Geologic Framework and Anthropogenic Impacts on the Hydrology and Ecology of St. Catherines Island, Georgia

A Presentation to the Southeastern Section
of the
Geological Society of America
April 1, 2021

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This research was supported by Georgia Sea Grant, the St. Catherines Island Research Foundation and Georgia Southern University.

St. Catherines Island (SCI), Georgia

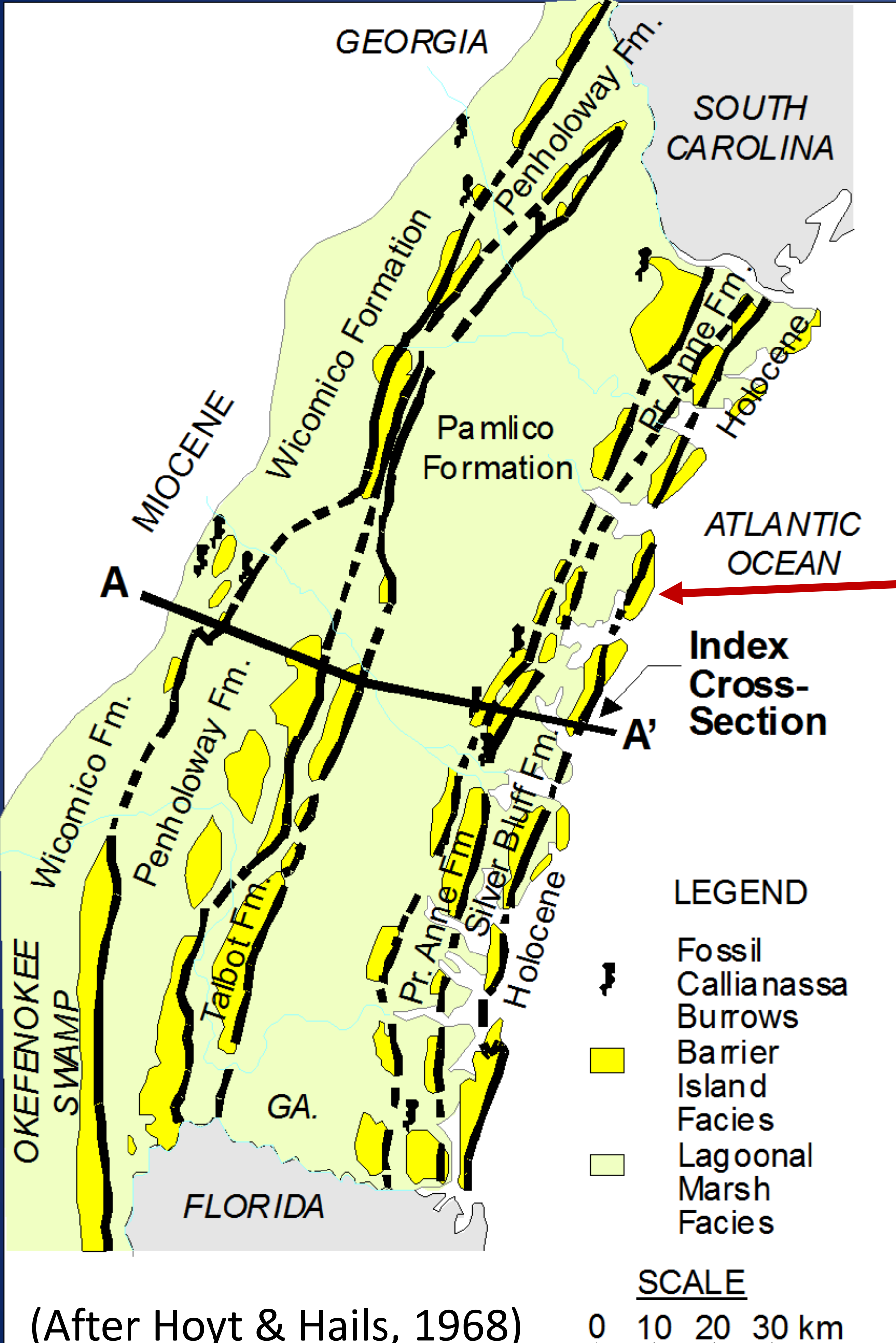
20 km long,
2 to 5 km wide

Pleistocene core with some Holocene cover and flanking Holocene ridge and swale terrain

5,000 years of resource exploitation by humans (AMNH)!

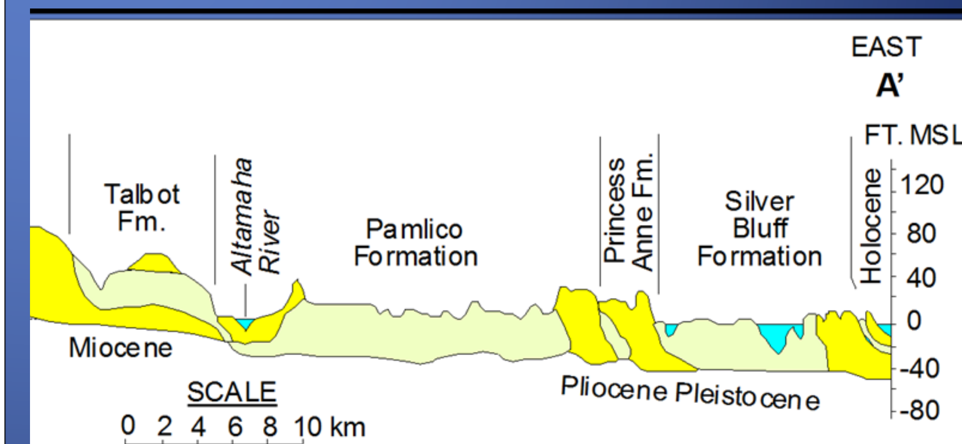
SCI Geological Setting:

Pleistocene Silver Bluff Shoreline Complex core with flanking and covering Holocene sediments



(After Hoyt & Hails, 1968)

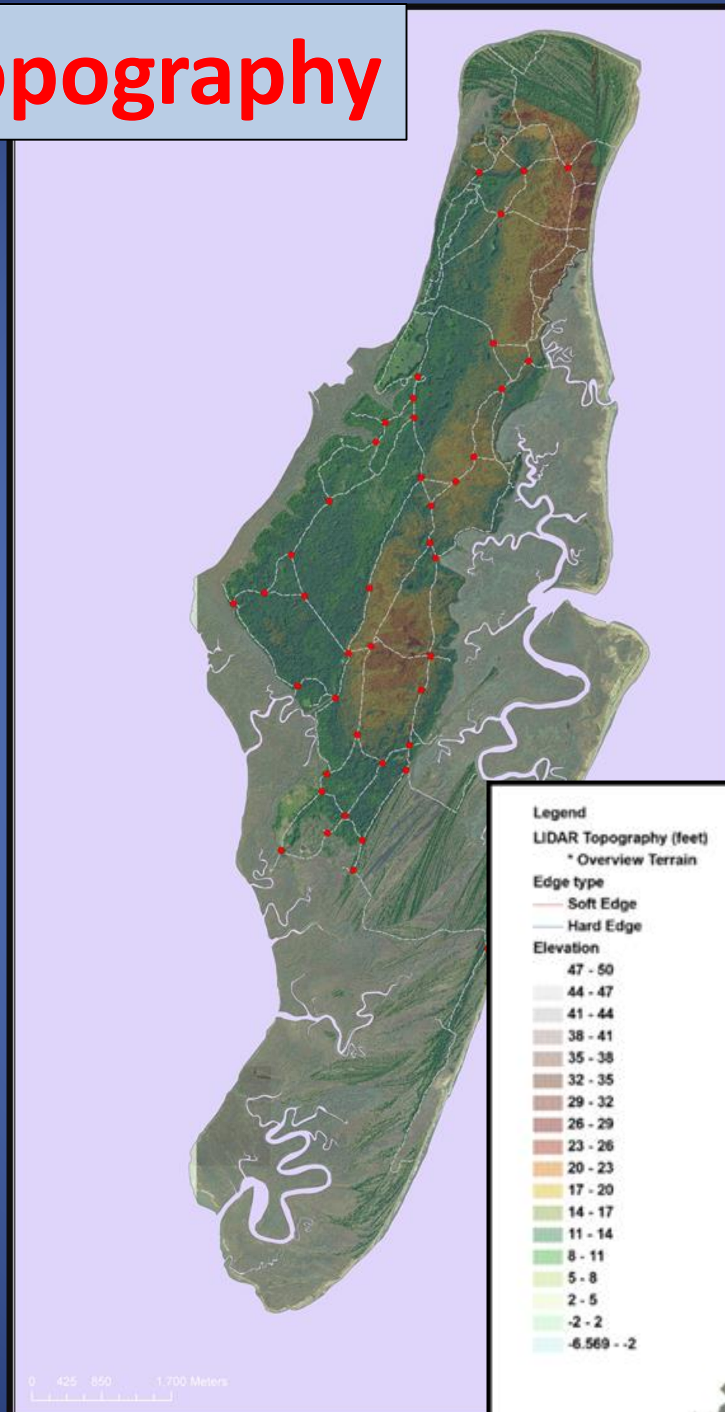
St. Catherines Island



(After Hoyt & Hails, 1968)

SCI Core Topography

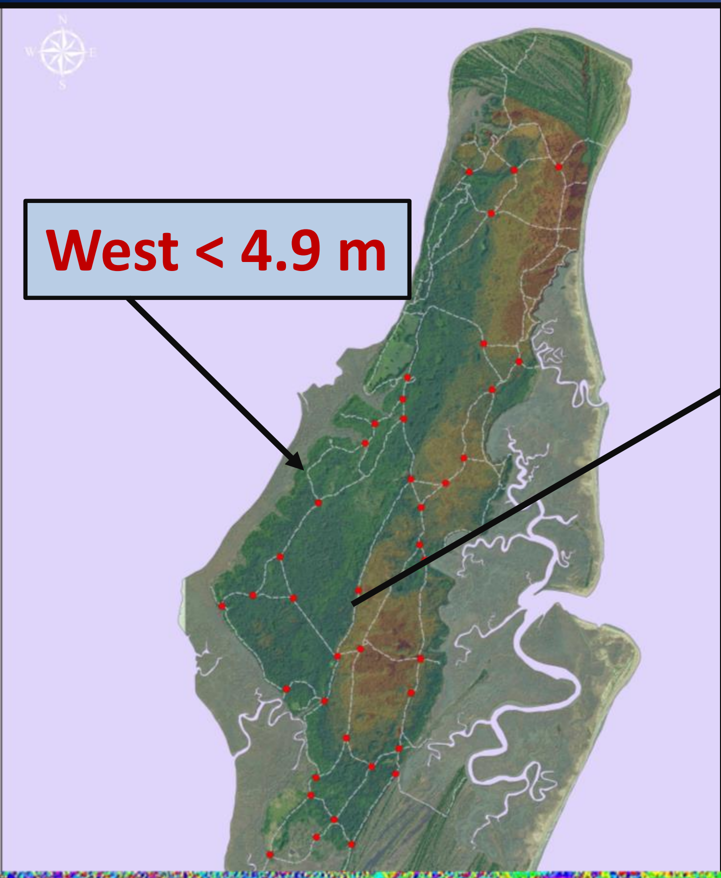
Western core lowlands and axial depression elevation:
 0.6 to 4.9 m elevation

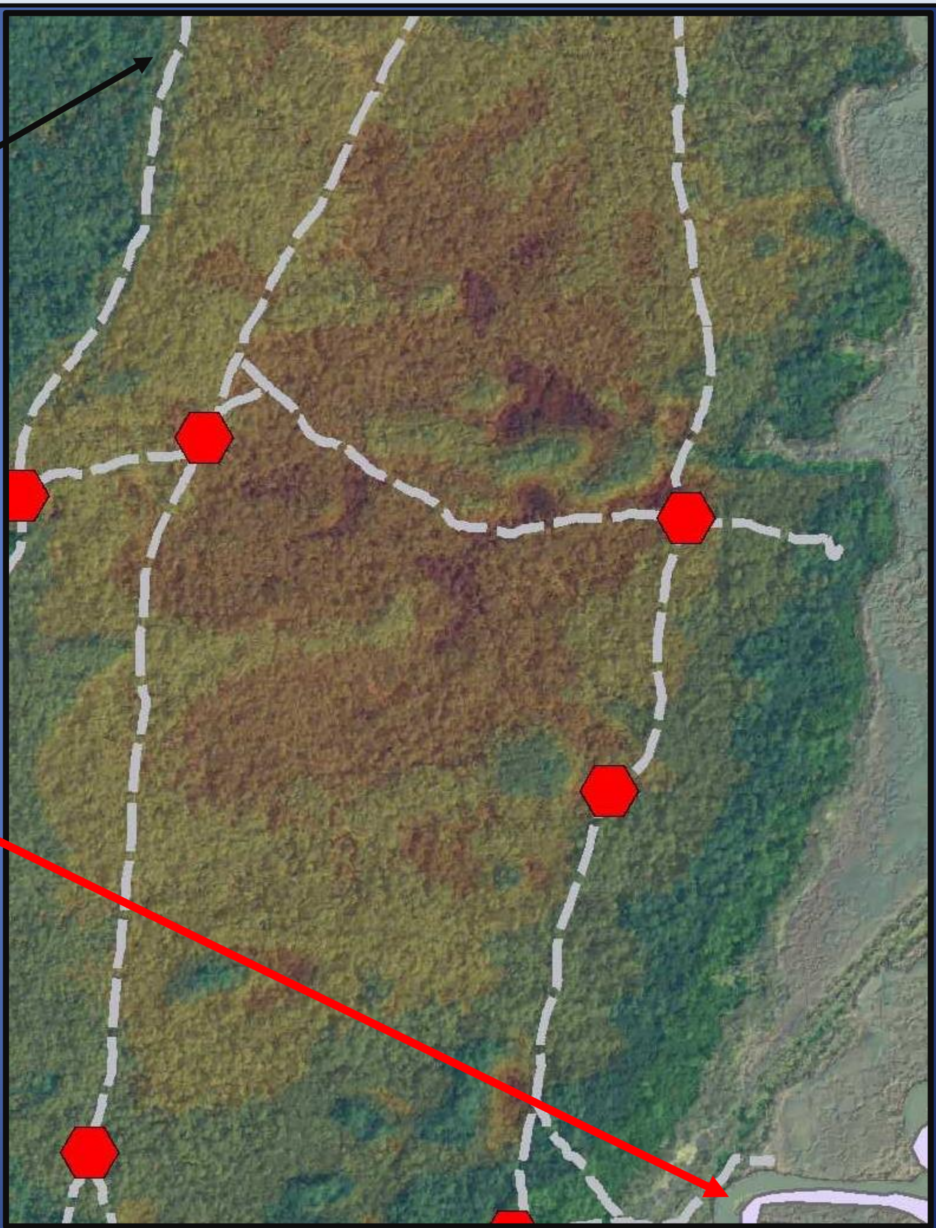


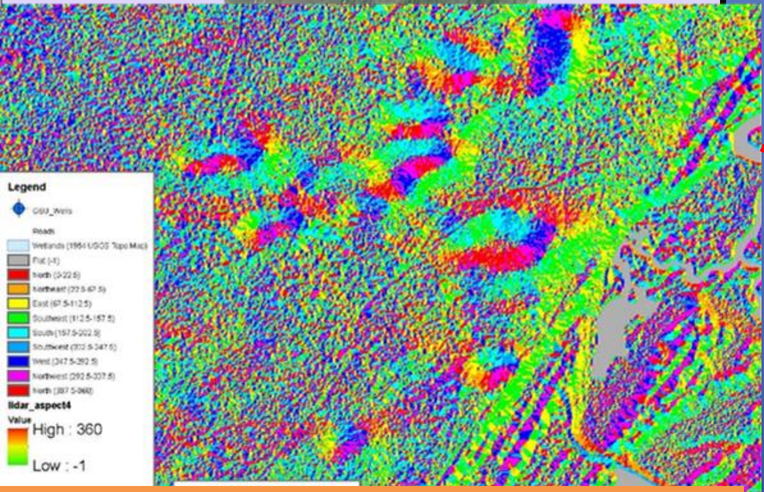
Eastern core elevation:
 4.3 to 7.9 m elevation

LiDAR based map from Brian Meyer

Core hole data - surficial sand thickness: East > 10.7 m







LIDAR Surface Slope Aspect Map

Hydrologic Evolution of St. Catherines Island

- **<u>1753 journal of Jonathan Bryan on SCI</u>**:
- "…the middle of the island appears a perfect Meadow being a large Savannah of about a Mile or Mile and half wide and four or five miles long, and finely water'd with Springs…"
- …"the cristial [crystal] Streams…"
- Palynoflora from cores verifies former wetlands.
- Mandarin-Rutledge soils mark former wetlands on USDA soil maps

(Hayes & Thomas, 2008; Ferguson, Rich, Vance, 2010)

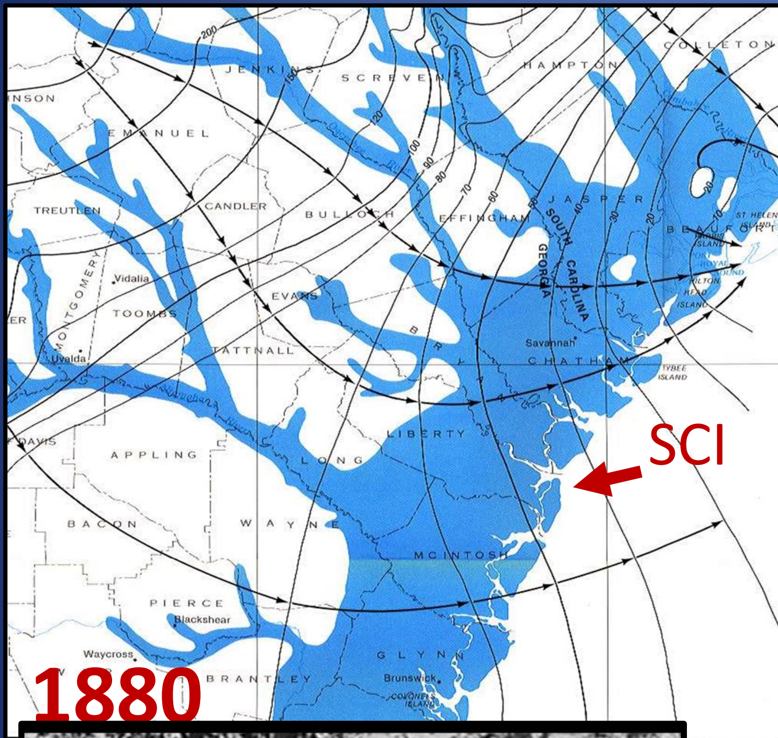
Central Depression vibracores

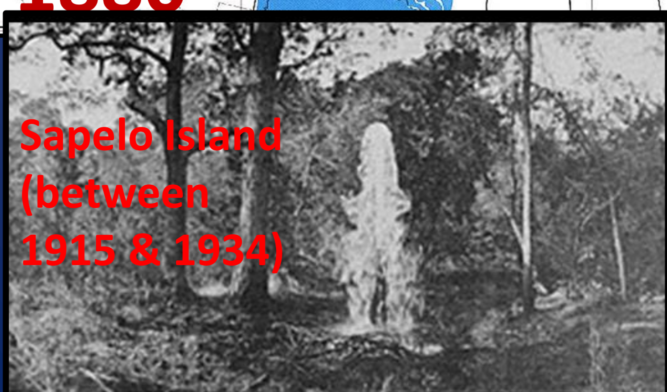
Organic sediment with fresh water palynoflora

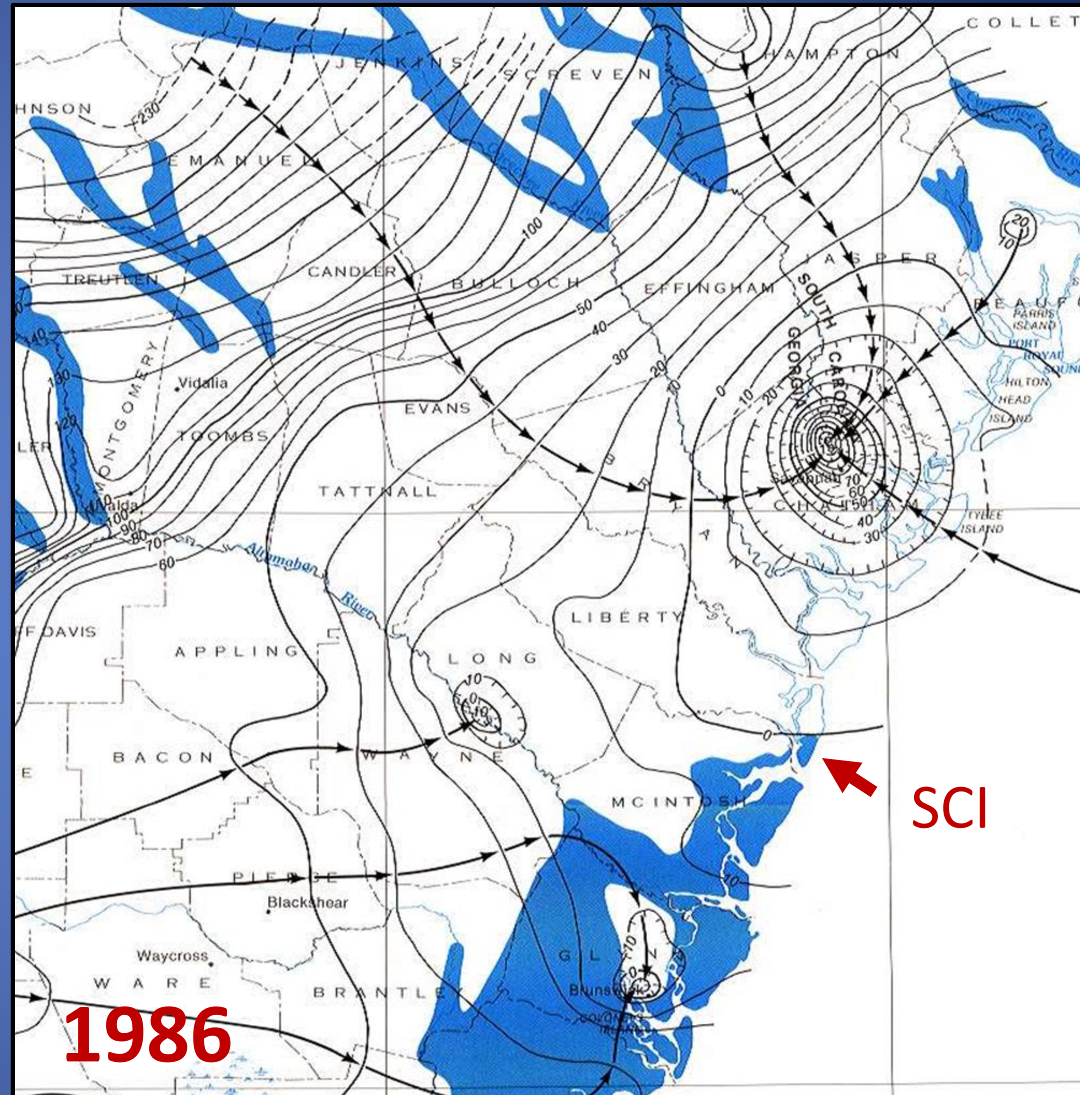
Ghost shrimp burrows

Upper Floridan aquifer - (Krause and Randolph, 1989)

Blue – areas of potential artesian flow



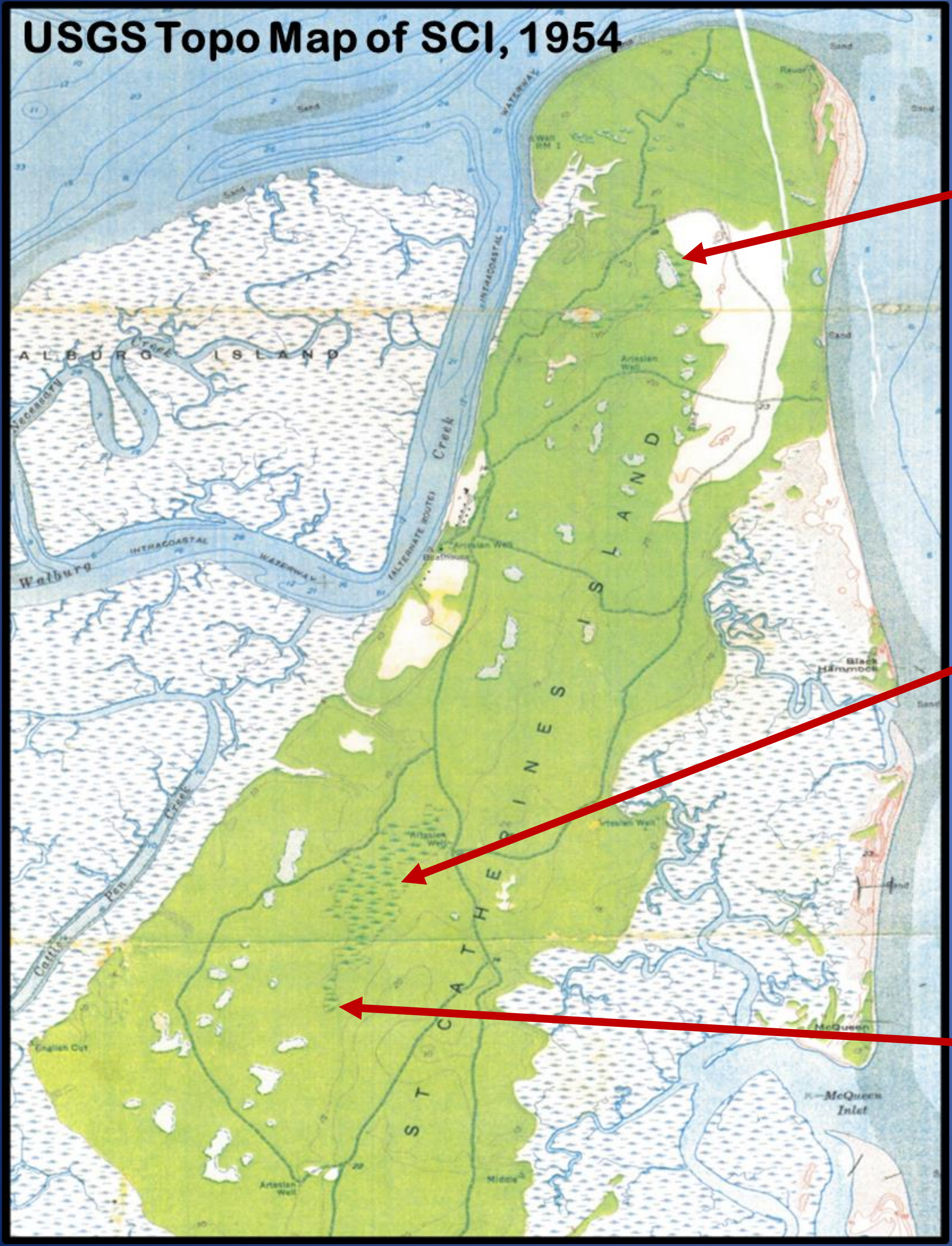




1880 – SCI on ~45 ft potentiometric contour

1986 – SCI on sea level potentiometric contour

Ecological Succession: open wetlands→ swamp→ maritime forest



Investigating SCI Hydrogeology

Field Research: Vibracoring, Geoprobe coring, sampling existing Floridan wells, shallow well installation and monitoring.

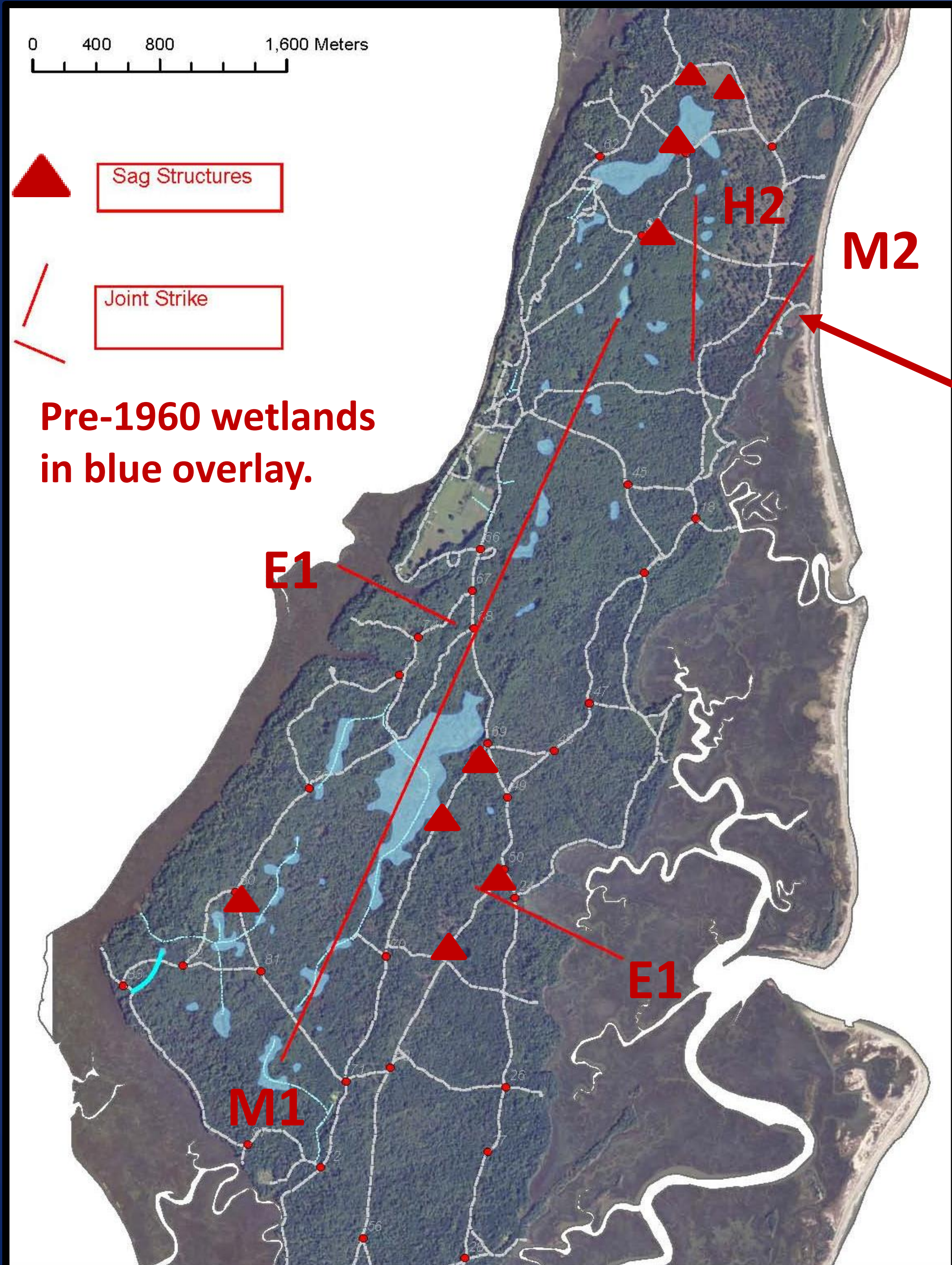
Geophysics: GPR & Resistivity profiling

Lab: water chemistry, palynology, radiocarbon dating (Beta Analytic)

SCI Hydrologic History

- The "crystal springs" described by Bryan in 1753 were certainly Artesian springs tapping the Upper Floridan aquifer.
- The occurrence of these springs <u>requires</u> a breach in the confining layers above the Upper Floridan aquifer.
- Near surface structural evidence?
- Aqueous chemistry evidence?

Structural Components of St. Catherines Island

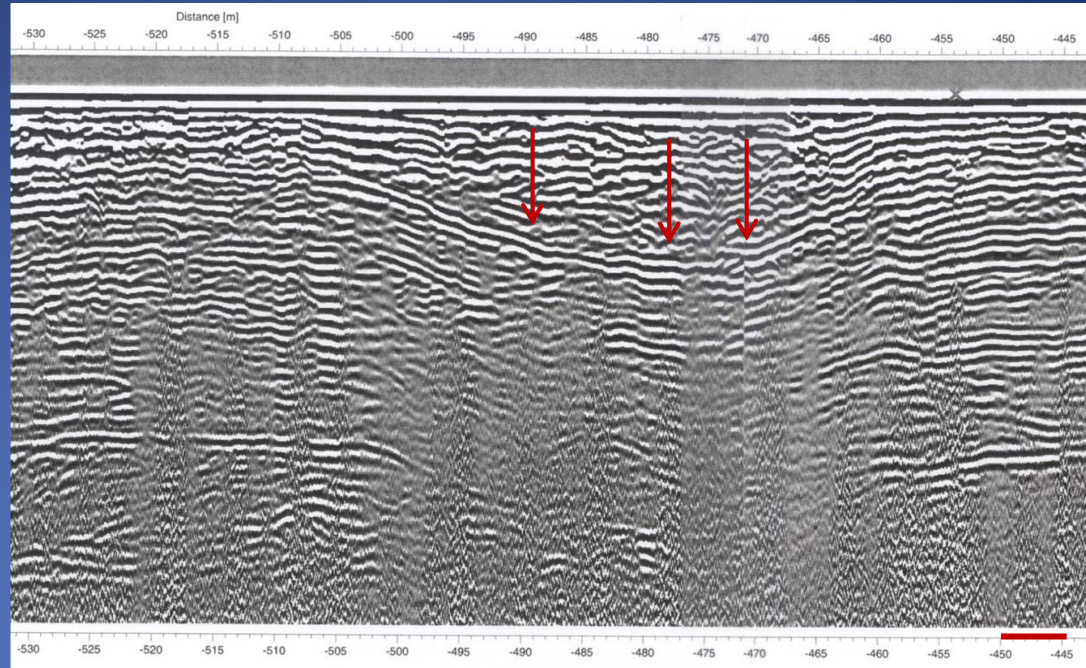


Yellow Banks Joint Trend

Coastal Plain joint trends after Bartholomew et al., 2007

N24ºE trend (M1) is same as interpreted Brunswick fault trend of Maslia and Prowell (1988) and Atlantic Coast Fault System

Sag Structures on 100 MHz GPR Profiles

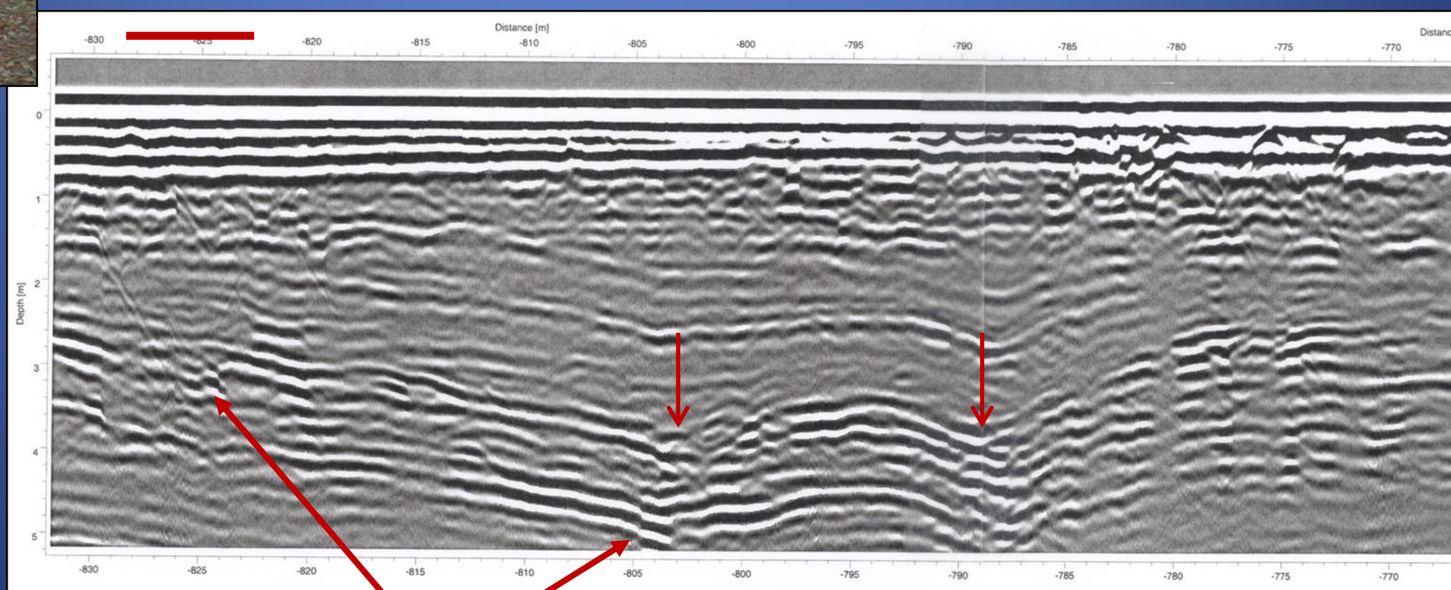


~ 2 m

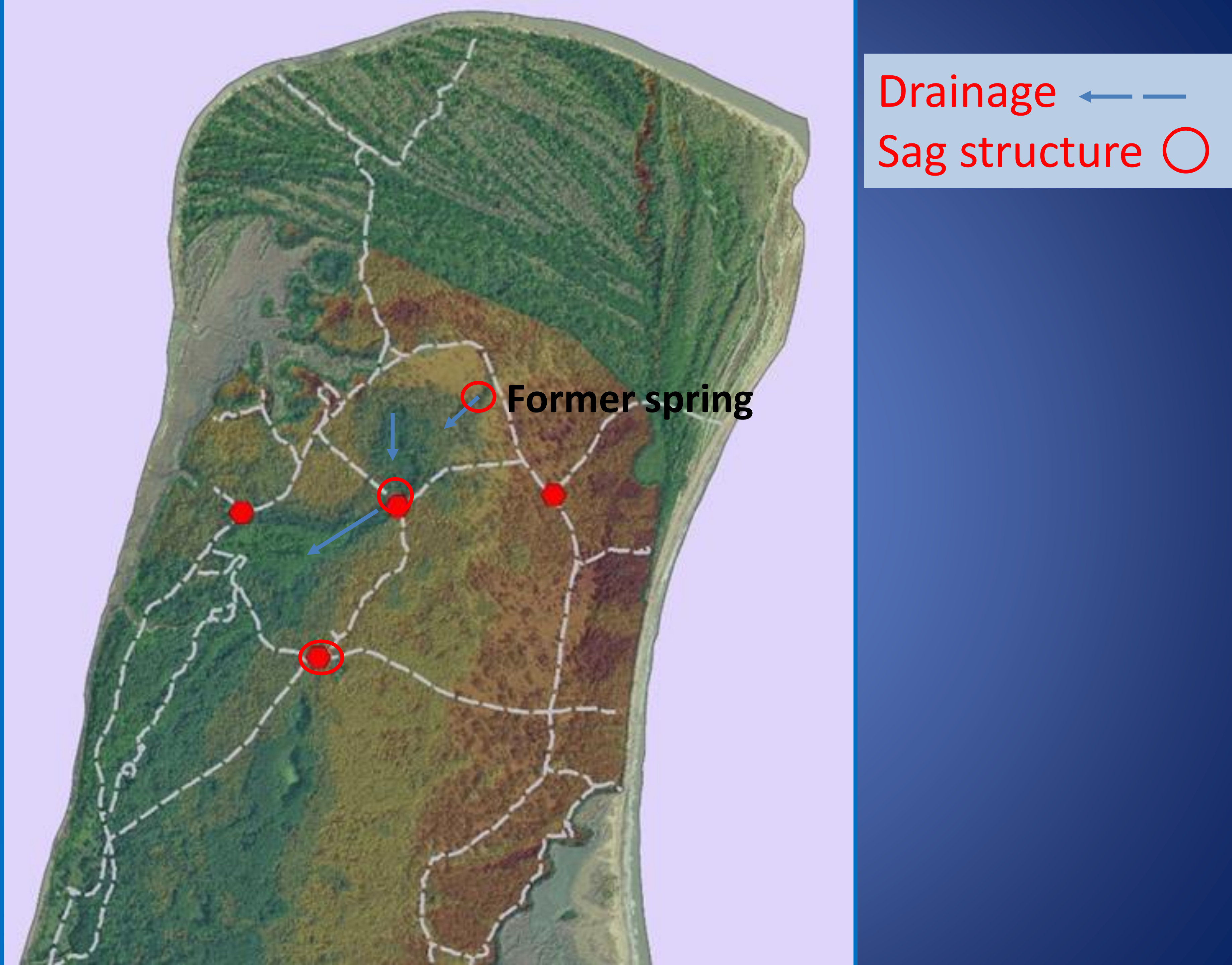
5 m

5 m

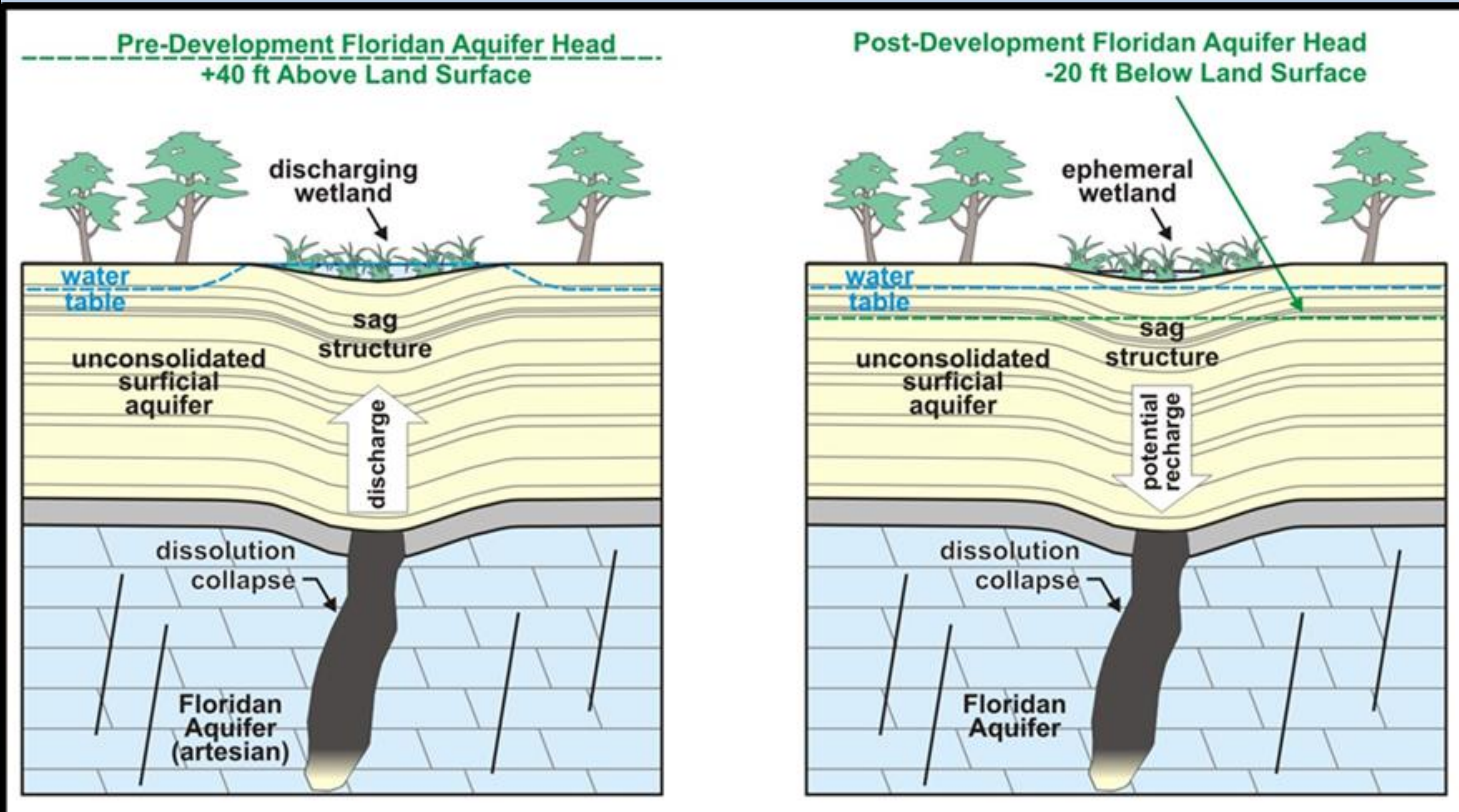
~2 m



faults


Former spring
Drainage
Sag structure

SCI sag structures are interpreted as hypogene karst features produced by focused flow and dissolution of Upper Floridan carbonate rocks along faults and joints.

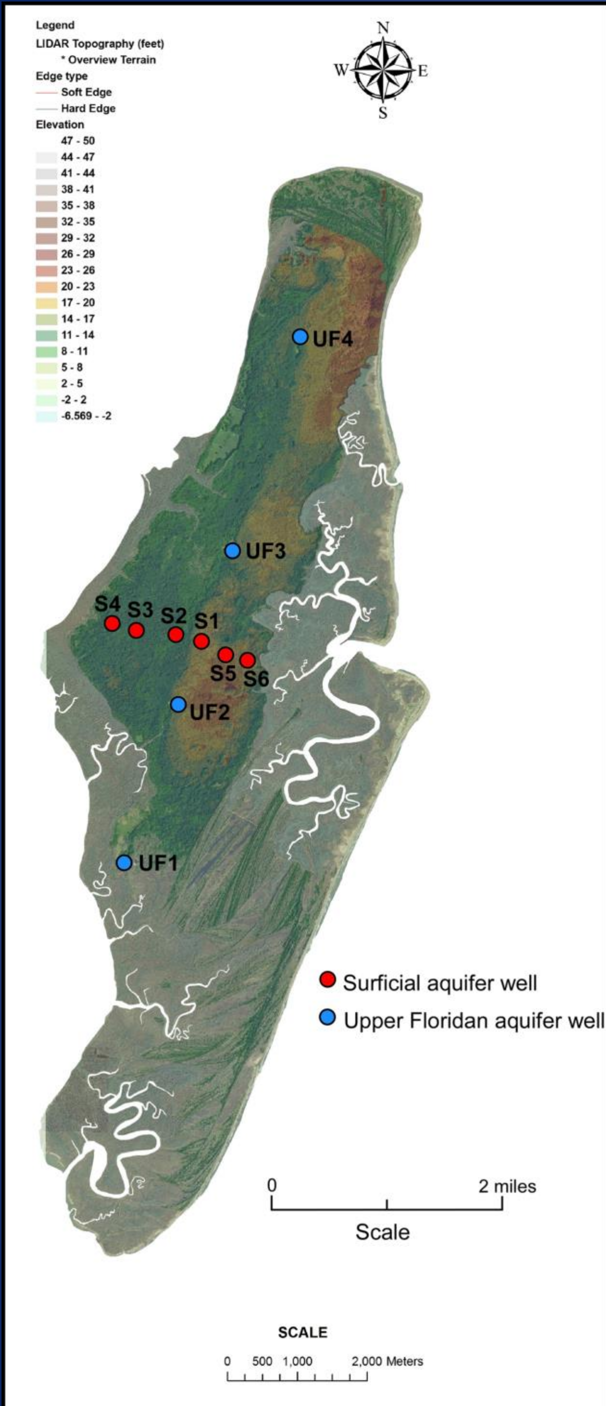


Graphic by Brian Meyer

Initial Sinkhole Development – Bulloch County, GA Feb. 2019

origin by cavern collapse in Upper Floridan carbonates (> 300 ft)

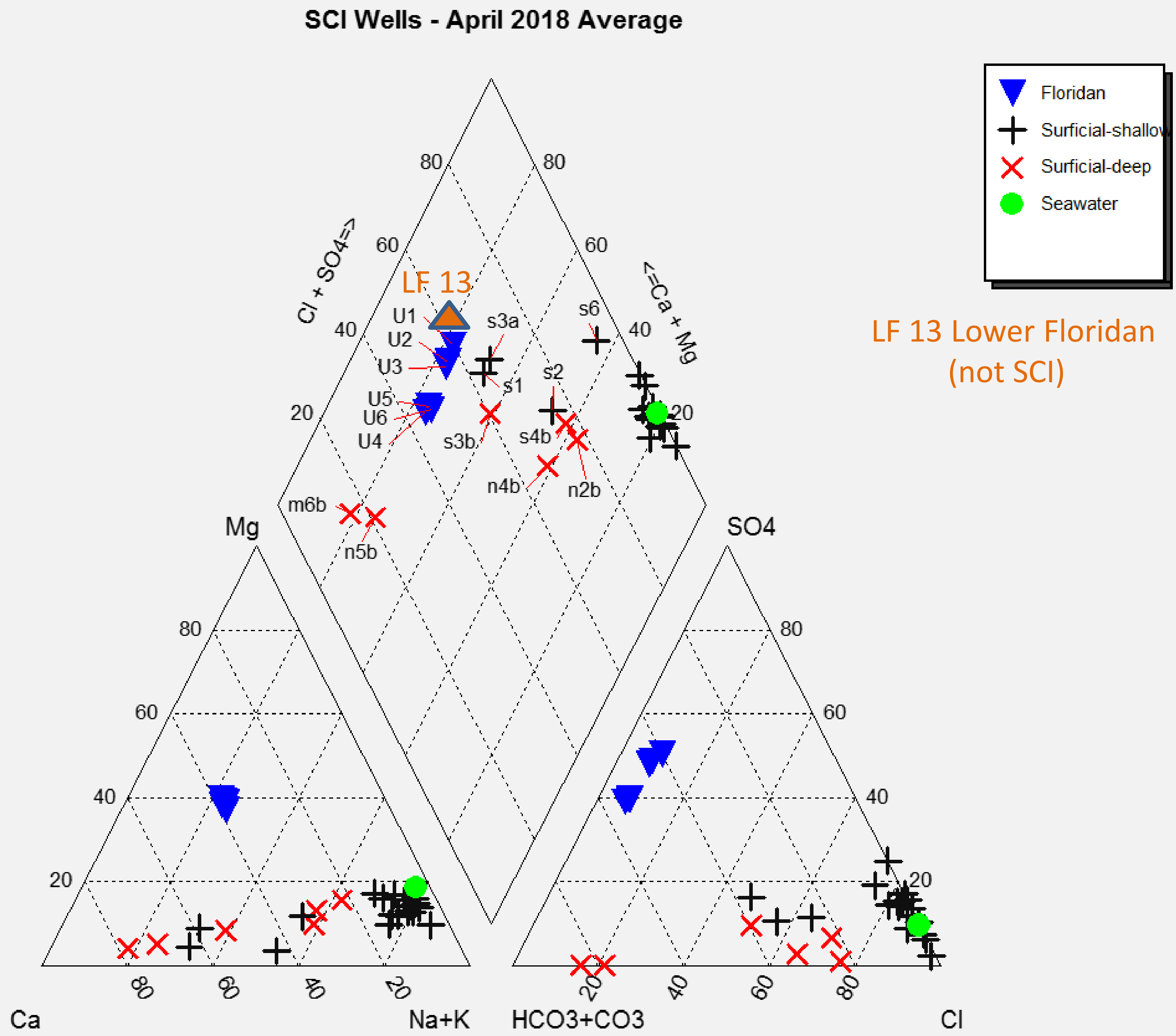
Note: The water from the Floridan well in the house nearby turned muddy when this depression appeared.



Water Chemistry - Floridan Wells

Sampling and analyses from Upper Floridan wells indicate saline water intrusion from below (Reichard et al., 2014).

Salt water source is Lower Floridan and intrusion occurs via upconing along faults as it does at Brunswick, GA.

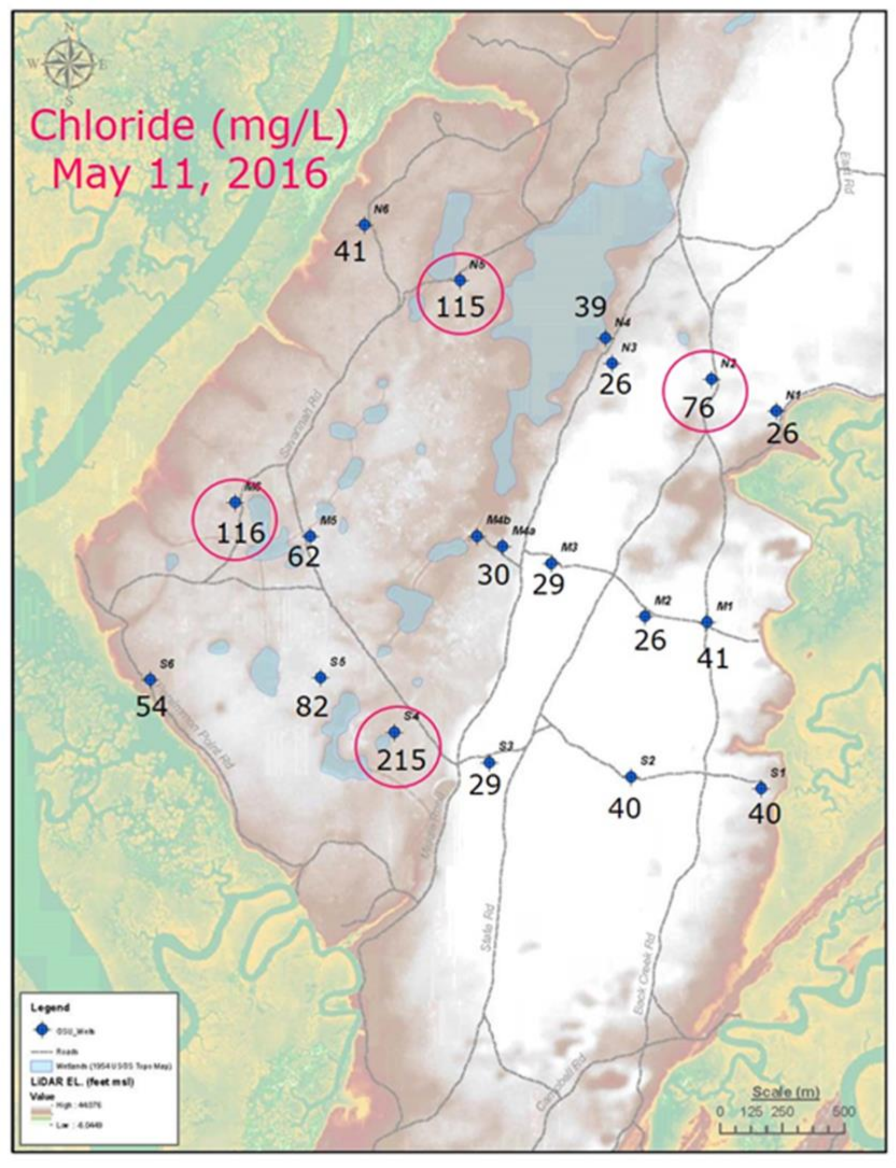


LF 13 Lower Floridan
(not SCI)

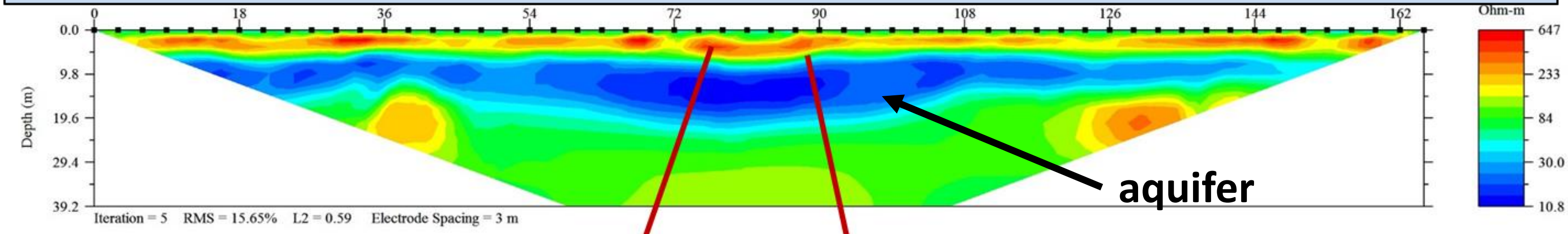
Surficial Aquifers Also Display Salt Water Intrusion

Shallow well field consists of 18 wells (<7.3 m deep), 6 wells (13.4 – 14.6 m deep)

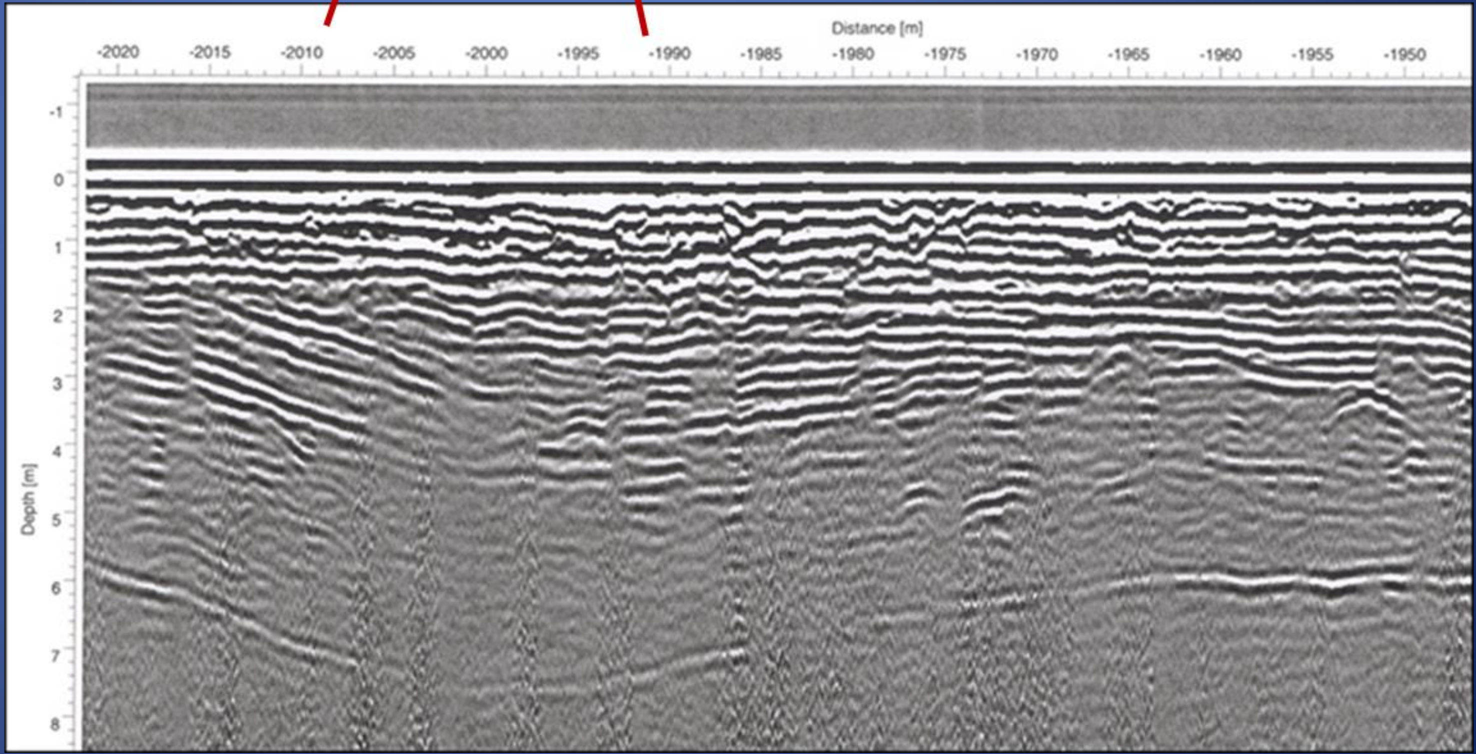
"Snapshot" of chloride concentration in the surficial aquifer on St. Catherines. Circled wells have concentrations that change rapidly in response to King Tide events.



Exploring Links Between Structure and Hydrology



Resistivity Profile



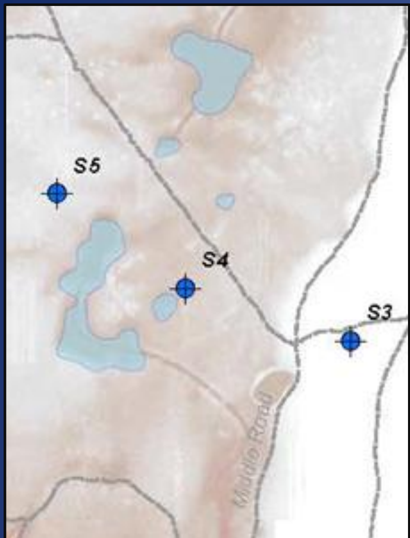
Sag Structure - 100 MHz GPR profile

Resistivity Profiles, Core & well data (site S4):

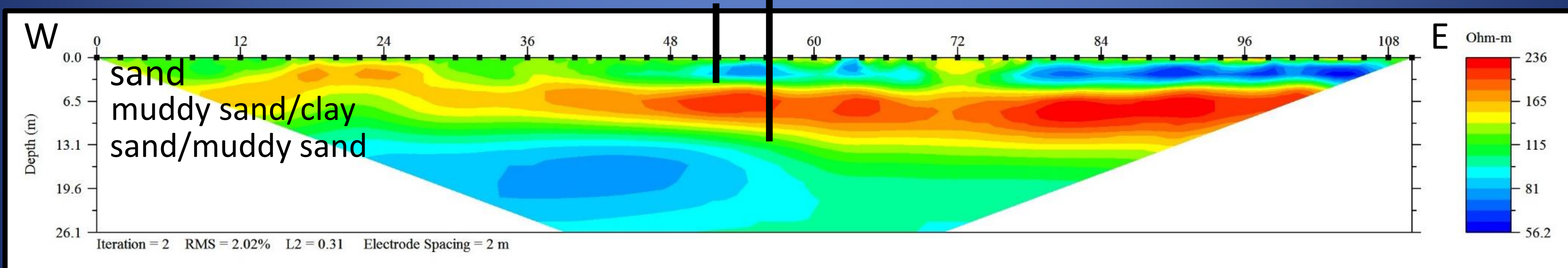
0 – 1.5 m: hydric black sandy top soil
1.5 m - 7.3 m: sand
(3.0 m - plant clast 9516-9401 BP)
} **Water Table Aquifer**

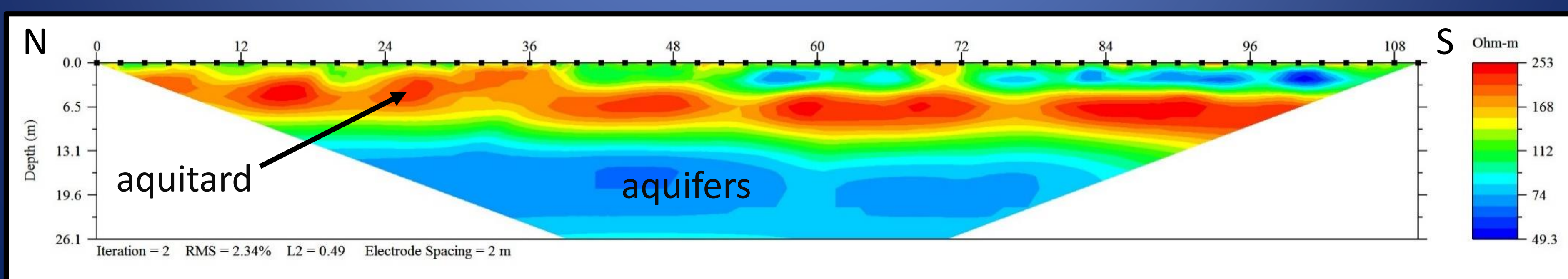
7.3 m – 12.2 m: dense muddy sand & clay } **Aquitard**

(7.6 m – plant clast >43,500 BP)
12.2 – 13.4 m: sand & muddy sand
} **Semi-confined Aquifer**



Wells: shallow - Cl 39.28
deep - Cl 26.96

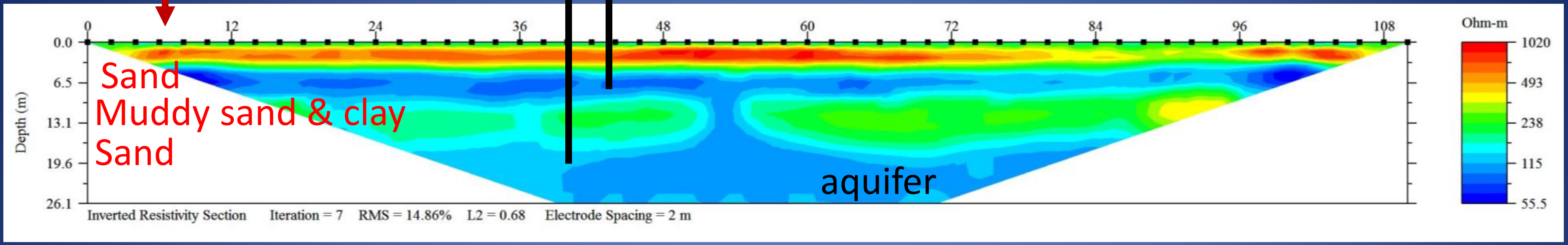




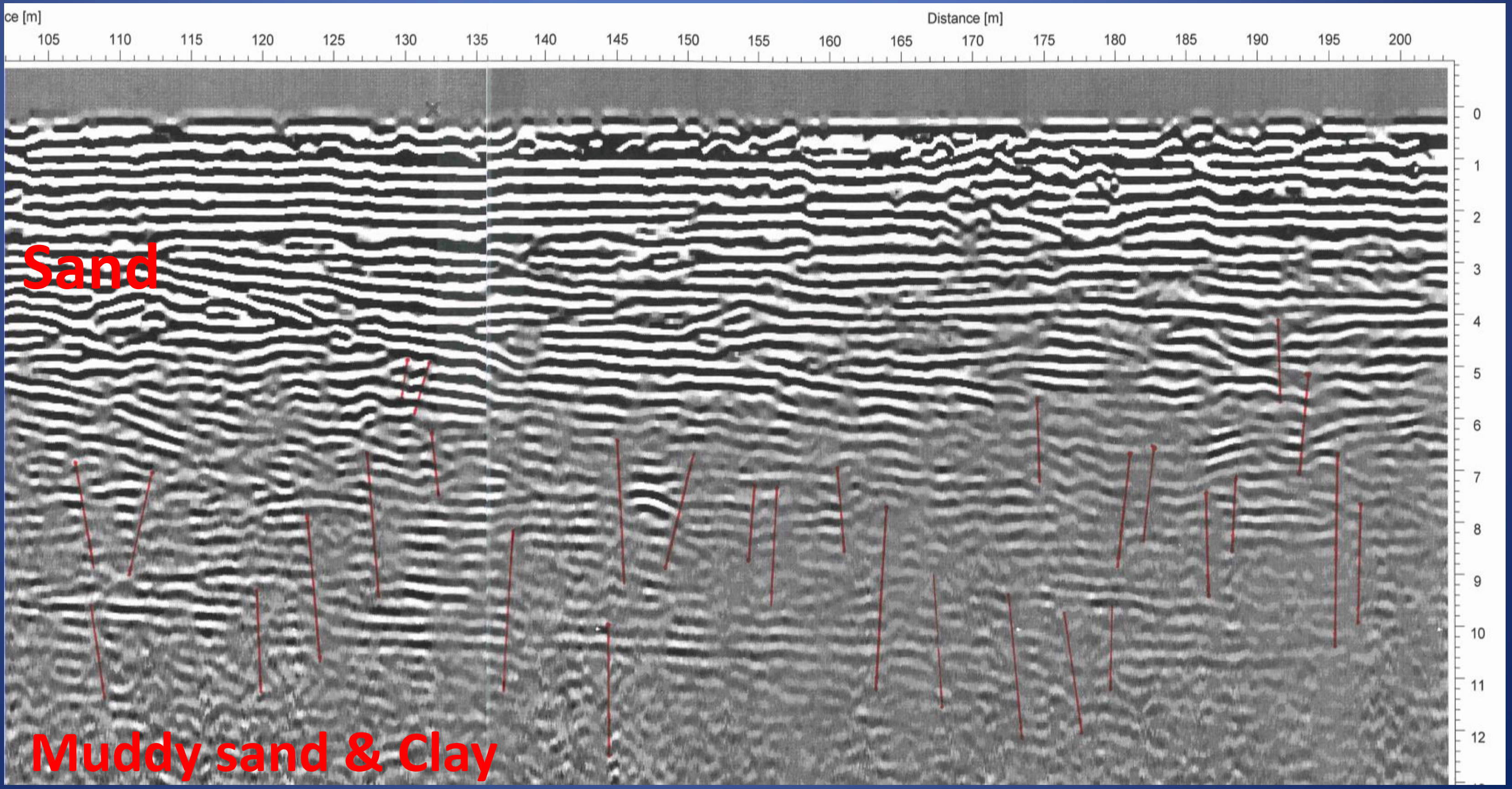
Resistivity Profile across S3 Well Site

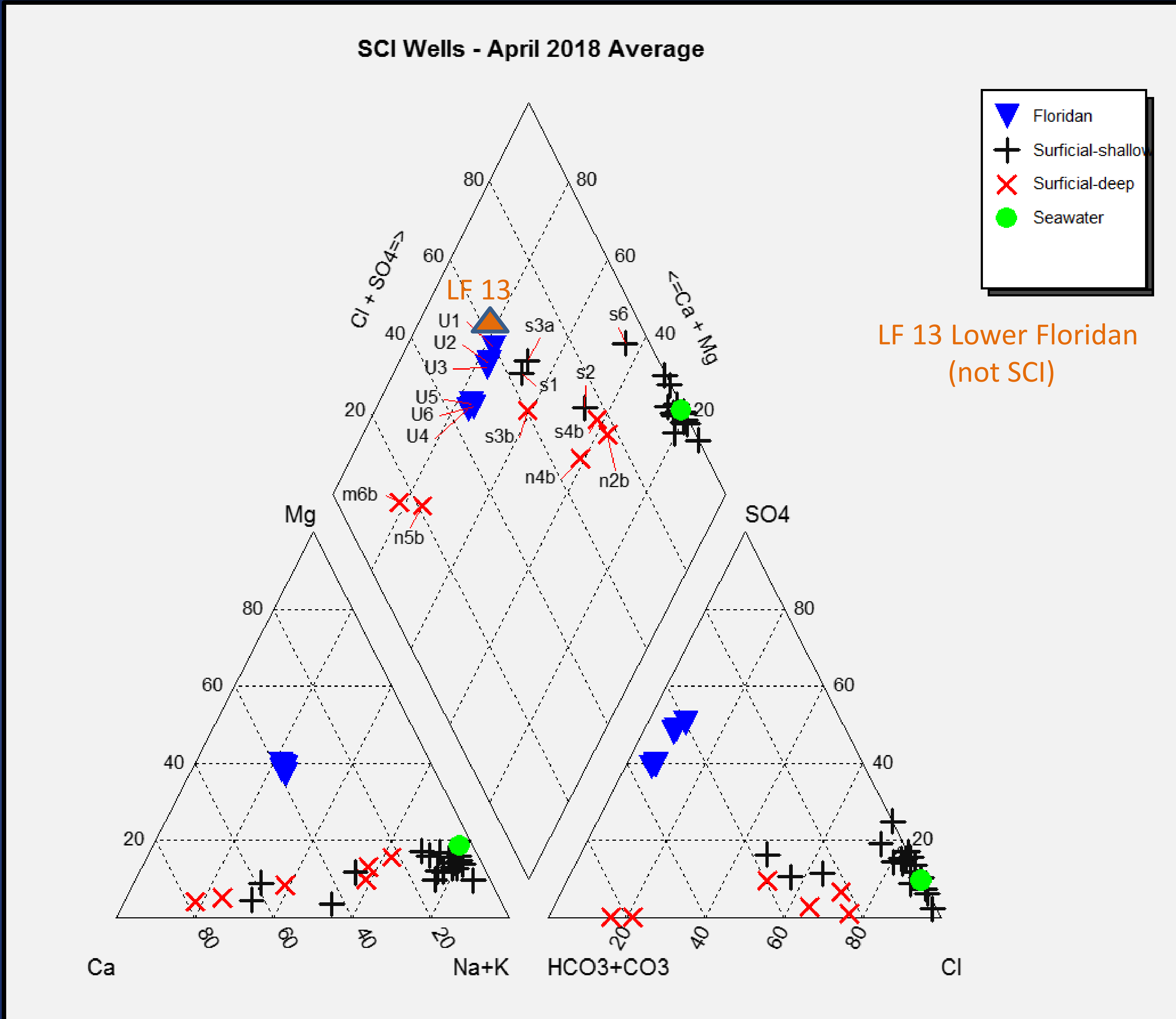
Core Data

Wells: shallow Cl 28.5
deep Cl 28.1



100 MHz GPR profile




SCI Wells - April 2018 Average
Floridan
Surficial-shallow
Surficial-deep
Seawater
LF 13
LF 13 Lower Floridan (not SCI)
Cl + SO4=>
<=Ca + Mg
Mg
SO4
Ca
Na+K
HCO3+CO3
Cl
U1
U2
U3
U4
U5
U6
s1
s2
s3a
s3b
s4b
s6
n2b
n4b
n5b
m6b

Summary - Conclusions

- **Upper Floridan**: Up coning of Lower Floridan saline water permitted by fault zones enhanced by dissolution in carbonates.
- **Shallow aquifers**: Water table aquifer, and deeper semi-confined aquifer, with local communication.
- **Shallow aquifers:** Strong focused response to king tides and storm surges favors structural pathways
- **Shallow aquifers**: Lateral invasion of sea water along fault splays.
- Former artesian springs **require faults**. Offset in subsurface marker bed across lineament supports shallow fault splays.

Acknowledgements

Georgia Sea Grant – major research funding

St. Catherines Island Research Foundation – logistical support and housing

Dept. of Geology and Geography – Georgia Southern University

Georgia Southern University research assistants - Albert Killingsworth and Jaynie Gaskin

<u>GSU & Ga State Student assistants</u>: Ryan Diederich, Anne Delua, Erin Brinkman, Scott Thorson, Clara Rucker, Tanner Avery, Douglas Madrid, Jake Swanson, Amber Degon, Jake Lindsay, Lo Anderson, Steven Dobson, John Bankhead, Tim Herold, John Jackson, Sarah walker, Darci Kaiser, Montana Carter, Steve Sullivan, Bailey Williams, Katherine Curran, Sydney Shaw, Daniel Grey, Emily Fischer, Sheri Williams, Isaiah Deane, Toby Johnson, William Laaker