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Development of Karst Traces in the Santa Fe Basin




February 23, 2019

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Development of Karst Traces in the Santa Fe Basin

A Field Trip of the Southeastern Geological Society

Field Trip Guidebook 76
February 23, 2019

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Cover Photo Credits:

Top Left:
Ichetucknee Trace, north of Columbia City Elementary School - view southeast from Bishop Road; G. Maddox (2019);
Top right:
Rose Creek Swallet: Upchurch et al 2019, Figure 8.23;
Bottom Left:
Ichetucknee Main Spring – view east: G. Maddox (2005);
Bottom Right:
Flooding of the Ichetucknee Trace after Hurricane Frances in September 2004: Florida Geological Survey.

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Field Trip Overview

Friday, February 22

Activities begin with a social hour at the Fairfield Inn (538 S.W. Corporate Drive, Lake City, FL). A social hour will begin at 5:30, followed by a catered dinner (Sonny's BBQ). Presentations will begin at 7:30.

After dinner, Rick Copeland (AquiferWatch Inc.) will give a brief introduction of the evening's speakers. Each presentation will be 20 minutes. Sam Upchurch (SDII-Global Inc.) will give a presentation regarding the origin and evolution of Karst Traces, with emphasis on north-central Florida. Christopher Williams (Florida Geological Survey) will give a presentation pertaining to the geomorphology of the Santa Fe and Ichetucknee basins. Gary Warren (Florida Fish and Wildlife Conservation Commission) will emphasize talk about rare and uncommon species in karst environments.

Saturday, February 23

Beginning at 8:00 AM, participants will leave the Fairfield Inn and commence the field trip. During the day, attendees will visit eight stops. Each one represents a significant karst feature located along the Ichetucknee Trace and the Paradise Ravine. Lunch will be provided at Ichetucknee Springs State Park, at the headwaters of the Ichetucknee springs group. A presentation will be given by Sam Upchurch, plus Gary Maddox and Rick Copeland (AquiferWatch Inc.) will discuss concerns of nutrients in the water resources of the area. The trip will end back at the Fairfield Inn at about 5:00 PM.

Sunday, February 24

Sunday's activities are optional. Attendees will meet at Ichetucknee Springs State Park at 9:00 AM and take a kayak/canoe trip down the Ichetucknee River. Sam Cole (biologist with the Ichetucknee Springs State Park), will lead and discuss many aspects of the river. If attendees plan on taking the canoe trip, they need to sign up for the trip on Friday evening (Rick Copeland). The kayaks / canoes will be at available for pick up at the head springs at 9:00. In addition, an optional box lunch will be available Take-Out on the river, at the southern end of the park. Sign up for the optional lunch is on Friday evening (Rick Copeland).

Development of Karst Traces in the Santa Fe River Basin

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Introduction and Acknowledgements

Florida is known for its numerous karst features and many are found in the Santa Fe River basin in the north-central portion of the state. Some of the most spectacular features tend to be found along the Cody Scarp (Escarpment), a feature dominated by fluviokarst retreat.

The field trip begins in the headwaters of the Ichetucknee Trace and follows the trace to its resurgence in Ichetucknee Springs State Park. After lunch, the trip tracks a smaller trace, the Paradise Ravine, and then returns to Lake City. The purpose of the trip is to educate the attendees on the origin and development of karst traces and how the receding escarpment has played a significant role in the development of the local landforms. For this reason, at each stop, experts will discuss various aspects of karst hydrogeology. At the headwaters of the Paradise Ravine (Jess's Hole), attendees will not only learn important geologic information, they will learn about Jess and the unfortunate tragedy that happened to him

The first article in the guidebook is by Drs. Sam Upchurch and Tom Scott (SDII-Global Inc.). They discuss the origin and evolution of karst traces. They are also the lead authors in a recently published book, *The Karst Systems of Florida, Understanding Karst in a Geologically Young Terrain.* The second article, written by Dr. Christopher Williams and Levi Hannon (Florida Geological Survey). They are in the process of completing a revised geomorphology map (and text) of Florida. They describe the major geomorphic districts and provinces located within the Santa Fe River Basin, that includes the Ichetucknee River basin. They also briefly discuss the evolution of the major land features within the basin. Of note, they present an argument for renaming the eastern portion of the Cody Scarp (east and south of Madison County) to the Big Bend Escarpment. They point out that the western portion of the scarp was formed by coastal process, whereas the formation of the eastern and southern portion of the escarpment is being formed by on-going fluviokarst activities; thus, a new name is needed.

The importance of karst is not restricted to the science of hydrogeology. The karst features also influence the biota. In the third article, Dr. Colette Jacono (Florida Museum) reveals important aspects of the plant life that can be found within the Paradise Ravine Trace. In addition, Dr. Gary Warren, in his talk during the Friday evening (February 22) discussed rare and uncommon species in karst environments.

Our society's understanding of geology is an on-going process. We are forever obtaining additional information, which in turn, allows our society to gain a better knowledge of various scientific processes such as hydrogeology and karst topography. This increased knowledge produces more informed citizens and makes our society a better place to live in. Recognizing the importance of improving our geological knowledge, the federal and the state governments have joined forces. They operate a program referred to as STATEMAP. In the fourth article, Rick Green (Florida Geological Survey) discusses the STATEMAP program and how it operates.

The field trip itself could not have come together without the help of the following contributors: Pete Butt of Karst Environmental Services, Sam Cole, and Colette Jacono. Special appreciation goes to Sam Upchurch and Tom Scott, lead authors of the book that partially inspired the trip (references on page 37 of guidebook).

The first portion of Saturday's trip closely aligns with prior trips conducted along the Ichetucknee Trace by Jim Stevenson beginning in the late 1990's, with help from staff at the Florida Geological Survey and members of the former Florida Springs Task Force. We acknowledge and thank him for his efforts to educate Florida's citizens, leaders and elected officials, showing them how surface water and ground water interact within the Ichetucknee Basin by "following the water" south from source to spring.

We would like to thank the officers of the Southeastern Geological Society for sponsoring the trip. They include President Jennifer Coor of the U.S. Army Corps of Engineers, immediate Past President Dr. Jon Bryan of Northwest Florida State College, Vice President Dr. Jonathan Valentine of the University of South Florida, Secretary Cortney Cameron of the Southwest Florida Water Management District, and Treasurer Andy Lawn of HSW Engineering Inc.

We would like to thank the following property owners for allowing the attendees of the trip to visit their property. They include Celest Beck, Scott Butsch, Brian Ferguson, and Charles Timmons. Finally, I would like to especially thank Debbie Copeland and Lory Maddox, who both assisted in the logistical planning of the trip.

Gary Maddox, Rick Copeland, and Kate Muldoon
Tallahassee, FL

February 2019

Road Log

8:00 AM – *Depart* ***Fairfield Inn (see Map 2):***

- Turn left onto SW Corporate Drive and proceed 0.1 mile to SW Florida Gateway Drive;

- Turn left onto SW Florida Gateway Drive and proceed 0.4 miles to the traffic light at U.S. 90;

- Turn right (east) onto U.S. 90 and work your way over to the left lane. Proceed 0.3 miles, passing beneath the I-75 overpass. Turn left (north) at the traffic light onto NW Commerce Drive;

- Continue on NW Commerce Drive 1.2 miles, passing the Lake City Medical Center (on your left) before the road curves left (west). NW Commerce Drive becomes NW Fairway Drive as the road curves right, paralleling I-75 and entering a housing subdivision;

- Turn right (east) onto NW Egret Lane, and proceed 0.1 mile to NW Harris Lake Drive;

- Turn left (north) onto NW Harris Lake Drive and proceed 0.3 miles to Harris Court (on the right). Park on road shoulder;

- *Arrive at* ***STOP #1 – Lake Harris polje***

GPS Coordinates for STOP #1: 30.19648
-82.68607

8:45 AM – *Depart* ***STOP #1 – Lake Harris polje (see Map 3):***

- Continue around Harris Court 0.3 miles, which loops back around to NW Harris Lake Drive. Back-track, returning to U.S. 90 following the route above;

- Turn left onto U.S. 90 at the traffic light and proceed east 2.2 miles toward Lake City. Turn right onto State Road 10A (SW Baya Drive) and proceed 1.0 mile east to U.S. 441 (South Marion Avenue);

- Turn right onto U.S. 441 (South Marion Avenue) and proceed 0.5 miles south to SE Clements Place. This is the road just past a white church and just before the Florida Department of Transportation building;

- Turn left onto SE Clements Place and proceed 0.3 miles to the end of the road, at the County Park;

- *Arrive at* ***STOP #2 – Alligator Lake***

GPS Coordinates for STOP #2: 30.17532
-82.63250

9:45 AM – *Depart* ***STOP #2 – Alligator Lake (see Map 4):***

- Take SE Clements Place back (west) to U.S. 441 and turn left (south);

- Proceed 0.2 miles south on U.S. 441 to SW St. Margarets Street;

- Turn right on SW St. Margarets Street and proceed 0.2 miles west to U.S. 41 (SW Main Boulevard);

- Turn left (south) onto U.S. 41 (SW Main Boulevard) and proceed 0.1 mile south to the junction with State Road 47;

- Veer right onto State Road 47 and proceed 3.5 miles south-southwest to the I-75 interchange;

- Just before the I-75 interchange, turn right into the "Park & Ride" parking lot;

- *Arrive at* ***STOP #3 – Cannon Creek Sink***

GPS Coordinates for STOP #3: 30.11939
-82.65537

10:45 AM – *Depart* ***STOP #3 – Cannon Creek Sink (see Map 5):***

- Turn right onto State Road 47 and proceed underneath the I-75 overpass. Travel 0.3 miles to the traffic light at County Road 242;

- Turn right onto County Road 242 and proceed 2.0 miles to the intersection with SW Dyal Avenue / SW Sisters Welcome Road;

- Turn left onto SW Dyal Avenue and proceed 0.9 miles to a left-hand bend in the road. Park on the road shoulder;

- *Arrive at* ***STOP #4 – Dyal Sink***

GPS Coordinates for STOP #4: 30.10693
-82.69645

11:30 AM – *Depart* ***STOP #4 – Dyal Sink (see Map 6):***

- Continue south on SW Dyal Avenue 0.2 miles to SW King Street;
- Turn left and proceed a short distance east (0.2 miles) to Bishop Road;
- Turn right onto Bishop Road and proceed 1.6 miles south to State Road 47;
- Turn right onto State Road 47 and travel south for 0.8 miles to Columbia City;
- Turn left onto County Road 240 (at the flashing yellow lights) and park along the road shoulder;
- *Arrive at* ***STOP #5 – Rose Creek Swallet/Sink***

GPS Coordinates for STOP #5: 30.06888
-82.69611

12:30 PM – *Depart* ***STOP #5 – Rose Creek Swallet / Sink (see Map 7):***

- Return to State Road 47 and turn left (south). Travel 8.0 miles to the intersection with County Road 238 (SW Elim Church Road);
- Turn right onto County Road 238 (SW Elim Church Road) and proceed northwest for 3.6 miles to the Ichetucknee Springs State Park – North Entrance;
- Enter the Park and follow the Park Road past the Entrance Station, turning right and parking in the first parking lot;
- *Arrive at* ***STOP #6 – Ichetucknee Main Spring (Lunch stop)***

GPS Coordinates for STOP #6: 29.98513
-82.76254

2:30 PM – *Depart* ***STOP #6 – Ichetucknee Springs (see Map 9):***

- Drive back to the Park Entrance and turn right onto County Road 238 (SW Elim Church Road). Proceed 8.0 miles southeast, back to State Road 47;

- Turn right onto State Road 47, and travel south 2.2 miles to Fort White;

- Turn left at the traffic light onto U.S. 27. Travel 6.6 miles southeast to SW County Road 138;

- Turn right (west) onto SW County Road 138 and proceed 0.7 miles. Park in driveway and on shoulder of road near driveway at 824 County Road 138;

- *Arrive at* ***STOP #7 – Paradise Ravine***

GPS Coordinates for STOP #7: 29.85349
-82.65350

3:30 PM – *Depart* ***STOP #7 – Paradise Ravine (see Map 10):***

- Turn around and back-track (east) to U.S. 27;

- Turn left onto U.S. 27 and proceed 1.0 mile to SW Bonifay Glen Road;

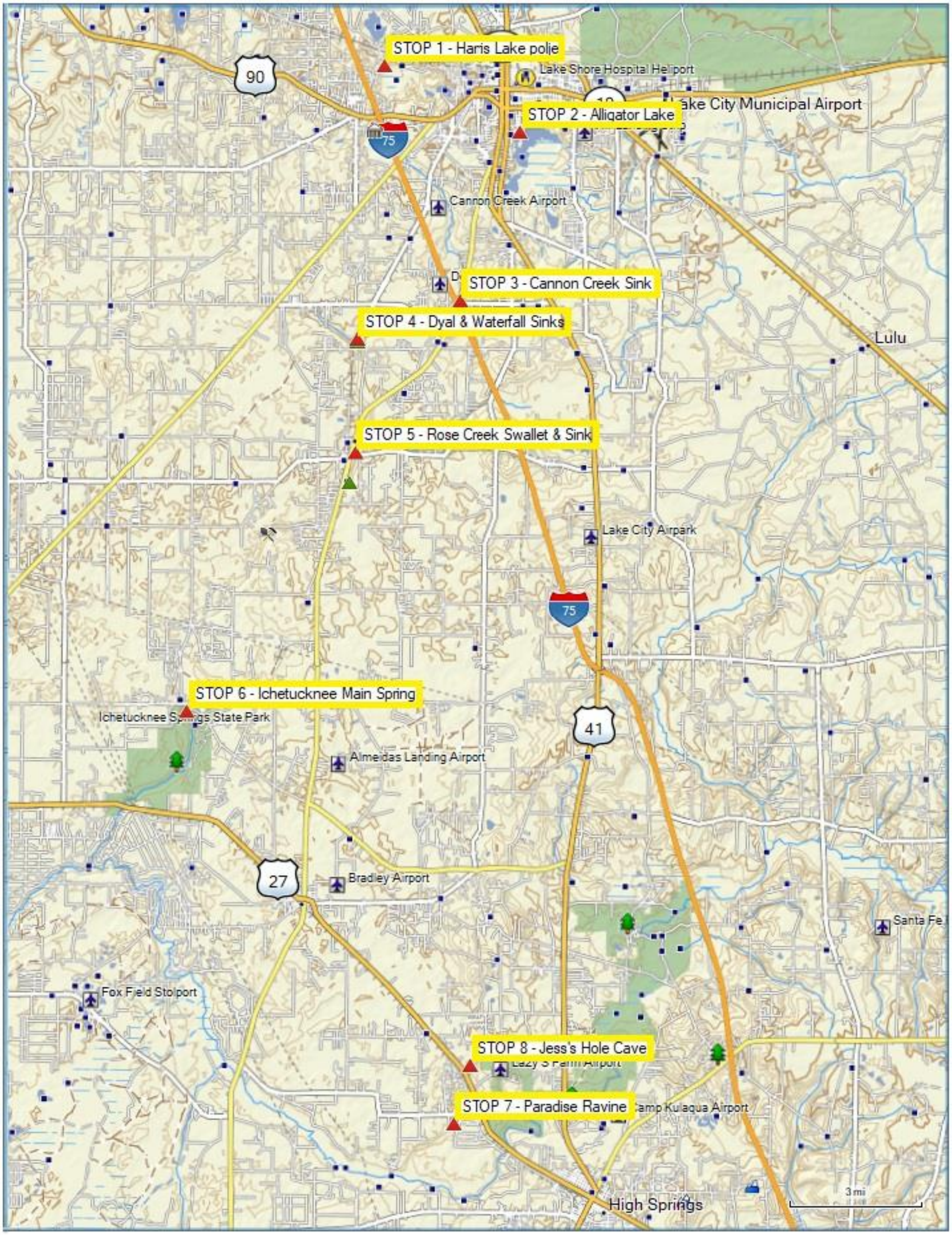
- Turn right onto SW Bonifay Glen Road and proceed 0.25 miles to the second driveway on the left, marked with a sign "Scott's Drywall Service" (309 SW Bonifay Glen Road). Park along SW Bonifay Glen Road;

- *Arrive at* ***STOP #8 – Jess's Hole Cave***

GPS Coordinates for STOP #8: 29.86842
-82.64690

To return to Lake City / Fairfield Inn, return to U.S. 27 and turn left (southeast), travelling 4.3 miles to High Springs. Turn left onto U.S. 41 (North Main Street) and proceed 0.3 mi (about 3 blocks) to the traffic light in downtown High Springs at the junction of U.S. 41-441 (NW Santa Fe Blvd.). Turn left onto U.S. 41-441 (NW Santa Fe Blvd.) and travel 11.9 miles north to I-75. Turn left (north) onto I-75 and travel 13.6 miles north to Exit 427 - U.S. 90 (see ***Map 1***).

GPS Coordinates for Fairfield Inn: 30.17436
-82.68879



Map 1 - Overview of field trip stops

Map 2 - Fairfield Inn to STOP #1: Lake Harris polje

STOP #1 – Lake Harris polje

Lake Harris sits inside an excellent Florida example of a polje. A polje is a karst feature comprised of coalescing sinkholes, with subsequent sedimentation forming relatively flat-bottomed depressions, some quite large. Poljes are usually defined by steep-walled margins; however, in Florida the overlying sedimentary mantle often obscures this feature.

Note the steep drop-off just past the Lake City Medical Center (on your left) on the way to the field trip stop – this is the southern edge of the polje, obscured by a mantle of sediments.

We will be observing this karst feature from a vacant lot within a residential community. Please be respectful of the residents here, who have consented to allow us early morning access to this site. Please do not park in or block any driveways.

Departing STOP #1, we will return to U.S. 90 and proceed east toward the southern part of Lake City. Along the way, you will see other sinkhole lakes and karst features.

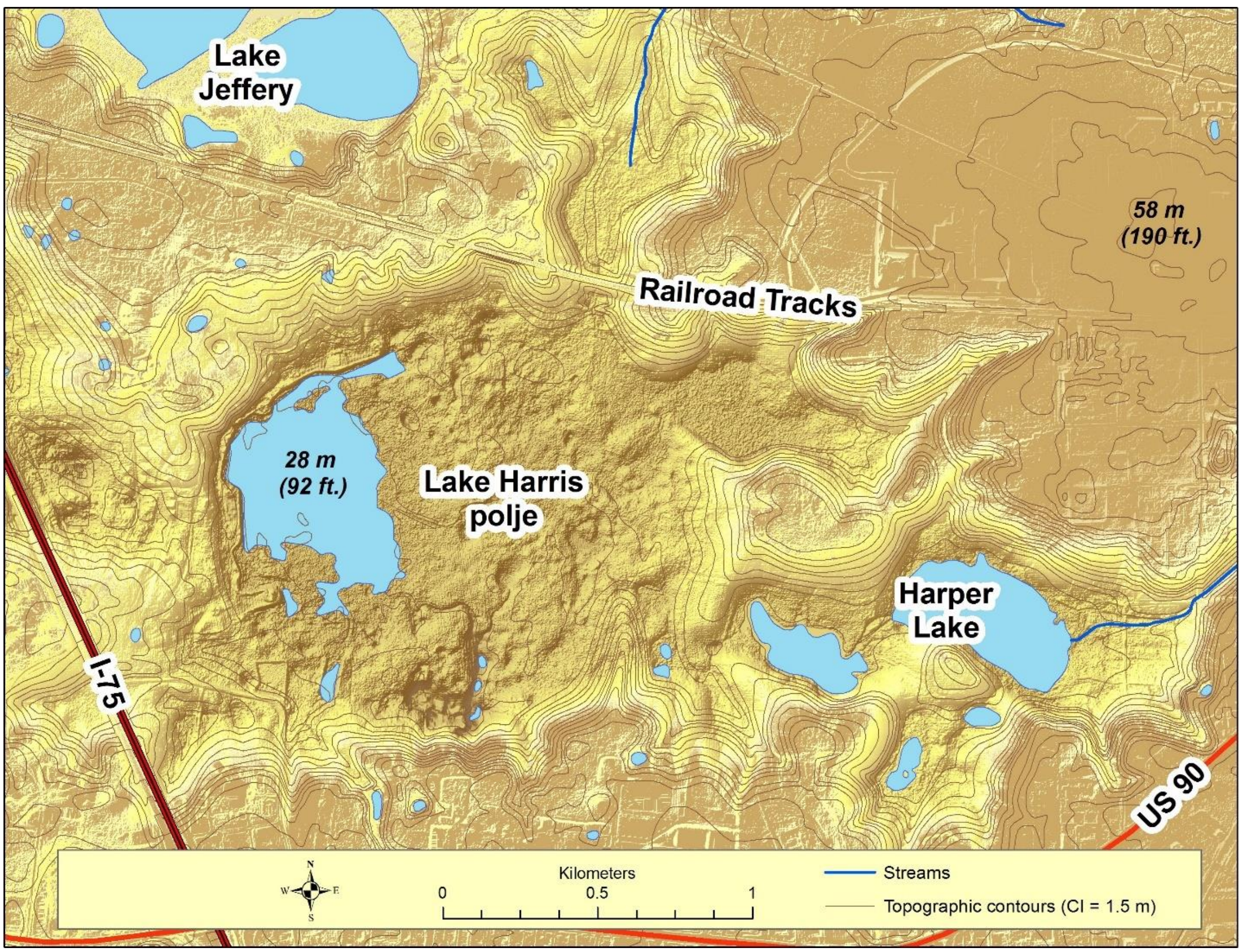
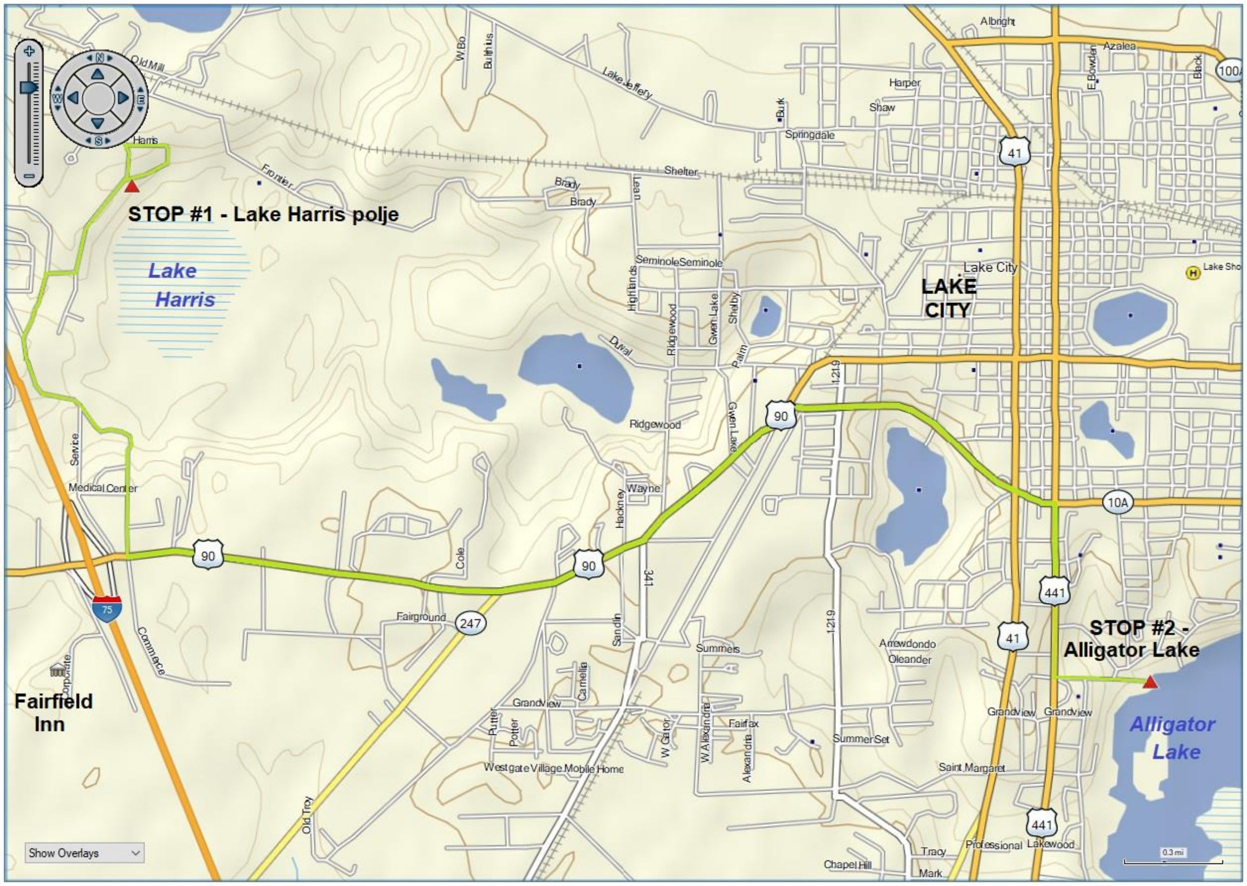


Figure 1 - LiDAR map of the Harris Lake polje near Lake City, Florida. Note that surface water drains from Lake City into the basin via several ephemeral streams and intermediate sinkhole lakes, and that the lake basin drains internally to the unconfined Floridan aquifer system (revised from Upchurch et al; 2019, Figure 8.39).



Map 3 - STOP #1 to STOP #2: Alligator Lake

STOP #2 – Alligator Lake

Alligator Lake is one of several large, internally-drained karst lakes, which occur just above the Big Bend (Cody) Escarpment in North Florida. These lakes contain “plugged” ponors which, given the right hydrological conditions, can rapidly open and drain these lakes downward into the upper Floridan aquifer system. This lake was, until 1987, the recipient of Lake City’s treated sewage and continues to receive much of the city’s stormwater runoff. To help with water quality restoration, a series of “treatment wetlands” have been constructed in the eastern and southern portions of the lake bed.

During periods of extreme precipitation, Alligator Lake can overflow, following an ephemeral stream channel southward into Clay Hole Creek just east of U.S. 41-441. The significance of Alligator Lake is that it is believed to be one of the major upgradient sources of ground water eventually discharging through the Ichetucknee Springs Group.

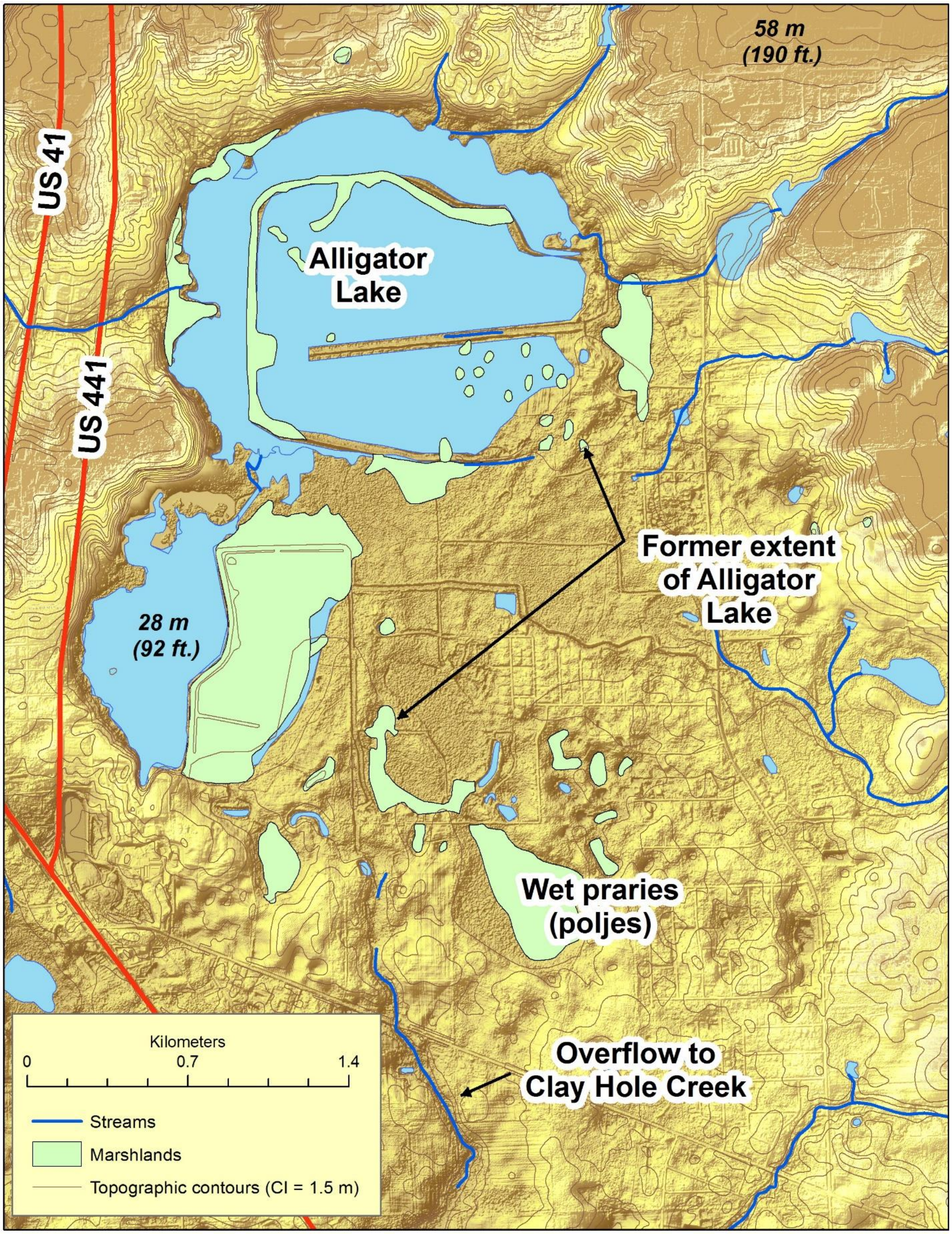


Figure 2 - LiDAR map showing major karst features in and around Alligator Lake (from Sam Upchurch).

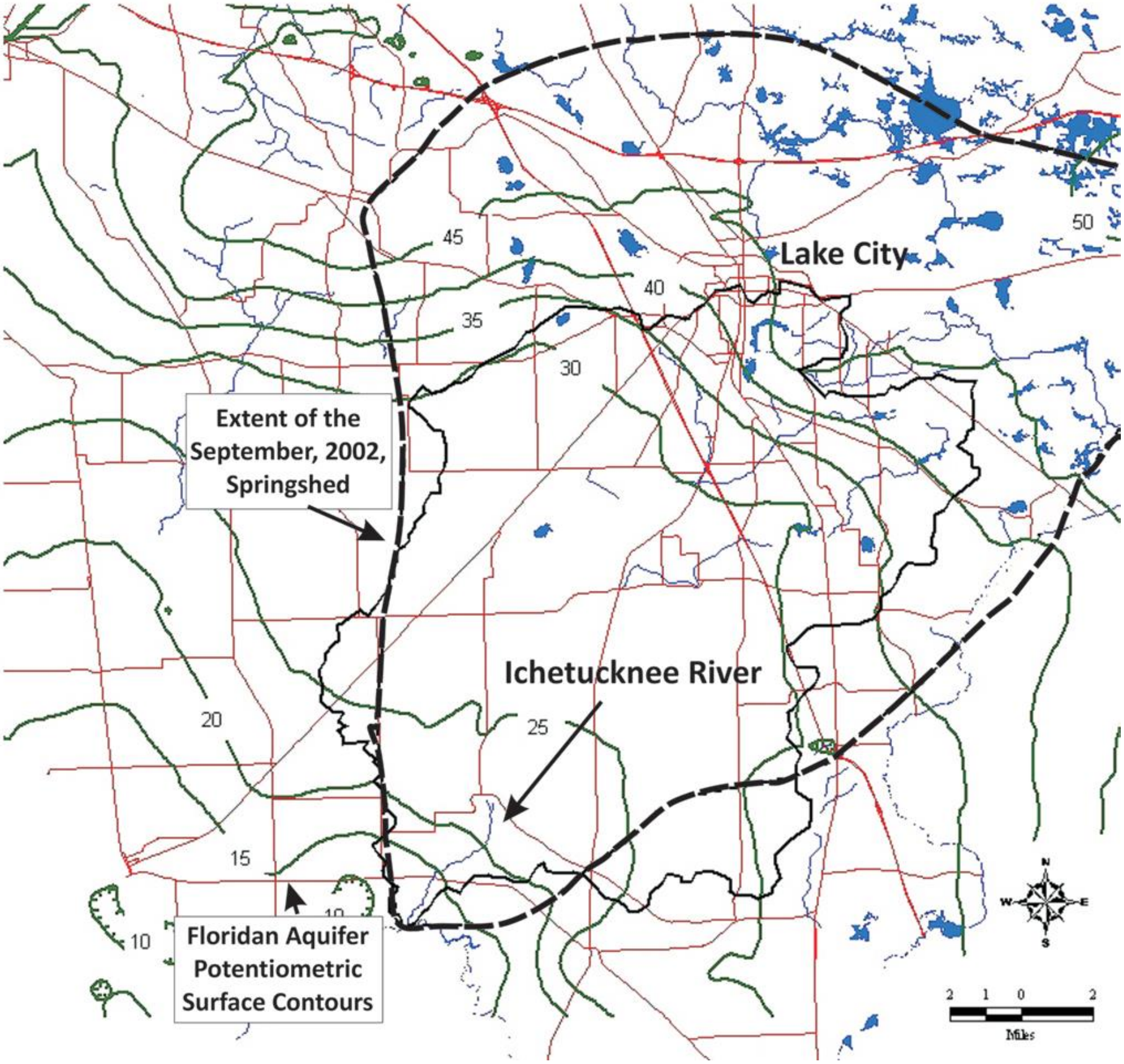


Figure 3 - The Ichetucknee Springshed as identified from September 2002 Upper Floridan aquifer potentials. Contour interval is 5 ft (1.5 m). (Data and map originally from Champion and Upchurch 2003; excerpted from Upchurch et al; 2019, Figure 8.20).

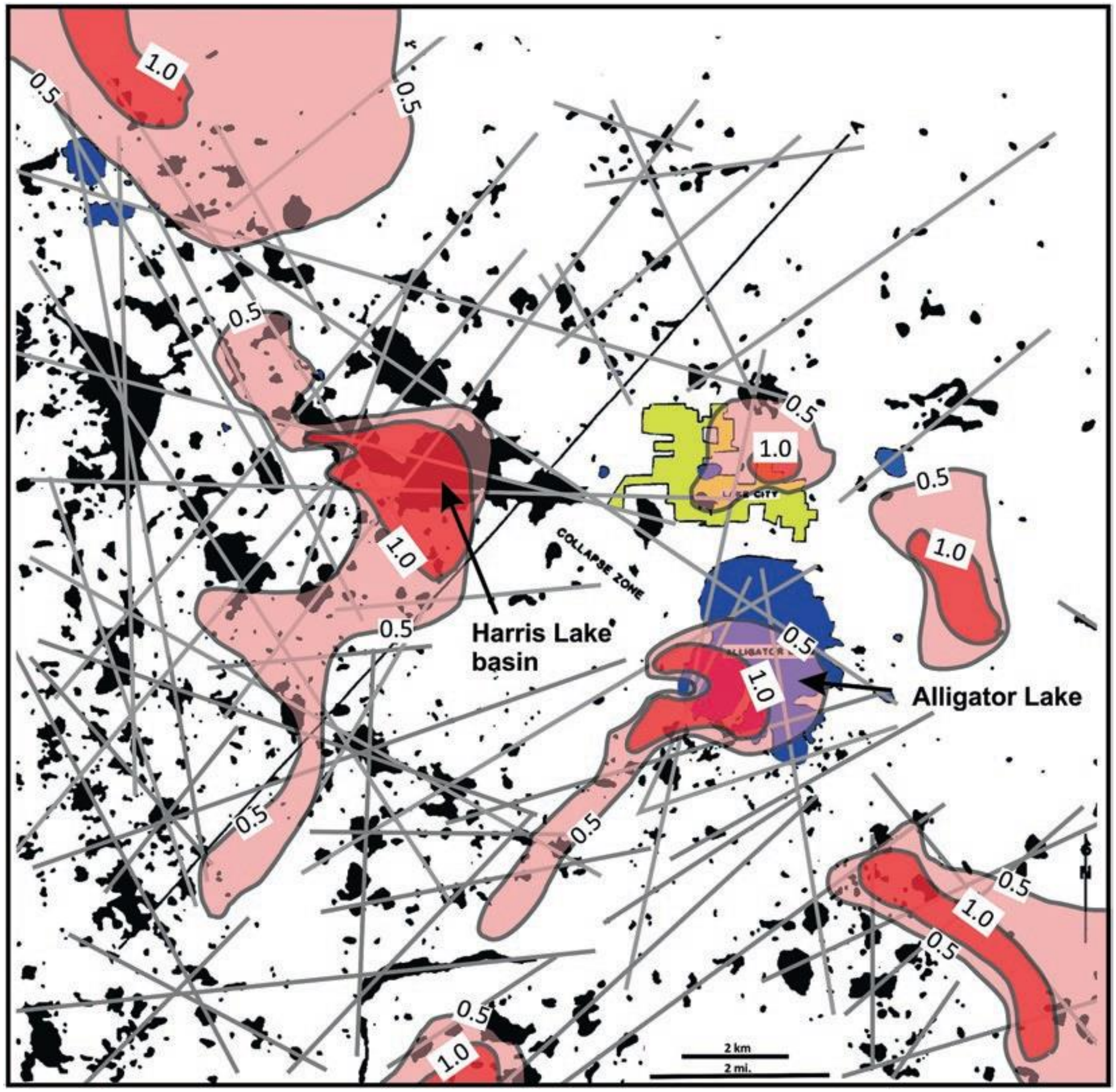
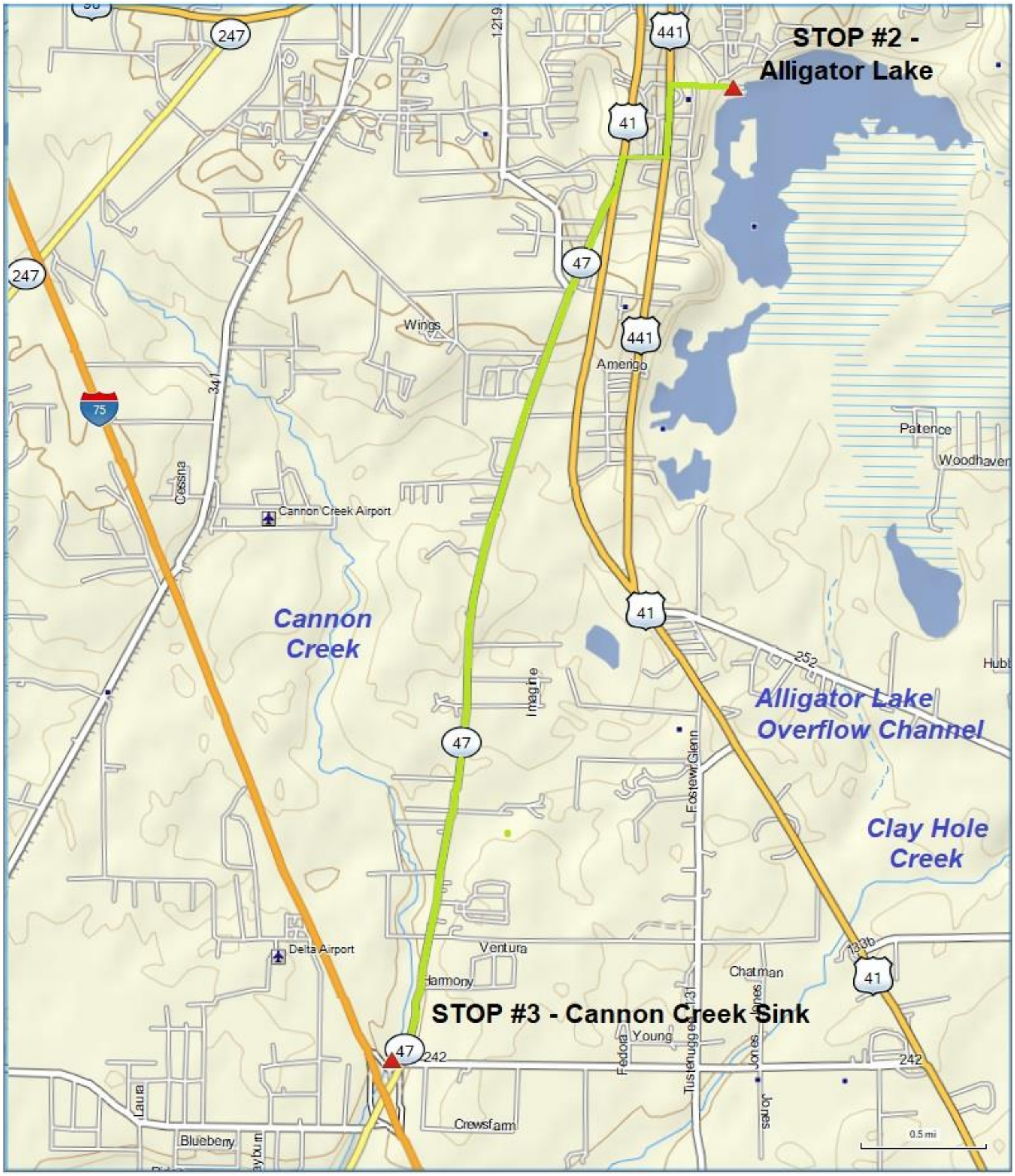


Figure 4 – Distribution of photolineaments and orthophosphate in Upper Floridan aquifer water near Lake City, Florida in 1975. Gray lines are photolineaments, irregular black polygons are closed topographic depressions (paleosinkholes), and tinted areas delineate elevated orthophosphate concentration contours (o-PO_4^{3-}mg/L). The regional hydraulic gradient is to the southwest (Upchurch et al; 2019, Fig 6.23).



Map 4 - STOP #2 to STOP #3: Cannon Creek Sink

STOP #3 – Cannon Creek Sink

Cannon Creek begins as a small surface water stream above the Big Bend (Cody) Escarpment near the intersection of State Road 247 and I-75, flowing southeast and then south until it sinks in a series of ponors just below the toe of the scarp near the intersection of State Road 47 and I-75. During dry periods, flow is captured at the upper Cannon Creek Sink. During wet periods, when the discharge from Cannon Creek exceeds the infiltration capacity of the upper sink, excess water flows overland to a second ponor, and then from there through a series of ditches paralleling State Road 47 until it ultimately discharges into Clay Hole Creek.

A dye trace was attempted here in the early 2000's, to determine the fate of subsurface flow. However, due to lack of rainfall in the weeks immediately following injection, no detections of dye were ever discovered.

There are additional ponors downstream, in the bed of Clay Hole Creek, including Black Sink, Lime Sink and Dyal Sink, which is our next field trip stop.

Figure 5 - Cannon Creek Sink during low water. The main sink is located at the head of the channel in the upper left center of the photo. A second overflow sink is located just behind the photographer. (Upchurch et al, 2019; Figure 8.22).

Map 5 - STOP #3 to STOP #4: Dyal Sink

STOP #4 – Dyal Sink

Dyal Sink is one of the downstream ponors within the Clay Hole Creek / Ichetucknee Trace. Between the last stop (Cannon Creek Sink) and Dyal Sink, there are other ponors in the trace, including Black Sink and Lime Sink. During extended periods of low precipitation, this trace is mostly dry; during periods of heavy rainfall, the trace becomes a surface stream. On rare occasions of extraordinarily high precipitation, the ponors are overwhelmed by the volume of surface water, leading to overland flooding of portions of the Ichetucknee Trace.

In May 2003, the Florida Springs Task Force retained Karst Environmental Services (KES) to conduct dye traces from Dyal and Black sinks to Rose Creek Sink and Ichetucknee Springs. Here is an excerpt from the executive summary of their work, from the final report:

"Ten pounds of fluorescein dye were released at Dyal Sink and twenty pounds of rhodamine WT dye were released at Black Sink on Day One of the trace, May 15, 2003, by KES personnel. Water samples and charcoal dye samplers, including background samples, were placed, collected and replaced at scheduled intervals at eight monitoring locations within the Rose Creek Cave System and from six water supply wells in the surrounding area. Over 540 water samples and charcoal samplers were collected, of which 171 were analyzed. Additional charcoal samplers were collected from the Ichetucknee Springs Group, south of Rose Creek Cave System.

The first detection of dye was that of Fluorescein, detected in a residential well about 1300 feet southwest of Dyal sink, three days after dye release. Rhodamine WT from Black Sink was positively detected at thirteen sampling locations; eight locations within the Rose Creek Cave System and two wells at the Columbia City Elementary School and three of the Ichetucknee Springs. The first show of dye within the Rose Creek Cave System occurred by Day 26 of the study. The first show of dye at the Columbia City Elementary School appeared by Day 25 of the trace, with levels rising significantly in subsequent samples. This demonstrates a hydrologic connection between Black Sink and the Rose Creek Cave System.

Fluorescein was also detected at the eight sampling stations within the Rose Creek Cave System, with that dye arriving between Days 34 and 125. This demonstrates a hydrologic connection between Dyal Sink and the Rose Creek Cave System.

Rhodamine WT was also detected in traps placed and collected between Days 65 and 125 at Mission Spring, Blue Hole(Jug) Spring and Devil's Eye Spring, with ambiguous detections of Fluorescein at Mission and Devil's Eye Springs. This supports the results of previous traces that demonstrated connections between the Ichetucknee Springs Group and Rose Sink, and now show a connection of these springs to Black and Dyal Sinks." (Butt and Murphy, 2003).

As you travel along County Road 242 on your way to Dyal Sink, you will pass by a series of center-pivot spray irrigation fields near the intersection with SW Dyal Avenue. This is the Lake City Wastewater Treatment Facility, where treated effluent has been spray-irrigated since 1987, when Lake City's treated sewage was no longer discharged into Alligator Lake. Unfortunately, these sprayfields lie immediately adjacent to and upgradient from the Clay Hole Creek / Ichetucknee Trace. In 2006, Wetland Solutions produced a white paper detailing a plan to construct treatment wetlands in the northern portion of the sprayfield (Keller & Knight, 2006). These treatment wetlands allow for the removal of nutrients from treated wastewater before it is spray-irrigated. The treatment wetlands were completed and went online in 2016.

Figure 6 – The Ichetucknee Trace, seen crossing a farm field between Dyal and Rose Creek sinks. View looking southeast from Bishop Road, just north of Columbia City Elementary School (G.Maddox, 2019).

Figure 7 - Flooding of the Ichetucknee Trace resulting from Hurricane Frances in September 2004. (Photograph courtesy of the Florida Geological Survey, in Upchurch et al; 2019, Figure 8.24).

Figure 8 - Rose Creek Sink, near Columbia City. This karst window and swallet exposes Upper Floridan aquifer water, which is free of significant particulates or organics. When Rose Creek flows, it is captured by this swallet, thus introducing surface water with particulates, organics and other constituents to the aquifer (Upchurch et al; 2019, Figure 8.23).

Map 6 - STOP #4 to STOP #5: Rose Creek Swallet/Sink

STOP #5 – Rose Creek Swallet/Sink

The Ichetucknee Trace runs general southward from Dyal Sink, intersecting with Rose Creek about 0.6 mile north of Rose Creek Sink (see ***Map 6***). Rose Creek swallet/sink is a prominent karst feature located at the western terminus of Rose Creek in Columbia City. During dry periods, the swallet/sink lies within a dry swale, punctuated by perched ponds and wetlands. When wetter conditions prevail and Rose Creek flows, its surface waters drop first into an upstream ponor located about 400 feet northeast of Rose Creek Sink proper. When surface water volumes overwhelm the upstream ponor, overland flow reaches Rose Creek Sink, which takes the remaining overland flow underground. The ponor is linked to Rose Creek Sink via an underwater cave tunnel. Additional mapping by cave divers have linked Rose Creek Sink to McCormick Sink, another karst window lying along the Ichetucknee Trace about 0.6 miles south. Rose Creek Sink has been connected to the Ichetucknee Springs Group via dye-tracing.

Looking at the 1:24,000 topographic coverages for the area, the Ichetucknee Trace can be followed overland from Rose Creek Sink to Ichetucknee Main Spring (***STOP #6*** **– Ichetucknee Main Spring (Lunch stop)***)*, located in Ichetucknee Springs State Park, several miles to the south-southwest. Up until the early 2000's, Ocala Limestone was mined for aggregate by Suwannee-American Cement LLC at the Kirby Limerock Mine, which sits directly atop the Ichetucknee Trace about 2.6 miles southwest of Rose Creek Sink. Although not physically mapped in the area, it was determined that continued mining might possibly breach the underwater conduits carrying ground water from Rose Creek Sink to Ichetucknee Springs, potentially causing severe effects on spring water clarity and water quality. This notion is based on prior cave mapping in Florida which shows that major shallow subsurface conduits usually follow closely beneath paleo surface water stream traces, perhaps formed when surface waters were pirated underground. Subsequent negotiations between Suwannee-American, who was at the time seeking an air permit for their new cement facility east of Ichetucknee Springs State Park, and the Florida Department of Environmental Protection resulted in the mine tract being transferred into state ownership, thereby terminating active mining there. The Kirby Limerock Mine tract is now administered by Ichetucknee Springs State Park, as is the Rose Creek Sink parcel, also purchased by the State of Florida to protect Ichetucknee Springs.

Immediately upslope, to the west of Rose Creek Sink, is one of the earliest stormwater retention basins built by the Florida Department of Transportation. This one was constructed in the early 2000's at the urging of Jim Stevenson and the Florida Springs Task Force, to capture stormwater runoff coming down from State Road 47 and the convenience store / gasoline station located adjacent to the sink. Before construction of this retention pond, stormwater runoff from Columbia City was conducted directly into Rose Creek Sink.

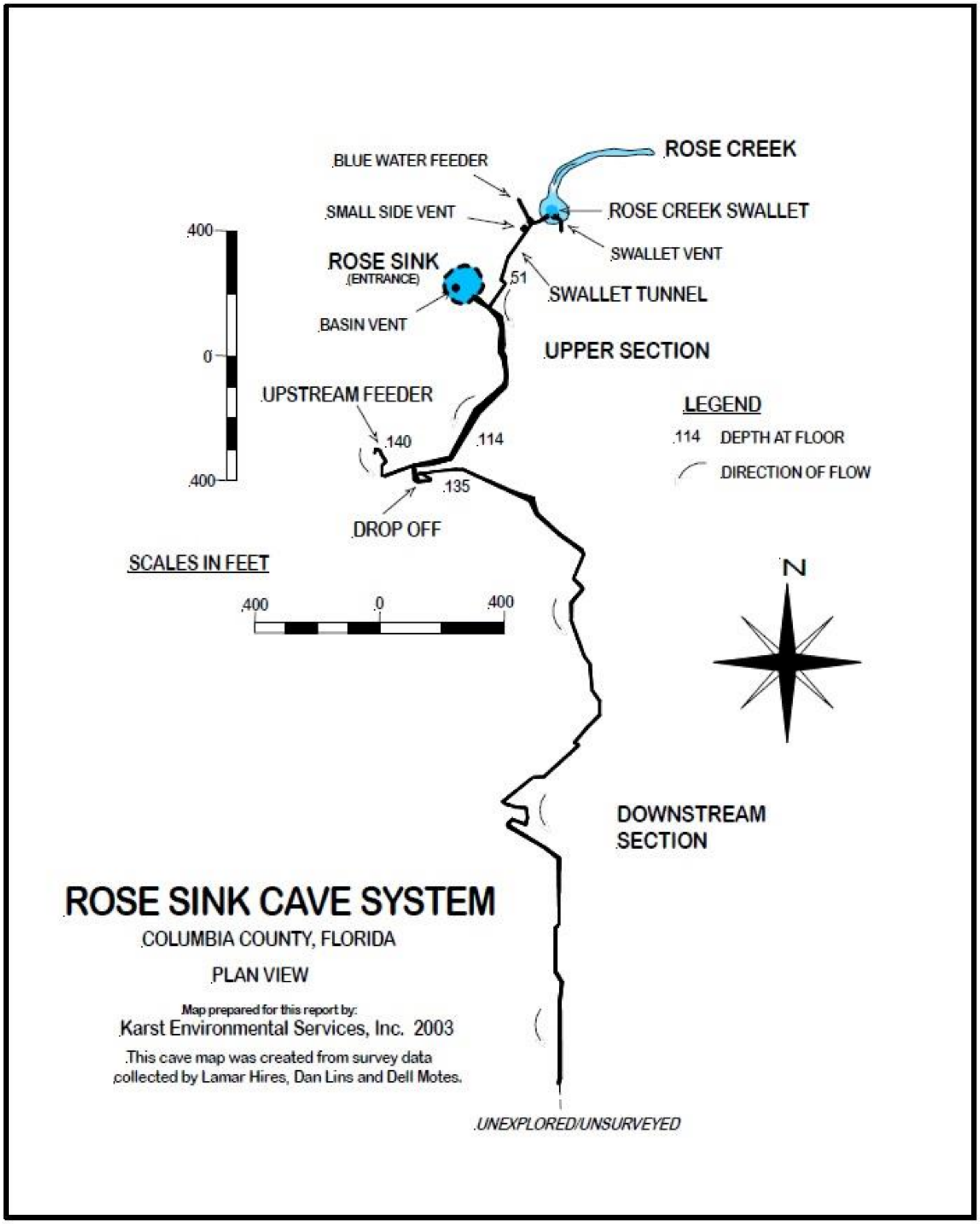


Figure 9 - Rose Creek Cave System map (Butt and Murphy, 2003).

Map 7 - STOP #5 to STOP #6: Ichetucknee Main Spring

STOP #6 – Ichetucknee Main Spring (Lunch stop)

The southern terminus of the Ichetucknee Trace crosses the Park's north entrance access road as it curves southwest into the first parking lot. Adjacent to the parking lot are several picnic tables overlooking Ichetucknee Main Spring, where we will have lunch. Ichetucknee Main Spring is an historic second-magnitude spring issuing from a northeast-southwest-trending linear vent, approximately 30 feet deep (depending on current river stage). A one-mile long hiking trail leads to Blue Hole (Jug) Spring, an historic first-magnitude spring in its own right (***Map 8***). Blue Hole is popular with cave divers, as it is the only Park spring with an accessible cave.

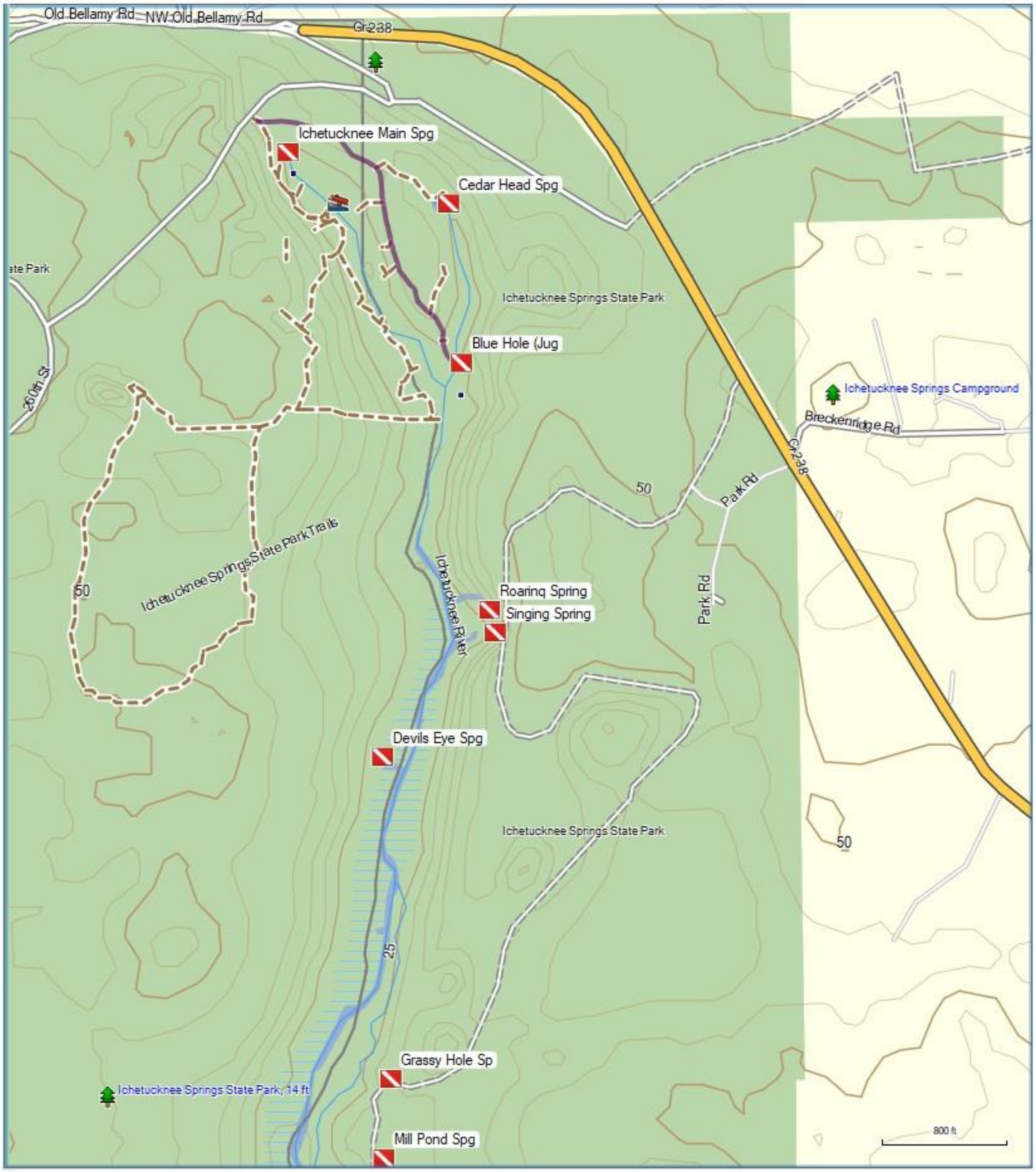
The current site of Ichetucknee Springs State Park is steeped in Florida history. The following is a short historical summary of what is widely considered to be the "crown jewel" of Florida state parks, from the Florida Department of Environmental Protection's state park history website:

"Perhaps the Ichetucknee's greatest historical treasure is the Mission de San Martin de Timucua. This Spanish/Native American village was one of the major interior missions serving the important Spanish settlement of St. Augustine. The mission, built in 1608, flourished through most of that century. The river and springs were used consistently by even earlier cultures of Native Americans, dating back thousands of years.

During the 1800s, early travelers on the historic Bellamy Road often stopped at Ichetucknee Springs to quench their thirst. Later that century, a gristmill and general store was located at Mill Pond Spring. With high quantities of limestone at or just below the ground surface, the area became early headquarters for North Florida's phosphate industry in the late 1890s and early 1900s. Small surface mines are still visible throughout the park. Continuing through the 1940s, cypress and longleaf pine forests were harvested by the local timber and naval store industries.

Ichetucknee Springs State Park was purchased by the state of Florida in 1970 from the Loncala Corporation to preserve one of the state's outstanding natural wonders. In 1972, the U.S. Department of the Interior declared the Ichetucknee Spring a National Natural Landmark."

The Ichetucknee Main Spring and Blue Hole are open for swimming year-round. Tubing the upper river within the Park is permitted annually from Memorial Day through Labor Day; during the rest of the year the river can be explored by canoe/kayak, and Blue Hole cavern is open to certified cave divers. The numerous trails within the Park are best explored during the cooler months.



Map 8 - Area adjacent to Ichetucknee Main Spring in Ichetucknee Springs State Park, showing the locations of major springs and trails.

Map 9 - STOP #6 to STOP #7: Paradise Ravine

STOP #7 – Paradise Ravine

Paradise Ravine has been a location of interest to locals for some time; however, two of the guidebook authors (Copeland & Maddox) were first made aware of its existence by Dr. Colette Jacono during AquiferWatch ground water sampling in the area during the spring of 2017. Dr. Jacono is a botanist who lives adjacent to the ravine and has studied the unique flora that occur there. She was interested in learning about the geology of this feature, and we were interested in learning about the plant communities present, so we met up with her and local environmentalist Merrillee Malwitz-Jipson for a follow-up trip down the ravine in February 2018. It became apparent to us that this feature was a paleo discharge channel, now mostly dry except for a few shallow wet depressions. While we observed and discussed the geology, Dr. Jacono showed us some of the unique botanical species present, some of which only grew on weathered limestone outcrops along the ravine. On another follow-up trip in the fall of 2018, we explored the impressive sinkhole complex and cave features which lie at the head of the ravine (***STOP #8*** **– Jess's Hole Cave**).

The Ravine appears to be a fluviokarst valley, located about 3.6 air miles northwest of the Town of High Springs. The ravine begins at a series of large sinkholes on private property, and from there runs south-southwest for approximately 3.7 miles to the Santa Fe River, just upstream from Rum Island Spring. The ravine is steep-sided, except near the southern end adjacent to the Santa Fe River, with areas of weathered limestone bluffs. The elevation of the floor of the ravine is remarkably flat, possibly due to more recent sedimentation. Floor elevations vary from about 25 feet above mean sea level at the mouth of the ravine to 35 feet in the upper portions of the ravine; however, most of the floor of the ravine is within the 30-foot elevation contour. The top edge of the ravine is consistently defined by the 50-foot contour line on the 1:24,000 topographic map of the area. Field observations and the pattern of contour lines show that small side valleys entering Paradise Ravine are angled southward, indicating that water flow was largely moving in a downstream direction, from north to south. The ravine footprint closely resembles topographic features seen at currently active spring runs, such as the Ichetucknee River and its tributary spring runs.

From the geomorphic features observed so far, it appears that this ravine might represent a former spring run, active in the past when the local ground water potentiometric surface was higher than it currently is. The valley also lies at the southern end of a north-south zone of potentially increased karst dissolution, as evidenced by the relatively high density of karst depressions and sinkhole wetlands present in a somewhat narrow zone extending about eight miles north from the head of the ravine, as seen on the 1:24,000 topographical coverage (***Figure 12***). Another intriguing possibility is that Paradise Ravine was once an alternative discharge location for the historic Santa Fe River resurgence. The current Santa Fe River Rise lies 3.3 miles to the east of Jess's Hole.

Paradise Ravine is entirely on private property. We have arranged access to a portion of the ravine with a local resident; please be courteous to the area landowners by not blocking driveways and by parking completely off the pavement.

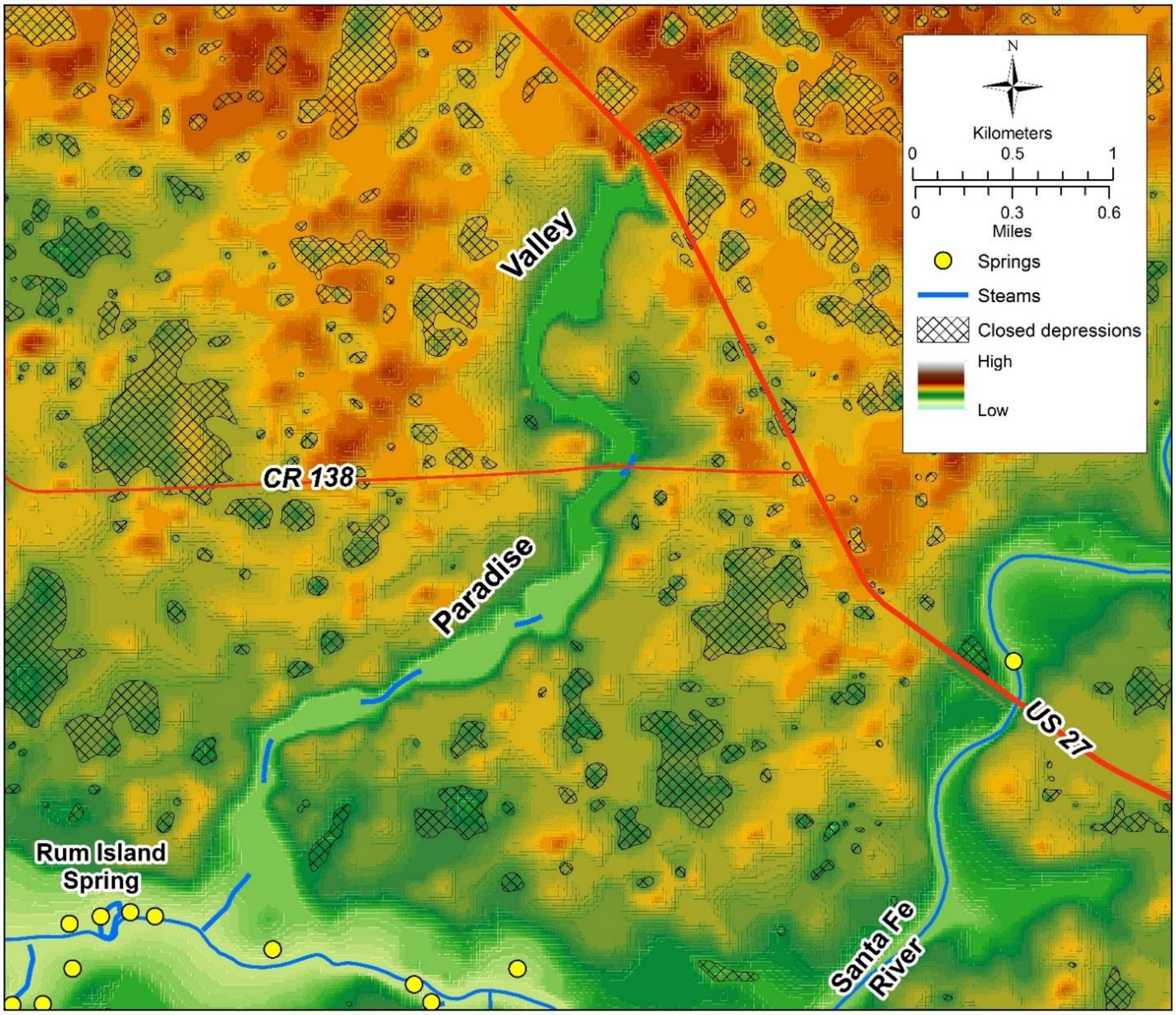


Figure 10 – LiDAR image of Paradise Ravine (Valley), showing the area topography and closed depressions (from Sam Upchurch).

Figure 11 – Drs. Colette Jacono and Rick Copeland study the unique flora found growing on weathered Ocala Limestone in Paradise Ravine (G.Maddox, February 2018).

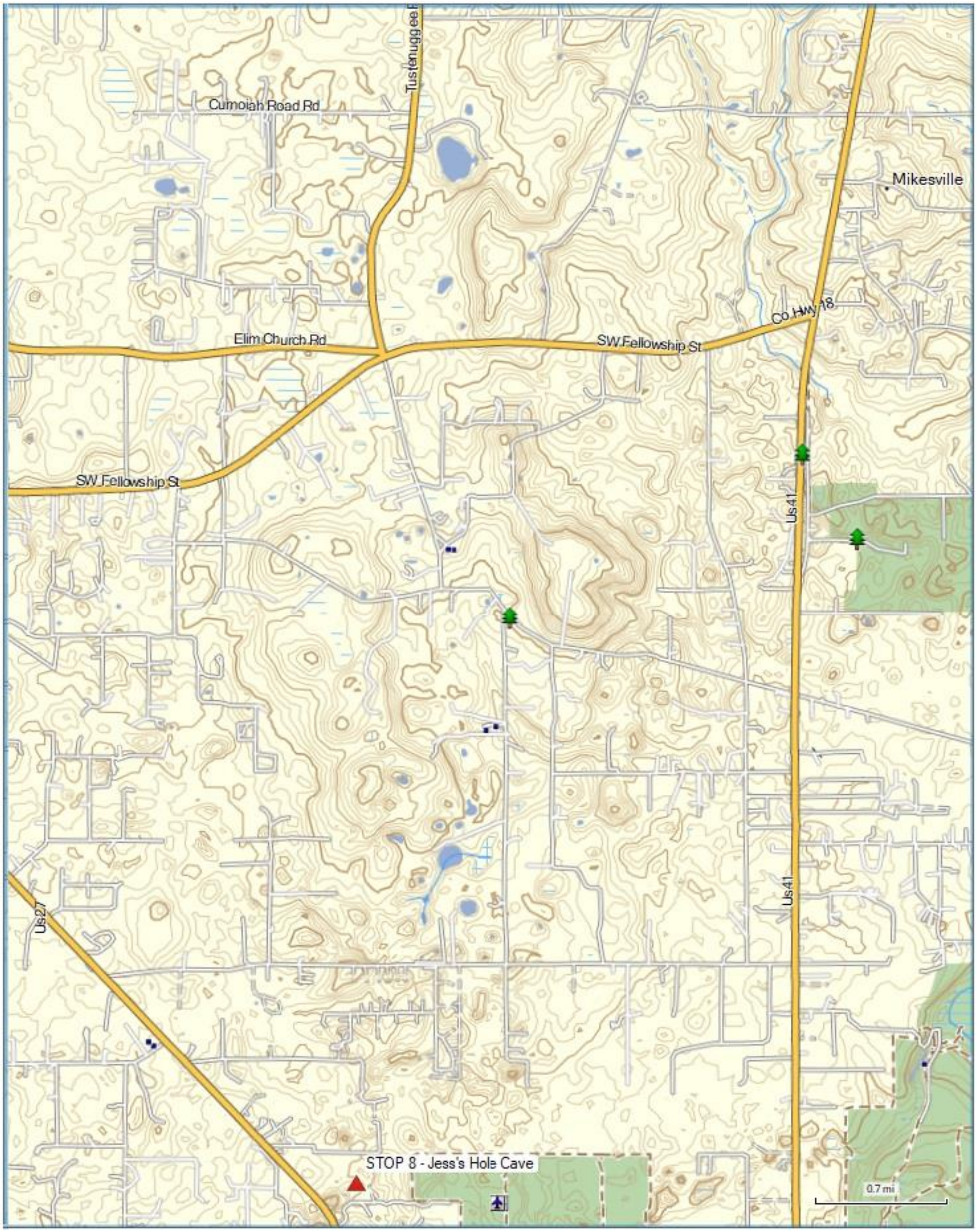


Figure 12 – Region of numerous dolines, sinkholes and karst wetlands trending north from Jess's Hole Cave, as seen on portions of the USGS 1:24,000 Fort White, Mikesville, High Springs SW and High Springs topographic coverages.

Map 10 - STOP #7 to STOP #8: Jess's Hole Cave

STOP #8 – Jess's Hole Cave

Jess's Hole Cave lies at the head of Paradise Ravine, within an area of deep sinkholes and ravines. The cave is named for Jess Preston, a local man who disappeared at the cave in 1922. Speculation at the time was that he had fallen into the vertical entrance to the cave, which drops approximately 50 feet down to water. Fast-forward to 1989, when cave divers exploring the underwater cave at the bottom of the drop discovered a skull, bones and a pair of boots. The details of this story are fascinating and are recounted in the included newspaper articles (***Figure 14***, ***Figure 15***).

The complex of deep sinkholes located at the head of Paradise Ravine currently lie on private property. The parcel containing Jess's Hole is owned by Scott Butsch, who has rigged a series of metal ladders chained together to allow diver access to Jess's Hole Cave. Scott is a cave diver, who has mapped the underwater cave system. Jess's Hole and the other adjacent sinks are believed by Scott and others to be part of a paleo spring system that may have once discharged ground water into Paradise Ravine.

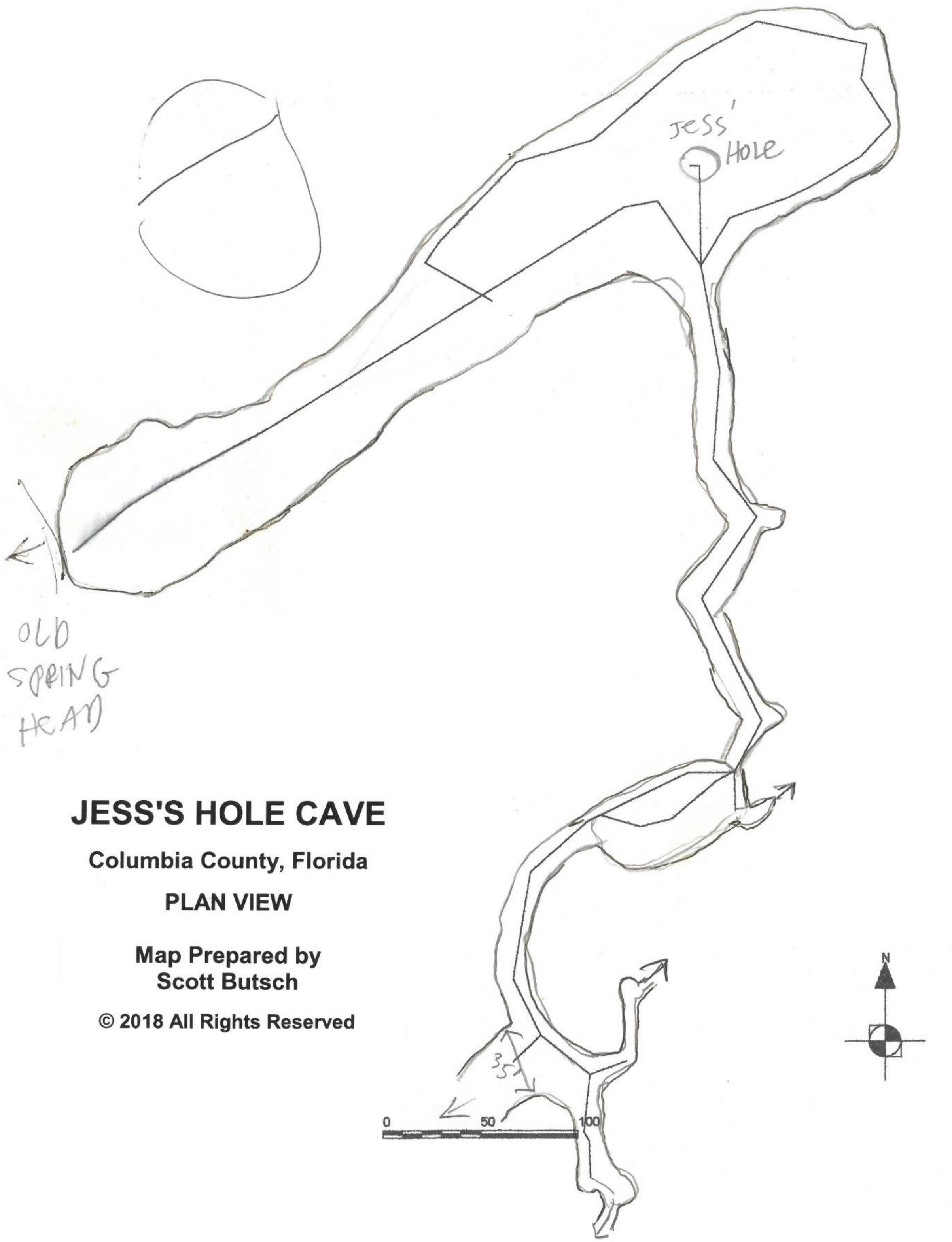


Figure 13 – Jess's Hole Cave map (Scott Butsch, 2018).

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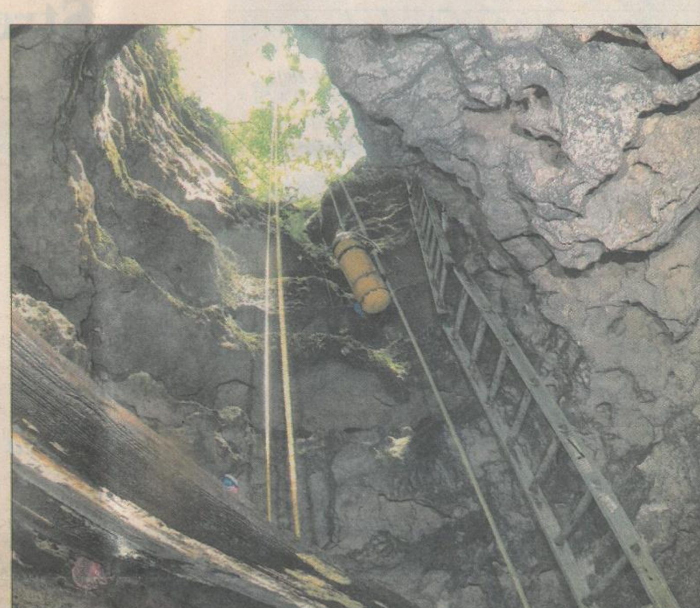
LIFE ON EARTH

By Pamela Faith

"Hopes are white stones shining up from the bottoms of pools, and every clear day we reach in up to the shoulder, selecting a few and rearranging the others, drawing up our arms smoothly back into the air, leaving no scar on the water." – Natalie Kusz



Photos by Pamela Faith

I went on an adventure yesterday which found me descending a 50-foot hole in the earth by means of four metal ladders held together by chains. There was water at the bottom—fifty feet of water, connected to the aquifer and the Santa Fe River, and my two traveling companions and I shone our flashlights around the walls of the hole to find the rock cave we'd come to explore. The water was a chilly 69 degrees, and we swam into the cave and perched on a ledge, shining a flashlight above us to illuminate a ceiling full of hundreds of bats; a solid, writhing mass of small brown bats, like balls of brown popcorn, all moving and climbing over one another, with some taking off in flight above our heads. It was very dark with the flashlight off, and cool, and quiet except for the squeakings and mutterings of the creatures above us, with only the faint light from the cave's entrance in the distance. Complete peace.

The cave is called Jess's Hole, and we've lived here almost four decades without knowing of its existence a mere 20 miles away from us.

Jess's Hole has a mystery. A hundred years ago, a young man fell into the hole and drowned. His skull and bones were found 66 years later, and they were taken to a medical examiner in Lake City, where they were studied and written about in the Lake City Reporter and a world news magazine and eventually a cave diving magazine. For 28 years, the mortuary has held onto the bones—this year, the remains were finally cremated, and now the funeral home would like the ashes returned to the cave from where they came.

The thing is, no one really knows the youngster's name or how he died.

Rumor has it that the young man was born in 1888 and was 34 years old when he fell into the 50-foot hole. He may have had Down's Syndrome or polio. A memorial service was supposedly held for him the next day at the site. When his bones were discovered they were given the name Jess Preston, but several local people insisted his name was actually Jess Hollingsworth.

A hundred years is a long time to wait for a burial.

The deep hole is a peaceful last resting spot. Deer bones share the water now. A large debris cone has formed below the surface. If one puts on scuba gear and goes exploring, an enormous room exists under the water, 200 feet across. Two tunnels lead from this room, one 350 feet long, 40 to 50 feet wide, with a 25 to 30-foot ceiling. A second passage is twice as long.

Albino crayfish live in the water, reportedly the largest ever found in our river system. They live off the occasional bat that falls in the water, or deer, or human. Water turtles show up now and then. The water level rises and falls with the level of the nearby river.

It would be nice to have a ceremony when the ashes are laid to rest. It would be nice to use the correct name, and know the story of how they came to be there.

Anyone who thinks they have information can call the cave's owner, Scott Butch, at 386-454-8378, or email him at sdscdive@aol.com. He'd love to hear from you.

Pamela Faith is an artist and gardener. She can be contacted at ourobserver2@aol.com, subject line Life on Earth.

Figure 14 – Newspaper account #1 of the history of Jess's Hole (from the Columbia County Observer, August 2016; courtesy of Scott Butsch).

LIFE ON EARTH

By Pamela Faith

Earth and ocean want their mysteries. It is not meant for light and human knowledge to shine into every unlit corner of the ocean, the earth, and the universe.
— Linda Hogan

Jess Preston's family got a present last month. They helped write the last chapter in a family legend that has been ongoing for almost a century.

The story begins in the late 1800s with the birth of a boy named Jess in a small log cabin in Columbia County. His mother was one of thirteen children. Jess was crippled in some way, possibly because of polio.

In 1922 when Jess was about 34 he said goodbye to his aunt, mounted his horse and rode away to explore the woods. His family never saw him again.

Next day his horse was found tied to a tree at the edge of a steep sinkhole that plunged fifty feet into the earth. The footing was treacherous and Jess had trouble walking; the family could only assume he had fallen to his death. A ceremony was held for him and the sinkhole began to be called Jess Hole.

More than seven decades passed. Family members married, died, and moved away. They were unaware that in 1989 two scuba divers exploring Jess Hole found a skull, a set of bones, and a pair of boots. The authorities were called and the bones were removed and taken to the medical examiner's office where they remained for the next 27 years.

In 2006 the bones were cremated, and finally in the summer of 2016 a concentrated effort was made to find family members to claim them. The property tax roles were consulted and they contacted Scott Butsch, the current owner of the sinkhole property.

Scott loves his land, and the sinkhole, and often explored its deep waters with his scuba-diving friends. He had always been fascinated by the local stories of how Jess Hole got its name but no one he'd met could absolutely confirm the facts.

So he asked *The Observer* to run an article requesting information, and finally the puzzle pieces began to fall into place. Enter Thomasine Cason Thomas, Jess Preston's second cousin. Thomasine had heard the story of Jess all her life. She knew his whole name. She knew his mom and his aunt, and she still lives near the family property a half-mile from Jess Hole.

The funeral home was contacted and a date was set in late November to pass the remains of Jess on to his family.

And on a lovely autumn day last month ten of us gathered at Jess Hole to pay our last respects.

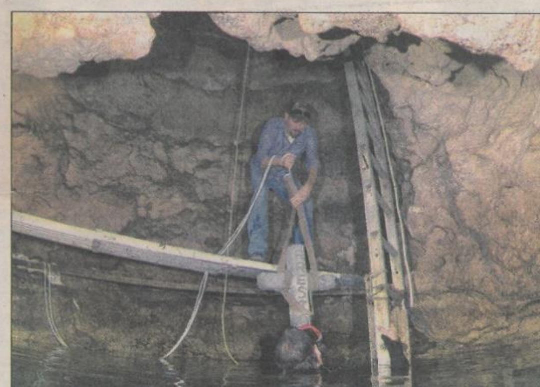
A funeral home representative signed the ashes over to Thomasine and she gave them to Scott. He mixed the ashes into a bucket of quick-drying cement to form the base for a concrete cross he had already fashioned with Jess's name.

He and Jess's family members lowered the cross by ropes and ladders down to the bottom of the sinkhole, and then Scott and a fellow scuba diver lowered the cross another 50 feet into the underground water to the top of the debris cone where Jess's bones were originally found.

And 94 years after Jess Preston disappeared he was finally set to rest.

A YouTube video of the ceremony may been seen at https://www.youtube.com/watch?v=J4PX_6yMLjg

Photo provided to The Observer



Pamela Faith is an artist and gardener. She can be contacted at ourobserver2@aol.com, subject line Life on Earth.

Figure 15 – Newspaper account #2 of the history of Jess's Hole (from the Columbia County Observer, December 2016; courtesy of Scott Butsch).

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Articles

Origin and Evolution of Karst Traces

Sam B. Upchurch (SDII Global Corporation, Tampa, Florida)
Thomas M. Scott (SDII Global Corporation, Tampa, Florida;
Florida Geological Survey, Tallahassee, Florida)

Abstract
Karst traces are dry stream valleys that have resulted from capture of streams at karst escarpments by swallets that develop as the streams cut into limestone during scarp retreat. Florida has many such traces that range from simple stream to sink systems with a normally dry, abandoned stream channel downgradient from the swallet, to dry stream valleys populated by many karst windows (former swallets) and sediment-filled sinkholes, to completely collapsed cave systems. In all cases, the dry stream valleys flood when the infiltration capacities of the swallets are exceeded.

The karst traces terminate in resurgences characterized by brown, humic substance-rich water or springs. These resurgences and springs reflect a cave system that connects the swallets to the resurgences and springs. In many cases, the cave system roughly parallels the dry stream valley and the spring/resurgence is located at the terminus of the trace. In other cases, the trace ends by discharge to the downgradient, master stream and the resurgence or spring is not located at the terminus of the trace. In Florida, the best examples of karst traces originate in the Cody Scarp of northern Florida.

Introduction
In our recent book, *The Karst Systems of Florida* (Upchurch et al. 2019), we defined karst traces as normally dry fluvial systems created by capture of streams that flow from areas of low recharge onto karst plains. These dry valleys are characterized by one or more swallets that capture flow and a valley that floods when the infiltration capacities of its swallets are exceeded.

The term karst trace is not defined in the glossaries and encyclopedias available to us (Monroe 1970, Field 2002, Gunn 2004, Neuendorf et al. 2005), so we opted to introduce the term in our book. We first became familiar with informal use of the term in the late 1990s when the leader of the Florida Department of Environmental Protection's Springs Task Force, Jim Stevenson, began conducting tours of the Ichetucknee "Trace." The meaning of the term was clear. As Stevenson explained, the Ichetucknee Trace was a pathway created by capturing of a stream in a series of swallets along a topographic low created by the stream as it drained from the adjacent Cody Scarp (a fluviokarst escarpment; Upchurch 2014a) to the Santa Fe River.

While writing our book, we realized that the Ichetucknee Trace is not unique. Rather, it is one example of a series of fluvial systems that:

1. Drain from relatively impermeable "uplands" onto highly permeable, karst plains;
2. Consist of a normally dry valley punctuated by swallets that capture discharge from tributaries and in the main valley;

3. Flood when the infiltration capacities of the swallets is exceeded; and
4. Represent a form of fluviokarst with headward erosion and scarp retreat.

This paper explains our reasoning as to the origin and evolution of traces in Florida with examples, two of which we will view on this field trip.

Definition of a Trace

Where streams are captured by swallets, there is often a surface-water over-flow system. During flood events the ability of the swallet(s) in a stream's pathway to capture flow may be overwhelmed. When this occurs, the overflow follows a path that is termed a "trace" in Florida. Traces are characterized by a series of (1) sinkholes and karst windows and (2) a normally dry stream valley, which floods sequentially downstream during flood events. The normally dry stream valley is characterized by fluvial sediment deposits and often by recognizable terraces of perched, fluvial sediment and small limestone platforms created during incision into the host limestone.

Given that the streams are captured by swallets, there is an associated cave system that normally drains the swallet at the head of the trace and by transition from a perennial to ephemeral stream. The resurgence of this "underground river" may be located at the toe of the trace (e.g., the Ichetucknee drainage system) or some distance away from the trace and dry valley (e.g., the Alapaha River drainage system).

Traces range, in order of development, from (1) streams captured by a single swallet with an overflow pathway to a higher order stream at its terminus, to (2) dry streams with a swallet at its head and a resurgence at its terminus, through (3) fluviokarst streams characterized by multiple swallets and resurgences, to (4) collapsed cave systems wherein the roof of the cave has failed over a significant reach of the drainage system. In the latter case, overflow follows the collapsed cave system. Collapsed cave systems in Florida may drain the limestone aquifer and serve as karst windows or they may be wet sloughs that terminate at the higher order stream. On this weekend's fieldtrip, we will view portions of a collapsed cave system (Paradise Valley) that originates at what may be an abandoned swallet and ends at the Santa Fe River.

Evolution of Traces

The attributes of traces (normally dry valleys) and wet sloughs associated with swallet-to-spring drainage systems include:

1. A primary, more-or-less linear feature (the trace or slough on the land surface) and a cave in the subsurface that is characterized by a series of shallow to moderate depressions (karst windows, sinkholes) that connect the resurgence to a swallet or swallets upgradient;
2. The conduit upon which the karst windows and other sinkholes develop is a well-defined cave that carries the river or stream water, normally without significant dilution or filtration so the water emerging from the resurgence remains colored by humic substances;
3. Tributary caves may supply a large proportion of water to the conduit and resurgence, especially during periods of low surface-water flow (e.g., the contribution of the Old Bellamy Cave system to discharge at the Santa Fe River Rise resurgence; Martin and Screaton 2000);
4. Tributary streams and/or dry valleys often terminate in swallets at or near the main trace or slough; and

5. The traces and sloughs appear to be related to fluviokarst escarpment retreat as they only extend onto the limestone of a karst plain between the main-stem, high-order stream and uplands.

These observations suggest a model for fluviokarst scarp retreat (Fig. 1). Imagine an upland underlain by relatively impervious, clay-rich sediments. This scenario is consistent with the concept that the relatively impermeable, Miocene Hawthorn Group once extended completely across the Ocala Platform in the past (Time Step 1, Fig. 1; Scott 1981). Note in Fig. 1 that the Miocene Hawthorn Group is subdivided into two highly generalized strata. The upper stratum has high clay content with beds of variably phosphatic clay, sand, limestone, and dolostone content. The lower stratum is more carbonate rich. The same sediment types are present, but limestone and dolostone are more prevalent. This simplification of Hawthorn stratigraphy was suggested by Miller (1978) and is useful for understanding scarp retreat.

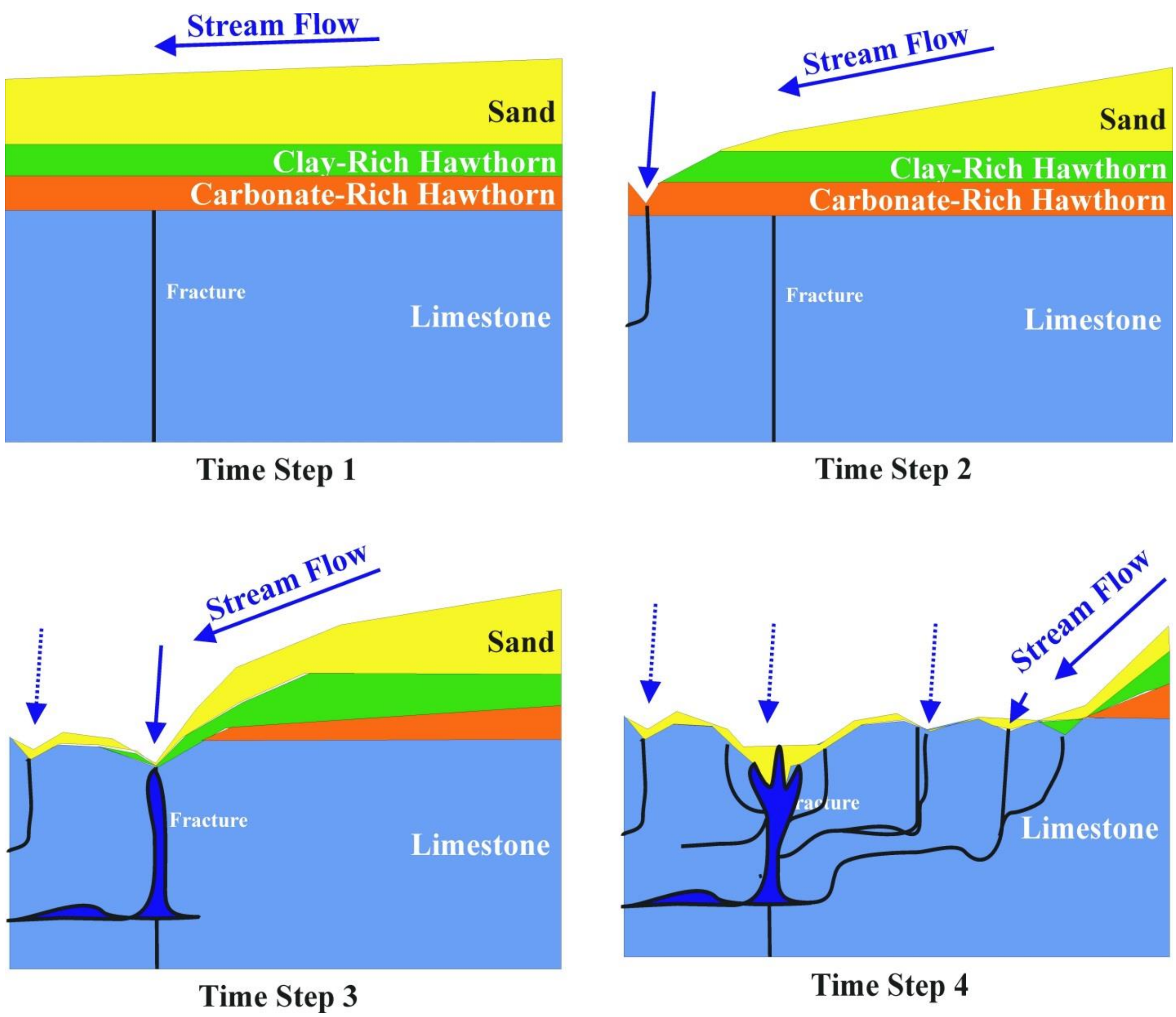

Fig. 1 - Sequence of events as a karst escarpment and trace are formed by headward erosion of a stream over a karstic limestone. From Upchurch et al. (2019, Fig. 8.17).

As long as the upper, clay-rich Hawthorn sediments remain thick and sustain low recharge rates, streams, lakes, and swamps exist and a topographic or hydrogeologic upland is present.

Copeland (2005) and Upchurch et al. (2019) pointed out that there are transitions from low-recharge areas onto karst plains in Florida that have no topographic expressions. Weakly developed traces have been observed where these transitions exist. For example, streams draining the western margin of the San Pedro Bay go underground, develop traces, and emerge at springs. The San Pedro Bay has a poorly developed and indistinct scarp on its west side, so one would hardly call the margin of the feature an escarpment.

With time the clay-rich Hawthorn Group sediments are stripped away by headward erosion and a karst escarpment forms (Time Step 2, Fig. 1). At some point, the retreating stream valley intersects limestone and a subterranean drainage system begins to develop. The initial capture site (a swallet) is within the underlying Eocene or Oligocene strata.

Under normal flow, the stream is captured by a swallet near the toe of the developing escarpment. Initially, conduiting in the developing cave system is probably mostly vertical and may be related to joints or fractures in the carbonate rock. The abundant, vertical solution channels exposed in the Haile Quarry near Newberry reflect this type of karst conduiting (Fig 2). As the stream continues to erode headward, into the uplands underlain, in northern Florida, by Hawthorn Group sediments, the fluviokarst escarpment develops (Time Step 3, Fig. 1). Time Steps 3 and 4 (Fig. 1) illustrate the continued evolution of the fluviokarst escarpment, the string of active and normally abandoned swallets (now karst windows), and a normally dry valley that connects the swallet and karst windows. This is a karst trace.

Fig. 2 – Vertical solution pits exposed in the Ocala Limestone of the Haile Quarry near Newberry.

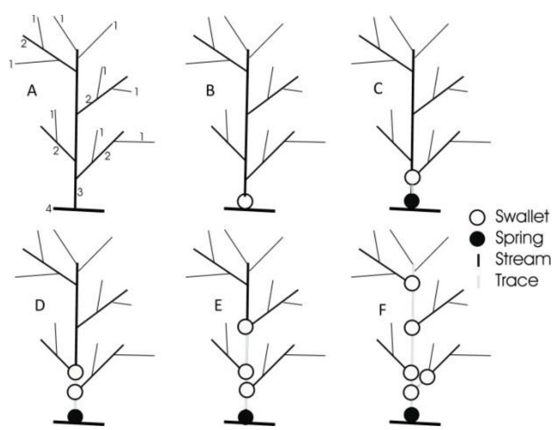

Fig. 3 – Model for swallet development during fluviokarst scarp retreat. Numbers in panel A represent Horton's (1936) stream orders. From Upchurch et al. (2019, Fig. 8.18).

As the scarp retreats and the cave systems become enlarged, the vertical conduiting becomes more and more integrated and horizontal passages that lead to a resurgence or nearby spring develop and dominate flow. Well-defined trace systems with perennial streams at their source in northern Florida are associated with caves that more-or-less parallel the trace and that discharge as resurgences which discharge humic-substance-rich, discolored water[1] downgradient, often at or near a base level defined by regional, high-order streams or the sea. Traces that are fed by ephemeral streams, such as the Ichetucknee Trace springs, usually discharge clear water.

A drainage network developed under these conditions would likely produce a dendritic pattern such as shown in Fig. 3. Horton's (1936) stream orders are identified on Fig. 3a for ease of discussion. As the 3rd-order stream and 4th-order river system erode downward (Time Step 2, Fig. 1), they encounter limestone and develop a swallet that captures water from the 3rd-order stream (B, Fig. 3). As headward erosion continues, swallets begin to develop upstream on the 3rd-order stream. Based on our observations of the Ichetucknee trace system and similar traces in northern Florida, the swallets appear to preferentially develop near where major surface-water tributaries enter a master stream (2nd-order streams flowing into the 3rd-order stream in Fig. 3).

At some point, headward erosion begins to encourage swallet development on the lower-order streams; again at or near stream intersections (D through F, Fig. 3). The low-order streams become fragmented by this process and simply become relict drainage systems with linear depressions and valleys that reflect the earlier, low-order drainage.

The swallets fragment the former drainage system and collect water that drains off the highlands into one or more caves. This acidic water erodes into the limestone and a well-developed cave system replaces the surface drainage. This fragmented drainage system is commonly graded to the main stem, 4^{th}- or higher order stream and a resurgence develops (C, Fig. 3).

Some Examples

<u>*Stream to Swallet Systems*</u> – Simple, stream to swallet systems are common in north Florida. Figure 4 illustrates several such examples from the Alapaha River basin in Florida. Here, Alligator Creek, the Little Alapaha River, and Tiger Creek represent examples of drainage pattern development wherein stream-to-sink drainage exists (cf., B, Fig. 3). In all three cases, the streams disappear underground. Discharge of the water associated with these stream-to-sink systems represents fragmented drainage associated with the Alapaha River. As no springs are known along the Alapaha below the swallet swarm

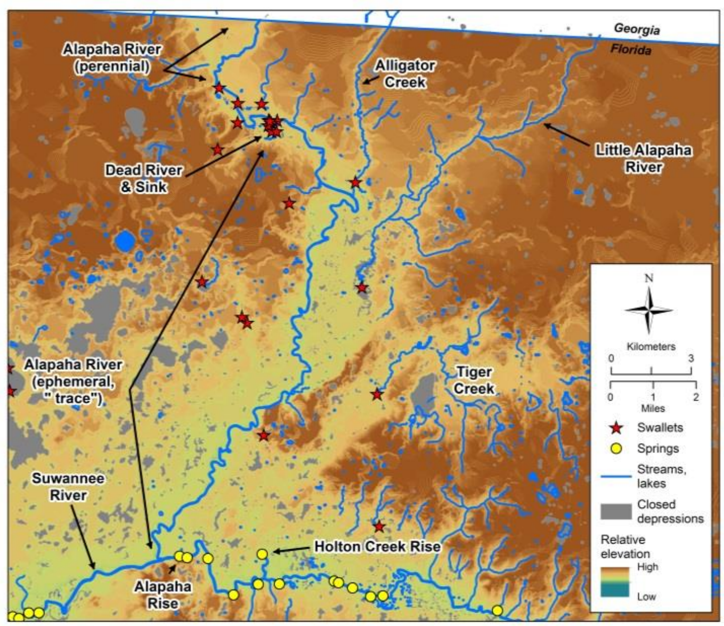

Fig. 4 – The Alapaha River drainage basin in Hamilton County, northern Florida. Elevations are based on digital elevation model of the area.

[1] Upchurch et al. (2019, Chapter 5) discuss the chemically aggressive character of waters discharging from upland areas and containing humic substances. The humic substances contribute significantly to carbonate-rock dissolution, so these systems are more likely to erode limestone and develop karst.

near Dead River (Fig. 4), the water captured by these former tributary systems undoubtedly discharges at springs along the Suwannee River – perhaps at the Alapaha and Holton Creek rises (Fig. 4), which are known resurgences of the Alapaha River.

Alligator Creek and the Little Alapaha River drain into swallets near the Alapaha River and are clearly tributaries of the river that no longer drain directly into the Alapaha. Alligator Creek has a narrow trace to the river and, during high flow, discharges directly to the river. The trace from the Little Alapaha to the main stem river is about 2 miles long and also serves as an overflow channel.

Tiger Creek is not considered to be part of the Alapaha River drainage basin. Its trace heads southwest and appears to have once been tributary to the Suwannee River. The trace appears to terminate near Holton Creek Rise (Fig. 4), the likely discharge point for water captured by the Tiger Creek swallet. Therefore, the Tiger Creek drainage basin appears to reflect the next stage of trace development (Panel C, Fig. 3).

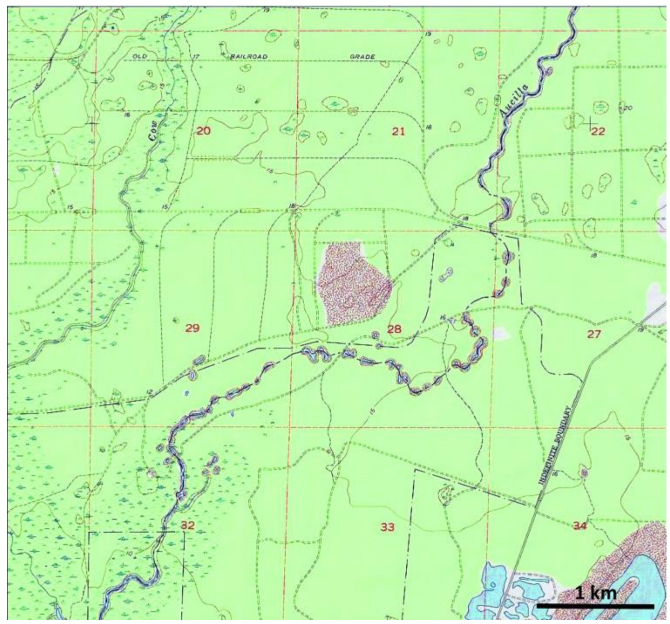

Fig. 5 – The "string of pearls" swallets on the Aucilla River.

The Alapaha River also fits into the stage depicted in Panel C, but its trace remains as a seasonally active river. The Alapaha River Basin encompasses roughly 100 mi.^{2} (259 km^2) of central Hamilton County (Conover and Leach 1975). This area represents less than 10% of the Alapaha River drainage basin, which covers approximately 1,700 mi.^{2} (4,400 km^2) and extends northward nearly 99 mi. (160 km) into southern Georgia. As a result of this relatively large drainage basin, there is strong perennial flow above the swallet swarm. At Jennings, median flow of the Alapaha is 15.4 m^3/s (544 ft.^{3}/s). At low to moderate flow, the river is totally captured at the swallet swarm near Dead River (Fig. 4). In-stream discharge only reaches the Suwannee River during periods of high flows and floods, when discharge above the swallets is about 10–14 m^3/s (350-490 ft.^{3}/s; Upchurch 2014b). About 50% of the time, the lower river is dry owing to the capture of discharge from the upper river at the swallets. When the stream channel is carrying water, the measured median flow in the normally dry river reach is 1.6 m^3/s (57 ft.^{3}/s; at Jasper). Dye tracing of water that enters the upper Floridan aquifer at Dead Sink emerged from the Alapaha and Holton Creek rises after about 6 days (Greenhalgh et al. 2016, personal communication).

<u>*Traces with Multiple Swallets*</u> - The Aucilla River trace is an example of a trace with many swallets (Fig.5). The presence of the "string of pearls" array of sinkholes on the Aucilla Trace represents an advanced stage of scarp retreat accompanied by development of multiple swallets as the river valley cut down into the limestone. The Aucilla goes underground and passes

southwest to Nutall Rise, a large resurgence approximately 8 km (5 mi.) downgradient. As can be seen, many of the sinkhole/swallets have begun to coalesce, forming short segments of elongated karst windows that formed by cave collapse. The primary pathway of the underlying cave may not follow the string of swallets exactly, but it is close.

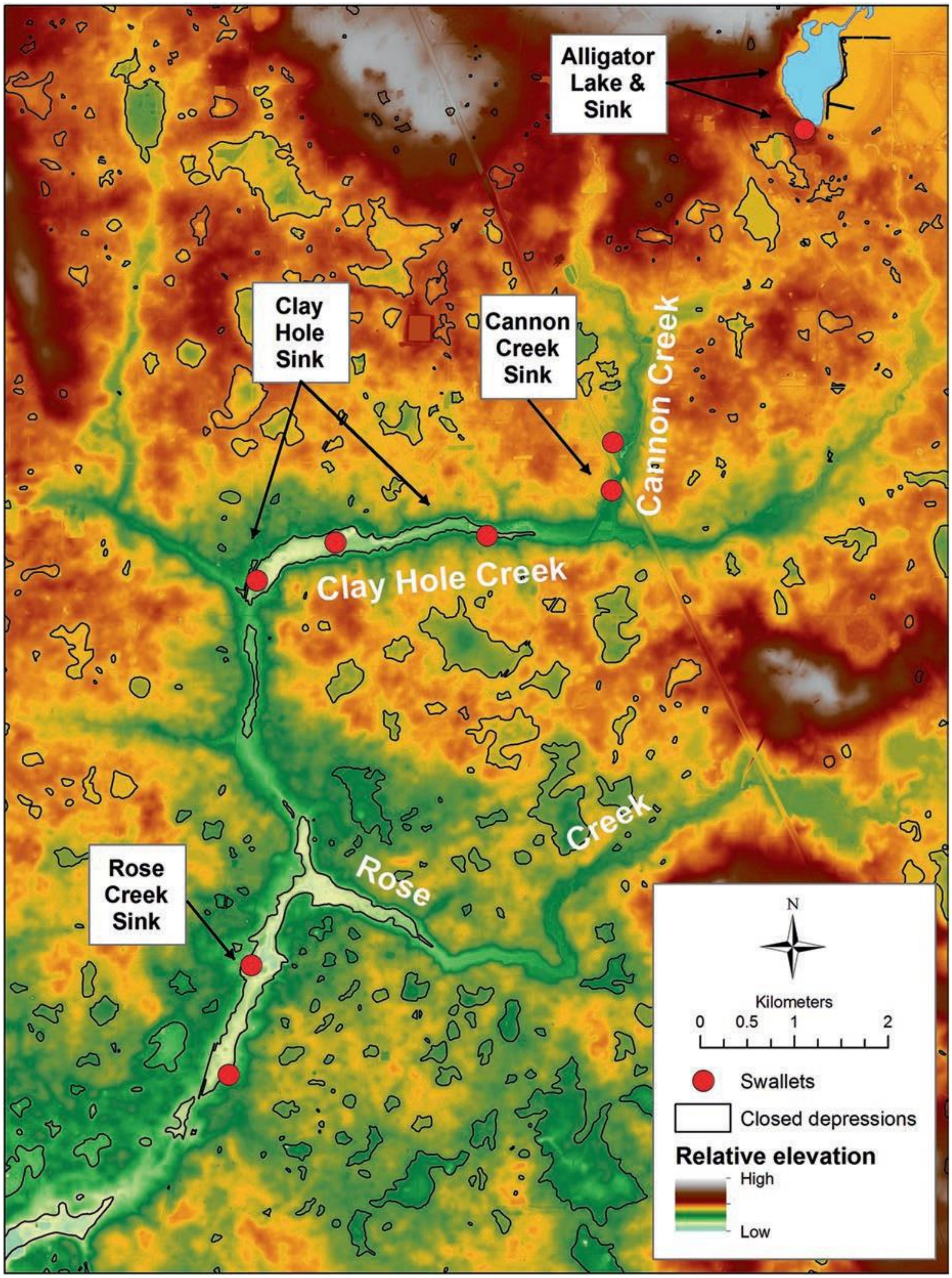

Fig. 6 – LiDAR map of the northern part of the Ichetucknee Trace showing the locations of major tributary streams and swallets

The Ichetucknee Trace (Fig. 6) is not heavily populated by swallets, but the relict stream valley is unusually well displayed. Since the focus of this guidebook is on the Ichetucknee Trace, little will be said here. Figure 6 illustrates the well-developed, dry stream valley. Clay Hole Sink is a coalescent sinkhole that includes Dyal Sink, which we will visit on the field trip. Dyal Sink is near the intersection of an unnamed tributary with the trace. Rose Creek Sink is a swallet near the intersection of Rose Creek and the Ichetucknee valley.

Collapsed Caves – We will visit one of the two best developed collapsed cave systems in northern Florida. This karst valley, Paradise Valley (Fig. 7a) begins at a sink at the head of the valley and just northwest of Jess' Hole, which we will visit. This sink may have once been a swallet. However, it is also possible that it was a resurgence or spring at one time. The valley terminates at the Santa Fe River near Rum Island and several other springs.

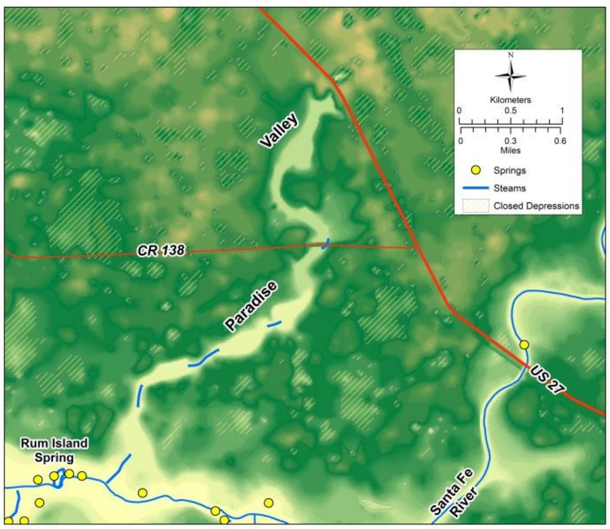

Fig. 7a – Paradise Valley, a collapsed cave with an unknown headwater origin. This valley may have been a spring run.

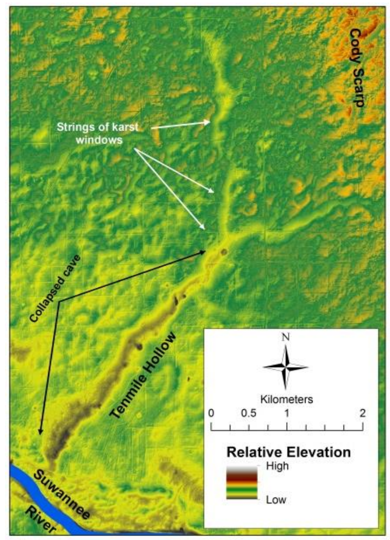

Fig. 7b – Tenmile Hollow, a collapsed cave that clearly has a tributary system and represents the culmination of trace development.

The best example of a cave system that has collapsed after developing a "string of pearls" array of karst windows is Tenmile Hollow (Fig. 7b). This collapse feature is located approximately 5.6 km (3.5 mi.) southeast of Wes Skiles Peacock Springs State Park in Suwannee County. It has a well-developed surface-water drainage system that terminates in a string of swallets. Downgradient from the swallets, the underlying cave has collapsed. The trace, which includes the swallets and collapsed cave, terminates at the Suwannee River.

There are several similar collapse features in the vicinity of Tenmile Hollow. All originate with dendritic drainage systems that lie within the Cody Scarp. These linear, dry valleys or sloughs have been interpreted as representing the culmination of trace development during fluviokarst scarp retreat.

Summary and Conclusions

Karst traces form during the retreat of a fluviokarst escarpment. As such, they represent excellent examples of fluviokarst. They begin by headward erosion of a stream into a scarp formed by relatively low recharge sediments at the top of the scarp. As the stream cuts downward, through the relatively low permeability sediments and into limestone, a swallet begins to capture the stream and the stream valley downgradient from the swallet ceases to carry water under normal conditions. As time and headward erosion progress, the scarp migrates and additional swallets develop to capture the stream. As each swallet forms, the ones downgradient are abandoned and remain either as karst windows in the thalweg of the dry stream valley or as swallets that capture tributary water.

The result, in Florida, is a normally dry stream valley populated by partly filled sinkholes, abandoned swallets, and karst windows. At the head of the trace (dry valley) there are one or more active swallets. During extreme runoff events, the infiltration capacities of the swallets may be exceeded, at which time the valley floods.

The karst traces terminate in resurgences characterized by brown, humic substance-rich water or as springs with minimal discoloration. These resurgences and springs reflect cave systems that connect the swallets to the resurgences and springs. In many cases, the cave systems roughly parallel the dry stream valley (e.g., the Aucilla River trace) and the spring/resurgence is located at the terminus of the trace. In other cases, the trace ends by discharge to the downgradient, master stream and the resurgence or spring is not located at the terminus of the trace (e.g., the Alapaha River trace).

In Florida, the best examples of karst traces are found at the toe of the Cody Scarp where streams drain the adjacent highlands and are captured where they enter the karst plains. Examples exist that range from simple stream to sink systems with a normally dry, abandoned stream channel downgradient from the swallet, to dry stream valleys populated by many karst windows (former swallets) and sediment-filled sinkholes, to completely collapsed cave systems.

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Santa Fe Basin Geomorphology Using a New Statewide Florida Framework

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Abstract
A new, comprehensive, statewide geomorphology of Florida publication is coming to fruition at the Florida Geological Survey. Ten districts divide the state into broad regions of similar landforms and processes, each district is further broken down into provinces that are within each district. Three provinces and two districts, Branford Karst Plain and Alachua Karst Hills of the Ocala Karst District and Raiford Ridges of the Okefenokee Basin District, encapsulate much of the Santa Fe Basin. These districts and provinces are discussed in more detail to highlight the variation of surficial and near surface geology, geologic processes, and the resulting landforms observed in the Santa Fe Basin, and particularly, to establish a foundational framework to discuss karst in the region.

Introduction
The Florida Geological Survey is completing a new, comprehensive, statewide geomorphology of Florida publication. The geomorphic unit discussions are part of an updated geomorphic map and framework for Florida that incorporates digital elevation models and 3D geologic information collected since earlier published works on the geomorphology of Florida. Several previous works discuss vast regions, or statewide geomorphology (White, 1958; Puri and Vernon, 1964; White 1970; Brooks 1981). The new work has the advantages of LiDAR for nearly 75% of the state, containing abundantly more continuous surface data than USGS topo quads. Digital compilation of mapping uses discrete polygons rather than generalized areas which were common in some of the earlier Florida geomorphology publications. Another distinction is that the basis for classification has been driven by linking the underlying geology and surficial and near-surface processes with landform development in Florida.

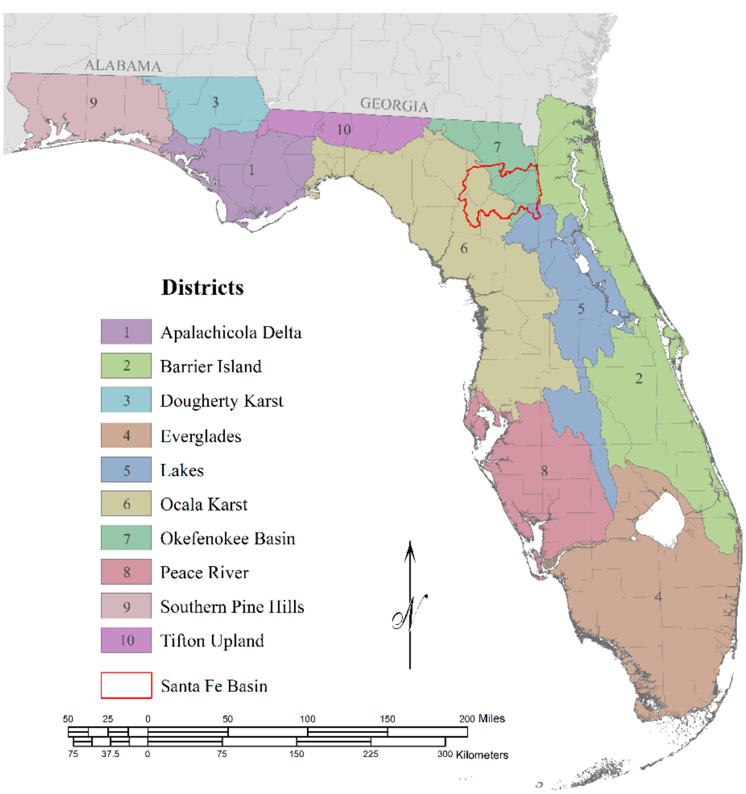

Figure 1. Statewide Geomorphic Districts.

Florida is divided into ten districts; these comprise the larger regions of the state in which processes, related to coastal and fluvial systems, underlying geology, and karst processes distinctly affect different areas of the state (Figure 1). Each district is defined by the dominant processes at work that create unique landforms in a region, and which are identifiable as distinct from adjacent districts.

Districts are further classified into provinces; which are smaller regions within a single district. Provinces have discrete surficial and near-surface processes, and underlying geology, which together form distinct landforms within a district and are identifiable from adjacent provinces.

Each district and province are not described herein. Key for this discussion is an awareness of the districts statewide, and to put in context the districts and provinces that relate to the Santa Fe Basin (Figures 2a & 2b).

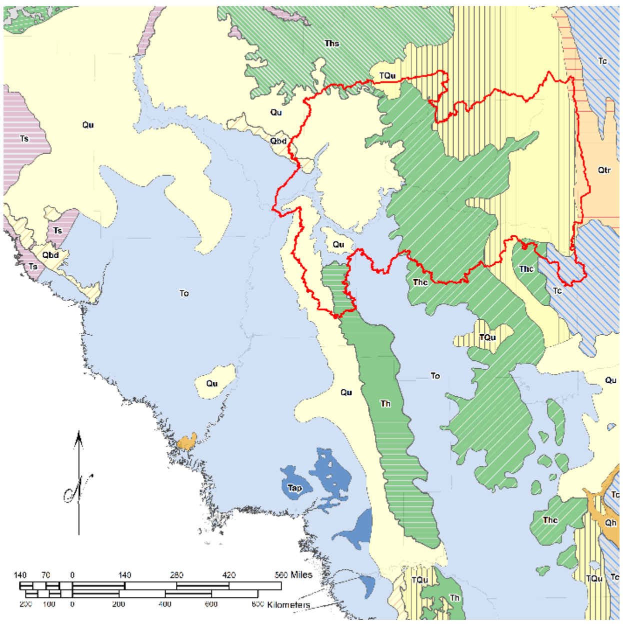

Figure 2a. Geology of Santa Fe Basin and adjacent regions (after Scott et al., 2001).

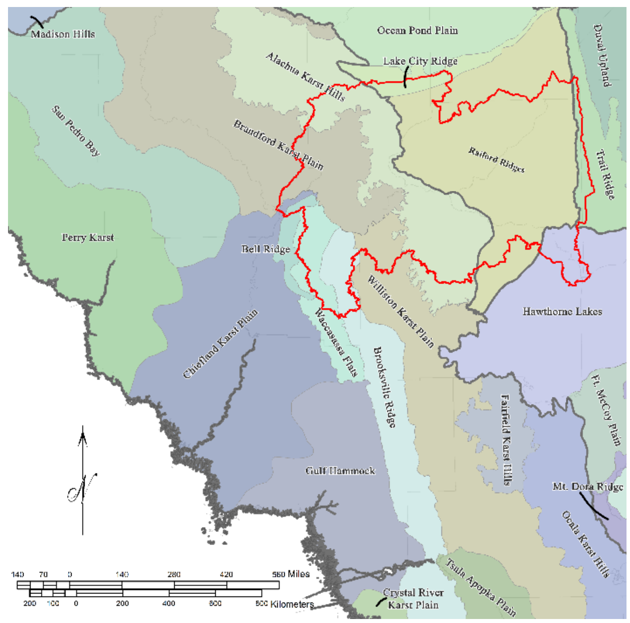

Figure 2b. Geomorphic provinces of Santa Fe Basin and adjacent regions.

Districts within the Santa Fe Basin include the Okefenokee Basin District and the Ocala Karst District, comprising most of the region. Minor regions of the headwaters of the Santa Fe Basin are within the Lakes District and Barrier Island District. The present discussion will be limited to the districts and provinces comprising the majority of the Santa Fe Basin. These include Branford Karst Plain and Alachua Karst Hills of the Ocala Karst District, and Raiford Ridges of the Okefenokee Basin District.

Cody Escarpment versus Big Bend Escarpment

Reference will be made in this discussion to the Big Bend Escarpment. This term is applied to the portion of the Cody Escarpment from eastern Jefferson County east and south to Alachua County that is dominated by fluviokarst escarpment retreat. Where originally defined, the Cody Escarpment is primarily a coastal erosional escarpment with very limited examples of karst-induced retreat (Figure 3). The separation of the Cody Escarpment from the Big Bend

Escarpment is done to isolate the major processes at work in each. Furthermore, the coastal erosional escarpment, now with the benefit of LiDAR, can be recognized to more closely mimic the present Gulf of Mexico shoreline in northern Florida, and is traceable at least as far south as Citrus County. However. this feature is nowhere as well-defined or has as much topographic relief as originally described at Cody, Florida.

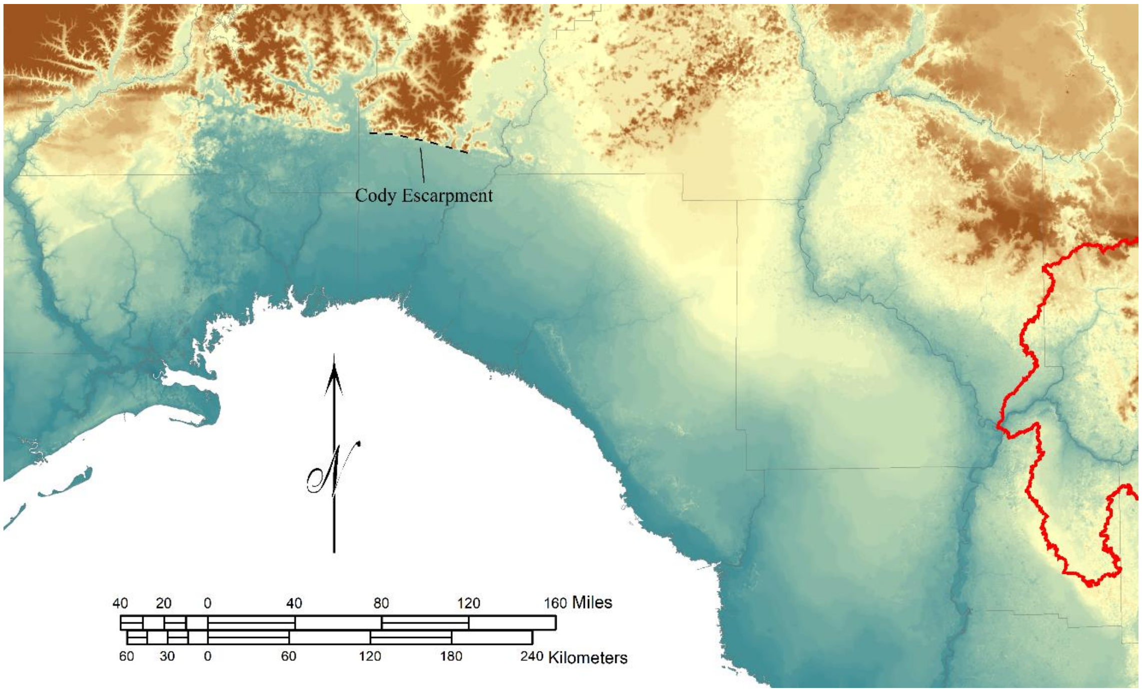

Figure 3. Cody Escarpment differentiated from other areas to the east, which have been known as the Cody Escarpment, but are called the Big Bend Escarpment for this discussion. Red line marks the boundary of the Santa Fe River Basin.

Ocala Karst District

The Ocala Karst District encompasses a broad area of northwestern peninsular Florida from Franklin County in North Florida to Hillsborough and Pinellas counties in west-central peninsular Florida, but this discussion focuses on the northern portion of the district. Dissolution of carbonate rocks has created distinct landforms that characterize the Ocala Karst District, including caves, caverns, numerous springs, siphons, swallets, and resurgences.

The Ocala Karst District developed on the crest of the Ocala Platform, a high on the Tertiary limestone formations of the Florida Platform. These limestones range in age from the middle Eocene to the early Miocene. The carbonate rocks are present at or near the surface, except where buried by Miocene to Recent siliciclastic sediments. The type of sinkholes and their abundance changes, grading from solution sinks where limestone is at or near the surface to cover-collapse sinks as the overlying sediment thickness increases.

Ocala Limestone is present at or relatively near the surface throughout the Ocala Karst District except along the western edge where it is covered by Suwannee Limestone, and Miocene to

Recent siliciclastics, and the southern edge where it is covered by Suwannee Limestone, Tampa Member of the Arcadia Formation, and Miocene to Recent siliciclastics, or where it has been eroded and Avon Park Formation is at the surface. The Suwannee Limestone has been eroded from the central part of the Ocala Karst District but is near the land surface in the northern portion of the Ocala Karst District, except where covered by the St. Marks Formation or Miocene to Recent siliciclastic sediments. Much of the Hawthorn Group in the northern Ocala Karst District is dominantly siliciclastic. Any of the carbonate rocks of the Ocala Platform are susceptible to dissolution, thus impacting landform development in the Ocala Karst District. The Ocala Limestone and Suwannee Limestone are usually more susceptible to karst processes than the dolostones common in the upper Avon Park Formation.

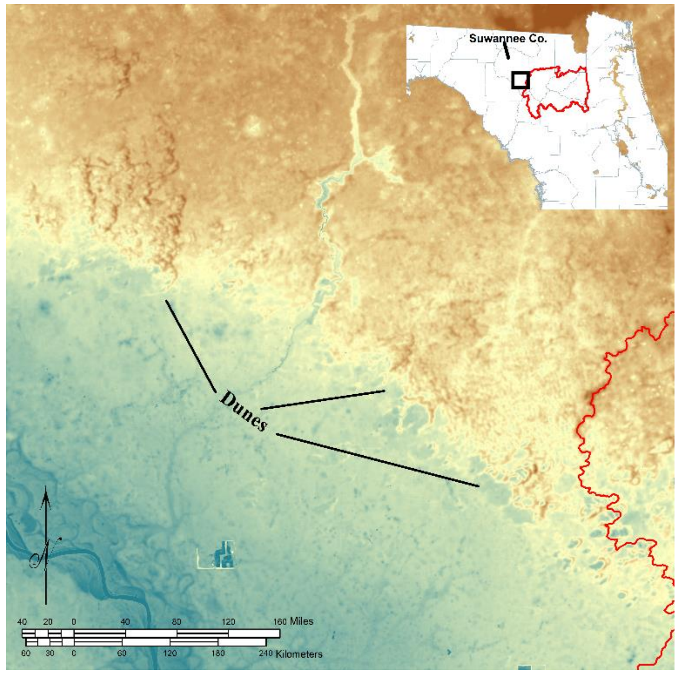

Figure 4. Southern Suwannee County dunes.

Most of the karst plains in Florida, relatively flat carbonate rock land surfaces with thin siliciclastic cover sediments, are found in the Ocala Karst District. The Brooksville Ridge and the hills bordering the Okefenokee Basin District and the Lakes District consist of Hawthorn Group and undifferentiated Tertiary/Quaternary sediments. These latter hills include limited outcrops of Coosawhatchie Formation and Statenville Formation (Scott et al., 2001).

Elevations within the district range from sea level along the Gulf of Mexico to just over 300 feet (91 meters) on Brooksville Ridge. The coastal and inland karst plains are relatively flat. The coastal karst plains slope gently toward the Gulf of Mexico. This is mostly due to erosional planation of rising and falling sea level throughout the Pleistocene. The topography over the remaining of the district consists of gently rolling hills with minor elevation changes related to aeolian dune fields or remnants of Miocene to Recent siliciclastics that overly the foundational Eocene to Miocene carbonate rocks. However, on Brooksville Ridge, the terrain looks more like the Lakes District and relief may exceed 200 feet (61 meters).

Branford Karst Plain

The Branford Karst Plain extends from Madison and Hamilton counties southward to the Santa Fe River. It is narrowly demarcated along the Suwannee River and its tributaries in the north and includes much of Suwannee County and southern Columbia County along the Suwannee and Santa Fe rivers.

The Ocala Limestone underlies the southern portion of the Branford Karst Plain. The northern part of the karst plain is developed on the Suwannee Limestone (Scott et al., 2001). Dissolution of these limestones is common throughout the province and at the escarpment boundaries with several of the surrounding ridges and Karst hills. Silicified boulders of Ocala Limestone and Suwannee Limestone are common throughout the karst plain. Varying thicknesses of undiffer-differentiated Quaternary siliciclastic sediments overlie the carbonates throughout the area. Sand dunes have developed in portions of the province and can be recognized on LiDAR (Figure 4).

The Branford Karst Plain is formed on a karstified, dissolving limestone surface that is relatively flat. Elevations generally decrease to the south toward the Gulf Coast. Local changes in elevation are typically associated with aeolian dunes or incised valleys, particularly along the Suwannee and Santa Fe rivers. Elevations in the Branford Karst Plain range from 10 feet (3 meters) MSL along the Suwannee River and Santa Fe River to more than 150 feet (45.7 meters) MSL, though the elevation is rarely over 100 feet (30.5 meters).

The Big Bend Escarpment divides the Branford Karst Plain from the Alachua Karst Hills. This karst and fluviokarst, evolving, retreating escarpment is a distinct boundary between the higher elevations in the Alachua Karst Hills and lower, much flatter, elevation and topography in the Branford Karst Plain.

Neither modern nor ancient coastal processes are active or noted in the Branford Karst Plain, but landforms sculpted by fluvial processes are abundant in the province. It is well drained and there are numerous springs. The most obvious fluvial features are the incised valley and meanders of the Suwannee River, in addition to the Withlacoochee and Alapaha rivers, and the Santa Fe River on the southern border of the province.

Numerous other surface streams and several traces and sloughs, such as Ichetucknee Trace, Little River, and Peacock Springs Slough, traverse the landscape. Traces are the remnant valleys of streams that have been abandoned by swallet stream capture, but they may be reoccupied during high flow events if the karst capture drainage system is overwhelmed. Erosion of overlying sediments places surface waters in contact with carbonate rocks that are susceptible to dissolution and karstification. Surface drainage development may also be related to past periods of time when the

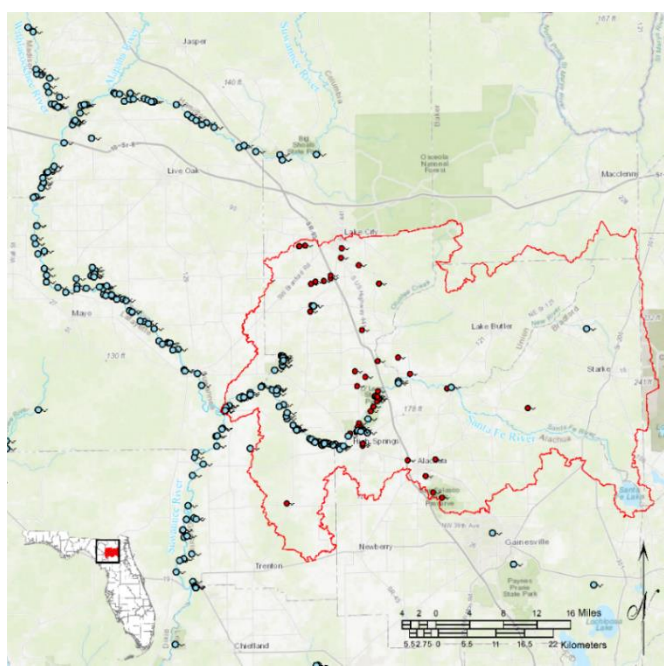

Figure 5. Rivers, springs (blue points), and swallets (red points) in the Santa Fe Basin.

potentiometric surface of the Floridan Aquifer System was lower, and the springs at the ends of the traces may once have been swallets capturing the surface flow (see Figure 5 for locations of springs and swallets in the region). Many traces have developed other swallets, and these have interrupted the overland flow, allowing surface drainage to recharge directly into underground karst conduits. Sloughs, also present in Branford Karst Plain, are similar, but may have a mix of overland and subterranean flows, thus including a mix of wetlands and swamps within the former valley.

Several examples of traces, sloughs, and fluviokarst were previously discussed as part of fluvial processes in the Branford Karst Plain. Over much of the province, limestone is at or near the surface under a thin cover of siliciclastic sediments, mostly quartz sand. Given the open atmospheric connection, much of the province has shallow karst depressions and interior drainage through well-developed horizontal and vertical conduits. The border of the Branford Karst Plain with the Alachua Karst Hills follows the Big Bend Escarpment. Streams flowing from the Alachua Karst Hills disappear into swallets near the toe of the Big Bend Escarpment, limiting surface drainage on parts of the Branford Karst Plain.

The escarpment edge between the Alachua Karst Hills and Branford Karst Plain is a region of aggressive limestone dissolution and aquifer recharge. The aquifer recharge water reappears in karst windows and springs which are plentiful in the Branford Karst Plain, particularly along the Suwannee, Santa Fe, Withlacoochee, and Alapaha rivers. Therefore, the fringes of the Branford Karst Plain are regions where karst landforms continue to develop and evolve, most notably swallets and sinkholes, and escarpment toe lakes, uvalas, and poljes. These processes may seem stationary over human timescales, but over millennia the boundaries of the Branford Karst Plain slowly march inland as the overlying siliciclastic materials erode into the dissolving limestones below.

Alachua Karst Hills

The Alachua Karst Hills extend from northern Suwannee County to central Alachua County. The surface of the province is frequently covered by undifferentiated Tertiary/Quaternary siliciclastic sediments. Suwannee Limestone and/or Ocala Limestone underlie the Statenville and Coosawhatchie formations within the province. The Suwannee Limestone is missing under the southern portion of the Alachua Karst Hills (Scott et al., 2001). Dissolution of carbonate beds in the Hawthorn Group, but particularly of the Suwannee Limestone and Ocala Limestone, has significant impacts on the local landforms, particularly based upon how the overlying siliciclastics respond to voids left by dissolution.

Rolling hills, comprised of siliciclastic sediments of the Hawthorn Group that were formed by dissolution of the underlying limestones and downward transport of the overlying sediments through karst features, characterize the Alachua Karst Hills. Elevations range from 40 feet (12.2 meters) MSL to just over 200 feet (61 meters) MSL.

The Alachua Karst Hills are at a higher elevation than the adjacent Branford Karst Plain. The boundary between them follows the Big Bend Escarpment, which is being formed by karstification at the boundary where surface water flows over the clayey siliciclastic sediments common to the Hawthorn Group formations of the Alachua Karst Hills and enters the limestones, dissolving and eroding them at the edges of the karst plains. The Raiford Ridges are at a similar elevation but are marked by the overall northeast to southwest trend of ancient beach ridges that are lacking on the landforms of the Alachua Karst Hills.

No modern coastal processes are active on the Alachua Karst Hills. However; the Lake City Ridge is an ancient coastal beach ridge feature. Dissolution of limestone under the northern portion of the province provides accommodation space for erosion of the overlying sands of the former western extent of the Lake City Ridge into the voids developing in the underlying limestone. The western extension of the Lake City Ridge once continued through the northern portion of the Alachua Karst Hills, roughly following the route of US Highway 90 (Figure 6). Karst has significantly overprinted much of the coastal origin of the west end of the Lake City Ridge. Therefore; the Lake City Ridge is not interpreted on the geomorphic map as a depositional feature through the northern Alachua Karst Hills. These karst erosional processes have caused the retreat of the uplands and created the Branford Karst Plain southwest of the Alachua Karst Hills.

Most of the Alachua Karst Hills are well drained, but swampy conditions occur in some of the low-lying areas. The hills are more subdued in the northern part of the Alachua Karst Hills where it is underlain by Statenville Formation or relatively thin Coosawhatchie Formation and undifferentiated Tertiary/Quaternary sediments. Higher hills with some development of dendritic drainage in the southern part of the province have formed where thicker deposits of Coosawhatchie Formation exist.

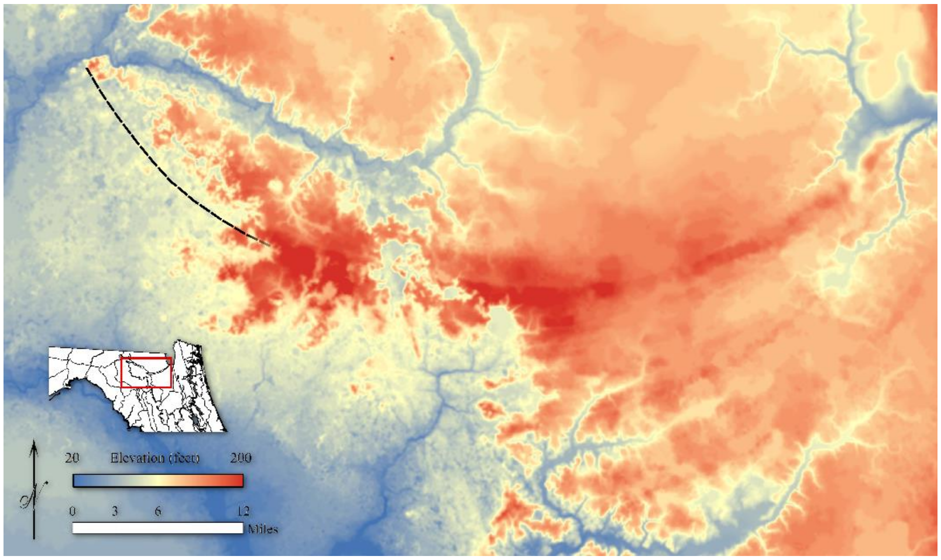

Figure 6. Lake City Ridge former extent prior to karstification in the northern portion of the Alachua Karst Hills.

Dissection of the landscape by overland drainage is most prevalent in the Alachua Karst Hills where a thick cover of siliciclastic sediments limit karst capture of surface water. Many streams drain off the province toward Olustee Creek and the Suwannee and Santa Fe rivers. Olustee

Creek and the Santa Fe River drain the eastern side of the southern part of the Alachua Karst Hills. After they merge, the Santa Fe River bisects the province as it continues to the Branford Karst Plain.

Many of the smaller streams flow into wet prairies at the toe of the Big Bend Escarpment and are captured by swallets along the western edge of the Alachua Karst Hills and adjacent portions of the Branford Karst Plain. Surficial erosion of the overlying Hawthorn Group sediments exposes the underlying limestones. Eroded siliciclastics are transported into the limestone, moving the escarpment inland. This occurs via both small-scale processes at the toe of the ridges, in this case the Alachua Karst Hills, and larger-scale fluvial systems. These processes effectively remove and transport overlying sediments above the escarpment and expose the limestones to dissolution.

Few springs exist in the Alachua Karst Hills. Internal drainage of the province occurs through swallets and sinkholes, and not only ones found in the vicinity of the Branford Karst Plain boundary. One example of this is at Devil's Millhopper Geological State Park in Gainesville, a rock-collapse sinkhole. Common karst features of the Alachua Karst Hills include previously mentioned sinkholes and swallets, but also uvalas and poljes.

Okefenokee Basin District

The Okefenokee Basin extends into northern peninsular Florida from Georgia. In Florida, it islocated in Baker, Hamilton, and Columbia counties southward to northern Alachua County. Ocala Limestone is exposed in the Santa Fe River Valley and Suwannee Limestone crops out in the Suwannee River and Alapaha River valleys in the Okefenokee Basin District. Miocene formations of the Hawthorn Group and Tertiary/Quaternary siliciclastic sediments underlie most of the district. The Statenville and Coosawhatchie formations occur at or near the surface in the western to southwestern portions of the district. Undifferentiated Tertiary/Quaternary siliciclastic sediments underlie the eastern portion of the district and form the Lake City Ridge and Raiford Ridges (Scott et al., 2001).

The Tertiary/Quaternary siliciclastic sediments that comprise the Lake City Ridge and Raiford Ridges, and the Trail Ridge sediments to the east, occur along and delineate the southern and eastern boundaries of the Okefenokee Basin. The sediment dams created by these ridges formed a basin for the Okefenokee Swamp, including Ocean Pond Plain and regions to the north in Georgia. The ridge and swale topography with trellis drainage, particularly in the Raiford Ridges, have distinct impacts on landform development. Suwannee Limestone and Ocala Limestone dissolution have the most impact on surficial karst landforms, particularly at the edges of the Okefenokee Basin District where it borders the Lakes District, and the Ocala Karst District where the limestone formations approach the land surface.

Elevations within the Okefenokee Basin District range from around 50 feet (15.2 meters) MSL along the St. Marys, Suwannee, Alapaha, and Santa Fe rivers to more than 210 feet (64 meters) MSL on Lake City Ridge. Approximately 90% of the district is above 115 feet (35.1 meters) MSL. Lower elevations are concentrated along the river valleys.

In Ocean Pond Plain, hills are absent, and the entire area is relatively flat. The Raiford Ridges include hilly topography of former beach ridges trending northeast to southwest. This trend is sub-parallel to the northeast to northwest arc of the Lake City Ridge, which is noted for its complete arc orientation and its higher elevation than Ocean Pond Plain to the north and Raiford Ridges to the south.

Raiford Ridges

Raiford Ridges lie south of Lake City Ridge in Columbia, Baker, Bradford, Union, and Alachua counties. Raiford Ridges are comprised of undifferentiated Tertiary/Quaternary siliciclastic sediments and are underlain by Coosawhatchie Formation where the overlying undifferentiated sediments have been breached by a combination of fluvial erosion and karstification (Scott et al., 2001). While some carbonate rocks exist within the Coosawhatchie Formation, where present, they are dominated by dolostones and dolosilts that are less vulnerable to dissolution. Carbonate rocks of the Suwannee Limestone and Ocala Limestone, where nearer the land surface in the southern and western part of Raiford Ridges, are more susceptible to dissolution, and karst landforms occur.

Raiford Ridges have well-drained, low hills and intervening swampy lowlands that are the remnants of coastal deposition of beach and dune ridges and swales. The swampy nature of the low-lying areas is due to the low permeability of the clayey Coosawhatchie Formation sediments. Elevations in the Raiford Ridges range from about 50 feet (15.2 meters) MSL near Bay Branch, and St. Marys, New, and Santa Fe rivers to 200 feet (61 meters) above MSL. Away from the lower elevation incised terrain along these streams, about 85% of the province elevations lie between 120 feet (36.6 meters) MSL and 175 feet (53.3 meters) MSL.

Lake City Ridge is distinct from Raiford Ridges because of its higher elevation and relative lack of surface drainage. This is due to Lake City Ridge being a local drainage divide. The boundary with the Alachua Karst Hills and Williston Karst Plain is noted by change in elevation as dissolution of limestone and the action of karst processes cut into the hills.

Broad, shallow karst depressions are infrequently noted over most of the Raiford Ridges, many nearer to stream drainages where siliciclastic cover over the underlying limestones has been reduced. These features have greater change in elevation relative to the uplands of Raiford Ridges toward the boundaries with the provinces to the south and west. Karst features are present in the transition zones between the Raiford Ridges and the Alachua Karst Hills, Williston Karst Plain, and Hawthorne Lakes. Escarpment toe lakes are most common at the boundary with the Williston Karst Plain and Hawthorne Lakes, but these features are included in the adjacent provinces, not Raiford Ridges. The cover subsidence and cover collapse features form at the boundaries where the overlying siliciclastic sediments thin and the underlying limestone is closer to the land surface.

Conclusion

The important geomorphology and geology to comprehend is that the headwaters of the Santa Fe Basin begin in areas containing relatively thick siliciclastic deposits of undifferentiated Tertiary/Quaternary sediments or Hawthorn Group overlying Suwannee Limestone and/or Ocala Limestone. As the siliciclastic cover thins, some surface water is captured in various karst depressions, but other waters maintain surface flow until limestone is at or near the surface, and water is then captured in swallets and poljes. On the karst plains, only a few large rivers, such as the Suwannee and Santa Fe, maintain an overland component of flow. Karst plain drainage is internal and is often directed to swallets and karst depressions, with some examples of traces and sloughs. Geomorphic discussion and 3D geology of the region provide a much clearer picture of the processes responsible for creating the landforms observed today. These landforms continue to evolve through dissolution of limestone, and weathering and transport of siliciclastic materials.

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Late Winter/Early Springtime Plants of Paradise Ravine

Colette C. Jacono (Florida Museum)

The geology of Paradise Ravine contributes a combination of limestone undersurface, topographic depression, and minor seepage that provide a specialized and, until recent times, secluded plant community. For example, the wake-robin (*Trillium maculatum*) is a relict species that has been sheltered here since the last glacial retreat. Despite an increase in deer browsing, diversity remains high in that 50 species of limestone-loving/calciphilic plants can easily be seen in today's short traverse.

Predominating overhead we find a towering canopy of mixed hardwood trees. Some of the largest trees are species of oaks that frequent bluffs and river banks. Recognize the swamp chestnut oak (*Quercus michauxii*) by its large oval leaves with toothed margins and velvety undersides. Its leaves turn rich colors in autumn.

Fig. 1. Shumard's oak is restricted to scattered regions of northern Florida.

Shumard's oak (*Q. shumardii*) is known for leaves having three lobes on each side terminating in the bristle tips characteristic of red oak (Fig. 1).

A little lower down-slope, tremendous trunks of swamp laurel oak (*Quercus laurifolia*) produce buttressing roots, an adaptive advantage for tall trees in damp soils. Its diamond shape helps distinguish the leaves of swamp laurel oak from other oaks that also bear simple leaves with entire margins.

The high bluffs are populated with a stately evergreen, the southern magnolia, (*Magnolia grandiflora*) as well as a smaller, understory, and semi-deciduous species, the Florida maple (*Acer floridana*). Still clothed in its golden leaves of the season past, the Florida maple will retain its leaves until they are pushed off by the developing buds of new leaves later in spring.

Fig. 2. Sugarberry carries a light colored, smooth bark marked by moss, its own corky outgrowths, and a variety of lichens (left to right).

Common on the lower slopes and bottomlands of the ravine are the lichen encrusted trunks of towering sugarberry trees (*Celtis laevigata*) (Fig. 2). Though primarily smooth, the sugarberry bark is known for producing corky outgrowths in bumps or elongated patterns.

Two smaller trees, both from the birch family and with leaves similarly ovate shaped and toothed, associate with sugarberry on the lower slopes. The American hornbeam (*Carpinus caroliniana*) is quickly identified by a smooth bark that fits tightly over its fluted trunk. The hornbeam contrasts sharply with that of its cousin, the ironwood (*Ostrya virginiana*), which bears a shaggy bark that sheds continually in thin strips.

Fig. 3. Fissures and furrows define the bark of sweetgum.

Scattered throughout the ravine, sweetgum (*Liquidamber styricaflua*) shows little preference for where it sets down roots (Fig. 3). Recognize sweetgum in early spring by its deep, dark fissures in its bark. Deep and frequent bark fissures correlate with arthropod abundance and feeding habitat for bark foraging birds, such as nuthatches, warblers, and woodpeckers. A pair of pileated woodpeckers recently nested and raised its young along the upper ravine.

Massive vines of muscadine grape (*Vitis rotundifolia*), some nearly as old as the trees on which they clamber, contribute to the high canopy of the mixed hardwoods. During the growing season when canopy leaves offer an abundance of shade, the ravine maintains a localized climate of moderate temperature and humidity. In winter, this mostly deciduous canopy allows sunshine to penetrate to the understory, encouraging herbaceous groundcovers and spring flowers to hasten an early start.

Spectacular in early rising, the spotted wakerobin (*Trillium maculatum*) inhabits rocky slopes on the northern and eastern walls (Fig. 4). These herbaceous perennial monocots return every year from swollen, underground rhizomes equipped with contractile roots which push and pull their bases into the limestone substrate. Each stem ends in a whorl of three leaves below a single flower. The flower is composed of three sepals, three petals and a stigma also divided into three. Its seeds are embedded in three sections of a fleshy berry and the berry decorated with a fleshy aril attractive to dispersal agents.

Fig.4. The plants at Paradise Ravine constitute the southernmost intact community of spotted wake-robin known in North America.

Along the rock slopes, three species of violet, clumps of ebony spleenwort (*Asplenium platyneuron*), bunches of a woodland sedges (*Carex*) and the wildflower Carolina scaly-stem (*Elytraria caroliniensis*) are beginning to awaken (Figs. 5, 6).

Fig.5. The primrose-leaf violet (*Viola primuliflora*) lodges among liverworts on the northern rock wall of Paradise Ravine.

Fig.6. Clusters of ebony spleenwort, violets, and woodland sedges find footing in the crevices and hollows of eroded limestone.

Along the far west of the upper wall, patches of the only native bamboo in North America, switchcane (*Arundinaria gigantea*) offer avian habitat to the forest mid-story.

The northeastern margin of the ravine, although once the richest in habitat, has been lost to development and a retaining wall placed where terrestrial orchids, the spring coralroot (*Corallorhiza wisteriana*) and the Florida Threatened cranefly orchid (*Tipularia discolor*) occurred twenty years past.

Continuing south along the towering outcrops of the eastern wall, a host of liverworts, woodland sedges (*Carex* and *Cyperus*), a bunch grass (*Dichanthelium*), and swards of marsh fern (*Thelypteris ovata*) erupt in galleries of green.

A single individual of a delicate fern called modest spleenwort (*Asplenium verecundum*), might be found, clinging perhaps to the same rock where a total of eleven plants were first recorded in the late 1950s (Fig 7.). Meanwhile, the invasive spider brake fern (*Pteris multifidi*) has made its mark on the lower part of the same rock inhabited by modest spleenwort. When invasive species enter a specialized habitat, they often occlude the less aggressive and vulnerable native plants. Early intervention could help protect this habitat.

Fig.7. Modest spleenwort is a delicate fern species listed as Endangered in Florida. "State Endangered entails that collection, whether on public or private land, requires State permit."

Many other understory species add diversity to the ravine. Watch your step for young upstarts of the anglepod milkvine (*Gonolobus suberosus*) (Fig. 8). A black-flowered, vining milkweed, anglepod is well-documented as host for the monarch butterfly. The anglepod remains Threatened in Florida.

Fig. 8. Lacking tendrils, the Anglepod milkvine climbs by twining its stem around stems of understory herbs and small trunks before reaching lower branches of shrubs and trees on which it will flower.

Low in the bottomlands, the rattlesnake fern (*Botrychium virginianum*) produces a single-leaf before it sends up its spore bearing branch. Soon after the rattlesnake fern falls dormant for the remainder of the year (Fig. 9). This fern occurs less frequently since the hurricanes of the early 2000's resulted in significant treefall and widespread gaps in the canopy.

Fig. 9. The rattlesnake fern prefers deep shade and extensive moisture.

Understory tangles of catbrier (*Smilax glauca*) have increased with the disturbance and light penetration following heavy treefall. In turn, more light allows for summer flowering of the swamp milkweed (*Asclepias perennis*) (Fig. 10). Its habitat of bottomland pools has returned where, in past years, the surface had remained dry.

Tree removal along the ravine margins contributes to an encroachment of light and increase of erosion and surface run-off that will continue to impact the frequency and ultimate diversity of the unique species that are presumed to have inhabited this geological site for many thousands of years.

Fig.10. Swamp milkweed is a perennial herb reoccurring each year from underground storage roots and blooms with white flowers well into late summer.

Inventory of Late Winter/Early Springtime Plants of Paradise Ravine

Ferns

Asplenium platyneuron	modest spleenwort
Asplenium verecundum	ebony spleenwort
Botrichium virginianum	grape fern
Pleopeltis polypodioides	resurrection fern
Pteris multifida	spider brake fern
Thelypteris (Christella) ovata	marsh fern

Trees, Shrubs and Woody Vines

Acer negundo	box elder
Acer floridanum	Florida maple
Bignonia capreolata	crossvine
Campsis radicans	trumpet creeper
Carpinus caroliniana	American hornbean
Carya glabra	pignut hickory
Celtis laevigata	sugarberry
Cocculus carolinus	Carolina moonseed
Cornus florida	dogwood
Eonymous americanus	hearts-a-bursting
Gonolobus suberosus	anglepod milkvine
Juniperus virginiana	red cedar
Liquidambar styraciflua	sweet gum
Magnolia grandiflora	southern magnolia
Morus rubra	red mulberry
Ostrya virginiana	ironwood
Persea borbonia	red bay
Ptelea trifoliate	wafer ash
Quercus falcata	southern red oak
Quercus hemisphaerica	laurel oak
Quercus laurifolia	swamp laurel oak
Quercus shumardii	Shumard's oak
Quercus virginiana	live oak
Rubus spp.	blackberry
Sabal palmetto	sabal palm
Smilax glauca	catbrier
Tilia americana	basswood
Toxicondendron radicans	poison ivy

Herbs and Grass-like Plants

Arisaema dracontium	greendragon
Arundinaria gigantea	switchcane
Asclepias perennis	swamp butterflyweed
Carex spp.	woodland sedges
Corallorhiza wisteriana	spring coralroot
Cyperus spp.	woodland sedges
Dichanthelium spp.	witch grass
Dioscorea floridana	Florida yam
Mikania scandens	climbing hempvine
Oplismenus hirtellus	basket grass
Panicum anceps	beaked panicum
Sanicula sp.	black snakeroot
Tillandsia bartramii	Bartram's airplant
Tillandsia usneoides	spanish moss
Tipularia discolor	cranefly orchid
Trillium maculatum	spotted wakerobin
Viola walteri	Walter's violet
Viola primulifolia	primrose-leaf violet
Viola sororia	common blue violet
Vitis rotundifolia	Muscadine

A Brief Introduction to the Florida Geological Survey STATEMAP Program

Rick Green (Florida Geological Survey, Tallahassee, Florida)

The Florida Geological Survey (FGS) STATEMAP program was established in 1994 with an award from the National Cooperative Geologic Mapping Program (NCGMP). The NCGMP was created in 1992 by the National Geologic Mapping Act (NGMA). This act was re-authorized by Congress in 1997, 1999, and 2009. It is up for renewal in 2019. The NCGMP's objectives are to "develop geologic maps, create associated national geologic databases, supply the data to the public, and increase public awareness of the application of geologic information to land-use management." The NCGMP has three components: FEDMAP, EDMAP, and STATEMAP. Funding for the NCGMP has fluctuated over the years from a low of just under $20M to as high as $28M annually.

The FEDMAP component develops new ways to understand basic earth science processes and produces high-quality digital geologic products, regional analyses, and multidimensional geologic models. Funding for FEDMAP, which is available only to the USGS, is $16.9M annually. Part of these funds are used for the National Geologic Map Database (NGMDB) which provides a centralized location for over 90,000 geologic products from over 600 publishers. If you have not taken the time to check out this incredibly valuable resource, it is highly recommended.

The EDMAP component is designed to train the next generation of geologic field mappers. Funds are awarded via a competitive grant process to universities and is used to help train graduate and undergraduate students in field-mapping techniques. Funding for EDMAP is $500,000 annually.

The STATEMAP component, which awards funding to State Geological Surveys via a competitive grant process, is utilized for generating new geologic maps and/or compiling older (non-digital) geologic maps. All funds awarded are required to be matched dollar-for-dollar by non-federal funds. Funding for this component of the program has been $6.9M annually for the last five years. Areas selected for mapping by the FGS STATEMAP program are chosen based upon recommendations and mapping priorities established by the State Mapping Advisory Committee (SMAC). In October of each year, the SMAC meets to select the area which will be proposed to the U.S. Geological Survey for funding under the STATEMAP Program, and to refine the five-year geologic mapping plan for the state. This committee is currently comprised of nearly two dozen professional geologists (P.G.s) from around Florida with a combined total of over 580 years of experience.

Since 1994, the FGS has received yearly funding from the USGS STATEMAP program to continue geologic mapping in Florida. The program has ranked in the top five for each state for the last several years in funding level. From 1994 through 2011, the FGS STATEMAP program produced geologic maps of portions (half) of 1:100,000 scale quadrangles utilizing a combination of Federal and State funds. The first FGS STATEMAP award of $30,000 was used to map the eastern half of the 1:000,000 scale Homestead quadrangle. This was matched by $30,000 of time from FGS staff. As more grant funds and more staff time became available over the years, the program was able to increase the areas mapped and expand the program statewide. In 2012, the program began to map full 1:100,000 scale quadrangles due to increased funding and matching ability from FGS staff. To date, the FGS has mapped approximately 28,000 square miles of Florida under grants from the USGS STATEMAP program. The FGS has been awarded $2,956,875.26 and has matched $2,981,924.52 for a total of 25 projects to date.

Over the past twenty-five years, the FGS STATEMAP Program has employed and trained dozens of people in numerous aspects of Florida geology, geomorphology, and hydrogeology. FGS STATEMAP Program alumni have gone on to accomplish many things, including becoming Professional Geologists, Professional Engineers, Academics, and Geographic Information Specialist Professionals (including one working for Environmental Systems Research Institute (ESRI) as an Instructor. The reach of the program is both internal (two of the section heads at the FGS got their start working in the STATEMAP Program), and nationwide (Colorado, Florida, South Carolina, Texas, and Washington, D.C.). Several alumni are currently working for State agencies (Colorado Department of Natural Resources, Florida Department of Environmental Protection, Florida Department of Transportation, and the Texas Commission on Environmental Quality), while other alumni have entered the private sector in various consulting positions. Although the primary goal of the STATEMAP Program is to produce high quality geologic products, additional benefits of this program can be seen in the number of well-trained geoscience professionals that have been a part of the program.

STATEMAP projects, which are based on a year-long grant cycle, involve literature review, examination of as many cores and cuttings samples as time allows (typically several hundred), several weeks' worth of field mapping, and drilling of new cores for cross-section control. Mapping takes place at 1:24,000 scale, with the final products being produced at 1:100,000 scale. Mapping areas have ranged from sixteen 1:24,000 scale quadrangles (~1,000 square miles; 2,590 square KM) to twenty-four 1:24:000 scale quadrangles (2,048 square miles; 5,300 square KM) per year. Each mapping project results in the publication of a revised surficial geologic map, geomorphology map Series (OFMS), and an Open-File

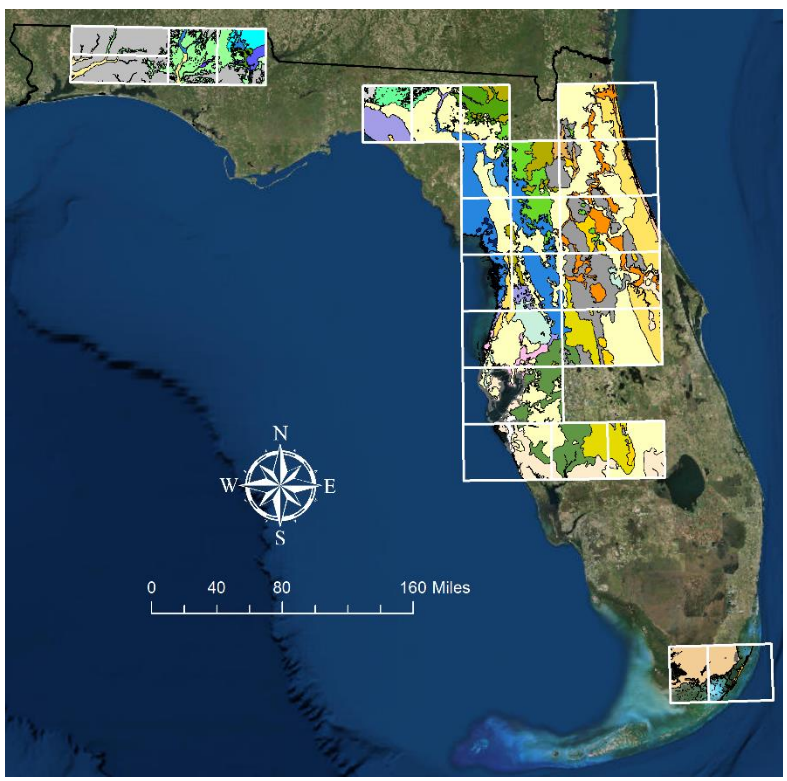

Figure 1. Areas mapped by Florida Geological Survey STATEMAP Program.

resulted in the production of new geologic maps for sixteen and one-half 30 x 60 minute quadrangles, 136 new geologic cross-sections, and dozens of new publications.

All of the STATEMAP products produced between 1994 and 2018 are available on the FGS website via a Story Map. This web-based ESRI product is an innovative way for citizens and consultants to access "all things STATEMAP". The page provides several ways to "drill down" and view geology for areas that have been mapped. Examples include a Photo Map showing selected field photos from mapping areas, interactive examples of various quadrangles (Saint Petersburg, Jacksonville, Orlando, Saint Augustine, and Tarpon Springs) which allow a user to click map polygons for more information, and a page where published products from each of 25 different projects can be downloaded.

The following links will let you download STATEMAP products for the Ichetucknee River and Santa Fe River basins and vicinity (western and eastern portion of the Gainesville quadrangle, and the eastern portion of the Lake City quadrangle).

If you are interested in learning more about the FGS STATEMAP Program or SMAC, you can reach out to Rick Green at the FGS: Rick.Green@dep.state.fl.us

Link URLS from article above:

STATEMAP program –

https://floridadep.gov/fgs/research/content/statemap-story-map

National Cooperative Geologic Mapping Program (NCGMP) –

https://ncgmp.usgs.gov/

National Geologic Mapping Act (NGMA) -

https://ncgmp.usgs.gov/about/ngm_act/ngmact1992.html

1997 -

https://ncgmp.usgs.gov/about/ngm_act/ngmact1997.html

1999 –

https://ncgmp.usgs.gov/about/ngm_act/ngmact1999.html

2009 –

https://ncgmp.usgs.gov/about/ngm_act/ngmact2009.html

FEDMAP –

http://ncgmp.usgs.gov/about/fedmap.html -

National Geologic Map Database (NGMDB)

https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

EDMAP -

http://ncgmp.usgs.gov/about/edmap.html

STATEMAP –

http://ncgmp.usgs.gov/about/statemap.html

Homestead quadrangle –

http://publicfiles.dep.state.fl.us/FGS/FGS_Publications/STATEMAP/high_res/OFMS83_Homestead_East.zip

Story Map -

https://floridadep.gov/fgs/research/content/statemap-story-map

western -

http://publicfiles.dep.state.fl.us/FGS/FGS_Publications/STATEMAP/high_res/OFMS93_Gainesville_West.zip

eastern -

http://publicfiles.dep.state.fl.us/FGS/FGS_Publications/STATEMAP/high_res/OFMS94_Gainesville_East.zip

Lake City quadrangle –

http://publicfiles.dep.state.fl.us/FGS/FGS_Publications/STATEMAP/high_res/OFMS97_LakeCity_West.zip