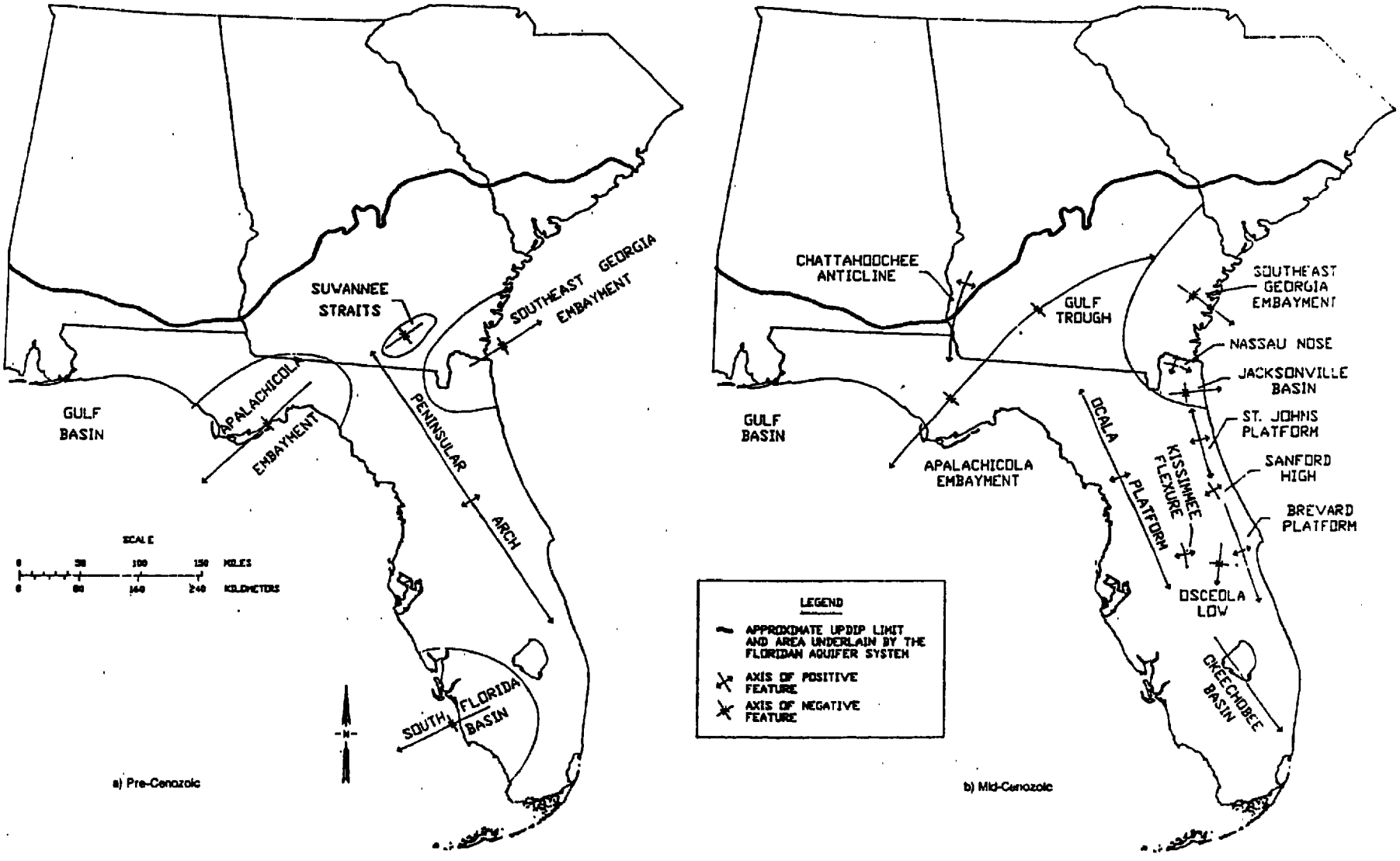

Figure 2. Structural Features of Florida
a) Pre-Cenozoic
b) Mid-Cenozoic

During the Late Oligocene to Early Miocene, an episode of renewed uplift occurred in the Appalachians (Stuckey, 1965). With a renewed supply of sediments being eroded and entering the fluvial transport systems, siliciclastic sediments flooded the marine environment near the southeastern North American coastline. The influx of massive quantities of these sediments filled the Gulf Trough and encroached onto the carbonate platform through longshore transport, currents and other means. At first, the sands and clays were mixed with the carbonate sediments. Later, as more and more siliciclastics were transported south, the carbonate sediment deposition declined to only limited occurrences. Siliciclastic sediments, with varying amounts of carbonate in the matrix, dominated the depositional environments. The carbonate depositional environments were pushed further to the south until virtually the entire platform was covered with sands and clays. The influx of siliciclastics has diminished somewhat during the later Pleistocene and the Recent resulting in carbonate deposition occurring in limited areas around the southern portion of the Florida Platform.

The Miocene-aged siliciclastics appear to have completely covered the Florida Platform providing a relatively impermeable barrier to the vertical migration of ground water (Stringfield, 1966; Scott, 1981). This aquiclude protected the underlying carbonate sediments from dissolution. Erosion breached the confining unit by the early Pleistocene (?) allowing aggressive waters to dissolve the underlying carbonates. The progressive dissolution of the limestones enhanced the secondary porosity of

the near-surface sediments of the Floridan aquifer system and allowed the development of numerous karst features.

Karst features formed in the Florida peninsula at least as early as the latest Oligocene as determined from the occurrence of terrestrial vertebrate faunas (MacFadden and Webb, 1982). Based on subsurface data from the interpretation of FGS cores, it appears that the development of karst in Florida occurred during the Paleogene. Unpublished work by Hammes and Budd (progress report to the FGS, U. Hammes and D. Budd, University of Colorado, 1990) indicates the occurrence of numerous "intraformational disconformities" which resulted in the development of "karst, caliche and other subaerial exposure features...". These disconformities were the result of sea level fluctuations on a very shallow water, carbonate bank depositional environment. At this time there is no documentation of large scale karst features forming during these episodes of exposure.

Structure

The oldest structures recognized as affecting the deposition of sediments of the Florida Platform are expressed on the pre-Middle Jurassic erosional surface (Arthur, 1988). These include the Peninsular Arch, South Florida Basin, Southeast Georgia Embayment, Suwannee Straits and the Southwest Georgia Embayment or Apalachicola Embayment. These structures affected the deposition of the Mesozoic sediments and the Early Cenozoic (Paleogene) sediments. The structures recognized on the top of the Paleogene section are somewhat different than the older features. The

younger features, which variously affected the deposition of the Neogene and Quaternary sediments, include the Ocala Platform, Sanford High, Chattahoochee Anticline, Apalachicola Embayment, Gulf Trough, Jacksonville Basin (part of the Southeast Georgia Embayment), Osceola Low and the Okeechobee Basin (Figure 2). For more specific information on these structures and their origins refer to Chen (1965), Miller (1986) and Scott (1988a).

The occurrence and condition of the aquifer systems are directly related to their position with respect to the structural features. The Floridan aquifer system lies at or near the surface under poorly confined to unconfined conditions on the positive features such as the Ocala Platform, Sanford High and the Chattahoochee Anticline. Within the negative areas, (the Apalachicola Embayment, Jacksonville Basin, Osceola Basin and the Okeechobee Basin) the Floridan aquifer system is generally well confined. The intermediate aquifer system is generally absent from the positive structures and best developed in the negative areas. The surficial aquifer system may occur anywhere in relation to these structures where the proper conditions exist.

The occurrence and development of the beds confining the Floridan aquifer system also relate to the subsurface structures. On some of the positive areas (Ocala Platform and Chattahoochee Anticline) the confining beds of the intermediate confining unit are absent due to erosion and possibly nondeposition. In those areas where the confining units are breached, dissolution of the carbonate sediments developed a karstic terrain. Dissolution of the limestones enhanced the porosity and permeability of the

Floridan aquifer system including the development of some cavernous flow systems.

Geomorphology

Florida's land surface is relatively flat and has very low relief. The surface features of Florida are the result of the complex interaction of depositional and erosional processes. As sea level fluctuated during the later Cenozoic, the Florida Platform has repeatedly been inundated by marine waters resulting in marine depositional processes dominating the development of Florida's geomorphology. The relict shoreline features found throughout most of the state are most easily identified at lower elevations, nearer the present coastline. Inland and at higher elevations, these features have been subjected to more extensive erosion and subsequent modification by wind and water. In those areas of the state where carbonate rocks and shell-bearing sediments are subjected to dissolution, the geomorphic features may be modified by development of karst features. The extent of the modification ranges from minor sagging due to the slow dissolution of carbonate or shell to the development of large collapse sink-holes. The changes that result may make identification of the original features difficult.

White (1970) subdivided the State into three major geomorphic divisions, the northern or proximal zone, the central or mid-peninsular zone and the southern or distal zone (Figure 3). The northern zone encompasses the Northwest Florida Water Management District and the northern portions of the Suwannee River and St.

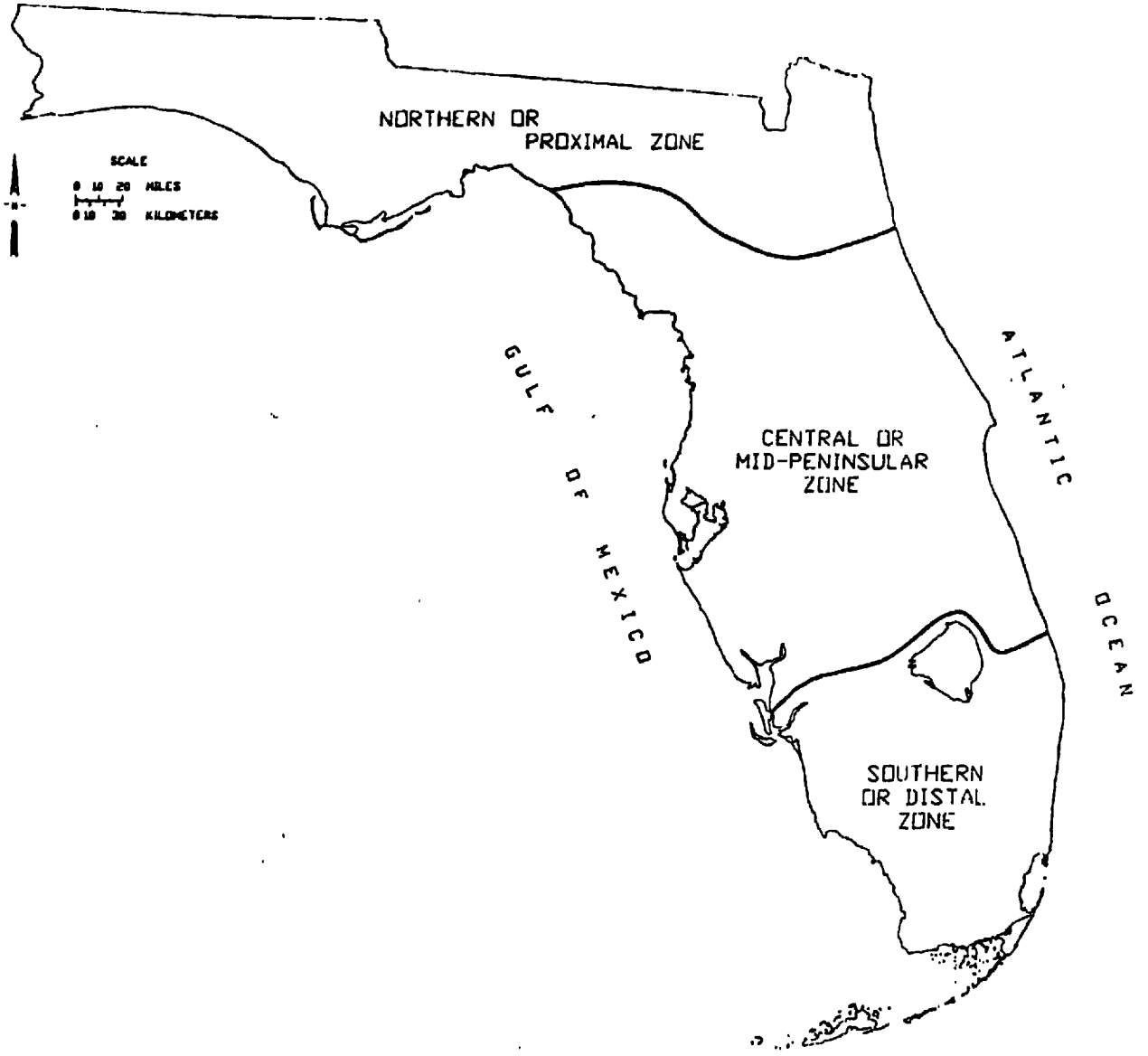

Figure 3. Geomorphologic Provinces of Florida

Johns River Water Management Districts. The central zone includes the southern portions of the Suwannee River and St. Johns River Water Management Districts, the Southwest Florida Water Management District and the northern part of the South Florida Water Management District. The southern zone comprises the remainder of the South Florida Water Management District.

In a broad general sense, the geomorphology of Florida consists of the Northern Highlands, the Central Highlands and the Coastal Lowlands (White, Vernon and Puri in Puri and Vernon, 1964). White (1970) further subdivided these features as shown in Figures 4 through 8. In general, the highlands are well drained while the lowlands often are swampy, poorly drained areas. The highland areas as delimited by White, Vernon and Puri in Puri and Vernon (1964) often coincide with the areas of "high recharge" as recognized by Stewart (1980). Only a few, limited areas of "high recharge" occur in the Coastal Lowlands.

Many of the highland areas in the peninsula to the central panhandle exhibit variably developed karst features. These range from shallow, broad sinkholes that develop slowly to those that are large and deep and develop rapidly (Sinclair and Stewart, 1985). The development of the karst features and basins has a direct impact on the recharge in the region. The karst features allow the rapid infiltration of surface water into the aquifer systems and offer direct access to the aquifers by pollutants.

Lithostratigraphy and Hydrostratigraphy

The aquifer systems in Florida are composed of sedimentary

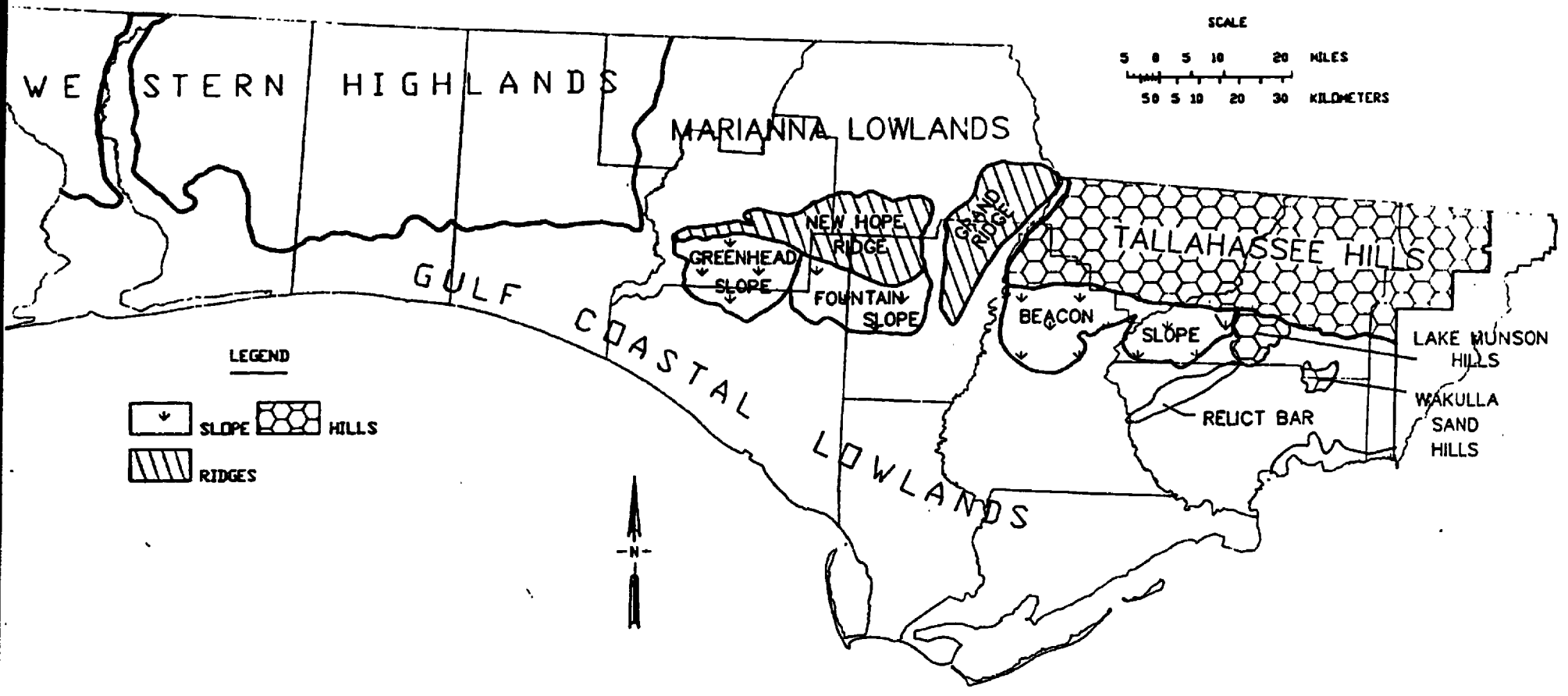

Figure 4. Geomorphologic Features of Northwest Florida Water Management District (NWFWMD) (after White, Puri and Vernon in Puri and Vernon, 1964)

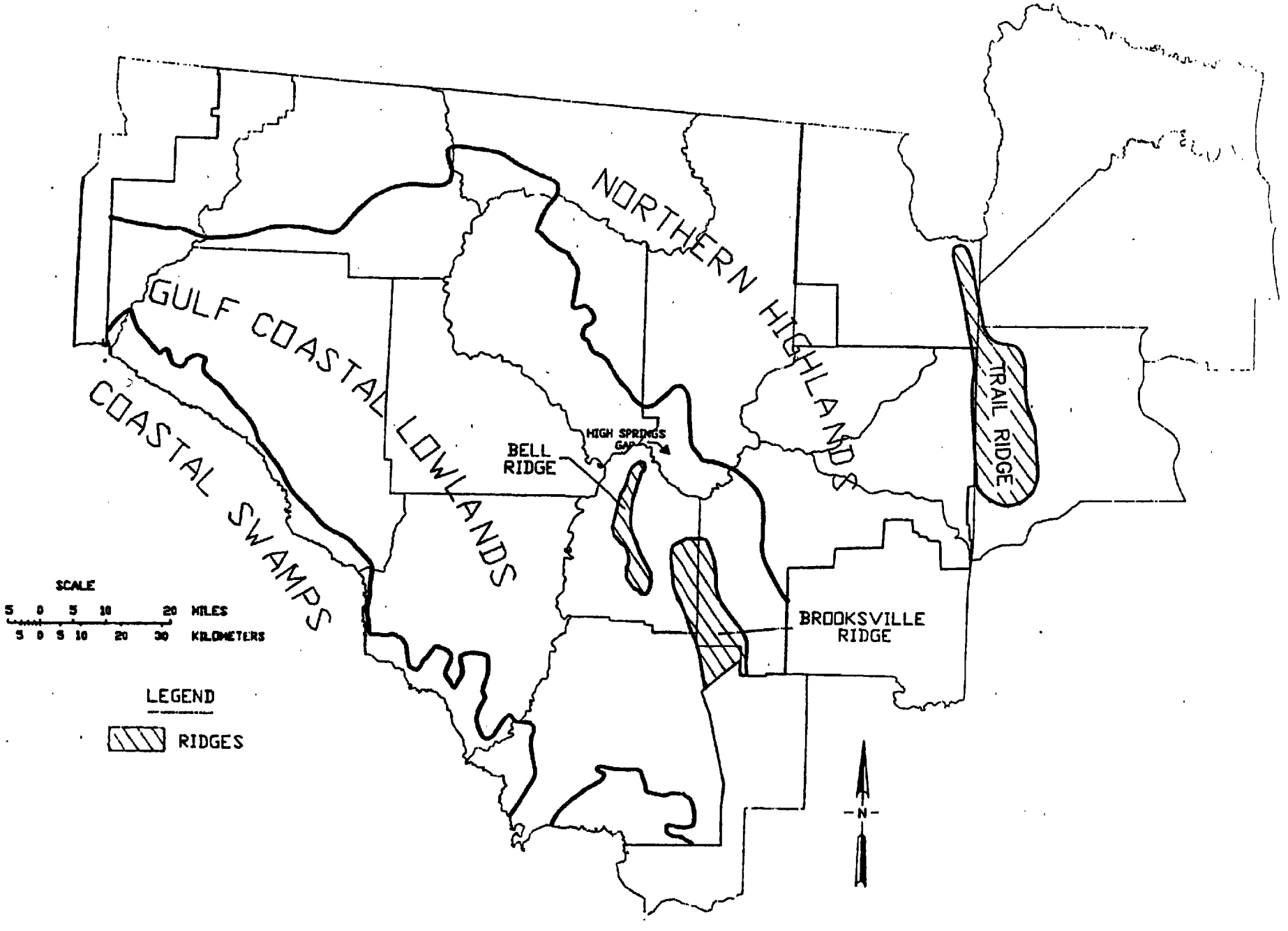

Figure 5. Geomorphologic Features of Suwannee River Water Management District (SRWMD) (after White, 1970)

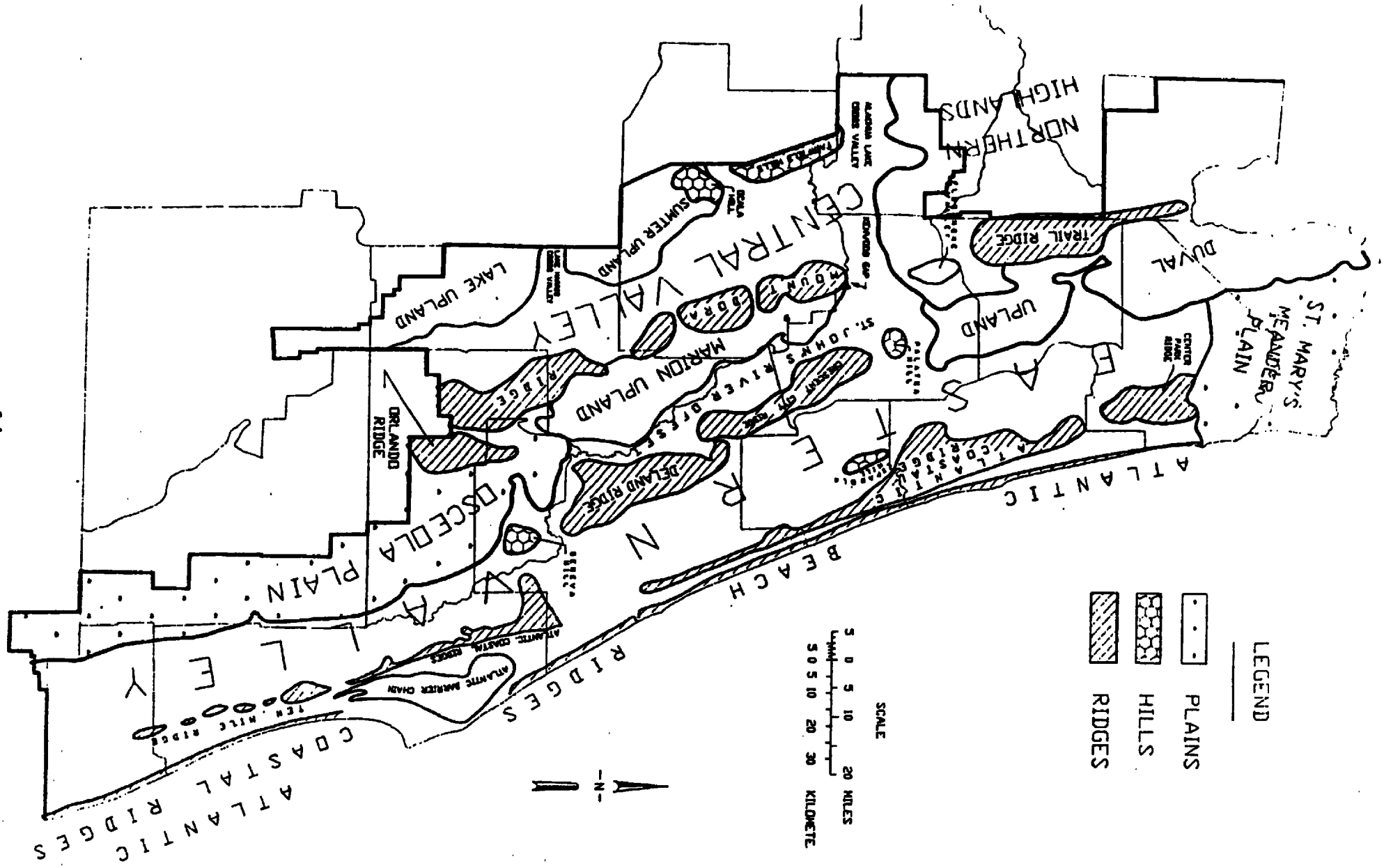

Figure 6. Geomorphologic Features of St. Johns River Water Management District (SJRWMD) (after White, 1970)

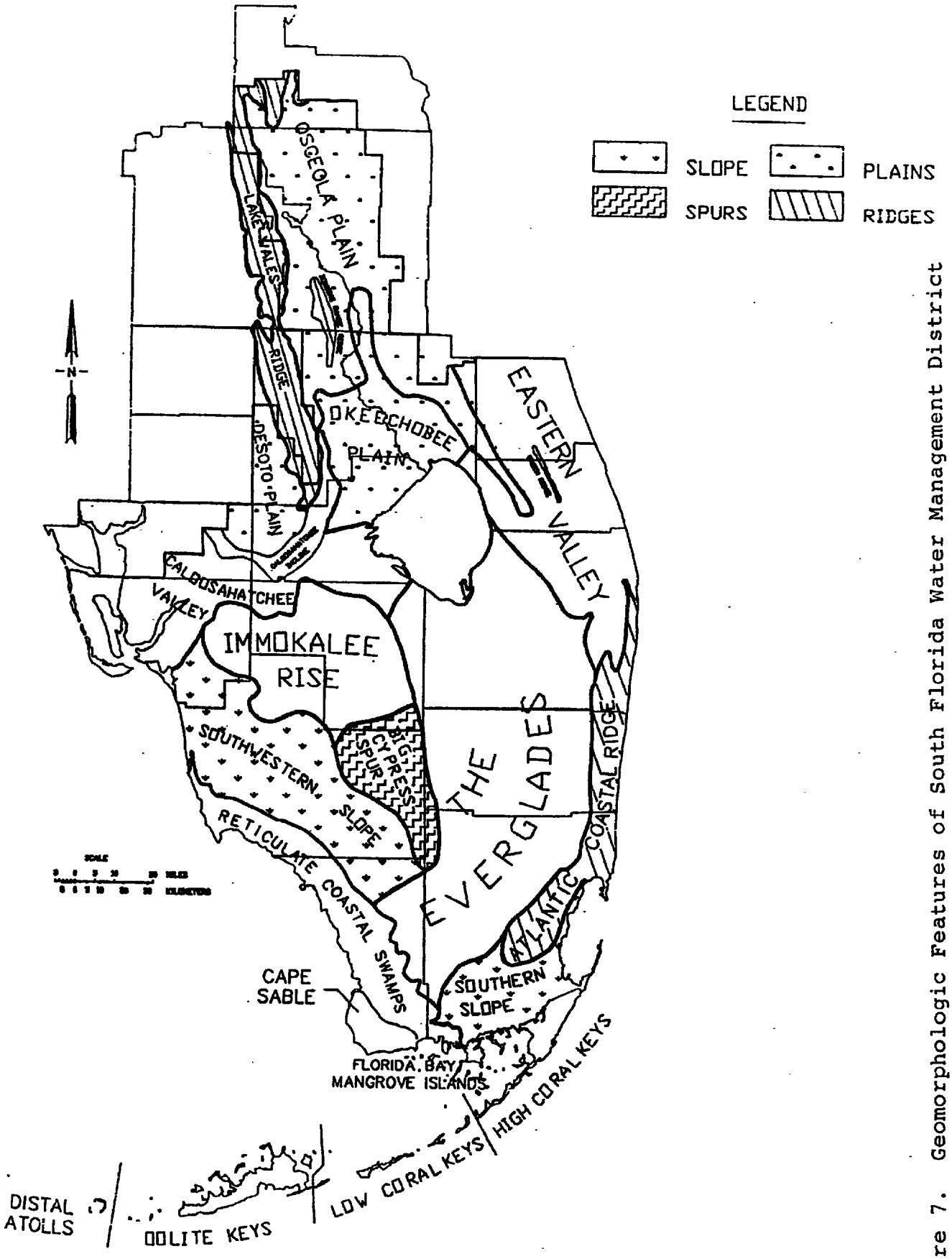

Figure 7. Geomorphologic Features of South Florida Water Management District (SFWMD) (after White, 1970)

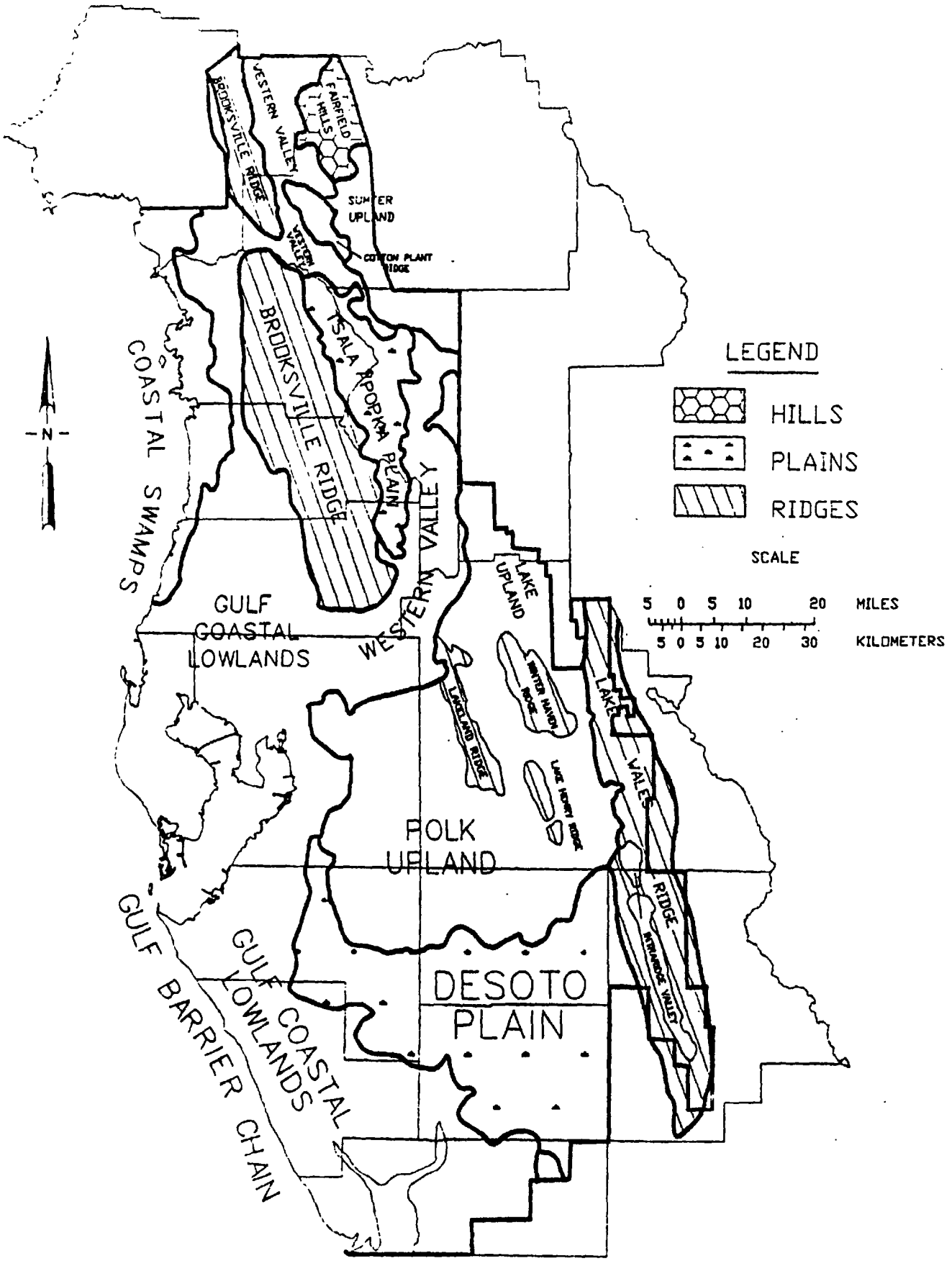

Figure 8. Geomorphologic Features of Southwest Florida Water Management District (SWFWMD) (after White, 1970)

rock units of varying composition and induration which are subdivided into geologic formations based on the lithologic characteristics (rock composition and physical characteristics). Lithostratigraphy is the formal recognition of the defined geologic formations based on the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). Many units are related by the similarities of the sediments while others may be defined on the sediment heterogeneity. An aquifer is a body of sediment or rock that is sufficiently permeable to conduct ground water and to yield economically significant quantities of water to wells and springs (Bates and Jackson, 1987). Florida's primary aquifers are referred to as aquifer systems due to the complex nature of the water-producing zones they contain. The aquifer systems are identified independently from lithostratigraphic units and may include more than one formation or be limited to only a portion of a formation. The succession of hydrostratigraphic units forms the framework used to discuss the ground-water system in Florida (Figure 1) (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

The lithostratigraphic and hydrostratigraphic framework of Florida shows significant variability from north to south and west to east in the peninsula and the panhandle. The formational units discussed are only those Cenozoic sediments that relate to the Floridan aquifer system, the intermediate aquifer system/confining unit and the surficial aquifer system.

Lithostratigraphy

The lithostratigraphic units that comprise the aquifer systems in Florida occur primarily as subsurface units with very limited surface exposures. As a result of the generally low relief of the state, virtually all the lithostratigraphic descriptions are from well cuttings and cores used to study the sediments. Geophysical logs have proven useful in studying the sediments and attempting regional correlations (Chen, 1965; Miller, 1986; Scott, 1988a; Johnson, 1983).

The following description of the lithologic parameters of the various units associated with the aquifer systems is brief and generalized. More complete information concerning these groups and formations can be obtained by referring to Florida Geological Survey and U. S. Geological Survey publications relating to specific areas and/or specific aquifers. State-wide data concerning the thickness and tops of sediments of Paleocene (67-55 mya) and Eocene (55-38 mya) age (chronostratigraphic units) can be found in Chen (1965) and Miller (1986). Miller (1986) provides this data for Oligocene (38-25 mya) and Miocene (25-5.3 mya) sediments. Scott (1988) provides detailed information on the Miocene strata in the eastern panhandle and peninsular areas. The Plio-Pleistocene (5.3-.01 mya) and the Holocene (.01 mya -Present) sediments which make up the surficial aquifer system, are discussed in a number of references which are cited in the appropriate section of this paper. Figure 1 shows the lithostratigraphic nomenclature utilized in this text.

Cenozoic Erathem

Tertiary System

Paleocene Series

In general, most of the Paleocene sediments in the Florida peninsula form the sub-Floridan confining unit and only a limited portion of these rocks are part of the Floridan aquifer system. Siliciclastic sediments predominate in the Paleocene section in much of the panhandle (Chen, 1965; Miller, 1986). The siliciclastic sediments are composed of low permeability marine clays, fine sands and impure limestone (Miller,1986) which lie below the base of the Floridan aquifer system. Following Miller (1986), the siliciclastic sediments are referred to as "Undifferentiated Paleocene Rocks (Sediments)" and are not discussed further.

The siliciclastic sediments grade laterally into carbonate sediments across the Gulf Trough in the eastern panhandle (Chen, 1965). Carbonate sediments, mostly dolostone, occur interbedded with evaporite minerals throughout the Paleocene section in the peninsula (Chen, 1965). These sediments are included in the Cedar Keys Formation and occur throughout the peninsular area and into the eastern panhandle.

Cedar Keys Formation

The Cedar Keys Formation consists primarily of dolostone and evaporites (gypsum and anhydrite) with a minor percentage of limestone (Chen, 1965). The upper portion of the Cedar Keys consists of coarsely crystalline, porous dolostone. The lower portion of the Cedar Keys Formation contains more finely

crystalline dolostone which is interbedded with anhydrite. The Cedar Keys Formation grades into the Undifferentiated Paleocene Sediments in the eastern panhandle (Miller, 1986) which equate with the Wilcox Group (Braunstein et al., 1988).

The configuration of the Paleocene sediments in peninsular Florida reflect depositional controls inherited from the pre-existing Mesozoic structures, including the Peninsular Arch, Southeast Georgia Embayment, and the South Florida Basin (Miller, 1986). The Cedar Keys Formation forms the base of the Floridan aquifer system throughout the peninsula except in the northwestern-most peninsular area where the Oldsmar Formation forms the base (Miller, 1986). The upper, porous dolostone comprises the lowest beds of the Floridan aquifer system. The lower Cedar Keys Formation is significantly less porous, contains evaporites and forms the sub-Floridan confining unit.

Eocene Series

The sediments of the Eocene Series that form portions of the Floridan aquifer system are carbonates. During the Early Eocene, deposition followed a distribution pattern similar to the Paleocene carbonate sediments. However, through the Eocene, carbonate-forming environments slowly encroached further north and west over what had been siliciclastic depositional environments during the Paleocene. The Eocene carbonate sediments are placed in the Oldsmar Formation, Avon Park Formation and the Ocala Group. The Eocene carbonate sediments comprise a large part of the Floridan aquifer system.

Claiborne Group

The Lower to Middle Eocene Claiborne Group unconformably (?) overlies the undifferentiated Lower Eocene and Paleocene sediments. The Claiborne Group consists of the Tallahatta and Lisbon Formations which are lithologically nearly identical and are not separated. The group is composed of glauconitic, often clayey sand grading into fine-grained limestone to the south (Allen, 1987). The Claiborne Group ranges from 250 to 400 feet below NGVD and is up to 350 feet thick (Allen, 1987). It is unconformably overlain by the Ocala Limestone.

Oldsmar Formation

The Oldsmar Formation consists predominantly of limestone interbedded with vuggy dolostone. Dolomitization is usually more extensive in the lower portion of the section. Pore-filling gypsum and thin beds of anhydrite occur in some places, often forming the base of the Floridan aquifer system (Miller, 1986).

The Oldsmar Formation is recognized throughout the Florida peninsula. It grades laterally in the eastern panhandle into Undifferentiated Lower to Middle Eocene sediments equivalent to the Claiborne Group. The undifferentiated sediments are marine shales, siltstones, fine sandstones and impure limestones (Miller, 1986).

Avon Park Formation

The Middle Eocene sediments of peninsular Florida as originally described by Applin and Applin (1944) were subdivided,

in ascending order, into the Lake City Limestone and the Avon Park Limestone. Miller (1986) recommended the inclusion of the Lake City in the Avon Park based on the very similar nature of the sediments. Miller also changed the term limestone to formation due to the presence of significant quantities of dolostone within the expanded Avon Park Formation.

The Avon Park Formation is primarily composed of fossiliferous limestone interbedded with vuggy dolostone. In a few, limited areas of west-central Florida, evaporites are present as vug fillings in dolostone.

The Avon Park Formation occurs throughout the Florida peninsula and the eastern panhandle in a pattern very similar to the underlying Oldsmar Formation. The oldest rocks cropping out in Florida belong to the Avon Park Formation. These sediments are locally exposed on the crest of the Ocala Platform in west-central peninsular Florida.

The carbonate sediments of the Avon Park Formation form part of the Floridan aquifer system and serve to subdivide it into an upper and lower Floridan in many areas. Miller (1986) recognized that portions of the Avon Park Formation are fine-grained and have low permeability, often acting as a confining bed in the middle of the Floridan aquifer system. In Brevard County, for example, these low permeability beds are relied upon to keep less desirable water injected into the lower Floridan from migrating into the potable water of the upper Floridan.

Ocala Limestone

Dall and Harris (1892) referred to the limestones exposed in central peninsular Florida near the city of Ocala in Marion County as the Ocala Limestone. Puri (1957) raised the Ocala to group and recognized formations based on the incorporated foraminiferal faunas. As a result of the biostratigraphic nature of these subdivisions, formational recognition is often difficult. In keeping with the intent of the Code of Stratigraphic Nomenclature, in this text, the Florida Geological Survey is returning to the use of the Ocala Limestone terminology.

The lower and upper subdivisions of the Ocala Limestone are based on distinct lithologic differences. The lower subdivision consists of a more granular limestone (grainstone to packstone). The lower facies is not present everywhere and may be partially to completely dolomitized in some regions (Miller, 1986). The upper unit is composed of variably muddy (carbonate), granular limestone (packstone to wackestone with very limited grainstone). Often this unit is very soft and friable with numerous large foraminifera. In southern Florida, virtually the entire Ocala Limestone consists of a muddy (carbonate) to finely pelletal limestone (Miller,1986). Chert is a common component of the upper portion of the Ocala Limestone. The Bumpnose "Formation", a very early Oligocene fossiliferous limestone, is lithologically very similar to the Ocala Limestone. It is included in the Ocala Limestone in this report.

The sediments of the Ocala Limestone form one of the most permeable zones within the Floridan aquifer system. The Ocala

Limestone comprises much of the Floridan aquifer system in the central and western pahhandle. The extensive development of secondary porosity by dissolution has greatly enhanced the permeability, especially in those areas where the confining beds are breached or absent. The Ocala Limestone forms the lower portion of the Floridan in the western panhandle (Wagner, 1982). In much of the peninsular area, it comprises all or part of the upper Floridan.

By Late Eocene, carbonate sediments were deposited significantly further to the north and west than had previously occurred during the Cenozoic. The Ocala Limestone is present throughout much of the State except where the unit has been erosionally removed. This occurs in outcrop on the crest of the Ocala Platform and in the subsurface on the Sanford High, a limited area in central Florida and a relatively large area in southernmost Florida (Miller, 1986). Chen (1965) suggests that the Ocala Limestone is also absent in a portion of Palm Beach County in eastern southern Florida. The surface and thickness of the Ocala Limestone are highly irregular due to dissolution of the limestones as karst topography developed.

Oligocene Series

The carbonate sediments of the Oligocene Series form much of the upper portion of the Floridan aquifer system in Florida. The depositional pattern of the Oligocene sediments shows that carbonate sediments were deposited well updip to the north of the Florida Platform (Miller, 1986). In the central panhandle and to

the west, siliciclastic sediments began to be mixed with the carbonates.

The Oligocene sediments in peninsular Florida and part of the panhandle are characteristically assigned to the Suwannee Limestone. The Oligocene sediments in the central and western panhandle are placed in the Marianna, Bucatunna and Chickasawhay Formations (Miller, 1986). In the westernmost panhandle, the lower carbonates of the Suwannee Limestone grade into the siliciclastic Byram Formation (Braunstein et al., 1988).

Suwannee Limestone

The Suwannee Limestone consists primarily of variably vuggy and muddy (carbonate) limestone (grainstone to packstone). The occurrence of a vuggy, porous dolostone is recognized in the type area, the eastern to central panhandle and in southwest Florida. The dolostone often occurs interbedded between limestone beds.

The Suwannee Limestone is absent throughout a large area of the northern and central peninsula probably due to erosion. Scattered outliers of Suwannee Limestone are present within this area. Where it is present, the Suwannee Limestone forms much of the upper portion of the Floridan aquifer system. The reader is referred to Miller (1986) for a map of the occurrence of the Suwannee Limestone in the peninsula.

Marianna Limestone

The Marianna Limestone is a fossiliferous, variably argillaceous limestone (packstone to wackestone) that occurs in the

central panhandle. It is laterally equivalent to the lower portion of the Suwannee Limestone. The Marianna Limestone forms a portion of the uppermost Floridan aquifer system in the central panhandle region.

Bucatunna Clay Member of the Byram Formation

The Bucatunna Clay Member is silty to finely sandy clay. Fossils are generally scarce in the Bucatunna (Marsh, 1966). The sand content of the Bucatunna ranges from very minor percentages to as much as 40 percent (Marsh, 1966).

The Bucatunna Clay Member has a limited distribution in the western panhandle. It occurs from the western end of the state eastward to approximately the Okaloosa-Walton County line where it pinches out (Marsh, 1966). The Bucatunna Clay Member provides an effective intra-aquifer confining unit in the middle of the Floridan aquifer system in the western panhandle.

Chickasawhay Formation

Marsh (1966) describes the Chickasawhay Formation as being composed of highly porous limestone and dolomitic limestone. This is often interbedded with porous to compact dolomitic limestone to dolostone. The Chickasawhay Formation grades into the upper Suwannee Limestone eastward. Due to difficulty in separating the Chickasawhay from the Lower Miocene limestones in the western panhandle, both Marsh (1966) and Miller (1986) included thin beds of possible Lower Miocene carbonate in the upper portion of the Chickasawhay Formation. The permeable sediments of the

Chickasawhay Formation form part of the upper Floridan in the western panhandle (Wagner, 1982).

Miocene Series

The Miocene Epoch was a time of significant change in the depositional sequence on the Florida Platform and the adjacent Gulf and Atlantic Coastal Plains. During the early part of the Miocene, carbonate sediments continued to be deposited over most of the State. Intermixed with the carbonates were increasing percentages of siliciclastic sediments. By the end of the Early Miocene, the deposition of carbonate sediments was occurring only in southern peninsular Florida. Siliciclastic deposition dominated the Middle Miocene statewide with this trend continuing into the Late Miocene.

The basal Miocene carbonate sediments often form the uppermost portion of the Floridan aquifer system. The remainder of the Miocene sediments form much of the intermediate aquifer system and intermediate confining system. In some instances, these sediments may also be included in the surficial aquifer system.

Unusual depositional conditions existed during the Miocene as is evident from the occurrence of abundant phosphate, palygorskite, opaline cherts and other uncommon minerals plus an abundance of dolomite within the Hawthorn Group (Scott, 1988a). The presence of these minerals may influence ground-water quality in areas where the Miocene sediments are being weathered. Ground-water quality may also be affected where these sediments form the upper portion of the Floridan aquifer system or portions of the intermediate aquifer system.

Current geologic thought holds that in the peninsula the Miocene section is composed of the Hawthorn Group. The Tampa Formation is included as a member in the basal Hawthorn Group. In the panhandle, the Lower Miocene remains the Chattahoochee and St. Marks Formations, the Middle Miocene Alum Bluff Group and the Upper Miocene Choctawhatchee Formation and equivalents. Formations previously mentioned in the literature as being Miocene in age include the Tamiami, which is Pliocene in age, and the Miccosukee Formation which is now recognized as being Late Pliocene to possibly early Pleistocene in age.

The Miocene sediments are absent from the Ocala Platform and the Sanford High (Scott, 1988a). These sediments are as much as 800 feet thick in southwest Florida (Miller, 1986; Scott, 1988a), 500 feet thick in the northeastern peninsula (Scott, 1988a) and 900 to 1000 feet thick in the westernmost panhandle (Miller, 1986).

Chattahoochee Formation

The Chattahoochee Formation is predominantly a fine-grained, often fossiliferous, silty to sandy dolostone which is variable to a limestone (Huddlestun, 1988). Fine-grained sand and silt may also form beds with various admixtures of dolomite and clay minerals. Clay beds may also be common in some areas (Puri and Vernon, 1964).

The Chattahoochee Formation occurs in a limited area of the central panhandle from the axis of the Gulf Trough westward. It appears that the Chattahoochee grades to the west into a carbonate unit alternately referred to as Tampa Limestone (Marsh, 1966;

Miller, 1986) or St. Marks (Puri and Vernon, 1964; NWFWMD Staff, 1975). Northward into Georgia, this unit grades into the basal Hawthorn Group (Huddlestun, 1988). To the east of the axis of the Gulf Trough, the Chattahoochee Formation grades into the St. Marks Formation (Puri and Vernon, 1964; Scott, 1986). The gradational change between the Chattahoochee and St. Marks Formations occurs over a broad area of Leon and Gadsden Counties (Scott, 1986). The sediments of the Chattahoochee Formation comprise the upper zone of the Floridan aquifer system in the central panhandle.

St. Marks Formation

The St. Marks Formation is a fossiliferous limestone (packstone to wackestone). Sand grains occur scattered in an often very moldic limestone. The lithology of the St. Marks and the associated units in the Apalachicola Embayment and to the west are often difficult to separate (Schmidt, 1984). The St. Marks Formation lithology can be traced in cores grading into the Chattahoochee Formation (Scott, 1986). This formation forms the upper part of the Floridan aquifer system in portions of the eastern and central panhandle.

Hawthorn Group

The Hawthorn Group is a complex series of the phosphate-bearing Miocene sediments in peninsular and eastern panhandle Florida. The carbonate sediments of the Hawthorn Group are primarily fine-grained and contain varying admixtures of clay, silt, sand and phosphate. Dolostone is the dominant carbonate

sediment type in the northern two-thirds of the peninsula while limestone predominates in the southern peninsula and in the eastern panhandle area.

The siliciclastic sediment component consists of fine- to coarse-grained quartz sand, quartz silt and clay minerals in widely varying proportions. The clay minerals present include palygorskite, smectite and illite with kaolinite occurring in the weathered sediments.

The top of the Hawthorn Group is a highly irregular erosional and karstic surface. This unconformable surface can exhibit dramatic local relief especially in outcrop along the flanks of the Ocala Platform. Figures 12 through 19 show the top and thickness of the Hawthorn Group sediments which comprise the intermediate aquifer system/confining unit.

In the peninsula, the Hawthorn Group can be broken into a northern section and a southern section. The northern section consists of interbedded phosphatic carbonates and siliciclastics with a trend of increasing siliciclastics in the younger sediments. In ascending order, the formations in northern Florida are the Penney Farms, Marks Head and Coosawhatchie and its lateral equivalent Statenville (Scott, 1988a). The sediments comprising these formations characteristically have low permeabilities and form an effective aquiclude, the intermediate confining unit. In a few areas, permeabilities within the Hawthorn sediments are locally high enough to allow the limited development of an intermediate aquifer system.

The southern section consists of a lower dominantly phosphatic

carbonate section and an upper phosphatic siliciclastic section. In the southern area, in addition to increasing siliciclastics upsection, there is also a trend of increasing siliciclastics from west to east in the lower carbonate section. The Hawthorn Group in southern Florida has been subdivided into, in ascending order, the Arcadia Formation with the former Tampa Formation as a basal member, and the Peace River Formation (Scott, 1988a). Throughout much of south Florida, these sediments have limited or low permeabilities and form an effective intermediate confining unit. However, where the Tampa Member is present and permeable enough, it may form the upper portion of the Floridan aquifer system. In portions of southwestern Florida, the Hawthorn sediments are permeable enough to form several important producing zones in the intermediate aquifer system (Knapp et al., 1986; Smith and Adams, 1988).

The Hawthorn Group, Torreya Formation sediments in the eastern panhandle are predominantly siliciclastics with limited amounts of carbonates (Scott, 1988a). In this area, carbonates become increasingly important in the Gulf Trough where the basal Hawthorn sediments are fine-grained carbonates. The siliciclastic sediments are very clayey and form an effective intermediate confining unit. The carbonate sediments may locally be permeable enough to form the upper portion of the Floridan aquifer system.

Bruce Creek Limestone

Huddlestun (1976) applied the name Bruce Creek Limestone to late Middle Miocene limestones occurring in the Apalachicola

Embayment and coastal areas of the central and western panhandle. The Bruce Creek Limestone is a fossiliferous, variably sandy limestone (Schmidt, 1984). This lithology becomes indistinguishable, to the east, from lithologies found in the St. Marks Formation (Schmidt, 1984). The Bruce Creek Limestone is laterally equivalent to and grades into the lower portion of the Alum Bluff Group (Schmidt, 1984). The Bruce Creek Limestone forms part of the upper Floridan aquifer system in the central and western panhandle.

Alum Bluff Group

West of the Apalachicola River in the Florida panhandle, the Hawthorn Group is replaced by the Alum Bluff Group. The Alum Bluff Group includes the Chipola Formation, Oak Grove Sand, Shoal River Formation and the Choctawhatchee Formation (Braunstein et al., 1988). The formations included in this group are generally defined on the basis of their molluskan faunas and are of variable areal extents. These sediments can be distinguished as a lithologic entity at the group level and will be referred to as such in this text.

The Alum Bluff Group consists of clays, sands and shell beds which may vary from a fossiliferous, sandy clay to a pure sand or clay and occasional carbonate beds or lenses. The Jackson Bluff Formation is currently thought to be Late Pliocene in age; and, even though Huddlestun (1976) included it in the Alum Bluff Group, it was not included in the Alum Bluff Group on the latest correlation charts (Braunstein et al., 1988). Sediments comprising the Jackson Bluff Formation are very similar to those making up the

Alum Bluff Group.

The sediments comprising the Alum Bluff Group are generally impermeable due to the abundance of clay-sized particles. These sediments form an important part of the intermediate confining unit in the central panhandle.

Pensacola Clay

The Pensacola Clay consists of three members: lower and upper clay members and a middle sand member, the Escambia Sand (Marsh, 1966). Lithologically, the clay members consist of silty, sandy clays with carbonized plant remains (Marsh, 1966). The sand member is fine to coarse, quartz sand. Marine fossils are rarely present in the Pensacola Clay with the exception of a fossiliferous layer near the base (Clark and Schmidt, 1982). The Pensacola Clay grades laterally into the lower portion of the "Miocene Coarse Clastics" to the north and the Alum Bluff Group and the lower Intracoastal Formation to the east (Clark and Schmidt, 1982).

The Pensacola Clay forms the intermediate confining unit for the Floridan in the western panhandle. It lies immediately suprajacent to the limestones of the upper Floridan aquifer system.

Intracoastal Formation

Schmidt (1984) describes the Intraçoastal Formation as a "very sandy, highly microfossiliferous, poorly consolidated, argillaceous, calcarenitic limestone." Phosphate is generally present in amounts greater than one percent. This unit is laterally gradational with the Pensacola Clay and Mio-Pliocene

"Coarse Clastics" (Schmidt, 1984). The lower Intracoastal Formation is Middle Miocene while the upper portion is Late Pliocene. Wagner (1982) indicates that the Intracoastal Formation forms part of the intermediate confining unit in the central to western panhandle.

Pliocene-Pleistocene Series

The sediments of the Pliocene-Pleistocene Series occur over most of the State. These sediments range from nonfossiliferous, clean sands to very fossiliferous, sandy clays and carbonates. Lithologic units comprising this series include the "Coarse Clastics", Tamiami Formation, Citronelle Formation, Miccosukee Formation, Cypresshead Formation, Nashua Formation, Caloosahatchee Formation, Fort Thompson Formation, Key Largo Limestone, Miami Limestone, Anastasia Formation and Undifferentiated Pleistocene-Holocene sediments. The upper portion of the Intracoastal Formation is Pliocene and is discussed with the lower Intracoastal Formation under the Miocene Series. For a further discussion of the Plio-Pleistocene sediments in southern Florida, see Scott and Allmon (1992).

"Coarse Clastics"

The name "Coarse Clastics" has been applied to sequences of quartz sands and gravels in a number of areas around Florida. These sediments are often referred to in the literature as "Miocene Coarse Clastics" (for example, Puri and Vernon, 1964).

In northern Florida, these sediments are referred to as the

Cypresshead Formation of Late Pliocene to Early Pleistocene age (Scott, 1988b). In southern Florida, Knapp et al. (1986) referred to these sediments as the "Miocene Coarse Clastics" and placed them in the Hawthorn Group. In the panhandle, Marsh (1966) mentions the "Miocene Coarse Clastics" as sands and gravel with some clay which underlie the Citronelle Formation.

In the panhandle, the "Coarse Clastics" are variably clayey sands with gravel and some shell material (Clark and Schmidt, 1982). These siliciclastics occur in Escambia, Santa Rosa and western Okaloosa Counties in the western panhandle. They equate in part to the upper part of the Pensacola Clay, part of the Intracoastal Formation and part of the Alum Bluff Group.

In southern peninsular Florida, the coarse siliciclastics are fine to very coarse quartz sands with quartz gravel and variable amounts of clay, carbonate and phosphate. These sediments may equate with the Cypresshead Formation sediments in central and northern Florida.

These siliciclastic sediments form important aquifer systems in portions of southern and panhandle Florida. In the western panhandle, the "Coarse Clastics" form a portion of the Sand-and-Gravel aquifer, part of the surficial aquifer system. These sediments also comprise a portion of the surficial aquifer system in the peninsular area, especially in southern Florida.

Tamiami Formation

The Tamiami Formation consists of the Pinecrest Sand Member, the Ochopee Limestone Member, and the Buckingham Limestone Member

(Hunter, 1968). The various facies of the Tamiami occur over a wide area of southern Florida. The relationships of the facies are not well known due to: 1- the complex set of depositional environments that were involved in the formation of the sediments and 2- the Tamiami Formation most often occurs as a shallow subsurface unit throughout much of its extent. Many of the facies are important from a hydrogeologic perspective in an area of ground-water problems.

The limestone in the Tamiami Formation occurs as two types: 1- a moderately to well-indurated, slightly phosphatic, variably sandy, fossiliferous limestone (Ochopee) and 2- a poorly indurated to unindurated, slightly phosphatic, variably sandy, fossiliferous limestone (Buckingham). The sand facies is often composed of a variably phosphatic and sandy, fossiliferous, calcareous, quartz sand often containing abundant, well-preserved mollusk shells (Pinecrest). The sand varies from a well-sorted, clean sand with abundant well-preserved shells and traces of silt-sized phosphate in the type Pinecrest Sand Member (Hunter, 1968) to a clayey sand with sand-sized phosphate, clay-sized carbonate in the matrix and abundant, well preserved mollusk shells. Siliciclastic sediments (undifferentiated) of this age appear to occur along the eastern side of the peninsula but have not been assigned to the Tamiami Formation.

Sediments of the Tamiami Formation exhibit variable permeabilities and form the lower Tamiami aquifer and Tamiami confining beds of the surficial aquifer system (Knapp et al., 1986). Smith and Adams (1988) indicate that the upper Tamiami

sediments form the basal portion of the "water table aquifer" overlying the Tamiami confining beds.

Citronelle Formation

The Citronelle Formation is composed of fine to very coarse siliciclastics. The name was extended to include the siliciclastics comprising the central ridge system in the Florida peninsula by Cooke (1945). As it is currently recognized, the Citronelle Formation occurs only in the panhandle. The unit is recognized from central Gadsden County on the east to the western boundary of the State. The Citronelle Formation is composed of very fine to very coarse, poorly sorted, angular to subangular quartz sand. The unit contains significant amounts of clay, silt and gravel which may occur as beds, lenses or stringers and may vary rapidly over short distances. Limonite nodules and limonitic cemented zones are common.

The Citronelle Formation extends over much of the central and western panhandle. Previous investigators encountered problems in the separation of the Citronelle and the overlying terrace deposits and generally considered the thickness of the Citronelle including these younger sediments (Marsh, 1966; Coe, 1979). The Citronelle Formation grades laterally into the Miccosukee Formation through a broad transition zone in Gadsden County. The Citronelle Formation forms an important part of the Sand-and-Gravel aquifer in the western panhandle and produces up to 2,000 gallons of water per minute (Wagner, 1982).

Miccosukee Formation

Hendry and Yon (1967) describe the Miccosukee Formation as consisting of interbedded and cross-bedded clay, silt, sand and gravel of varying coarseness and admixtures. Limonite pebbles are common in the unit. The Miccosukee Formation occurs in the eastern panhandle from central Gadsden County on the west to eastern Madison County on the east. Due to its clayey nature, the Miccosukee Formation does not produce significant amounts of water. It is generally considered to be part of the surficial aquifer system (Southeastern Geological Society, 1986).

Cypresshead Formation

The name Cypresshead Formation was first used by Huddlestun (1988). It was extended into Florida by Scott (1988b). The Cypresshead Formation is composed entirely of siliciclastics; predominantly quartz and clay minerals. The unit is characteristically a mottled, fine- to coarse-grained, often gravelly, variably clayey quartz sand. As a result of weathering, the clay component of these sediments has characteristically been altered to kaolinite. Clay serves as a binding matrix for the sands and gravels. Clay content may vary from absent to more than fifty percent in sandy clay lithologies although the average clay content is 10 to 20 percent. These sediments are often thinly bedded with zones of cross bedding. The Cypresshead Formation appears to occur in the Central Highlands of the peninsula south to northern Highlands County, although the extent of the Cypresshead Formation has not been accurately mapped in this area. This unit may locally

comprise the surficial aquifer system where clay content is low.

Nashua Formation

The Nashua is a fossiliferous, variably calcareous, sometimes clayey, quartz sand. The fossil content is variable from a shelly sand to a shell hash. The dominant fossils are mollusks.

The extent of the Nashua in northern Florida is not currently known. It extends some distance into Georgia and appears to grade laterally into the Cypresshead Formation (Huddlestun, 1988). The Nashua Formation may produce limited amounts of water in localized areas where it forms part of the surficial aquifer system.

Caloosahatchee Formation

The Caloosahatchee Formation consists of fossiliferous quartz sand with variable amounts of carbonate matrix interbedded with variably sandy, shelly limestones. The sediments vary from nonindurated to well indurated. The fauna associated with these sediments are varied and often well preserved. Fresh water limestones are commonly present within this unit.

Sediments identified as part of the Caloosahatchee Formation by various investigators occur from north of Tampa on the west coast south to Lee County, eastward to the East Coast then northward into northern Florida (DuBar, 1974). The Caloosahatchee Formation as used here includes those sediments informally referred to as the Bermont formation (Dubar, 1974).

In most hydrogeologic investigations of southern Florida, the Caloosahatchee Formation is not differentiated from the Fort

Thompson Formation and other faunal units. The undifferentiated sediments form much of the surficial aquifer system.

Fort Thompson Formation

The Fort Thompson Formation consists of interbedded shell beds and limestones. The shell beds are characteristically variably sandy and slightly indurated to unindurated. The sandy limestones present in the Fort Thompson Formation were deposited under both freshwater and marine conditions. The sand present in these sediments is fine- to medium-grained. The sediments of Fort Thompson age in central Florida along the east coast, consist of fine to medium quartz sand with abundant mollusk shells and a minor but variable clay content.

The Fort Thompson Formation, as the Caloosahatchee Formation, is part of the undifferentiated sediments in southern Florida. It forms a portion of the surficial aquifer system.

Key Largo Limestone

The Key Largo Limestone is a coralline limestone composed of coral heads encased in a matrix of calcarenite (Stanley, 1966). Hoffmeister and Multer (1968) indicate that the Key Largo Limestone occurs in the subsurface from as far north as Miami Beach to as far south as the Lower Keys. The fossil reef tract represented by the Key Largo sediments may be as much as 8 miles wide (DuBar, 1974). Near the northern and southern limits of the Key Largo Limestone, it is overlain conformably by the Miami Limestone with which the Key Largo is, in part, laterally equivalent.

The Key Largo Limestone forms a part of the Biscayne aquifer of the surficial aquifer system. The Biscayne aquifer provides water for areas of Dade, Broward and Monroe Counties.

Miami Limestone

The Miami Limestone includes an oolitic facies and a bryozoan facies. The bryozoan facies underlies and extends west of the western boundary of the oolitic facies. The bryozoan facies consists of calcareous bryozoan colonies imbedded in a matrix of ooids, pellets and skeletal sand. It generally occurs as a variably sandy, recrystallized, fossiliferous limestone (Hoffmeister et al., 1967). The oolitic facies consists of variably sandy limestone composed primarily of oolites with scattered concentrations of fossils.

Hoffmeister et al. (1967) indicate that the Miami Limestone covers Dade County, much of Monroe County and the southern part of Broward County. It grades laterally to the south into the Key Largo Limestone and to the north into the Anastasia Formation. The oolitic facies underlies the Atlantic Coastal Ridge southward from southern Palm Beach County to southern Dade County.

The Miami Limestone forms a portion of the Biscayne aquifer of the surficial aquifer system. It is very porous and permeable due to the dissolution of carbonate by ground water as it recharges the aquifer system.

Anastasia Formation

The Anastasia Formation consists of interbedded quartz sands

and coquinoid limestones. The sand beds consist of fine to medium-grained, variably fossiliferous, calcareous, quartz sand. The contained fossils are primarily broken and abraided mollusk shells. The limestone beds, commonly called coquina, are composed of shell fragments, scattered whole shells and quartz sand enclosed in a calcareous matrix, usually sparry calcite cement.

The Anastasia Formation forms the Atlantic Coastal Ridge through most of its length (White, 1970). Natural exposures of this unit occur scattered along the east coast from St. Augustine south to southern Palm Beach County near Boca Raton. South of this area the Anastasia Formation grades into the Miami Limestone. Cooke (1945) felt that the Anastasia Formation extended no more than three miles inland from the Intracoastal Waterway. Field work by this author (Scott) suggests that the Anastasia may extend as much as 10 miles inland; although, Schroeder (1954) suggest that this unit may occur more than 20 miles inland.

The Anastasia Formation forms a portion of the surficial aquifer system along the eastern coast of the State. Ground water is withdrawn from the Anastasia Formation in many areas along the Atlantic Coastal Ridge where, locally, it may be the major source of ground water. Near the southern extent of the Anastasia Formation, it forms a portion of the Biscayne aquifer (Hoffmeister, 1974).

Undifferentiated Pleistocene-Holocene Sediments

The sediments referred to as the "undifferentiated Pleistocene-Holocene sediments" cover much of Florida effectively

hiding most older sediments. Included in this category are marine "terrace" sediments, eolian sand dunes, fluvial deposits, fresh water carbonates, peats and a wide variety of sediment mixtures. These sediments often occur as thin layers overlying older formations and are not definable as formations. As such, these sediments have been referred to by many different names including Pliocene to Recent sands, Pleistocene sands, Pleistocene Terrace Deposits.

The sediments incorporated in this category are most often quartz sands. The sands range from fine- to coarse-grained, nonindurated to poorly indurated and nonclayey to slightly clayey. Gravel may be present in these sediments in the panhandle area. Other sediments included in this group include peat deposits, some clay beds, and freshwater carbonates. The freshwater carbonates occur in many freshwater springs and in large areas of the Everglades.

Locally, these sediments may form a portion of the surficial aquifer system. The greatest thicknesses of these sediments occurs infilling paleokarst features where more than 300 feet of undifferentiated Pleistocene-Holocene sediments have been recorded (Florida Geological Survey, unpublished well data).

Hydrostratigraphy

Florida's ground-water resources occur in a complex lateral and vertical sequence of Cenozoic sediments comprised of both

siliciclastics and carbonates which underlie the entire state. Hydrostratigraphically, the section consists of several major aquifer systems defined on lateral extent, degree of confinement, and hydrologic parameters of the sediments. The Southeastern Geological Society's ad hoc Committee on Florida Hydrostratigraphic Unit Definition (Southeastern Geological Society (SEGS), 1986), in an attempt to alleviate many of the nomenclatural problems surrounding Florida's hydrostratigraphic units, defined the framework of the various aquifer systems occurring in the state. Most of the geologic community have accepted these definitions and are using the suggested nomenclature. Aquifers of lesser importance have been recognized in some areas of the state and are discussed in the literature on specific areas. This text will define and characterize only the major aquifer systems discussed by the SEGS (1986). These systems include the surficial aquifer system, the intermediate aquifer system or intermediate confining unit, and the Floridan aquifer system including the Claiborne aquifer and the sub-Floridan confining unit. Figure 1 indicates which formations form portions of the various aquifer systems throughout the state. Miller (1986) provides an excellent, in-depth discussion of the Floridan aquifer system and the associated shallower strata. It is recommended that the reader review Miller's volume for a more detailed description of the ground-water system in Florida.

Geologic Structures in Relation to Hydrostratigraphy

The occurrence, thickness and, to some extent, the aquifer

characteristics are directly related to the structural features present in a given area. The major positive features affecting the various aquifer systems include the Ocala Platform, Chattahoochee Anticline, Sanford High and the St. Johns and Brevard Platforms (Figure 2). The major negative features include the Gulf Basin, Apalachicola Embayment, Gulf Trough, Jacksonville Basin, Osceola Low and the Okeechobee Basin (Figure 2). These structures affected the deposition and erosion of the later Cenozoic sediments. Older structures, including the Peninsular Arch and the South Florida Basin (Figure 2), affected the lower portions of the Cenozoic section.

The surficial aquifer system is thin to absent on the positive features. Its thickness increases off the positive structures reaching maximum thicknesses in the Okeechobee, Jacksonville and Gulf Basins and the Apalachicola Embayment.

The intermediate aquifer system and intermediate confining unit also thin onto the positive features. Sediments forming these units are erosionally absent from the Chattahoochee Anticline, Ocala Platform and the Sanford High. These units thicken off the highs, reaching the maximum thicknesses in the basinal areas. As the sediments of the intermediate aquifer system and confining unit thicken, permeable beds become more commonly interbedded with the impermeable strata, resulting in a more fully developed intermediate aquifer system.

Eocene and Oligocene carbonate sediments of the Floridan aquifer system are exposed to thinly covered on the Ocala Platform and the Chattahoochee Anticline. These sediments are covered by a

thin intermediate confining unit on the flanks of the positive features. In these areas, the carbonates have been exposed to aggressive ground water developing an extensive karstic terrain. In the basinal areas, the carbonate sediments have not undergone such extensive dissolution due to the thick protective cover provided by the intermediate aquifer system and intermediate confining unit.

Aquifer Systems and Confining Units

Surficial aquifer system

The SEGS (1986) defines the surficial aquifer system as the "permeable hydrologic unit contiguous with the land surface that is comprised principally of unconsolidated to poorly indurated, (silici)clastic deposits. It also includes well-indurated carbonate rocks, other than those of the Floridan aquifer system where the Floridan is at or near land surface. Rocks making up the surficial aquifer system belong to all or part of the Upper Miocene to Holocene Series. It contains the water table, and the water within it is under mainly unconfined conditions; but beds of low permeability may cause semi-confined or locally confined conditions to prevail in its deeper parts. The lower limit of the surficial aquifer system coincides with the top of the laterally extensive and vertically persistent beds of much lower permeability."

The surficial aquifer system occurs throughout most of the

state. In many areas, it is used for small yield domestic and agricultural water supplies. However, in the western panhandle the surficial aquifer system, referred to as the Sand and Gravel Aquifer, supplies important amounts of water for municipal and industrial supplies. In the southeastern part of the state, the surficial aquifer system is called the Biscayne Aquifer and provides enormous quantities of water for the coastal communities in this area. Elsewhere in the state, the surficial aquifer system is of limited importance. Throughout the extent of the surficial aquifer system, the thickness varies significantly from a feather edge to more than 350 feet in southeastern Florida and 500 feet in the western-most panhandle (Scott et al., 1991). The top of the surficial aquifer system is the natural land surface. The base occurs where impermeable beds of the intermediate confining unit and aquifer system begin or, in those areas where the intermediate is absent, at the top of the Floridan aquifer system carbonates.

In many areas of the state, the surficial aquifer system lies on a karstified erosional surface developed on Eocene to Miocene carbonates. Karst processes have also affected the surficial aquifer system by forming collapse features which filled with surficial aquifer system sediments and may be in direct hydrologic contact with the Floridan aquifer system. Karst features also perforate the surficial aquifer system developing open sinkholes on the present land surface.

Northwest Florida Water Management District

The surficial aquifer system in the Northwest Florida Water

Management District (NWFWMD) occurs over most of the district. It is absent only in a limited portion of Wakulla, Leon and Jefferson Counties at the eastern edge of the district along the western flank of the Ocala Platform. It is thin to absent on part of the Chattahoochee Anticline in Jackson and Holmes Counties. Where the surficial is present it ranges in thickness from less than 10 feet in the east to more than 500 feet in the northwestern corner of the area (Scott et al., 1991).

The siliciclastic sediments comprising the surficial aquifer system in NWFWMD are part of the Citronelle and Miccosukee Formations, "Coarse Clastics" and the undifferentiated sediments of Pleistocene-Holocene age (Marsh, 1966; Scott, 1991). These sediments are primarily quartz sands with varying percentages of clay. Where the clay content becomes great enough to inhibit the transmission of ground water, localized impermeable beds may confine water creating artesian conditions within the surficial aquifer system. The surficial aquifer system yields greater quantities of water in the western panhandle where the Citronelle contains less clay and is thicker than in those areas where the clayey Miccosukee occurs.

Suwannee River Water Management District

The surficial aquifer system in the Suwannee River Water Management District (SRWMD) is present in several areas of the district. According to Ceryak (SRWMD, personal communication, 1991), the surficial aquifer system is present in adjoining portions of southern Madison, northeastern Taylor and northwestern

Lafayette Counties, western Hamilton County, eastern Suwannee County, much of Columbia and Union Counties, along the eastern edge of Bradford County under Trail Ridge and under Waccassassa Flats in central Gilchrist County. Sediments equivalent to the surficial aquifer system are present throughout much of the district but are not utilized for water resources. Thicknesses of the surficial aquifer system range from 10 to 30 feet but may reach 50 to 60 feet under Trail Ridge. The surficial aquifer system sediments in SRWMD are part of the undifferentiated sediments. The upper Hawthorn Group sediments may form the basal part of the system in the eastern-most portions of the district. These sediments are quartz sands with varying amounts of clay and carbonate. In localized areas the clay content of the sediments may form confining beds within the surficial system.

The base of the surficial aquifer system in the SRWMD occurs at the top of the impermeable sediments of the Hawthorn Group throughout much of the district. However, in the eastern portion of the district, the base may occur within the sediments of the upper Hawthorn Group. In other areas, the intermediate confining unit may be absent and the surficial aquifer system may lie directly on the carbonates of the Floridan aquifer system.

St. Johns River Water Management District

The surficial aquifer system in the St. Johns River Water Management District (SJRWMD) is an important source of potable water in Duval and Clay Counties and portions of Alachua and Putnam Counties. The coastal counties utilize the surficial to varying

degrees with Brevard County being a major user. Eastern Orange County also utilizes the surficial aquifer system. In other areas of the district, the surficial aquifer system may be used for limited domestic supplies. The surficial aquifer system thickness is highly variable, ranging from a few feet to in excess of 200 feet. The thickest sequence occurs in the Duval County area in the Jacksonville Basin, where the upper part of the Hawthorn Group (Coosawhatchie Formation) forms the base of the surficial aquifer system.

Sediments forming the surficial aquifer system in SJRWMD are lithostratigraphically assigned to the undifferentiated sediments, Cypresshead and Nashua Formations, Caloosahatchee Formation-equivalent shell beds and the Coosawhatchie Formation of the Hawthorn Group. The undifferentiated sediments and the Cypresshead Formation consist of quartz sands with varying percentages of clay. The Nashua Formation and Caloosahatchee Formation-equivalent beds are composed of varying admixtures of quartz sand, clay, shells and shell debris. Quartz sands and varying amounts of clay make up the Coosawhatchie Formation with limestone becoming prominent in portions of Duval and Nassau Counties. Locally, the sediments contain sufficient clay to form impermeable beds creating artesian conditions in the surficial aquifer system.

The base of the surficial aquifer system in the SJRWMD occurs at the top of the Hawthorn Group when those sediments are relatively impermeable. Where the Hawthorn (Coosawhatchie Formation) sediments are sufficiently permeable, the base of the surficial occurs within these sediments. In the area where the

Hawthorn Group is absent, the surficial aquifer system may extend down to the top of the Floridan aquifer system, as is the case in much of Volusia County.

Southwest Florida Water Management District

The surficial aquifer system occurs over much of the Southwest Florida Water Management District (SWFWMD). It is of generally limited value in the northern portions of the district and increases in importance to the south. SWFWMD data indicates that the surficial aquifer system is thin over much of the district (Scott et al., 1991). Thicknesses range from less than 25 feet in much of the northern part of the district on the Ocala Platform to 25 to 50 feet in the southern area and more than 250 feet under the Lake Wales Ridge.

Surficial aquifer system sediments in SWFWMD belong to the undifferentiated sediments in the northern half of the district. In the southern half of SWFWMD the sediments include the Tamiami, Caloosahatchee and Fort Thompson Formations. Along the Lake Wales Ridge, the surficial aquifer system is comprised of sediments belonging to the Cypresshead Formation and the undifferentiated sediments. In a limited area in central SWFWMD, the Bone Valley Member of the Peace River Formation, Hawthorn Group forms part of the surficial aquifer system. The sediments in these units generally consist of quartz sand with varying percentages of clay and shell except in the Bone Valley Member where phosphate forms a significant proportion of the sediment. Vacher et al. (1990) characterize the sediments as quartz sand with less than 10 percent

clay over much of the district. They also show shell content of the surficial aquifer system increasing toward the coast and to the south in the southern half of the district.

The base of the surficial aquifer system occurs at the top of the impermeable sediments overlying the carbonates of the Floridan aquifer system in the northern part of the district. When impermeable sediments of the Hawthorn Group are subjacent to the undifferentiated sediments they form the base of the surficial. The Hawthorn Group lies subjacent to the Cypresshead Formation under the Lake Wales Ridge and forms the base of the system. The Hawthorn Group sediments also form the base of the surficial aquifer system in southern SWFWMD where the Hawthorn underlies the Tamiami, Caloosahatchee and Fort Thompson Formations.

South Florida Water Management District

The surficial aquifer system is widespread in the South Florida Water Management District (SFWMD) constituting an important water resource. Although the surficial aquifer system is present over much of the district, it is the most important source of ground water in the southeastern portion of SFWMD, in Dade, Broward and Palm Beach Counties. In Lee, Hendry and Collier Counties, the surficial provides significant quantities of potable water for domestic and agricultural uses. Throughout the district, the surficial aquifer system varies in thickness from a few feet to more than 400 feet thick.

The sediments comprising the surficial aquifer system are from several lithostratigraphic units. In the north-central SFWMD area,

the surficial occurs in the undifferentiated sediments, Cypresshead Formation and shell beds of the Caloosahatachee/Fort Thompson Formations. In the western part of SFWMD, sediments of the Tamiami, Caloosahatchee and Fort Thompson Formations and the undifferentiated sediments make up the system. In the eastern area of SFWMD, the surficial aquifer system, in part referred to as the Biscayne Aquifer, consists of sediments from the Anastasia Formation, Miami and Key Largo Limestones, Fort Thompson Formation, and Caloosahatchee and Tamiami-equivalent sediments. In SFWMD, the base of the surficial system occurs at the first impermeable sediments in the Hawthorn Group. Occasionally, the upper Hawthorn Group sediments may form the basal portion of the surficial.

The lithostratigraphic units forming the surficial aquifer system consist of a complex array of facies. The sediments range from quartz sands to limestones with varying admixtures of shell and clay. As a result of the variability, the quality of the surficial aquifer system in SFWMD changes dramatically from place to place. Numerous investigations of these sediments have discussed the variable nature of the aquifer characteristics (for example, Causaras, 1985; Wedderburn et al., 1982; Shaw and Trost, 1984; Knapp et al., 1986; Smith and Adams, 1988).

Intermediate Aquifer System and Intermediate Confining Unit

The SEGS (1986) defines the intermediate aquifer system or intermediate confining system as including

> "all rocks that lie between and collectively retard the exchange of water between the overlying surficial aquifer

exchange of water between the overlying surficial aquifer system and the underlying Floridan aquifer system. These rocks in general consist of fine grained (silici)clastic deposits interlayered with carbonate strata belonging to all or parts of the Miocene and younger Series. In places poorly-yielding to non-water-yielding strata mainly occur and there the term intermediate confining unit applies. In other places, one or more low to moderate-yielding aquifers may be interlayered with relatively impermeable confining beds; there the term intermediate aquifer system applies. The aquifers within this system contain water under confined conditions."

"The top of the intermediate aquifer system or intermediate confining unit coincides with the base of the surficial aquifer system. The base of the intermediate aquifer is at the top of the vertically persistent permeable carbonate section that comprises the Floridan aquifer system, or, in other words, that place in the section where (silici)clastic layers of significant thickness are absent and permeable carbonate rocks are dominant."

The intermediate aquifer system or intermediate confining unit occurs over much of the state. It is absent from those areas where it was removed by erosion and the surficial aquifer system sediments, if present, lie immediately suprajacent to the carbonates of the Floridan aquifer system. Springs are a common feature of these areas. Surrounding the areas where these

sediments are missing, the intermediate aquifer system or intermediate confining unit is often perforated by karst features. Where this condition exists, the intermediate aquifer system and the intermediate confining unit allow water to pass through into the Floridan aquifer system or into the surficial aquifer system.

The regional significance of the intermediate aquifer system is quite limited. Statewide, this section is referred to as the intermediate confining unit. It serves to confine the Floridan aquifer system and forms the base of the surficial aquifer system. The sediments comprising this section are predominantly siliciclastic (quartz sand, silt and clay) with varying proportions of carbonates (limestone and dolostone) present. Much of the intermediate confining unit was deposited during the Miocene and Early Pliocene. It is interesting to note that in some areas Miller (1986) has included low permeability Oligocene and Eocene carbonates in contact with the Miocene sediments as part of the intermediate confining unit.

The top of the intermediate aquifer system or intermediate confining unit ranges from more than 350 feet below sea level to greater than 225 feet above sea level. Miller (1986) cites thicknesses of the intermediate confining unit (his upper confining unit) ranging from very thin or absent to greater than 1000 feet.

Northwest Florida Water Management District

The intermediate confining unit occurs over much of the NWFWMD serving to effectively confine the Floridan aquifer system. It is thin to absent over the Chattahoochee Anticline in portions of

Jackson and Holmes Counties. The intermediate confining unit is also thin to absent in eastern Wakulla, southeastern Leon and southern Jefferson Counties. The intermediate confining unit thickens dramatically under the western end of NWFWMD in Escambia County and in the Apalachicola Embayment under Gulf and Franklin Counties. Thicknesses range from less than 10 feet to greater than 1000 feet.

The ability of the intermediate confining unit to effectively confine the subjacent Floridan aquifer system is impaired in those areas where it has been breached by karst development. These areas include portions of Jackson, Holmes, Washington, Walton, Leon and Wakulla Counties (Sinclair and Stewart, 1985).

Siliciclastic sediments predominate in the intermediate confining unit in NWFWMD. Carbonate sediments are present in the sediments of the Apalachicola Embayment and east of the Apalachicola River. In western NWFWMD, the confining unit is the Pensacola Clay which grades eastward into the Alum Bluff Group. Further east, generally east of the Apalachicola River, the Hawthorn Group forms the intermediate confining unit. Within the Apalachicola Embayment, portions of the Intracoastal Formation form the intermediate confining unit.

The intermediate aquifer system is generally not an important water-bearing unit in NWFWMD. Permeable beds of limited extent are present locally and may provide limited amounts of water to small, domestic wells. The intermediate aquifer system/confining unit acts as an aquifer system primarily east of the Choctawhatchee River (Wagner, 1988). The permeable zones utilized for ground

water are siliciclastic and carbonate beds in the Intracoastal Formation (Barr and Wagner, 1981), the Alum Bluff Group and, to a very limited extent, the Hawthorn Group.

Suwannee River Water Management District

The intermediate confining unit is present in SRWMD under the Northern Highlands. This includes portions or all of Jefferson, Madison, Taylor, Lafayette, Hamilton, Suwannee, Columbia, Baker, Bradford, Union and Alachua Counties. Within this area, the thickness of the intermediate confining unit may exceed 300 feet (Scott, 1988) and confined to semiconfined conditions exist. It is thin to absent on the Ocala Platform and thickens on its flanks reaching the greatest thickness in the Jacksonville Basin. Karst features are common throughout this area except in the northeastern part of SRWMD (parts of Baker, Bradford and Union Counties). Outliers and sinkhole fill consisting of the sediments of the intermediate confining unit are common in the areas where the unit is absent.

Siliciclastic sediments dominate the intermediate confining unit in SRWMD. These sediments most often are part of the Hawthorn Group or materials that are residual from it ("Alachua Formation").

The intermediate aquifer system is interbedded with the impermeable beds of the intermediate confining unit. The intermediate aquifer system is developed in the sands and carbonates of the Hawthorn Group and attains a thickness of at least 234 feet in the northeastern portion of the district (Ceryak et al., 1983).

St. Johns River Water Management District

The intermediate confining unit and intermediate aquifer system occur throughout the SJRWMD except along the western district boundary in parts of Marion and Alachua Counties on the Ocala Platform. The combined confining unit and aquifer system ranges in thickness from less than ten feet to more than 500 feet. It is thickest in the Jacksonville Basin in northeastern SJRWMD. It thins over the St. Johns Platform, Sanford High and Brevard Platform in the central portion of the district then thickens into the Osceola Low and the Okeechobee Basin in southern SJRWMD.

The intermediate confining unit and intermediate aquifer system consist primarily of interbedded siliciclastic and carbonate sediments of the Hawthorn Group. Additionally, Plio-Pleistocene siliciclastic sediments suprajacent to the Hawthorn Group may act as part or, in the areas where the Hawthorn sediments are absent, the entire intermediate confining unit. The Hawthorn Group sediments are absent over much of the Sanford High and limited portions of the St. Johns and Brevard Platforms in southern Flagler County, much of Volusia County and northern Brevard County.

Karst conduits breaching the intermediate aquifer system and intermediate confining unit are common in much of the SJRWMD. Sinclair and Stewart (1985) indicate that the karst features are most abundant in parts of Clay, Putnam, Alachua, St. Johns, Flagler, Marion, Volusia, Lake, Seminole, Orange, Osceloa and Polk Counties. Small karst features are present in portions or all of Volusia, Seminole, Orange, Brevard, Osceloa and Indian River Counties. In Baker, Nassau, Duval and parts of Clay and St. Johns

Counties karst features are very few in number and the intermediate confining unit is not often breached.

The intermediate aquifer system is utilized for limited domestic and agricultural supplies. Permeable strata in the Hawthorn Group often exhibits rapid lateral and vertical variability resulting in a limited areal distribution of the water-producing units. The intermediate aquifer system is most often utilized in Nassau, Duval, Baker, St. Johns and Clay Counties where the Hawthorn Group sediments are thickest, infilling the Jacksonville Basin.

Southwest Florida Water Management District

The intermediate confining unit and intermediate aquifer system are present throughout most of SWFWMD (Buono et al., 1979). Although the sediments comprising this section are absent to very thin in the northern half of SWFWMD, they thicken to more than 650 feet in the southern end of the district (Buono et al., 1979; Scott, 1988). In the northern half of the district, the section is generally the intermediate confining unit and is thin to absent on the southern end of the Ocala Platform. In the southern half of SWFWMD, approximately from northern Polk and Hillsborough Counties south, the intermediate confining unit also contains permeable sediments forming the intermediate aquifer system. In this area, the sediments thicken to the south into the Okeechobee Basin (Buono et al., 1979; Scott, 1988).

Siliciclastic and carbonate sediments of the Hawthorn Group comprise the majority of the intermediate confining unit and

intermediate aquifer system in SWFWMD. In addition, some post-Hawthorn siliciclastics may form a limited portion of the intermediate confining unit in the northern half of the district. In the northern portion of the district, clayey sediments lying on the Floridan aquifer system carbonates belong in part in the Hawthorn Group and in part may be reworked Hawthorn sediments along with residuum from dissolution of carbonates.

Breaching of the intermediate confining unit and the intermediate aquifer system by karst features is common in the northern half of the district and along the Lake Wales Ridge in Polk County (Sinclair and Stewart, 1985). The southern portion of SWFWMD has limited karst development (Sinclair and Stewart, 1985) and few karst conduits penetrate the intermediate confining unit and intermediate aquifer system.

The intermediate aquifer system is utilized in the southern half of SWFWMD and becomes most important at the southern end of the district where the Floridan aquifer system is deeply buried and highly mineralized. The permeable strata of the Hawthorn Group and portions of the Tamiami Formation form the water-producing horizons providing variable quantities of ground water (Sutcliffe, 1975).

South Florida Water Management District

The intermediate confining unit and the intermediate aquifer system occur throughout SFWMD. However, the intermediate aquifer system is utilized in a limited number of counties along the western edge of the district. This section ranges in thickness from approximately 500 feet in the northern SFWMD area to more than

900 feet in the southernmost portion of the district (Scott, 1988). Much of the SFWMD area lies in the Okeechobee Basin.

Interbedded siliciclastic and carbonate sediments from the Hawthorn Group form the intermediate confining unit and intermediate aquifer system in SFWMD. Previously, some of the sediments currently included in the intermediate confining unit and intermediate aquifer system along the west coast were placed in the Tamiami Formation but are now considered part of the Hawthorn Group (Missimer, 1978; Wedderburn et al., 1982; Scott,1988). In the eastern part of the district, Tamiami-equivalent sediments may form the top of the intermediate confining unit (Causaras, 1985).

The importance of the intermediate confining unit and intermediate aquifer system in the western part of SFWMD has led to a number of studies in Charlotte, Lee, Hendry and Collier Counties (Sutcliffe, 1975; Wedderburn et al., 1982; Knapp et al., 1986; Smith and Adams, 1988;). There are three principle producing zones within the intermediate aquifer system in this area, the "Sandstone aquifer" named by Boggess and Missimer (1975), the "mid-Hawthorn aquifer" of Wedderburn et al. (1982) and the "lower-Hawthorn aquifer" of Knapp et al. (1984). These producing zones have been very important to the development of southwestern Florida.

Floridan Aquifer System

The SEGS (1986) defines the Floridan aquifer system as a "thick carbonate sequence which includes all or part of the Paleocene to Early [sic] Miocene Series and functions regionally as a water-yielding hydraulic unit. Where

overlain by either the intermediate aquifer system or the intermediate confining unit, the Floridan contains water under confined conditions. Where overlain directly by the surficial aquifer system, the Floridan may or may not contain water under confined conditions..."

"The top of the aquifer system generally coincides with the absence of significant thicknesses of (silici)clastics from the section and with the top of the vertically persistent permeable carbonate section. For the most part, the top of the aquifer system coincides with the top of the Suwannee Limestone, where present, or the top of the Ocala Group (Limestone)."

In limited areas the Avon Park Formation forms the top of the aquifer system. Sediments of the Arcadia Formation (Hawthorn Group), the Bruce Creek Limestone, the St. Marks Formation or the Tampa Member of the Arcadia Formation may form the top of the Floridan aquifer system (SEGS, 1986).

" The base of the aquifer system in panhandle Florida is at the gradational contact with the fine-grained (silici)clastic rocks belonging to the Middle Eocene Series. In peninsular Florida, the base coincides with the appearance of the regionally persistent sequence of anhydrite beds that lies near the top of the Cedar Keys Limestone (Formation) (SEGS, 1986)."

The Floridan aquifer system exhibits extreme variations in permeability resulting from a combination of original depositional conditions, diagenesis, structural features and dissolution of

carbonates and evaporites (Miller, 1986). The system has been extensively altered by karst processes in some areas of the state. Dissolutional and diagenetic processes have been extremely important in the development of the Floridan aquifer system from carbonate sediments deposited during the Paleocene through Early Miocene.

The thickness and lithology of the sediments suprajacent to the Floridan determine the surficial expression of the karst processes. On the Ocala Platform from Hillsborough and Polk Counties north to the state line, then westward into Leon and Wakulla Counties and on the Chattahoochee Anticline in Jackson and Washington Counties, carbonate sediments of the Floridan aquifer system crop out or are covered by a thin layer of unconsolidated siliciclastics (Sinclair and Stewart, 1985). In these areas, the carbonates have been exposed to extensive dissolution by aggressive ground waters percolating downward from land surface. Often the karst geomorphology has reached a relatively mature stage of development resulting in numerous surface depressions which often coalesce. The Floridan aquifer system exhibits well developed cavernous porosity and conduit flow paths. Most of Florida's major springs occur in this zone including Wakulla and Silver Springs.

The carbonates of the Floridan aquifer system lie beneath a variable thickness of post-Floridan siliciclastics and carbonates of the intermediate confining unit, intermediate aquifer system and the surficial aquifer system on the flanks of the Ocala Platform and the Chattahoochee Anticline. Although karst processes have affected the sediments of the Floridan in these areas, forming

dissolutional conduits and caverns, the karst topography is not as well developed as in the areas of thin cover. However, in these areas the karst features are often of large diameter and depth due to overburden thickness (Sinclair and Stewart, 1985).

The Floridan aquifer system lies subjacent to a thick sequence of post-Floridan sediments in the Okeechobee Basin, Jacksonville Basin, Gulf Trough, Apalachicola Embayment and the Gulf Basin of the western panhandle. In these areas, the carbonates of the Floridan have apparently not been subjected to extensive karstification. However, subsurface investigations of the limestones indicate some karstic modification of the sediments during subaerial exposure prior to the deposition of the sediments of the intermediate confining unit and intermediate aquifer system (U. Hamms and D. Budd, University of Colorado, personal communication, 1991).

The elevation of the top of the Floridan aquifer system varies significantly throughout the state. The top occurs at elevations in excess of 100 feet above National Geodetic Vertical Datum (NGVD) on the Ocala Platform and Chattahoochee Anticline to depths greater than 1100 feet below NGVD in southern Florida and 1500 feet below NGVD in the western-most panhandle (Miller, 1986). The thickness of the Floridan varies from less than 100 feet in the western half of the panhandle to in excess of 3500 feet in southwestern peninsular Florida (Miller, 1986).

The base of the Floridan aquifer system, the sub-Floridan confining unit, varies stratigraphically throughout the state. The SEGS (1986) indicates that the base of the Floridan in the

panhandle occurs in the Middle Eocene approximately at the top of the Claiborne Group. The base of the system in the peninsula generally is considered to occur within or near the top of the Paleocene Cedar Keys Formation (SEGS, 1986). Miller (1986) provides a more detailed picture of the variability of the stratigraphic positioning of the Floridan aquifer system base but indicates the same general regional trends.

Northwest Florida Water Management District

The Floridan aquifer system in NWFWMD supplies more than 90 percent of the water demand and is utilized in all the counties in the district except Escambia and part of Santa Rosa Counties (Wagner, 1988). It underlies the entire district but is too saline for potable water in the western end of the panhandle. The water quality over a broad area corresponding to the Apalachicola Embayment and the Gulf Trough and the coastal zone may be affected by the upconing of mineralized waters (Scott et al., 1991).

The top of the Floridan aquifer system in NWFWMD varies in elevation from 150 feet above NGVD in Jackson and Holmes Counties to greater than 1500 feet below NGVD in Escambia County (Miller, 1986; Scott et al., 1991). The thickness of the aquifer system ranges from approximately 100 feet thick in portions of Jackson and Holmes Counties on the Chattahoochee Anticline to more than 2800 feet thick in Franklin County in the Apalachicola Embayment (Scott et al., 1991).

In the western part of the district, the Floridan aquifer system is subdivided into an upper and lower aquifer separated by

a confining unit, the Bucatunna Clay. The confining unit thins and pinches out towards the east in Okaloosa County, where the Floridan becomes a single aquifer system (Marsh, 1966; Scott et al., 1991).

Carbonate sediments dominate the Floridan aquifer system with minor occurrences of siliciclastics. The siliciclastics generally occur intimately mixed with the carbonates and are more common in the upper portion of the aquifer system. Within the district, the Floridan aquifer system is composed of the Ocala, Marianna, Suwannee, Chickasawhay, and Bruce Creek Limestones and the St. Marks and Chattahoochee Formations.

Stratigraphically, the base of the Floridan aquifer system varies significantly throughout NWFWMD. In the Pensacola area, the base occurs within the Upper Eocene Ocala Limestone (Miller, 1986). Under the eastern end of the district, the base falls within the Paleocene Cedar Keys Formation. The depth to the base of the Floridan varies from -100 NGVD on the Chattahoochee Anticline to -3100 feet NGVD in the Apalachicola Embayment (Miller, 1986).

The Claiborne aquifer has been recognized within the sub-Floridan confining unit. The total extent of this aquifer is not known and it is not often utilized (Allen, 1987). It is composed of carbonate and siliciclastic sediments of the Claiborne Group.

The effects of karstification are most intense on and surrounding the Chattahoochee Anticline in Jackson, Holmes and Washington Counties and on the flank of the Ocala Platform in Leon and Wakulla Counties. In these areas, the aquifer system has been extensively altered by dissolution and often has many direct conduits from the surface into the Floridan. An extensive,

underwater conduit mapping project of the Woodville Karst Plain by the Woodville Karst Plain Project (Parker Turner, Florida State University, personal communication, 1991) is currently documenting the length and complexity of the dissolutional features of the area.

Suwannee River Water Management District

The Floridan aquifer system occurs throughout the SRWMD providing the vast majority of the water supplies. The top of the Floridan ranges from greater than 100 feet above NGVD in Jefferson County to more than 300 feet below NGVD in Bradford County (Scott et al., 1991). The thickness ranges from approximately 1100 feet in northern Jefferson County to 2200 feet in southern Jefferson County (Miller, 1986). The thicknesses of the Floridan aquifer system sediments in SRWMD show the effects of the Apalachicola Embayment and Gulf Trough in Jefferson County. These sediments also exhibit the thicker carbonate sequence deposited in the peninsular area.

Carbonate sediments deposited during the Paleocene through the Early Miocene comprise the Floridan aquifer system in SRWMD. The base of the system occurs near the top of the Paleocene Cedar Keys Formation (Miller, 1986). Carbonates of the Oldsmar and Avon Park Formations, the Ocala and Suwannee Limestones and the St. Marks Formation comprise the Floridan aquifer system in the district. The Suwannee Limestone forms a portion of the Floridan in approximately one half of the district while the St. Marks

Formation occurs in limited areas. When the Suwannee Limestone and the St. Marks Formation are absent, the Ocala Limestone forms the top of the system. In the southern portion of the district, the Ocala Limestone is absent due to erosion and the Avon Park Formation forms the top of the system.

The top of the sub-Floridan confining unit generally occurs within the Cedar Keys Formation throughout SRWMD (Miller, 1986). The positioning of the permeability barrier shifts locally within the upper part of the Cedar Keys Formation from the top of the unit to some distance below the top. The depth to the sub-Floridan confining unit varies from -1200 feet NGVD on the Ocala Platform to -2100 feet on the flank of the Gulf Trough (Miller, 1986).

The sediments of the Floridan aquifer system throughout SRWMD have been greatly affected by karstification. Sinkholes are very common in most areas and numerous springs are scattered across the district. The only area of minor karstification is in northernmost Columbia and Baker Counties.

St. Johns River Water Management District

The Floridan aquifer system is present throughout the SJRWMD containing potable water supplies in most areas. Salt water intrusion or upwelling is a concern in many of the coastal areas and along the St. Johns River Valley (Scott et al., 1991).

The top of the Floridan aquifer system in SJRWMD occurs at the highest elevations on the flank of the Ocala Platform in Alachua and Marion Counties. In this area, the uppermost Floridan sediments range from 50 to more than 100 feet above NGVD. The

upper surface of the system dips into the Jacksonville Basin, in the northern part of SJRWMD, where it may be more than -550 feet NGVD. To the south, the top of the Floridan reaches more than -350 feet NGVD (Scott et al., 1991). The thickness of the system ranges from approximately 1500 feet in Baker County (northwestern SJRWMD) to 2900 feet in southern Brevard County (Miller, 1986).

Carbonate sediments dominate the Floridan aquifer system within the district. Siliciclastic sediments, when present, occur mixed in carbonate lithologies and predominantly in the uppermost portion of the Floridan. The Ocala Limestone forms the top of the aquifer system over the majority of the district. In very limited areas of Volusia and Orange Counties, the Avon Park Formation occurs at the top of the Floridan. Sediments of Oligocene age occur at the top of the aquifer system along the east coast in southernmost Brevard County and in Indian River County. Miller (1986) shows small outliers of Suwannee Limestone at the top of the Floridan in the northern portion of the district. The majority of the aquifer system is comprised of the Avon Park and Oldsmar Formations.

The sub-Floridan confining unit occurs within the Cedar Keys Formation throughout the district. The positioning of the base of the Floridan varies from the top of the Cedar Keys Formation to within the upper portion of the formation (Miller, 1986). The top of the sub-Floridan confining unit varies from -1600 feet NGVD on the flank of the Ocala Platform to -3200 feet NGVD in the Jacksonville Basin and the Okeechobee Basin (Miller, 1986).

Karst processes have significantly altered the carbonates of

the Floridan aquifer system in much of the SJRWMD. Karst features are common in much of the central and western portions of the district (Sinclair and Stewart, 1985). The karstification in these areas is related to dissolution of the Ocala Limestone. In the southern half of the district, dissolution of the carbonate fraction of the Plio-Pleistocene sediments is responsible for the development of most of the karst features.

Southwest Florida Water Management District

The Floridan aquifer system underlies the entire SWFWMD area and contains plentiful, potable water supplies throughout most of the district. Areas of mineralized water along the coast and in portions of Charlotte and Sarasota Counties limit the availability of fresh water from the Floridan in these areas (Scott et al., 1991).

The top of the Floridan aquifer system in the SWFWMD displays two distinct elevational trends. The northern two thirds of the district (from central Polk and Hillsborough Counties northward) is relatively flat with elevations varying from sea level to between 100 and 150 feet above NGVD. The top of the Floridan in the southern one third of the district dips distinctly to the south dropping from sea level to more than 750 feet below NGVD along the southern district boundary (Scott et al., 1991). These trends are related to the positions of the Ocala Platform and the northern edge of the Okeechobee Basin.

The thickness of the aquifer system also displays distinct trends. The Floridan is more than 1400 feet thick in the northern-

most portion of the district and thins southward across the northern one third of SWFWMD to approximately 600 feet thick (Wolansky and Garbode, 1981). From the thinnest point of the Floridan aquifer system, it thickens into the Okeechobee Basin southward, reaching more than 2400 feet thick in the SWFWMD part of Highlands County (Wolansky and Garbode, 1981).

As in the rest of the peninsula, carbonate sediments dominate the Floridan aquifer system in SWFWMD. Siliciclastic-bearing carbonates and siliciclastic units in the basal Hawthorn Group may form the upper portion of the Floridan in part of the southern portion of SWFWMD. In much of the district, the Suwannee Limestone forms the top of the Floridan. In the northern most portion of SWFWMD, the Ocala Limestone and, in limited areas, the Avon Park Formation comprise the top of the aquifer system. The Avon Park and Oldsmar Formations form the main body of the Floridan in the district. The sub-Floridan confining unit occurs in the upper Cedar Keys Formation and varies from -1900 feet NGVD on the Ocala Platform to -4100 feet NGVD in the Okeechobee Basin (Miller, 1986).

Karstic alteration of the Floridan aquifer system has occurred throughout much of the district. In the southern portion of SWFWMD, where the Hawthorn Group thickens in the Okeechobee Basin, karst features are not as abundant (Sinclair and Stewart, 1985). In the northern two-thirds of the district and along the Lake Wales Ridge, karst features are quite common. Surficial karst features in much of southern SWFWMD are the result of dissolution of carbonate sediments and shell material in the Miocene through Pleistocene units.

South Florida Water Management District

Potable water supplies within the Floridan aquifer system in SFWMD are limited to the northern part of the district. The sediments of the Floridan occur throughout the district but in many areas do not contain acceptable quality water.

The top of the Floridan aquifer system occurs at elevations ranging from sea level in the northern most edge of the district (Orange County) to greater than 1100 feet below NGVD in southwestern SFWMD (Miller, 1986). Most of this area lies in the Okeechobee Basin. The thickness of the Floridan ranges from less than 2300 feet in Orange County to more than 3400 feet under parts of Palm Beach and Martin Counties and more than 3500 feet under western Lee County (Miller, 1986).

A thick sequence of carbonate sediments containing some beds of siliciclastics and siliciclastic-rich carbonates form the Floridan aquifer system in SFWMD. The majority of the sediments comprising the Floridan are carbonates with little to no siliciclastics. However, in southwestern Florida, sand beds have been noted in the Ocala Limestone (Missimer, personal communication, 1991). Siliciclastic-bearing carbonates and a few siliciclastic beds from the basal Hawthorn Group may form the upper beds of the Floridan aquifer system in some areas of the district. In general, the Suwannee Limestone forms the upper unit of the aquifer system with the Ocala Limestone and the Avon Park, Oldsmar and upper Cedar Keys Formations comprising the main mass of the system. The base of the Floridan aquifer system, the top of the sub-Floridan confining unit, occurs within the upper portion of the

Cedar Keys Formation (Miller, 1986). The top of the sub-Floridan confining unit ranges from -3000 feet NGVD on the northern edge of the Okeechobee Basin to -4400 feet NGVD in the deeper portion of the Okeechobee Basin.

The development of karst features in the sediments of the Floridan aquifer system in SFWMD has not been extensive. Throughout much of the district, the Floridan contains saline waters and has not been flushed by fresh water. The Floridan aquifer system is also buried by as much as 1100 feet of confining beds and other aquifer systems under much of SFWMD.

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