Karst Features and Hydrogeology in West-central Florida—A Field Perspective

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Abstract

Karst features in west-central Florida play a dominant role in the hydrogeologic framework of the region. Urban development in karst regions present unique problems for land- and water-resource managers and can potentially impact both land and water resources if not managed adequately. Understanding how karst features control ground-water flow and respond to varying hydrologic conditions is critical for effective long-term planning and resource management. This field guide highlights the karst features of west-central Florida and the geologic units of the region that define the hydrogeologic framework and influence ground-water flow and transport. The four field trip stops include: (1) an active limestone quarry where the representative carbonate units can be seen in cross section; (2) a dry cave system that intersects land surface showing where dissolution activity has created cavities that range from subterranean conduits to large caverns; (3) Chassahowitzka Springs, a coastal spring complex, where flooded karst features form spring vents, fissures, and highly-eroded limestone at or near land surface; and (4) Health Springs, a coastal spring located 2,500 feet down gradient from a golf course and waste-water treatment plant with a spray-effluent facility. At Health Springs, the existence of a preferential ground-water flow path was documented by timing the movement of artificially dyed ground water between a well in the spray field and the spring. Ground water from the upgradient area has impacted the spring by increasing nitrate concentrations above background levels. These stops provide an opportunity to examine various karst features typical of Florida, especially in the context of their susceptibility to impact from land- and water-resource development activities.

INTRODUCTION

Thick carbonate deposits underlying most of Florida comprise the Floridan aquifer system. The Floridan aquifer system is the principal aquifer in Florida and is among the most productive in the world. The high productivity of this aquifer is due to the development of secondary porosity caused by dissolution or karst processes (fig. 1). Karst processes characteristically develop zones of enhanced porosity within carbonate rocks creating a highly heterogeneous aquifer system with rapid rates of ground-water movement and recharge. Subsidence events caused by the collapse of materials into overlying caverns and caves can result in structural damage at land surface. More importantly karst-related features can create direct pathways for introducing surface contaminants into the ground-water system where remediation is difficult.

Most of Florida is prone to karst-related water-resource problems and examples of karst-related environmental impacts are well-documented. As karst features evolve, they also respond to changing hydrologic conditions. Evidence of hydrologic changes are generally observed at karst features. In west-central Florida examples of effects from hydrologic changes are well-documented. Ground water has been degraded by surface contaminants (Stewart, 1982). Springs have ceased to flow or have responded to upstream sinkhole formation by temporarily increasing discharge (Peek, 1951; Trommer, 1992). Lakes have been drained by sinkholes located in the lake sub-bottom due to lowering of ground-water levels (Stewart, 1982;

(William A. Wisner, 1972)

Figure 1—Mining exposed this typical karst limestone surface which exhibits the characteristically enlarged porosity created by dissolution (from Tihansky, 1999).

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Sinclair and others, 1985). Sinkholes have formed in response to drilling wells, clearing land, and rerouting surface-water drainage (Tihansky, 1999). Water-quality changes at a number of springs document significant increases in nutrient concentrations reflecting the influence of urban and agricultural land use in the ground-water basin (Jones and Upchurch 1993, 1996; Jones and others, 1994, 1997).

Activities impacting land and water resources place a measurable strain on the water resources of the region and affect the unique ecosystems in west-central Florida. Rerouting and reducing surface drainage and altering natural recharge patterns affects water resources by subjecting new areas to increased drainage and eliminating recharge from others. Such changes alter the equilibrium that exists between subsurface cavities and overburden materials. Development of ground-water resources for municipal, industrial, and agricultural water supplies places additional stresses on the hydrologic system and can alter the balance of the natural hydrologic cycle. Increased ground-water and surface-water withdrawals lead to regional ground-water declines that can induce sinkholes to form, contribute to dewatering of wetlands and lakes, reduce spring flow and stream discharge. When fertilizers and other agricultural chemicals are applied to land surface in a karst terrane, they are often transported rapidly into the aquifer materials where they degrade the ground-water quality. All of these examples demonstrate how activities associated with urban growth can increase the susceptibility of karst aquifers to contamination from surface-water drainage.

THE MANTLED KARST OF WEST-CENTRAL FLORIDA

The exposed land mass that constitutes the Florida peninsula is only part of a larger, mostly submerged carbonate platform that is partially capped with a mantling sequence of relatively insoluble sand and clay deposits (figs. 2 and 3) (Tihansky, 1999). In mantled karst regions, the carbonate units are not exposed at land surface, but their presence may be indicated by sinkholes and the hummocky topography that results as covering deposits settle into the irregular surface and voids within the highly soluble carbonate rocks beneath them. As a result of the depositional history and infilling processes, the sand and clay deposits vary in composition and thickness throughout Florida (fig. 3).

In west-central Florida, the thickness of the mantling deposits (overburden) overlying the carbonates influences the circulation and chemical

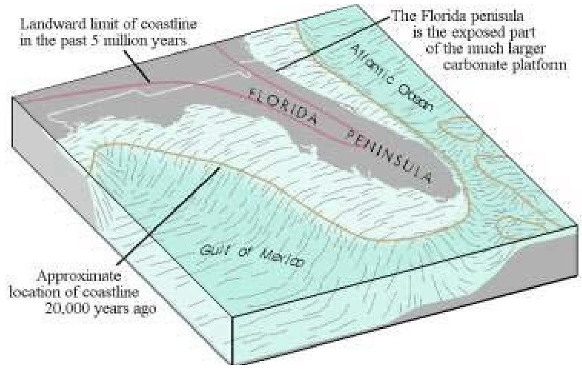
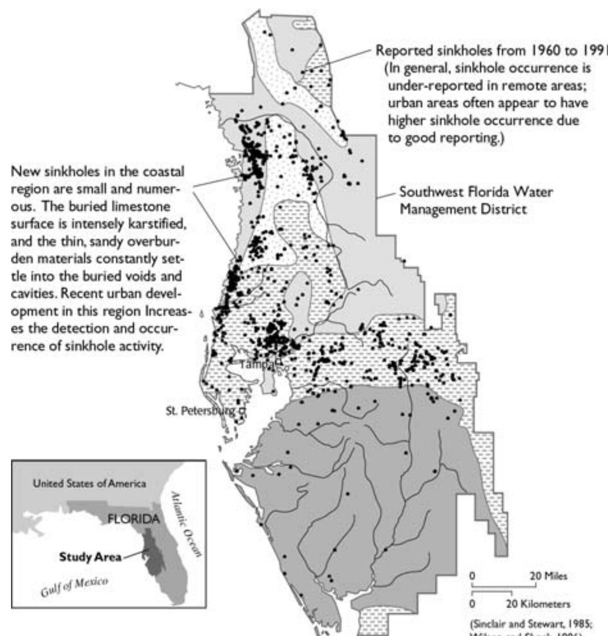


Figure 2—Changes in sea level have alternately submerged and exposed the carbonate platform (from Tihansky, 1999).



	TYPE AND THICKNESS OF OVERBURDEN	FREQUENCY OF SINKHOLES	TYPE OF SINKHOLES
	Thin; highly permeable	Generally few	Dissolution; cover-subsidence; cover-collapse
	30 to 200 feet thick; permeable sands are dominant	Numerous	Cover-subsidence–occur slowly; cover-collapse–usually induced
	30 to 200 feet thick; more clayey	Very numerous	Cover-collapse–occur abruptly
	Greater than 200 feet	Few	Cover-collapse–large diameter and deep

Figure 3—Type and thickness of materials mantling the carbonate units vary significantly in west-central Florida. Sinkhole occurrence throughout the region provides evidence of enhanced porosity at depth (from Tihansky, 1999).

quality of recharge waters to the Upper Floridan aquifer. Additionally, these deposits create distinct geomorphic regions that result in various types of karst features and influence ground-water flow.

The carbonate platform can be more than 3,000 feet (ft) thick and overlies a metamorphic basement (Miller, 1986). The occurrence of the top of carbonate rocks ranges from land surface to depths greater than 500 ft below land surface. The overburden deposits thicken toward the south and central parts of the platform (fig. 4). Throughout recent geologic time, the carbonate rocks of the Upper Floridan aquifer have been extensively and repeatedly subjected to chemical dissolution and depositional processes in response to sea level fluctuations (Randazzo, 1997). These chemical processes are most active near or at the water table (saturated/unsaturated interface) and near or at saltwater/freshwater interfaces (the seawater mixing zones). The spatial locations of interfaces are not temporally constant; and therefore, multiple horizons of concentrated karst features can occur within the carbonate strata. The wide fluctuations in sea-level stands over the Floridan platform were accompanied by periods of intense karst development (James and Choquette, 1988; Watts,1980). As sea- and ground-water levels rise and fall, the karst features continue to evolve. During high sea-level stands many of the karst features become submerged. Reversing head gradients convert sinkholes into flowing springs. Many of the numerous lakes and ponds of west-central Florida occupy depressions formed by overburden materials settling into cavities in the underlying limestone.

Karst features in Florida include sinkholes, springs, caves, disappearing streams, internally-drained basins, subsurface rather than surface drainage networks and highly transmissive but heterogeneous aquifers. Most of the documented karst features in west-central Florida are within 300 ft of land surface although cave divers have explored deeper passages in submerged caves. Also, exploratory well drilling has indicated the presence of enlarged fractures and cavities and associated flows at depths greater than 300 ft. General, in areas where the overburden ranges in thickness from 30 to 200 ft and the clay content is significant, subsidence activity is common and sinkholes are numerous (Sinclair and others, 1985) (fig. 3). Where permeable sands are predominant in the overburden sediments, cover-subsidence sinkholes develop gradually as the sands fall into underlying cavities. Where overburden contains more clay, cover-collapse type sinkholes are predominant. The more cohesive, less permeable clay-rich deposits deform, postponing failure until the underlying cavity grows too large and the overburden collapses into underlying voids.

South of Tampa Bay, the overburden materials thicken in excess of 200 ft and consist of cohesive siliciclastic sediments interbedded with carbonate sediments. Little surface expression of karst occurs, although the buried limestone units can have significant secondary porosity. Although sinkhole features are not common, when observed, they are usually large-diameter, deep, cover-collapse type sinkholes, indicating the presence of buried karst limestone.

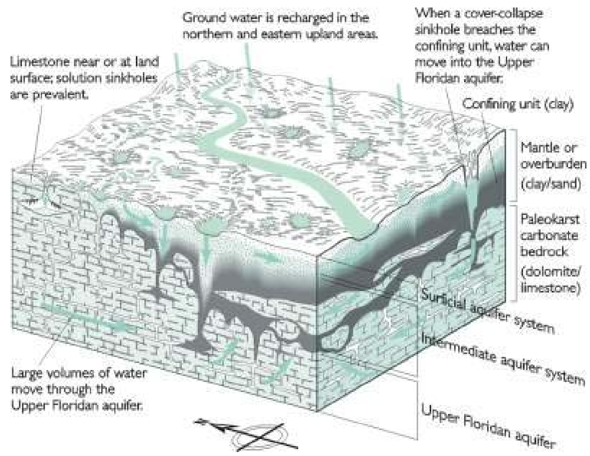


Figure 4—The regional geology influences the hydrogeologic setting and varies significantly in the west-central Florida region (from Tihansky, 1999).

Karstification and Hydrogeology

Karstification or post-depositional alteration of geologic units plays a critical role in the hydrogeology of west-central Florida. Throughout the carbonate units, specific flow zones have developed along fractures, fissures, and bedding planes. The enlarged openings in the carbonate rocks continue to concentrate ground-water flow potentially leading to further dissolution; creating sinks and springs. The well-developed interconnected secondary porosity creates the highly-transmissive zones in the carbonate aquifers.

Because karst features evolve in response to specific hydrologic conditions that have changed significantly over geologic time, many karst features are in areas where they could not form readily today. Florida's coastal springs originally formed as sinkholes in a recharge area where acidic waters were undersaturated with respect to calcite. These springs now occur in a modern discharge area where carbonate dissolution does not occur extensively.

Today, the coastal springs discharge millions of gallons per day of ground water from the Upper Floridan aquifer (Mann and Cherry, 1970).

SYSTEM	SERIES	STRATIGRAPHIC UNIT		HYDROGEOLOGIC UNIT	
QUATERNARY	HOLOCENE PLEISTO-CENE	UNDIFFERENTIATED SAND AND CLAY DEPOSITS		SURFICIAL AQUIFER SYSTEM	
TERTIARY	PLIOCENE	HAWTHORN GROUP	PEACE RIVER FORMATION	INTERMEDIATE AQUIFER SYSTEM OR INTERMEDIATE CONFINING UNIT	
TERTIARY	MIOCENE	HAWTHORN GROUP	ARCADIA FORMATION	INTERMEDIATE AQUIFER SYSTEM OR INTERMEDIATE CONFINING UNIT	
TERTIARY	MIOCENE	HAWTHORN GROUP	TAMPA MEMBER	FLORIDAN AQUIFER SYSTEM	UPPER FLORIDAN AQUIFER
TERTIARY	OLIGOCENE	SUWANNEE LIMESTONE		FLORIDAN AQUIFER SYSTEM	UPPER FLORIDAN AQUIFER
TERTIARY	EOCENE	OCALA LIMESTONE		FLORIDAN AQUIFER SYSTEM	UPPER FLORIDAN AQUIFER
TERTIARY	EOCENE	AVON PARK FORMATION		FLORIDAN AQUIFER SYSTEM	UPPER FLORIDAN AQUIFER; MIDDLE CONFINING UNIT
TERTIARY	EOCENE; PALEOCENE	OLDSMAR AND CEDAR KEYS FORMATIONS		FLORIDAN AQUIFER SYSTEM	LOWER FLORIDAN AQUIFER

Figure 5—Hydrogeologic framework (modified from Knochenmus and Robinson, 1996).

HYDROGEOLOGIC FRAMEWORK

The depositional environment and resultant hydrogeologic framework underlying west-central Florida, are discussed in Miller (1986) and Randazzo and Jones (1997). Hydrogeologic and stratigraphic units of west-central Florida are shown in figure 5. The massive carbonate sequence in west-central Florida is comprised of the Oldsmar and Cedar Keys Formations, the Avon Park Formation, the Ocala Limestone and the Suwannee Limestone. Overlying the carbonate sequence is the Hawthorn Group, comprised of interbedded carbonates and siliciclastics. Above the Hawthorn Group is an unconsolidated and undifferentiated unit comprised of quartz sand, clay, phosphate, organics (peat) and shell deposits that blanket nearly all of Florida in varying thickness and composition. Varying amounts of clay, generally at the base of the undifferentiated surficial deposits, provide confinement of the underlying rocks. However, throughout west-central Florida, karst features, such as sinkholes, breach clay deposits that would otherwise have provided confinement of the underlying carbonate rocks (Trommer, 1987).

Regionally, the carbonate units dip to the south and west and the overlying Hawthorn Group thickens and becomes a significant Intermediate aquifer system (fig. 6). Near the Gulf of Mexico, north of Tampa Bay, the carbonate rocks are at or near land surface and karst features can be observed. South of Tampa Bay, the clay units thicken, confining the carbonate units. Increased confinement reduces recharge of chemically aggressive water and the carbonate rocks are less susceptible to dissolution activity. Subsidence activity is less frequent and karst features are sparse at land surface (figs. 3 and 4).

Hydrostratigraphy

One or more aquifer systems separated by confining units, occur in west-central Florida. Correlation between geologic units and aquifer systems typically coincides with lithostratigraphic boundaries. The Surficial aquifer system is predominantly sand, the Intermediate aquifer system is interbedded siliciclastics and carbonates, and the Floridan aquifer system is massive carbonates. The relationship between lithostratigraphic and hydrostratigraphic units is described by the Southeastern Geological Society (1986), Green and others (1995) (fig. 5).

The uppermost aquifer, where present, is the Surficial aquifer system. The Intermediate aquifer

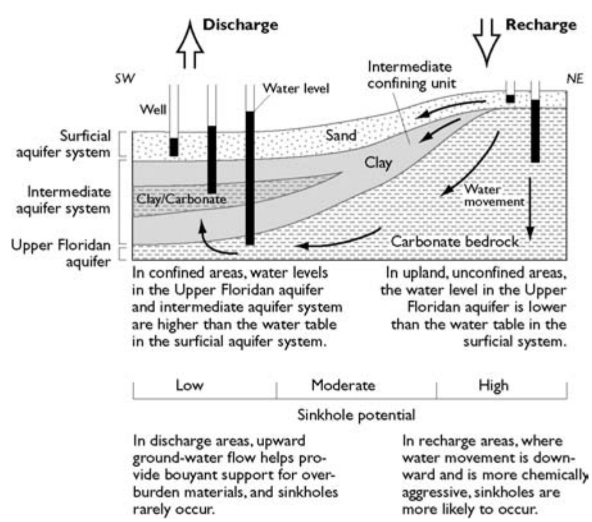


Figure 6—The potential for karst features to develop in west-central Florida is controlled by regional variations in geology and hydrology (from Tihansky, 1999).

system occurs south of Tampa Bay. When only the low permeability siliciclastic units of the Hawthorn Group are present, they form a confining unit that separates the Surficial and the Floridan aquifer systems. The Floridan aquifer system occurs throughout the state and is artesian where it is confined. The degree of confinement depends on the thickness and composition of the overburden materials.

Surficial Aquifer System

The Surficial aquifer system is composed primarily of Pliocene-Holocene unconsolidated siliciclastics (quartz sand, clay, organics and shell), and generally correlates with undifferentiated sand and clay deposits that blanket west-central Florida. Surficial deposits may be missing, having been eroded away and exposing limestone at the surface. In contrast, these same deposits may exceed 100 ft in thickness where they infill karst features or are remnants of ancient dune deposits. The limited thickness of the Surficial aquifer system in most areas of west-central Florida makes the aquifer a limited water resource. North of Tampa Bay, a regionally persistent surficial aquifer system does not occur and the underlying aquifer is unconfined. In areas to the south and east of west-central Florida, the surficial aquifer system is sufficiently thick to be utilized as a water supply.

Intermediate Aquifer System

The Intermediate aquifer system includes all permeable or water-bearing units and confining beds occurring between the overlying Surficial aquifer system and the underlying Floridan aquifer system (Duerr and Enos, 1991). Within west-central Florida, the intermediate aquifer system coincides with the Hawthorn Group and ranges from 0 to more than 700 ft thick. In the northern part of west-central Florida, the Hawthorn Group has been eroded leaving locally occurring patches of sediments (Scott, 1988). Generally, north of Tampa Bay, the Intermediate aquifer system (Hawthorn Group) is not regionally extensive. When the remaining sediments are predominantly clays, the unit is designated as the intermediate confining unit. In the northern region the remnant sediments are siliciclastics comprising the Peace River Formation and range in thickness from less than 10 ft to more than 140 ft.

Floridan Aquifer System

The Floridan aquifer system underlies all of Florida and parts of Georgia, Alabama and South Carolina. The Floridan aquifer system is divided into the Upper and Lower Floridan aquifers, generally separated by the middle confining unit (Miller, 1986, 1997). In west-central Florida, the thickness of the Upper Floridan aquifer ranges from 600 ft to more than 1,400 ft (Wolansky and Garbade, 1981). The top of the Upper Floridan aquifer is typically considered the occurrence of vertically persistent carbonates. The bottom of the Upper Floridan aquifer occurs within the lower Avon Park Formation, where vertically and laterally persistent evaporite minerals (gypsum and anhydrite) are present in the carbonate rocks (Ryder, 1985). These evaporites, which occur either as beds, vug fillings, or as intergranular minerals within the carbonate matrix, cause a major decrease in permeability. Referred to as the middle confining unit of the Floridan aquifer system, the evaporites are of regional extent and underlie the Upper Floridan aquifer throughout west-central Florida (Hickey, 1990).

In the west-central Florida, the Upper Floridan aquifer typically consists of the Avon Park Formation, Ocala Limestone and Suwannee Limestone. Additionally, in areas where the Tampa Member (Arcadia Formation) of the Hawthorn Group is hydraulically connected to the underlying carbonates (Suwannee Limestone), the Tampa Member is included in the Upper Floridan aquifer.

FIELD TRIP STOP DESCRIPTIONS

Four field trip stops provide access to various examples of karst features of west-central Florida. The map locations of the stops are included in the appendix at the end of this paper. From north to south, these stops include: 1-The Southdown Limestone Quarry, 2-Dry Caves of Citrus County, 3-Chassahowitzka Springs complex, and 4-Health Springs.

1-Southdown Limestone Quarry

The Southdown Quarry is an operating limestone quarry that mines limestone for aggregates and manufacture of concrete. Fine and coarse aggregate is manufactured from limestone deposits with softer deposits favored for limerock base material. Limestone varies from very hard and dense to soft and porous and may contain significant quantities of fossils. Karst features are often related to the introduction of allogenic materials into the pure carbonate units via solution pipes, sinkholes and fissures. The presence of silica sand and chert along joints and bedding planes often requires that mining activities process the materials either by selectively mining, blending materials, or removing fines.

Carbonate units exposed in this quarry include the Avon Park Formation, the Ocala Limestone and the Suwannee Limestone. The Middle Eocene Avon Park Formation (Miller, 1986) occurs in the subsurface throughout west-central Florida. This unit varies from light gray to brown dolostone to cream to light orange limestone with minor clay interbeds and dispersed organic laminations. Accessory minerals include chert, pyrite, and gypsum, with gypsum becoming more abundant with depth. Although the uppermost part of the Avon Park Formation varies between limestone and dolostone, dolostone predominates deeper within the unit, especially toward the south. Porosity in this formation is generally intergranular in the limestone section. Fracture porosity occurs in the more densely recrystallized dolostone, and intercrystalline porosity is characteristic of sucrosic textures. Pinpoint vugs and fossil molds are present to a lesser extent. The most diagnostic fossils include the foraminifers *Dictyoconus americanus* and *Coskinolina floridana*. The echinoid *Neolaganum (Peronella) dalli* is also common (J. Arthur, Florida geological Survey, 2000, written commun.).

The base of the Avon Park Formation occurs at depths ranging from 1,100 ft to 1,850 ft below sea level varying in thickness from 1,000 ft in the north to 1,500 ft south (Miller, 1986). In the field trip area, the top of the formation is encountered from within 20 ft of land surface to a depth of 425 below sea level in the southwest. In many cases, high gamma-ray activity at the top of the Avon Park Formation is due to thin (<2 inches) layers of organic material.

The Ocala Limestone unconformably overlies the Avon Park Formation. The Upper Eocene Ocala Limestone consists of white to light-gray to light-orange limestone with a diverse fossil assemblage. More specifically, the lithology of this formation ranges from a variably chalky wackestone or packestone in the upper parts to a biogenic packstone to grainstone in the central and lower parts of the unit. Accessory constituents include organics, clay, dolomite and chert. Porosity is variable within this unit and is generally moldic and intergranular with occasional macrofossil molds. This formation contains characteristic fossils such as the foraminifers *Lepidocyclina* spp., Nummulites (Operculinoides) and echinoids such as *Eupatagus antillarum*. Other fossils observed in the unit include mollusks, bryozoans and corals.

The Ocala Limestone is typically bound by unconformities. Depths to the top of the formation range from land surface to 285 ft below sea level. The Ocala Limestone extends throughout west-central Florida except for some regions to the north and east towards the central part of the state. The Ocala Limestone obtains a maximum thickness of 230 ft. These maximum depths and thicknesses occur in regions on the flanks of the Ocala Platform, which trends south-southeast.

Gamma-ray logs for the Ocala Limestone consistently exhibit low gamma-ray activity. In some southern areas, the Ocala Limestone gamma-ray signature is "quiet" when compared to the underlying Avon Park Formation and the overlying Suwannee Limestone. In cases where the Ocala Limestone is dolomitized, the gamma-ray logs may exhibit a slightly higher and more sporadic signal. Many peaks in the gamma-ray logs correlate with the presence of organics.

The Lower Oligocene Suwannee Limestone ranges from a light-gray to yellowish-gray packstone to grainstone. These carbonates are variably moldic with trace amounts of sand and clay within the upper parts. Trace amounts of chert and organics occur throughout the unit. Fossils in the unit include mollusks, echinoids (primarily *Rhyncholampus gouldii*), abundant miliolids and other benthic foraminifers including *Dictyoconus cookei*. This formation unconformably overlies the Ocala Limestone and is unconformably overlain either by Hawthorn Group units or UDSC sediments. In several areas towards the south, the Suwannee Limestone is less than 20 ft below land surface. It is limited in extent towards the north and is reported to occur as exposed remnant boulders where it thins (Campbell, 1989). Depth to the top of the Suwannee Limestone ranges from 80 ft below to 132 ft above sea level, where present. The unit thickens to the south and west, ranging up to 255 ft thick. The Suwannee Limestone is characterized by gamma-ray activity that has an overall higher count rate than the underlying Ocala Limestone. Additionally, there exists much more variability in its signature relative to the Ocala Limestone. This variability in the gamma-ray signature correlates with dolomite, clays and organics within the formation.

2-Dry Caves of Citrus County

The history of the development of caves visited during this field trip (Brinkmann and Reeder, 1994) is included in the field trip package. These caves were formed by structural and chemical processes. Structural uplift created northwest-southeast trending joints and dissolution was enhanced by geochemical reactions associated with ground-water mixing. The mixing of waters with variable salinity and acidity enhanced carbonate dissolution. The caves visited on this trip are fossil remnant segments from a much larger, interconnected cave system that formed in the Ocala and Suwannee Limestones. Subsequent lowering of base level by erosion and collapse has destroyed and infilled many of the original caves.

Peace Sign cave is predominantly a large sinuous conduit with the land surface opening occurring at the base of a tree. Vandal cave is a good example of how collapse and subsidence processes destroy the original cave features. Bats and other typical cave fauna are usually present in the smaller, less-frequently visited caves in this complex.

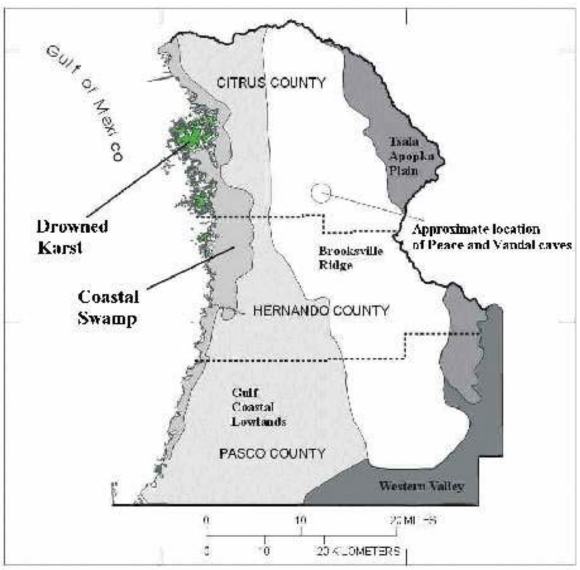


Figure 7—Physiographic regions of westcentral Florida (modified from White, 1970)

3-Chassahowitzka Springs Complex

The springs that contribute flow to the Chassahowitzka River occur in the physiographic region designated as the Coastal Swamp (White, 1970) (fig. 7). This region is an area of upward flow from the Upper Floridan aquifer and active sinkhole formation is minimal (0-2 karst features per square mile). To the east, in the sand hills of the Gulf Coastal Lowlands, recharge conditions, exist so the karst feature density is higher (10-25 solution features per square mile) and the well drained soils support a unique scrub habitat (HydroGeoLogic, 1997 and Wolfe, 1990).

The springs visited on this trip include the Chassahowitzka Main Spring, Bubba Spring (also known as Chassahowitzka Number 1), Crab Creek Head Spring and Baird Creek Spring. These springs contribute the majority of the freshwater flow to the Chassahowitzka Springs complex.

The Chassahowitzka River is a shallow, flat, and sluggish stream that meanders through about 6 miles of lowland swamps and tidal marshes to the Gulf of Mexico. At least 12 springs contribute flow to the Chassahowitzka River and have been described by Wetterhall (1965), Yobbi (1992), and Jones and others (1997) (fig. 8).

Subsurface geology is reflected in the types of spring vents observed in west-central Florida and can be viewed in the Chassahowitzka Springs complex. The types of spring vents include: (1) linear fracture, (2) circular rock vent (vertical pipe), and, (3) sediment filled vent (sand boil). The types of vents that form usually reflect characteristics of the rock. Hard, brittle zones in limestone units maintain larger openings such as caverns and fractures while softer limestones collapse more readily.

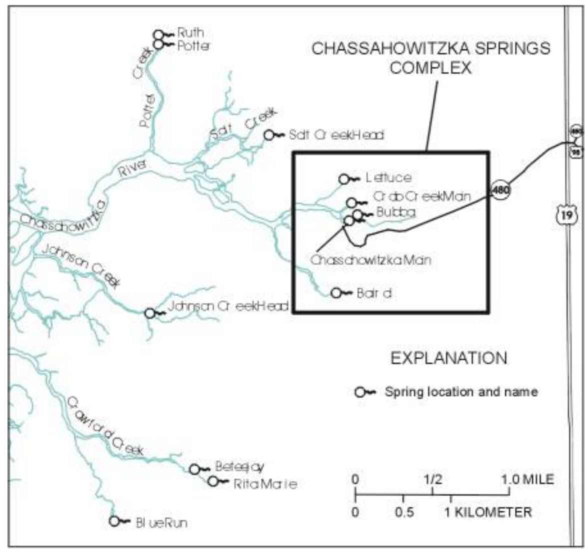


Figure 8—Springs and surface discharge network of the Chassahowitzka Springs complex.

The Chassahowitzka Main Spring is an example of a sediment-filled vent. The spring boils from a sand bottom along a crevice approximately 25-ft long and in 35 ft of water depth. The spring pool is approximately 150 ft in diameter and is a 50 ft wide cone located in the middle of the river channel. Salinity ranges from 700 to more than 4,000 microsiemens per centimeter (us/cm). The spring is affected by tides with flow ranging from near zero to more than 52 million gallons per day (80 cubic ft per second (ft^3/sec)).

Bubba Spring is the largest of several springs that contribute to flow in the unnamed tributary above

Chassahowitzka Main Spring. It is an example of a circular rock vent. It is comprised of two vertical pipes connected by a 15-foot horizontal conduit. The flow from Bubba Spring emanates from a small opening in the horizontal passage, midway between the two vertical pipes. Bubba Spring is the shallowest in the Chassahowitzka Springs complex and was fresh enough to be used as a water supply in the past. However, these waters are now contaminated by leakage from septic tanks.

Crab Creek Head Spring and at least three other springs that contribute flow to Crab Creek are additional examples of circular rock vents. Crab Creek Head Spring is located in 13 ft of water. The vertical pipe is intersected by a horizontal fracture about seven ft below the water surface. These springs discharge brackish water (greater than 3,000 us/cm) and spring flow is relatively constant at 3.2 million gallons per day (50 ft^3/sec).

Baird Creek Spring is an example of a linear fracture vent. The fissure is more than 20 ft long and is in about 4 ft of water. This spring discharges brackish water (greater than 5,000 us/cm) and the salinity varies significantly during a tidal cycle.

4-Health Springs—impacts of land use in a karst region

Health Springs serves as one of many examples where land-use activities in a karst terrane affect ground-water quality. The region contains coastal springs and karst uplands that are characterized by internal drainage and variable confinement between the surficial aquifer system and the Upper Floridan aquifer (fig. 9). Land use upgradient of the spring was used historically for citrus agriculture but at present includes an extensive golf course, a wastewater treatment facility, and residential and commercial properties. Activities at the wastewater

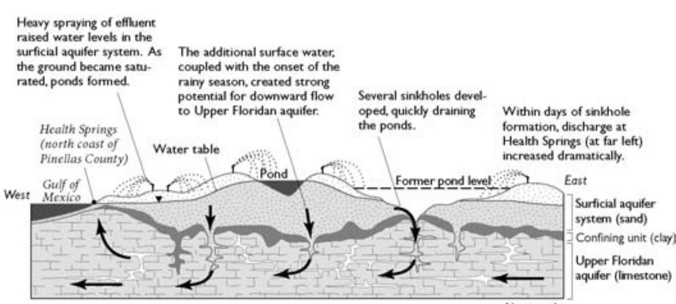


Figure 9—Sinkholes provide a direct hydrologic link between karst uplands and Health Springs along the coast (from Tihansky, 1999).

treatment plant have included land application of dried sludge, spray irrigation and ponding of treated effluent. The site is presently planned for a county park; however, elevated nutrient and bacteria concentrations in the spring discharge have delayed this action.

In April 1988, several cover-collapse sinkholes developed in an area where effluent from a wastewater treatment plant is sprayed for irrigation. Ponding of the effluent occurred while water levels were at their seasonal low. The maximum seasonal head difference combined with surface loading likely contributed to the formation of several sinkholes which drained the effluent into the ground-water system. Within several days of sinkhole formation, discharge at Health Springs, 2,500 ft downgradient, increased from 2 ft^3/sec to 16 ft^3/sec (Trommer 1992). A dye-tracer study confirmed the existence of a preferential ground-water flow path linking the upland spray field with the spring (Tihansky and Trommer, 1994). Dye injected into a well located in the sprayfield was detected in the spring water and in a well adjacent to the spring (fig. 10). Ground-water velocity was about 160 ft per day (ft/d) which is 250

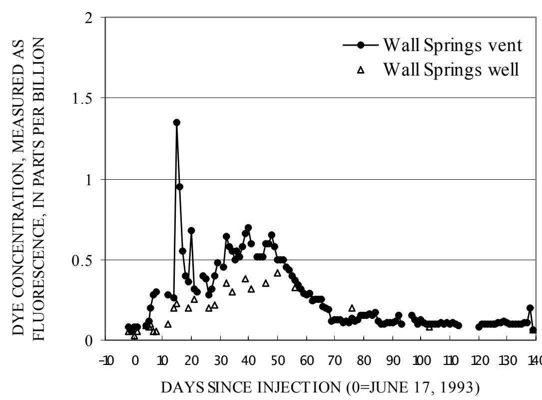


Figure 10—Dye concentrations, measured as fluorescence, at Health Springs and an adjacent well during a tracer test illustrate the rapid movement of ground water.

times greater than estimates of the regional ground-water velocity (0.65 ft/d) in this area.

Background nitrate concentrations for ground water in Florida generally are less than 0.02 milligrams per liter (mg/L). Water samples collected at Health Springs since 1982 have nitrate concentrations ranging from 2 to more than 10 mg/L. These elevated values reflect the impact of land use in the spring's recharge area.

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Conclusion

The four field trip stops provide a quick glimpse of the variability in the types of landforms and features characteristic of Florida karst. Examining the rocks in a quarry section reveals the variability of the units in terms of geologic fabric and texture. These initial differences often determine the type and extent of karst development and distribution of zones with enhanced secondary porosity. The heterogenous distribution of overlying mantling deposits further controls the development of karst. The dry caves and the flowing springs observed on this trip demonstrate how karst features function on both the recharge and discharge ends of the hydrologic realm. Each of these regions has unique and significantly different hydrologic controls and potential environmental impacts.

The full range of hydrologic impacts have been documented at Health Springs, where sinkholes and water-quality impacts in the recharge zone have been directly linked to water-quality changes in the discharge region at the spring.

The features observed on this trip include a full range of karst features in west-central Florida. More importantly, close examination of these features provides an opportunity to see how vulnerable water resources are to impacts related to karst landforms. Impacts to resources of the region range from loss of structural support and foundation integrity at land surface to degrading water quality in ground- and surface-water resources. Most of Florida is prone to karst-related impacts on land and water-resources, and the examples seen on this trip are representative of many other locations.

The distribution of highly variable transmissive zones creates a complex hydrogeologic framework and standard analytical and numerical methods often do not adequately quantify the complexities of karst flow systems. Further study of karst systems and increased understanding combined with effective management will minimize detrimental effects to water resources in karst regions.

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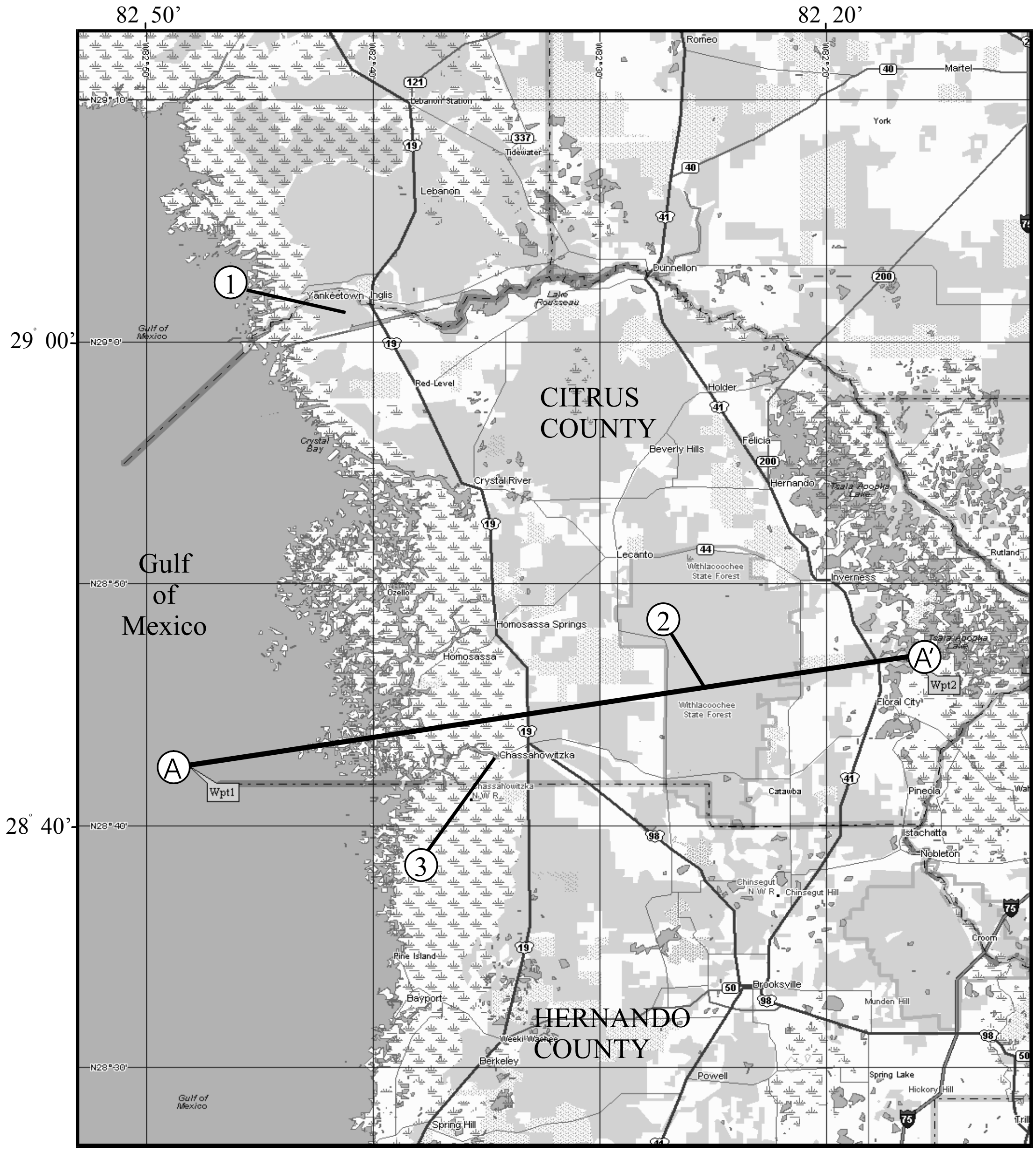
Appendix—Field trip stops 1-4. Stop 1 is Southdown Limestone quarry. Stop 2 is the dry cave complex of Citrus County, Stop 3 is the Chassahowitzka Springs complex. Stop 4 is Health Springs, known locally as Wall Springs, and the surrounding upland area. A representative topographic cross section A-A' shows the irregular topography and abrupt transition from upland to coastal plan. The section extends from upland dry caves (field trip Stop 2) to the coast near Chassahowitzka Springs (field trip Stop 3). Cross section B-B' shows the upland coastal strip of northwestern Pinellas County (field trip Stop 4) and the Lake Tarpon Basin separating the coast from the main peninsula of Florida.



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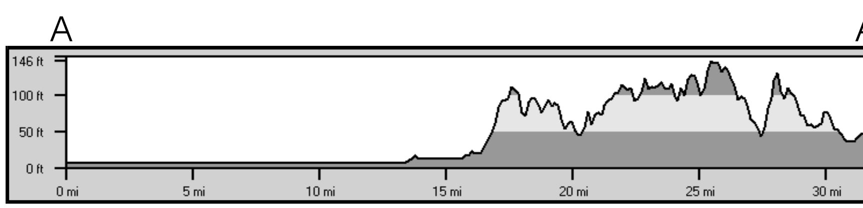

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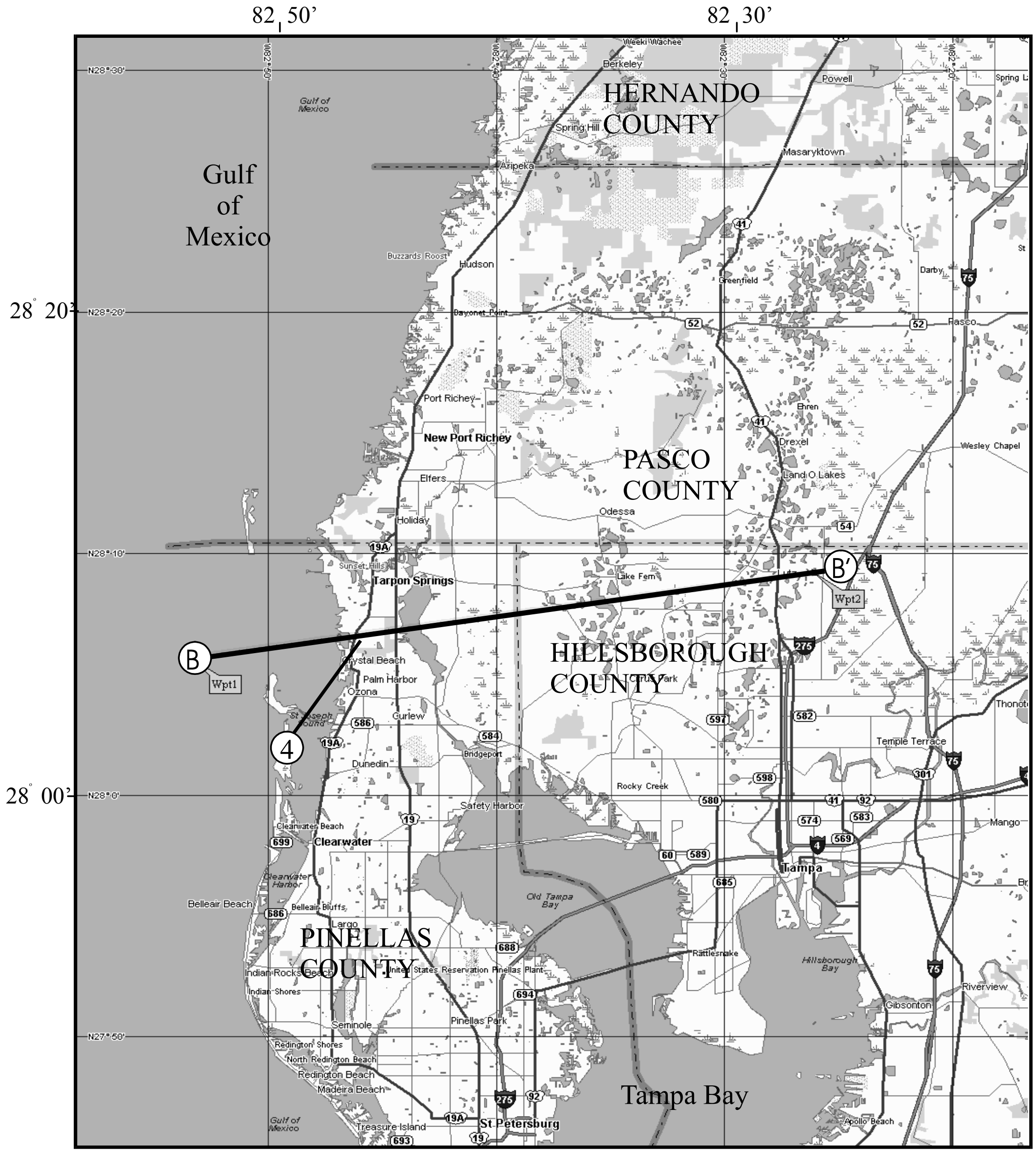

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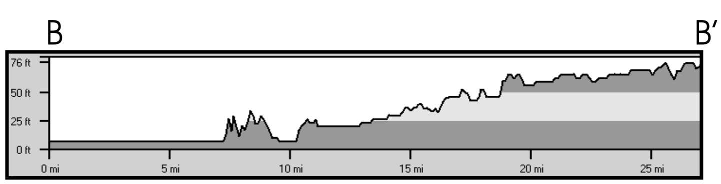

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