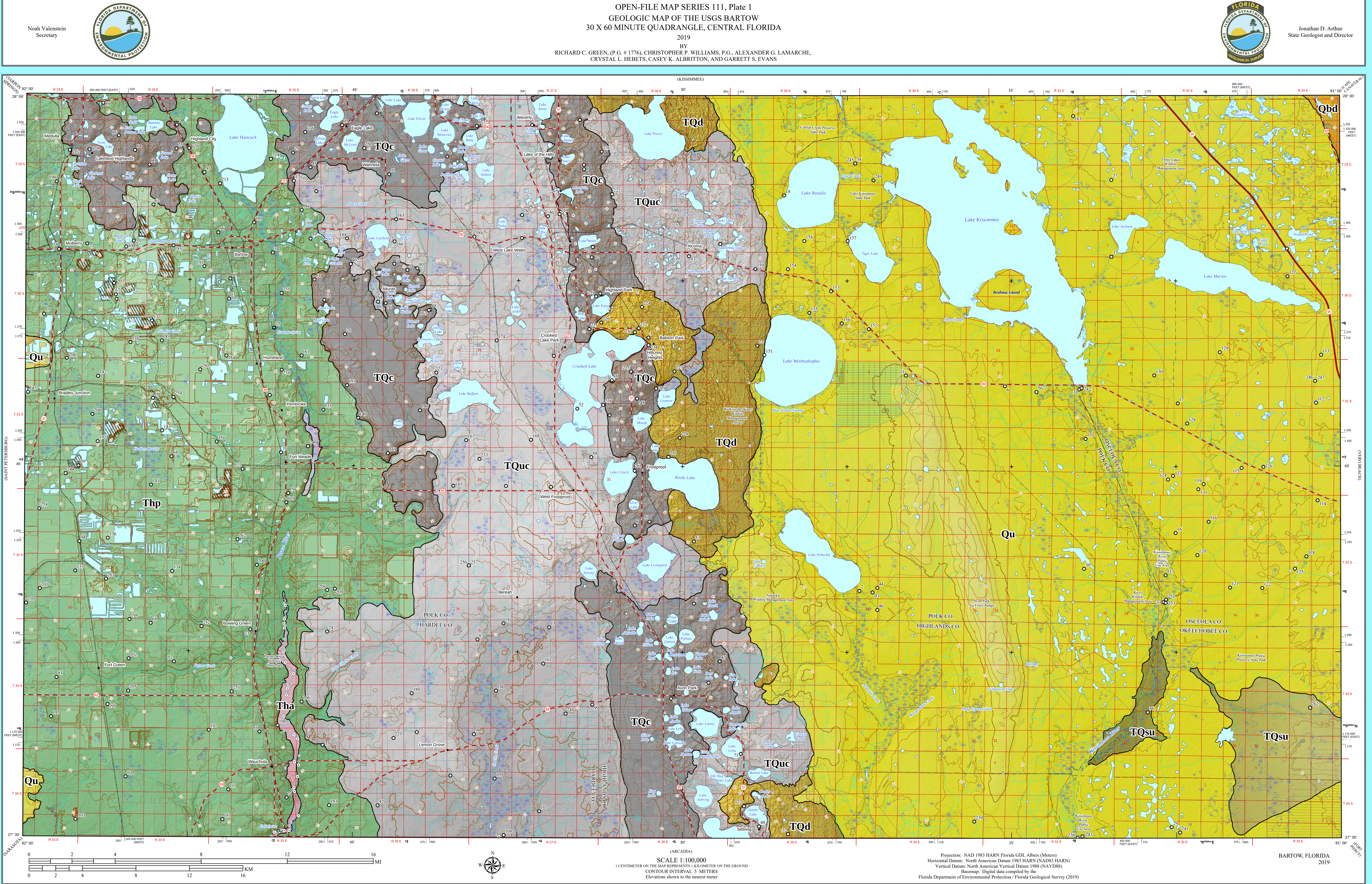




Quaternary beach ridge and dune
Qbd
Quaternary beach ridge and dune sediments (Qbd) are a subdivision of the undifferentiated Quaternary sediments that are noted on the basis of surficial expression of relict beach ridges and dunes. While not a formally recognized lithostratigraphic unit, Qbd is mapped in order to facilitate a better understanding of Florida's geology. Beach ridge and dune sediments are dominantly siliceous sands and are unconsolidated to poorly consolidated. Organics typically occur as disseminated organic matrix, roots and plant debris, carbonized remains, or charcoal.

Quaternary sediments
Qu
While not a formally recognized lithostratigraphic unit, undifferentiated Quaternary (Qu) sediments are mapped in order to better understand Florida's geology. These undifferentiated Quaternary sediments consist of white to gray to orange, fine to coarse-grained, clean to clayey unfossiliferous sands, sandy clays and clays with variable admixtures of organics.

Tertiary/Quaternary dunes
TQd
Tertiary/Quaternary dunes (TQd), while not a formally recognized lithostratigraphic unit, are mapped in order to facilitate a better understanding of Florida's geology. Where LIDAR is available, these dunes are readily differentiated from other units by their distinct topographic expression. These dune sediments contain fine-to-medium quartz sand with varying amounts of disseminated organic matter. They are generally found at elevations above 100 feet (30.5 meters) mean sea level, although there are areas along the flanks of the Lake Wales Ridge where elevations of these dune sands can be lower. Sands forming these dunes are derived from re-working of sediments from the Cypresshead Formation (TQc) and undifferentiated Quaternary sediments (Qu).

Undifferentiated reworked Cypresshead sediments
TQuc
Sediments mapped as undifferentiated reworked Tertiary/Quaternary Cypresshead Formation (TQuc) in the study area are the result of post-depositional reworking of Cypresshead Formation sediments. The reworked Cypresshead Formation sediments can range from white to gray to orange to light brown to grayish brown. They are fine to coarse quartz sands with scattered quartz gravel and varying percentages of clay in the matrix.

Cypresshead Formation
TQc
The Pliocene/Pleistocene Cypresshead Formation (TQc) is a mottled reddish-brown to reddish-orange to white, unconsolidated to poorly consolidated, fine- to very- coarse grained, variably clayey to clean quartz sand. Cross-bedded sands and bimodal sand size distributions are common within this formation. Discoid quartz pebbles, heavy mineral grains, and mica, are often present. Ghosts of nearshore marine mollusks are rare. The Cypresshead Formation is present throughout much of the study area and forms the core of the various ridges present in the region. The lower portion of the Cypresshead Formation frequently becomes a more weathered, finer-grained, well-sorted sand and silt. In cores, the unit is often characterized by beds of fine-grained, well-sorted sand with thin layers of clay dispersed throughout the sand. Occasional coarse sand beds may occur.

Undifferentiated Tertiary/Quaternary shelly sediments
TQsu
Undifferentiated Pliocene/Pleistocene shelly sediments (TQsu) typically consist of fine-to-medium quartz sand with variable amounts of calcareous silt, marine mollusk shells, and clay. Shells, which may vary from whole to fragments, are normally highly weathered and abraded and may occasionally become the dominant lithology. Other accessory minerals may include calcite, aragonite, mica, heavy minerals, and phosphate sand and gravel. A basal phosphate lag is often present. Colors range from light gray to light-olive gray. In the study area, TQsu is predominantly in the form of unconsolidated sands with varying percentages of shell fragments.

Hawthorn Group, Peace River Formation
Thp
The middle Miocene to lower Pliocene Peace River Formation (Thp) is composed of yellowish gray to olive gray, interbedded sands, clays and carbonates with the siliceous component being dominant. Phosphate sand and gravel are most common in the uppermost beds, although they are generally interspersed throughout the unit. The Peace River Formation contains a diverse fossil assemblage of marine and terrestrial fauna (e.g., shark teeth, ray spines, horse teeth, dugong, and whale ribs). Porosity types in the formation are generally intergranular.

Hawthorn Group, Arcadia Formation
Tha
The upper Oligocene to middle Miocene Arcadia Formation (Tha) is a yellowish gray to white, variably sandy (quartz and phosphoric) carbonate, intercalated with beds of siliceous-dominant sediments. Although limestone is present, dolomites are most common, ranging in grain size from micritic to medium, with the coarsest material being sucrosic. Minor

Gypsum stack
Mining activities in the central Florida phosphate district have created numerous "gypstacks" which are mounds of phosphogypsum derived sand and gravel. A basal phosphate lag is often present. Colors range from light gray to light-olive gray. In the study area, TQsu is predominantly in the form of unconsolidated sands with varying percentages of shell fragments.

LEGEND
Primary highway
Secondary highway
Light duty road, principal street
Railroad
County boundary
State lands and parks
Contours (5m)
Intermediate
Core
Cuttings
M-Series sample
Outcrop/exposure
Borrow pit
Quarry / sand mine
Spring
City/town
Index
Area affected by mining
Waterbody
Wetland
River or stream
Cross section line
U.S. Public Lands Survey Township/Range
U.S. Public Lands Survey Section
Base map: Coordinate Explanation
USGS 1:24,000
Quadrangle tick mark
1:175 = 1:275,000 FEET (WEST)
1:175 = 1:275,000 FEET (EAST)

CROSS-SECTION REFERENCE MAP (see Plate 2 and OFR108)
1 Tarpon Springs (OFMS 104)
2 Kissimmee (OFMS 110)
3 Cape Canaveral
4 Saint Petersburg (OFMS 109)
5 Vero Beach (to be mapped 2020)
6 Sarasota (OFMS 86)
7 Arcadia (OFMS 87/88)
8 Fort Pierce

ADJOINING MAPS
1 2 3
4 5 6
7 8

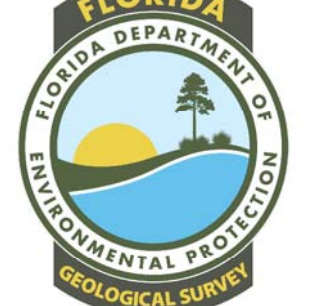
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850.617.4316
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Noah Valenstein
Secretary



OPEN-FILE MAP SERIES 111, Plate 2
GEOLOGIC CROSS-SECTIONS FOR THE USGS BARTOW
30 X 60 MINUTE QUADRANGLE, CENTRAL FLORIDA
2019
BY
RICHARD C. GREEN, (P.G. # 1776), CHRISTOPHER P. WILLIAMS, P.G., ALEXANDER G. LAMARCHE,
CRYSTAL L. HEBETS, CASEY K. ALBRITTON, AND GARRETT S. EVANS



Jonathan D. Arthur
State Geologist and Director

A WEST **A' EAST**

W-1864 W-14503 W-952 W-341 W-9259 W-19749 W-15336

R 24 E | R 25 E R 25 E | R 26 E R 26 E | R 27 E R 27 E | R 28 E R 28 E | R 29 E R 29 E | R 30 E R 30 E | R 31 E

LAKE HANCOCK LAKE ROSALIE LAKE KISSIMMEE

TD = 619' BLS TD = 667' BLS TD = 663' BLS TD = 732' BLS TD = 530' BLS TD = 860' BLS

SCALE 0 0.5 1 2 3 4 5 MILES
0 1 2 3 4 5 6 7 8 KILOMETERS
VERTICAL EXAGGERATION = 10 TIMES HORIZONTAL SCALE

B WEST **B' EAST**

W-18807 W-9277 W-9348 W-16308 W-623 W-11179 W-4503 W-1710 W-17141 W-9150

R 25 E | R 26 E R 26 E | R 27 E R 27 E | R 28 E R 28 E | R 29 E R 29 E | R 30 E R 30 E | R 31 E R 31 E | R 32 E

PEACE RIVER CROOKED LAKE LAKE WEEHYAKAPKA KISSIMMEE RIVER

TD = 585' BLS TD = 664' BLS TD = 620' BLS TD = 967' BLS TD = 976' BLS TD = 880' BLS

SCALE 0 0.5 1 2 3 4 5 MILES
0 1 2 3 4 5 6 7 8 KILOMETERS
VERTICAL EXAGGERATION = 10 TIMES HORIZONTAL SCALE

C WEST **C' EAST**

W-13712 W-14137 W-9049 W-9048 W-2842 W-437 W-17022 W-18629

R 25 E | R 26 E R 26 E | R 27 E R 27 E | R 28 E R 28 E | R 29 E R 29 E | R 30 E R 30 E | R 31 E R 31 E | R 32 E

PEACE RIVER LAKE ARBUCKLE KISSIMMEE RIVER

TD = 667' BLS TD = 1052' BLS TD = 720' BLS TD = 1238' BLS TD = 1000' BLS TD = 1043' BLS

SCALE 0 0.5 1 2 3 4 5 MILES
0 1 2 3 4 5 6 7 8 KILOMETERS
VERTICAL EXAGGERATION = 10 TIMES HORIZONTAL SCALE

D NORTH **D' SOUTH**

W-14503 W-18805 W-18807 W-1008 W-4123 W-9264 W-14137 W-9070

T 29 S | T 30 S T 30 S | T 31 S T 31 S | T 32 S T 32 S | T 33 S T 33 S | T 34 S

PEACE RIVER LAKE CHARLIE CREEK

TD = 667' BLS TD = 802' BLS TD = 836' BLS TD = 780' BLS TD = 1052' BLS

SCALE 0 0.5 1 2 3 4 5 MILES
0 1 2 3 4 5 6 7 8 KILOMETERS
VERTICAL EXAGGERATION = 10 TIMES HORIZONTAL SCALE

Figure 2. Correlation of stratigraphic units.

ERATHEM	SYSTEM	SERIES	AGE (B.S.)	LITHOSTRATIGRAPHIC UNIT	HYDROSTRAT. UNIT
CENOZOIC	QUATERNARY	BECKEN	0.01	UNDIFFERENTIATED QUATERNARY SEDIMENTS	SURFICIAL
		PLUVEAN	2.6	POWERED CYPRUSHEAD FORMATION	ACQUEDUC SYSTEM (SAS)
		BECKEN	5.3	UNDIFFERENTIATED TERTIARY/QUATERNARY BELLY SEDIMENTS	
		BECKEN	11.6	UNDIFFERENTIATED TERTIARY/QUATERNARY BELLY SEDIMENTS	
	TERTIARY	NEOGENE	16.0	PEACE RIVER FORMATION	
		OLIGOCENE	23.0	ARCADIA FORMATION	
		MIocene	27.8	TAMPA MEMBER	
		MIocene	33.9	NOCATEE MEMBER	
		PALEOCENE	37.8	SUWANNEE LIMESTONE	
		PALEOCENE	37.8	OCALA LIMESTONE	
PALEOGENE	37.8	AVON PARK FORMATION			
	37.8	AVON PARK FORMATION			

Figure 1. Location of cross-sections on geologic map.

Scale = 1:80,000

Projection: NAD 1983 HARN Florida GDL Albers (Meters)
Horizontal Datum: North American Datum 1983 HARN (NAD83 HARN)
Vertical Datum: North American Vertical Datum 1988 (NAVD88)

Legend

Map Units

- Qbd: Quaternary beach ridge and dune
- Qs: Undifferentiated Quaternary sediments
- TQsu: Undiff. Tertiary/Quaternary belly sediments
- TQd: Undifferentiated dunes
- TQuc: Undifferentiated reworked Cypresshead sediments
- Thp: Hawthorn Group, Peace River Formation
- Tha: Hawthorn Group, Arcadia Formation
- That: Hawthorn Group, Arcadia Formation, Tampa Member
- Thn: Hawthorn Group, Arcadia Formation, Nocatee Member
- Ts: Suwannee Limestone
- To: Ocala Limestone
- Tap: Avon Park Formation

Cross-Sections

- Qbd: Core
- Qu: Cuttings
- TQsu: Cross-section line
- TQd: City/town
- TQuc: County boundary
- Thp: USGS 1:24,000 Quadrangle
- Tha: USGS 1:24,000 Quadrangle tick mark
- That: Contact
- Thn: Inferred contact
- Ts: TD
- To: BLS
- Tap: Below land surface

Cross-Sections Legend

- Primary highway
- Secondary highway
- State lands and parks
- Waterbody
- Wetland
- River or stream
- Sample interval in feet
- Variable sample interval
- Roads

1:24,000 QUADRANGLE GRID

ADJOINING MAPS

1	2	3
4	5	6
7	8	

1 Tarpon Springs (OFMS 104)
2 Kissimmee (OFMS 110)
3 Cape Canaveral
4 Saint Petersburg (OFMS 109)
5 Vero Beach (to be mapped 2020)
6 Sarasota (OFMS 86)
7 Arcadia (OFMS 87/88)
8 Fort Pierce

Disclaimer

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NOTE: Geologic map and geologic cross-sections may appear to disagree slightly when depicting the upper unit due to the convention of not portraying undifferentiated sediments on the geologic map unless they are thicker than 20 feet (6.1 meters), whereas cross-sections will show all undifferentiated sediments thickness. Additionally, cross-section contacts are based on straight-line projection between wells, which can lead to apparent thickness between wells on the cross-section that are not supported by field evidence or other wells.

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E NORTH **E' SOUTH**

W-5464 W-623 W-1887 W-2842 W-14884 W-18535

T 29 S | T 30 S T 30 S | T 31 S T 31 S | T 32 S T 32 S | T 33 S T 33 S | T 34 S

LAKE WALKER LAKE MOODY LAKE LIVINGSTON BONNET LAKE

TD = 1056' BLS TD = 967' BLS TD = 1023' BLS TD = 1238' BLS TD = 1360' BLS TD = 1877' BLS

SCALE 0 0.5 1 2 3 4 5 MILES
0 1 2 3 4 5 6 7 8 KILOMETERS
VERTICAL EXAGGERATION = 10 TIMES HORIZONTAL SCALE

F NORTH **F' SOUTH**

W-15336 W-19748 W-9150 W-9144 W-18629 W-19735 W-15339

T 29 S | T 30 S T 30 S | T 31 S T 31 S | T 32 S T 32 S | T 33 S T 33 S | T 34 S

LAKE JACSON KISSIMMEE RIVER

TD = 860' BLS TD = 702' BLS

SCALE 0 0.5 1 2 3 4 5 MILES
0 1 2 3 4 5 6 7 8 KILOMETERS
VERTICAL EXAGGERATION = 10 TIMES HORIZONTAL SCALE

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STATE OF FLORIDA

FLORIDA GEOLOGICAL SURVEY

Jonathan D. Arthur, *State Geologist and Director*



OPEN-FILE REPORT 108

Text to accompany geologic map of the USGS Bartow 30 x 60 minute quadrangle, central Florida

By

Richard C. Green, (P.G. # 1776), Christopher P. Williams, Alexander G. Lamarche, Crystal L. Hebets, Casey K. Albritton, and Garrett S. Evans

2019

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ABSTRACT

The accompanying 1:100,000 scale geologic map (Open-File Map Series 111, Plate 1) depicts the areal distribution of bedrock and surficial geologic units for the U.S. Geological Survey (USGS) Bartow 30 x 60 minute quadrangle. The map was constructed using a combination of field mapping (at 1:24,000 scale), compilation of data from existing maps (various scales), core and cuttings analyses and descriptions, and analyses of various Geographic Information System (GIS) data sources. The resulting data were compiled in ESRI® ArcGIS® ArcMap™ 10.6.1 software for publication as part of the Florida Geological Survey Open-File Map Series. Mapped units range in age from late Oligocene to Holocene. Important resources in the mapped area include potable groundwater, sand, clay, phosphate, shells, and limestone. Numerous karst features are present in the study area.

The geologic map and accompanying plates produced for this area not only provide a greater understanding of the interaction between the geologic units, associated karst, springs, and ecosystems, but have utility as a land management tool for economic development, mineral and energy production, and environmental protection for Florida. Examples include designing new construction projects, siting new water supply wells, wastewater treatment plants, energy production facilities, waste management and storage facilities, locating sources of mineable resources, and protection of springs, surface and groundwater quality.

Keywords: Florida, geologic map, Avon Park Formation, Ocala Limestone, Suwannee Limestone, Arcadia Formation, Peace River Formation, Tampa Member, Nocatee Member, Hawthorn Group, Cypresshead Formation, geomorphology, hydrogeology, karst, sinkholes, Floridan aquifer system, Hardee County, Highlands County, Okeechobee County, Osceola County, Polk County, Bartow, Lake Kissimmee State Park, Kissimmee Prairie Preserve State Park, Three Lakes Wildlife Management Area.

INTRODUCTION

Florida Geological Survey (FGS) Open-File Report (OFR) 108 accompanies Open-File Map Series (OFMS) 111, which is comprised of three plates. Plate 1 depicts the near-surface geology of the USGS Bartow 30 x 60 minute quadrangle on a digital elevation model (DEM). Plate 2 depicts six geologic cross-sections, a stratigraphic correlation chart, and a geologic map with cross-section lines for the study area. Plate 3 is a geomorphology map, along with a DEM, showing locations of known springs and subsidence incident reports.

The study area is located in central Florida (Figure 1) covering portions of Hardee, Highlands, Okeechobee, Osceola, and Polk counties. It includes the communities of Avon Park, Bartow, Fort Meade, Mulberry, and Lake Wales. The quadrangle is bounded to the northwest by the USGS Tarpon Springs 30 x 60 minute quadrangle, (Green et al., 2012a; Green et al., 2012b), to the north by the USGS Kissimmee 30 x 60 minute quadrangle (Green et al., 2018a; Green et al., 2018b), to the south by the USGS Arcadia 30 x 60 minute quadrangle (Green et al., 1998; Green

et al., 1999), and to the west by the USGS St. Petersburg 30 x 60 minute quadrangle (Green et al., 2017a; Green et al., 2017b), previously mapped under the STATEMAP program. The Alafia (North Prong and South Prong), Kissimmee, and Peace rivers, along with numerous creeks and lakes, occur in the map area. Recharge to and discharge from the Floridan aquifer system (FAS) occurs throughout the study area. The FAS is the primary source of water for springs and drinking water in the region.

One objective for this report is to provide basic geologic information for the accompanying OFMS 111. Information provided by this report and the plates in OFMS 111 is intended for a diverse audience of professionals in geology, hydrology, engineering, environmental and urban planning, and laypersons, all of whom have varying levels of geologic knowledge. The maps can help users identify and interpret geologic features which impact activities related to groundwater quality and quantity, as well as aid in locating mineral resources, land-use planning, and construction project design. Applied uses of the maps and data in this report include: 1) identifying potential new mineral resources, 2) characterizing zones of geologic hazards, potential aquifer recharge, and confinement, 3) aiding water-management decisions on groundwater usage, 4) providing information on aquifer vulnerability to potential pollution, 5) ecosystem, wetlands, and environmental characterization, and 6) recreation.

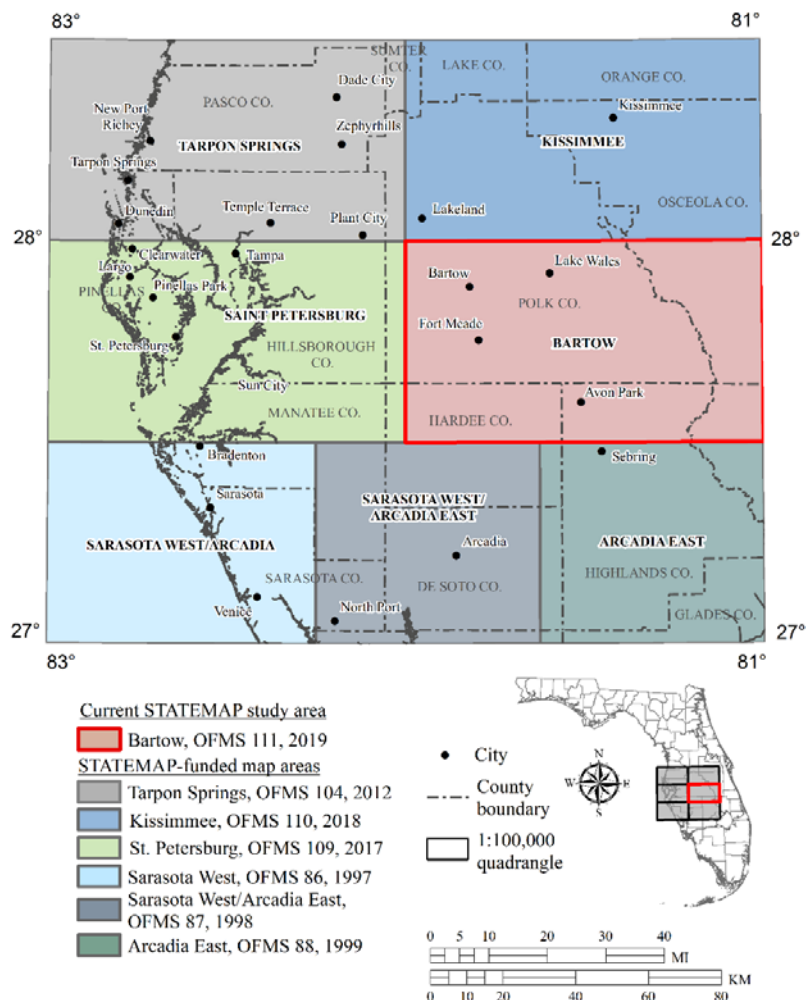


Figure 1. Nearby areas mapped under the FGS STATEMAP Program.

Methods

Mapping efforts consisted of: 1) reviewing and compiling existing geologic literature and data, 2) mapping geologic units in the field at 1:24,000 scale using standard techniques, 3) analyses of existing core and cuttings samples from the FGS sample repository, 4) drilling new cores, 5) collecting and describing outcrop samples, and 6) preparing a geologic map, geological cross-sections, and a geomorphic map of the area. Field work, performed during the fall of 2018 through the summer of 2019, consisted of sampling and describing numerous outcrops, as well as samples from river and pit exposures.

Thirty-three new geologic samples were added to the FGS surface-sample archives (M-Series) and four cores (1,106.5 feet or 337.3 meters total) were drilled. Approximately 80 outcrops were also examined during this project. In addition to the new M-series samples collected, 36 historical M-series samples were examined. All data, including over 300 wells from the study area and surrounding quadrangles, were compiled and analyzed by the authors. Figure 2 shows the locations of FGS cores, cuttings, outcrops, and M-series samples within the study area. The map and accompanying plates were developed in ESRI® ArcGIS® ArcMap™ 10.6.1 software for publication as part of OFMS 111.

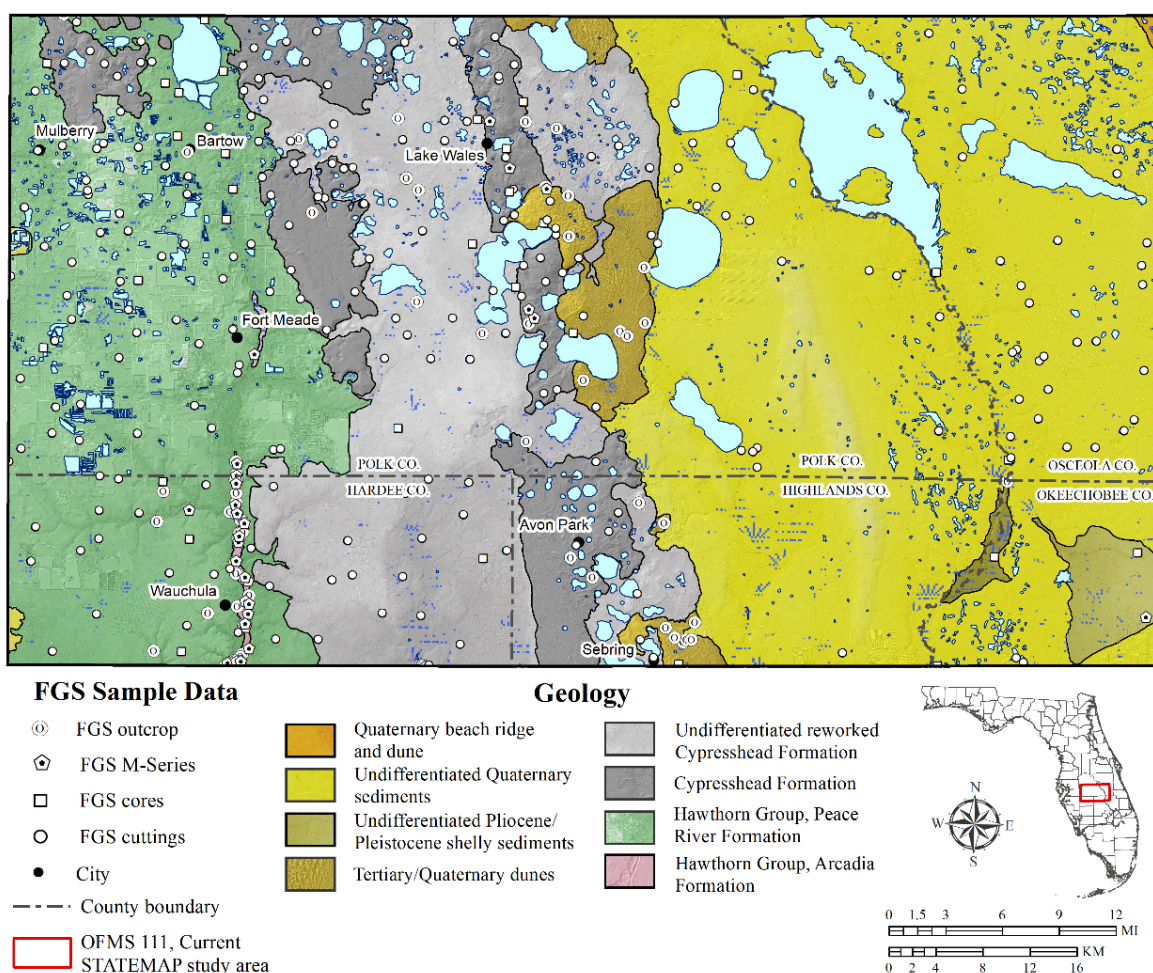


Figure 2. FGS cores, cuttings, and M-series samples used for models.

Due to incomplete light detection and ranging (LiDAR) data, a custom elevation model was created for this study area. Four datasets were used to create this elevation model: standard LiDAR elevation models comprised of three different collection years and quality levels with horizontal resolutions ranging from one foot (0.3 meters) to 16 feet (4.9 meters), and an elevation model based from topographic contours with a horizontal resolution of 32 feet (9.8 meters). Vertical resolution is between 1.6 feet (0.5 meters) and five feet (1.5 meters). LiDAR data currently exists for the entirety of Highlands, Polk, and Okeechobee counties. LiDAR was available for a majority of Osceola and Hardee counties; the missing areas were filled in using the contour-based DEM.

The hybrid elevation model was created by first combining all the existing LiDAR elevation models into a single raster (a matrix of cells [pixels] organized into a grid where each cell [pixel] contains a value representing an elevation). The lower-resolution, contour-based DEM was re-sampled and aligned to match the higher resolution LiDAR elevation models. A conditional statement was then used in ArcGIS to create a new hybrid raster by selecting an elevation value from the LiDAR grid if available. Where LiDAR was not available, elevation values were drawn from the lower resolution, contour-based DEM.

Top-of-unit rasters were created for several geologic units within the study area using the borehole descriptions completed during the course of this study. In order to produce interpolated top-of-unit rasters, the borehole depth for the top of each unit was first converted from depths below land surface into elevations referenced to mean sea-level. This conversion was performed by taking the elevation value of the well point from the digital elevation model raster and subtracting the depth value, resulting in the mean sea-level elevation for the top-of-unit raster.

The mean sea-level elevation data for each geologic unit was used to create a Natural Neighbor (NN) interpolation of the top-of-unit surface. The NN method of interpolation is a simple and exact interpolation method that relies on Voronoi tessellation (a partitioning of a plane into regions based on distances to points) to select a local subset of points and determine a weighted influence at every raster grid cell. The NN method produces a surface that passes through every data point in the input data set and thus does not attempt to account for error or outliers. This method is particularly useful for visualizing the ‘raw’ data for problematic areas and extreme outliers prior to building and optimizing the final model.

After examining the initial models created for each unit, it was evident that some of the predictive errors in the first model were directly attributable to either low data density, local outliers in the borehole data, or both. Outliers are a common occurrence in Florida geologic data for a variety of reasons, both human and natural, including: 1) Hawthorn Group units can be difficult to distinguish even for a trained professional geologist, and therefore some degree of uncertainty may exist in locating contacts, 2) many of the borehole samples are based on cuttings taken at intervals of 10 feet (3.1 meters), which introduces uncertainty in the elevation of the contacts even when the contact is clearly evident, and 3) the presence of karst in carbonate units can produce significantly different unit elevations in boreholes a short distance apart. In cases where the accuracy metrics of the modeled surfaces indicated large amounts of error due to outliers, an iterative modeling process was used to reduce the average standard error of the interpolated surface and the least-accurate boreholes were removed from the dataset via cross-validation to improve predictive accuracy. After the removal of outlier data points (generally fewer than five boreholes per unit), a new interpolated surface was generated.

Figure 3 is a boxplot used to illustrate the distribution and range of elevation values, relative to mean sea level (MSL), for each mapped unit found within the study area. The crossbar within

the box represents the median elevation value for each geologic unit. The upper and lower borders of each box correspond to the 25th and 75th percentiles, or the first and third quartiles, respectively; this area is also called the interquartile range and represents the middle 50% of the values in each group. The whiskers that extend from each boxplot reach no further than 150% of the interquartile range. Data that fall beyond the whiskers are considered outlier points and are represented by a dot.

Once the top of unit models were completed, they were exported to floating-point rasters whose cell size and borders were snapped to the hybrid digital elevation model. These interpolated surfaces were then subtracted from the elevation model to produce a raster showing overburden depth between each unit and land surface. The overburden rasters were then used to assist in drawing the final surficial geologic map for the study area.

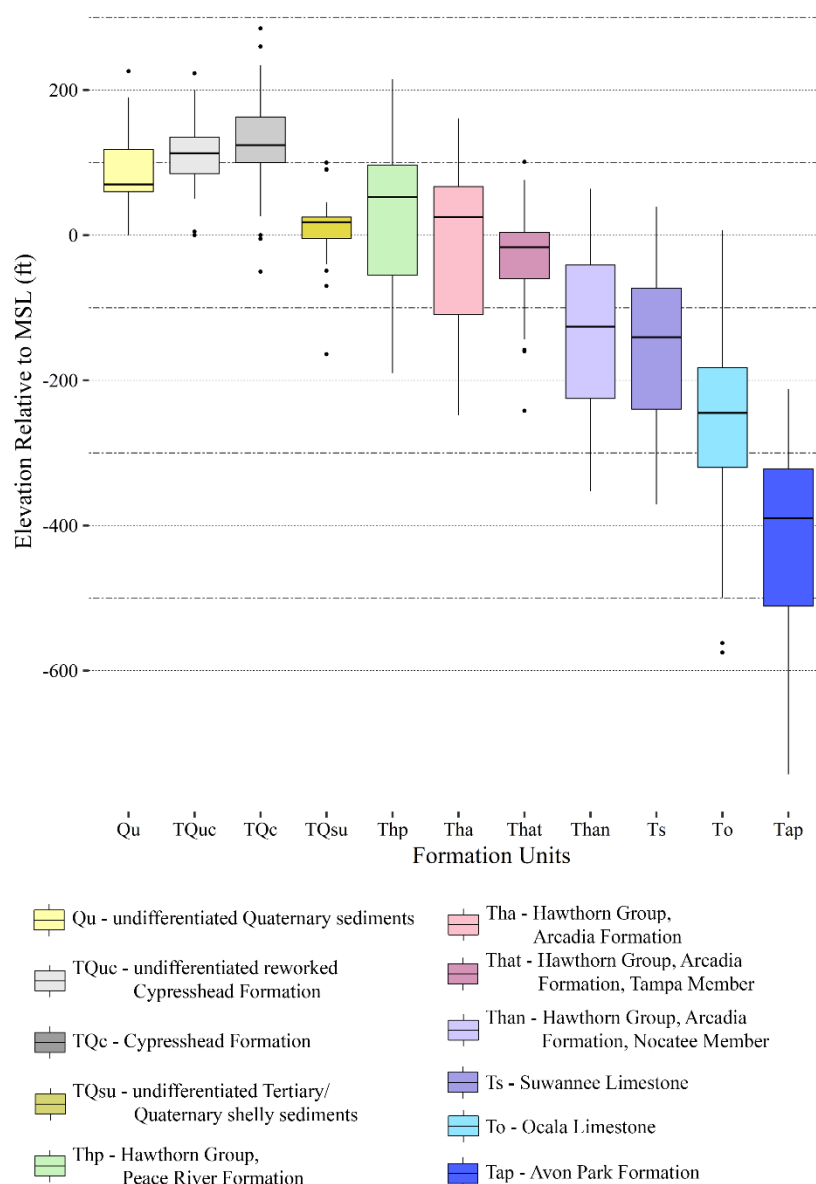


Figure 3. Boxplot of top of lithostratigraphic unit elevation ranges.

Much of the study area is blanketed by a veneer of undifferentiated Tertiary and Quaternary sediments. For this reason, and in keeping with geologic mapping practices developed by Scott et al. (2001), the authors have adopted the policy of mapping the first named geologic unit within 20 feet (6.1 meters) of the surface. If undifferentiated Quaternary (Qu) sediments or reworked Cypresshead Formation (TQuc) have a thickness greater than 20 feet (6.1 meters), then they appear as the mapped unit. If these undifferentiated or reworked sediments are less than 20 feet (6.1 meters) thick, then the underlying lithostratigraphic unit appears on the map. It is noted that the geologic map (OFMS 111, Plate 1) and geologic cross-sections (OFMS 111, Plate 2) may appear to disagree slightly when depicting the upper unit due to this convention. This is due to the fact that geologic cross-section contacts are based on straight-line projection between wells and, thus, may lead to apparent thicknesses of units between wells that are not supported by field evidence or other wells nearby.

Parts of the region are heavily vegetated, and public access in portions of the mapped area was hindered by the presence of numerous wetlands, phosphate mines, farms, ranches, privately-owned land, and military property. Fieldwork access was typically limited to public roads, State-owned, and County-owned lands. Furthermore, much of the western part of the study area is heavily impacted by current and historic mining of phosphate. As such, large sections of the mapped area were inaccessible. In these areas, the authors had to rely on historic data, cores, cuttings, outcrops and M-Series samples.

Previous Work

The current study builds on many previous geologic investigations in and around the present map area which were useful in preparing this report. Preliminary county geologic maps for Hardee (Scott and Campbell, 1993), Highlands (Arthur, 1993), Okeechobee (Scott, 1993a), Osceola (Scott, 1993b), and Polk (Campbell, 1993) counties were previously published at a 1:126,720 scale by the FGS. However, each of these OFMS geologic maps were constructed in an average time-frame of two weeks utilizing selected in-house geologic data with little-to-no extra field work. A statewide geologic map (Scott et al., 2001) was published by the FGS in digital format and provided a framework for the current, more detailed mapping. Although these maps provided a starting point for the detailed geologic mapping undertaken for this project, significant refinement of prior geologic maps was possible as a result this additional fieldwork and data.

Scott (1988) published detailed descriptions, structure contour maps, and isopach maps for units of the Hawthorn Group. Huddleston (1988) defined and discussed the Cypresshead Formation. Arthur et al. (2008) provided unit descriptions, structure contour and isopach maps of all of the major lithostratigraphic units investigated in this study.

This study benefited from the work performed during geologic mapping of the USGS Tarpon Springs 30 x 60 minute quadrangle (Green et al., 2012a; Green et al., 2012b), the Saint Petersburg quadrangle (Green et al., 2017a; Green et al., 2017b), the Kissimmee quadrangle (Green et al., 2018a; Green et al., 2018b), and the USGS Sarasota and Arcadia quadrangles (Green et al., 1997; Green et al., 1998; Green et al., 1999). Some of the field relationships and stratigraphic problems were worked out during those projects. Data gathered during work on the Tarpon Springs, Saint Petersburg, Kissimmee, Sarasota, and Arcadia quadrangles proved invaluable to the completion of this project.

GEOLOGIC SUMMARY

The near surface geology of the USGS 30 x 60 minute Bartow quadrangle is composed of a complex mixture of Tertiary to Quaternary carbonate and siliciclastic sediments. A combination of factors, including fluvio-deltaic deposition, marine deposition, dissolution of underlying carbonates (karstification), erosion of sediments as a result of eustatic changes in sea level, and structural features have influenced the geology of the study area.

The oldest unit to crop out in the Bartow quadrangle is the upper Oligocene to middle Miocene Arcadia Formation (Hawthorn Group). It crops out at various locations along the Peace River valley in the western portion of the map area (OFMS 111, Plate 1). Sediments of Pliocene/Pleistocene Cypresshead Formation, undifferentiated Tertiary/Quaternary shelly sediments, and undifferentiated Quaternary sediments overlie the Peace River Formation in the mapped area (OFMS 111, Plates 1 and 2).

The first predominantly carbonate unit encountered in boreholes in the mapped area is the Arcadia Formation (which includes the Tampa Member of the Arcadia Formation in the western portion of the mapped area). This unit is unconformably underlain by the lower Oligocene Suwannee Limestone in the western portion of the mapped area and the upper Eocene Ocala Limestone in the eastern portion of the mapped area (where the Suwannee Limestone is missing). The Suwannee Limestone, where present, is unconformably underlain by the Eocene Ocala Limestone. These latter two formations can both vary from wackestone to grainstone. Current authors and others (Brewster-Wingard et al., 1997) have noted that, lithologically, the contact between the Suwannee Limestone and the Ocala Limestone can be difficult to differentiate in cores and cuttings. At times there is a distinct contact between the two formations; however, this is not always the case.

Detailed descriptions of the lithology of all units found in the study area start on page 16 of this publication. Along with lithologic criteria, several diagnostic foraminifera and echinoids aid in distinguishing the Suwannee Limestone from the Ocala Limestone. Furthermore, there are some similarities between benthic foraminifera assemblages of the Suwannee Limestone and the Avon Park Formation (which unconformably underlies the Ocala Limestone) that help to distinguish these units from the Ocala Limestone. Both the Suwannee Limestone and Avon Park Formation contain *Fallotella* spp. which is found infrequently at the base of the Ocala Limestone (personal communication, Jonathan Bryan), as well as *Discorinopsis gunteri*, which is not found in the Ocala Limestone. The occurrence of *Nummulites* spp. and *Lepidocyclina* spp. in the Ocala Limestone helps to distinguish it from the Suwannee Limestone and the Avon Park Formation in the study area.

The Bartow quadrangle encompasses portions of the Alafia, Kissimmee, Peace, and Upper St. Johns river basins (Figure 4; Hydrologic Unit Codes: Basins, 1993). There are two historic springs within the study area: Zolfo Springs (Hardee County) and Kissengen Spring (Polk County). Zolfo Spring has not flowed since the 1960s when it was plugged with concrete. Kissengen Spring went dry in 1950 due to anthropogenic use of groundwater from wells.

Karst processes have extensively modified the topography of the region and continue to actively shape it today. Karst topography is characterized by solutional features, subterranean drainage, and caves (Poucher and Copeland, 2006). Downward infiltration of slightly acidic rain and surface water through preferential pathways, such as joints, fractures, and bedding planes, combined with groundwater fluctuations, cause dissolution of the carbonate rocks (Waltham et al., 2005; Upchurch et al., 2019).

Some of the most common karst landforms observed in the study area are sinkholes. Three types of sinkholes occur in the region: 1) solution-subsidence, 2) cover-subsidence, and 3) cover-collapse (Sinclair and Stewart, 1985; Upchurch et al., 2019). Solution-subsidence sinkholes occur where overburden is relatively thin. Downward percolating rain and surface water infiltrates into joints, fractures, and bedding planes slowly dissolving the carbonate rocks below generally forming a large, broad, shallow, low-angle surface depression (Tihansky, 1999; Upchurch et al., 2019). Cover-subsidence sinkholes occur where overburden is relatively thick. The overburden sediments, which consist primarily of low cohesion sediments, ravel into joints, fractures, and cavities below via infiltrating rain and surface water, resulting in a relatively small, gently sloped surface depression (Waltham et al., 2005; Upchurch et al., 2019). Cover-collapse sinkholes occur where the overburden contains some amount of cohesive sediments, such as clay, that acts mechanically as a bridge overlying a cavity within the carbonate rocks below (Waltham et al., 2005; Upchurch et al., 2019). The overburden sediments abruptly collapse into the cavity when either the weight of the overburden sediments exceeds the bridging sediment's load-bearing capacity, or when the potentiometric surface of groundwater within the carbonate rocks drops below bridging sediments, no longer providing the necessary buoyancy to help support those bridging sediments (Beck and Sinclair, 1986; Waltham et al., 2005; Upchurch et al., 2019).

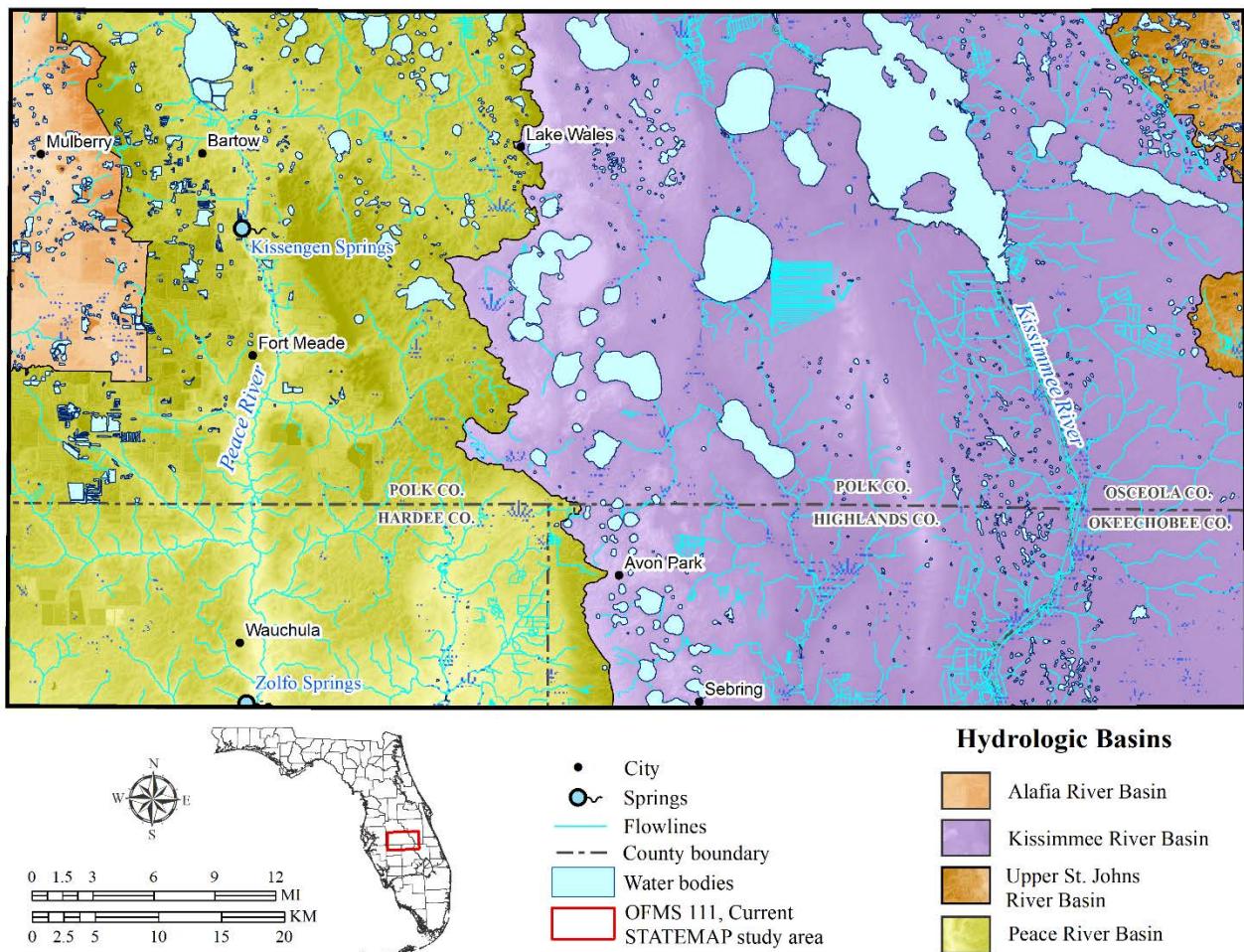


Figure 4. Location of selected river basins, springs, and other water bodies.

The variability of the karst observed within the study area is closely related to the thickness of overburden and the presence/absence of Hawthorn Group clays within the overburden mantling the region's carbonate rocks. Those clays are often the sediments that form a roof over any cavities which have formed within the carbonates.

Karst features are not common in the eastern portion of the study area. Karst lakes at the toe of the Lake Wales Ridge (i.e., Lake Weohyakapka and Lake Arbuckle), and shallow sag-pond cover-settlement features present in this area, are likely related to dissolution of mollusk shells in the underlying undifferentiated Tertiary/Quaternary shelly sediments. Karst features are more common in the central and northwestern part of the study area. A thick sequence of siliciclastic and carbonate sediments of the Hawthorn Group, Cypresshead Formation siliciclastic sediments, and undifferentiated Tertiary/Quaternary sediments overlie the Ocala Limestone or Suwannee Limestone in Polk and Highlands counties. Karst lakes and depressions caused by the dissolution of underlying limestone and collapse or subsidence of overlying sediments are common in this area.

Structure

Several structural features have affected the geology of the region (Figure 5). The Peninsular Arch, a structurally high area which affected deposition from the Cretaceous to the early Cenozoic, is the dominant subsurface feature of the Florida peninsula (Applin and Applin, 1944; Applin, 1951; Puri and Vernon, 1964; Williams et al., 1977; Schmidt, 1984; Miller, 1986; Scott, 1997). The axis of the Peninsular Arch, which cuts through the eastern portion of the study area, extends from southeastern Georgia to the vicinity of Lake Okeechobee in southern Florida in a general northwest to southeast trend. The crest of the arch passes beneath Alachua County and is highest in Union and Baker counties northwest of the study area. The arch was a topographic high during most of the Cretaceous Period and has Upper Cretaceous sediments deposited upon it (Applin, 1951). It formed a relatively stable base for Eocene carbonate deposition (Williams et al., 1977; Hine, 2013). The arch did not affect mid-Tertiary to Holocene sediment deposition (Williams et al., 1977; Scott, 1997; Hine, 2013).

The Ocala Platform is another prominent feature affecting the near surface units within the map area. Hopkins (1920) originally named this feature the Ocala Uplift. Vernon (1951) described the Ocala Uplift as a gentle flexure developed in Tertiary sediments with a northwest-southeast trending crest. Because there is continuing uncertainty about the origin of this feature, Scott (1988) used the term Ocala Platform, rather than Ocala Uplift, or Ocala Arch, since it does not have a structural connotation.

The current study area is on the southeastern flank of the Ocala Platform, which influenced late Tertiary sediment deposition. Miocene sediments of the Hawthorn Group are thought to have been deposited across the platform (Scott, 1981a; Scott, 1988; Scott, 1991a). Post-Miocene erosion has removed sediments of the Hawthorn Group from much of the crest of the Ocala Platform, exposing Eocene and Oligocene carbonates northwest of the mapped area (Cooke, 1945; Espenshade and Spencer, 1963; Scott, 1981b).

In addition to the Peninsular Arch and the Ocala Platform, the Bartow Quadrangle contains a portion of the Osceola Low (Figure 5), named by Vernon (1951). This feature, which occurs near the southern extents of the Peninsular Arch (Applin, 1951) and Ocala Platform, was believed by Vernon (1951) to be the northwest boundary of a downfaulted triangular block with as much as 300 feet of displacement in the Ocala Limestone in Osceola County.

The South Florida Basin (Applin and Applin, 1965; Winston, 1971) is a stratigraphic basin which contributed to the southward thickening of Mesozoic and early Cenozoic lithostratigraphic units in the southern Florida peninsula. This is evident in the southern portion of the north-south cross-sections (OFMS 111; Plate 2, cross-sections D-D', E-E', and F-F'). The reader is referred to Arthur et al., (2008) for a more complete discussion of structural features in the area.

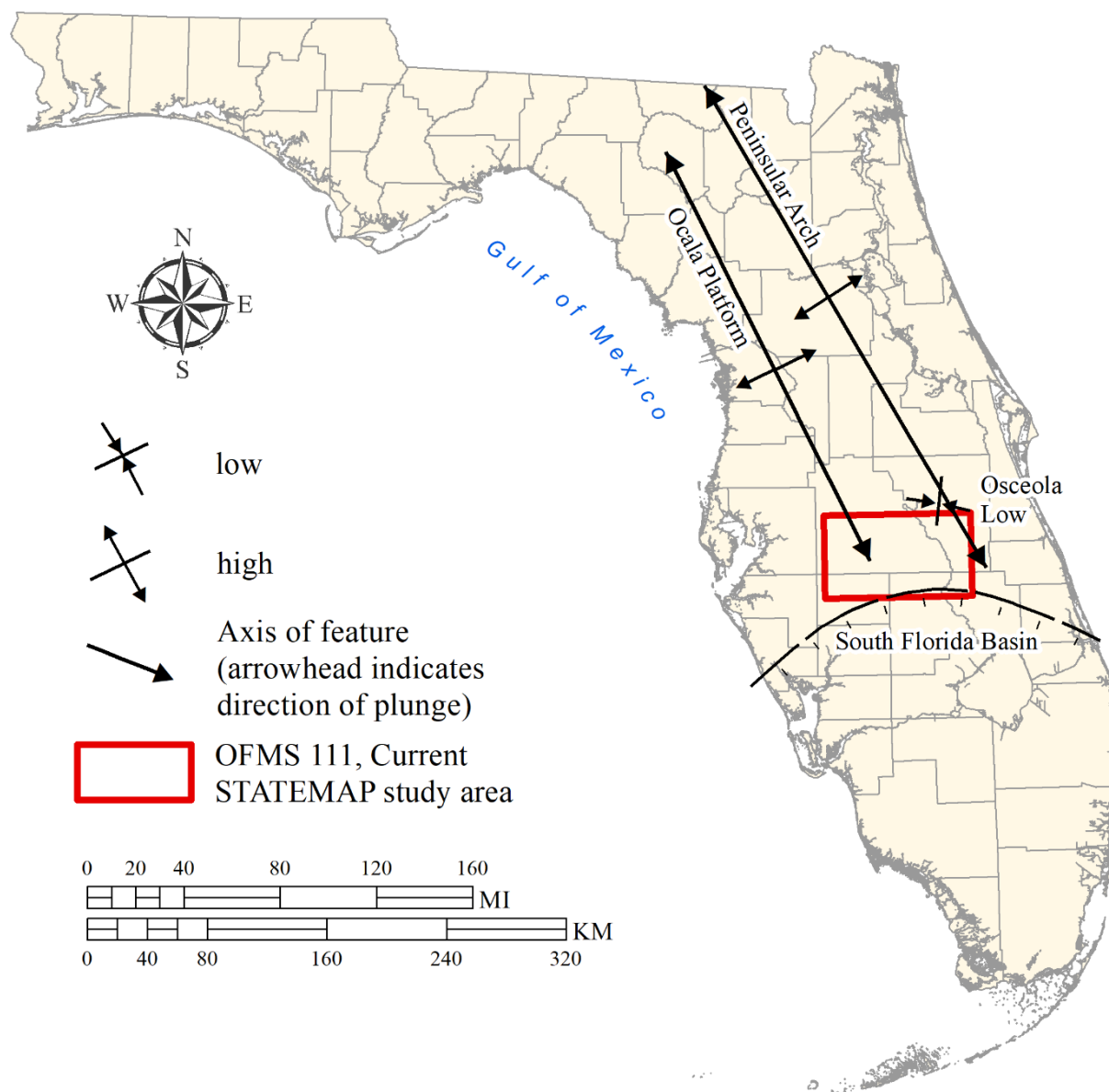


Figure 5. Principal subsurface structures of the Florida peninsula (modified from Arthur et al., 2008).

Geomorphology

The Florida Geological Survey is in the process of producing a new statewide geomorphic map of Florida (Williams et al., in preparation). The new map will synthesize over a century of

geomorphic writings and maps about Florida, along with the addition of new data and new interpretations of the geomorphology. *The Geomorphology of the Florida Peninsula* (White, 1970), in addition to work by former FGS colleague, Dr. Thomas M. Scott, are central to the new statewide map. Recent data and technology, including the addition of significant LiDAR data, and new possibilities for digital geomorphological mapping that employ spatiotemporal and geocomputational approaches to data analysis, are allowing the FGS to revise nomenclature and refine boundaries. In the section which follows, all geomorphology unit names and discussions are from Williams et al. (in preparation).

The new map will divide the geomorphology by regional units (districts) and sub-regional to local units (provinces; Figure 6). Districts are defined by regional groupings in which the geomorphology and near-surface geology are combined to form map polygons that are distinct from adjacent districts. Definition of the more localized provinces and their landforms are important for the characterization of the districts.

Given the significance of karst, paleo-shoreline, and marine erosion and deposition in Florida, these processes are important to the identification of both provinces and districts. The study area falls within three geomorphic districts: the Barrier Island District, the Lakes District, and the Peace River District (OFMS 111; Plate 3, Figure 3). These districts are further subdivided into provinces (OFMS 111; Plate 3, Figure 4). The geomorphic districts and provinces below are discussed in alphabetical, not geographical, order.

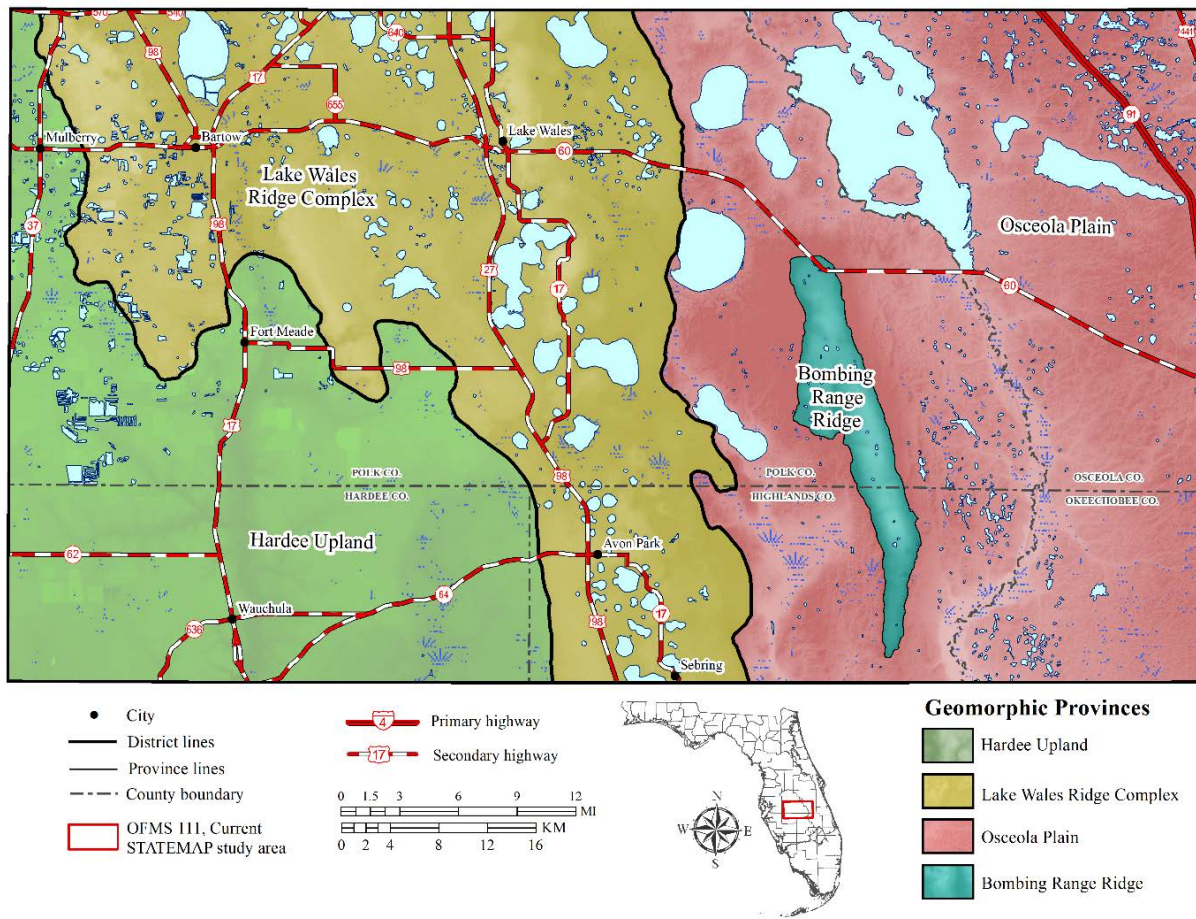


Figure 6. Geomorphic provinces.

Barrier Island District

The Barrier Island District, characterized by beach ridges, dunes, and relict lagoons, extends into Florida from Georgia, southward to the vicinity of Lake Okeechobee (OFMS 111, Plate 3, Figure 3). Elevations of the Barrier Island District range from sea-level to just over 300 feet (91.4 meters) above mean sea-level (MSL). Elevations in the Bartow quadrangle portion of the district range from five feet (1.5 meters) to 150 feet (45.7 meters) above MSL.

Beach-ridge plains occur in several of the provinces in the district. Elevations of these beach-ridge plains range from sea level in the Atlantic Coastal Complex to about 135 feet (41.1 meters) above MSL. Drainage in the district is strongly controlled by the relict beach ridges, forming distinct trellis drainage. Of the eight provinces in the district, only the Osceola Plain and Bombing Range Ridge are present in this study area.

While modern coastal processes are dominantly erosional, with net littoral and longshore transport from north to south, there are many older depositional coastal features in the mapped area. Beach-ridge plains and shore-parallel dunes represent the preserved depositional features of former shorelines. The swales between beach ridges are often swampy and contain many lakes, extensive linear swamps and wetlands, and tributary streams.

In the Barrier Island District, relict lagoons are dissected by two major rivers, the St. Johns River and the Kissimmee River. A relict lagoon in the Upper St. Johns River Valley extends uninterrupted from the southern end of the district to southern Volusia County (see OFMS 111, Plate 3, Figure 4). White (1970) recognized a relict lagoon, now occupied by the Kissimmee River, on the western Osceola Plain.

The entire Osceola Plain is underlain by undifferentiated Tertiary/Quaternary marine shelly sediments, which supports the lagoon hypothesis. These rivers also largely follow trellis drainage patterns consistent with coastal depositional landforms.

Cypresshead Formation, undifferentiated Quaternary sediments, or regions geomorphically interpreted as Quaternary beach ridge and dune dominate the surficial geology over much of the Barrier Island District (see OFMS 111, Plates 1 and 3). These lie unconformably on units ranging from the Avon Park Formation to the Hawthorn Group (Scott et al., 2001).

Sinkhole activity is rare in the district. Where observed, it is typically related to dissolution of shell concentrations, particularly mollusks, near the land surface (Upchurch et al., 2015). These are usually expressed as shallow (a few feet, about one meter) cover-settlement features which may form where the undifferentiated Tertiary/Quaternary shelly sediments are present.

Osceola Plain

The surficial geologic units exposed on the Osceola Plain are undifferentiated Tertiary/Quaternary shelly sediments, undifferentiated Quaternary sediments, and Quaternary beach ridge and dune sediments, the latter covering approximately the eastern quarter of the province. Although the Cypresshead Formation occasionally occurs in the subsurface along the western edge of the province, undifferentiated Tertiary/Quaternary shelly sediments are most common beneath the surficial quartz sands. In the Bartow quadrangle, these overlie Peace River and Arcadia formations (Hawthorn Group) as these units thicken to the south. Both the Ocala Limestone and Avon Park Formation underlie the Hawthorn Group and become more deeply buried from north to south in the province (see OFMS 111, Plate 2). These formations appear to have the most impact on karst landforms in the northern part of the province, near many of the largest lakes, where sediments of the Hawthorn Group are relatively thin.

Although the province has the topographic form of a terrace, it is unlikely that it is related to one single stand of sea level (White, 1970). Most of the terrain is relatively flat, with about 80% of elevations falling between 50 and 75 feet (15.2 and 22.9 meters) above MSL. Elevation and local relief increase to the north of the Bartow quadrangle where the Econlockhatchee River and other tributaries of the St. Johns River are more developed and incised than other drainages in the province. Elevations within the province range from five feet (1.5 meters) to 120 feet (36.6 meters) above MSL and 35 feet (10.7 meters) to 98 feet (29.9 meters) above MSL in the Bartow quadrangle.

The Kissimmee River drains much of the western portion of the Osceola Plain southward to Lake Okeechobee and the Everglades. The eastern portion of the province is a beach-ridge plain with subtle ridges and swampy swales characterized by trellis drainage. Many of the streams flowing east to the St. Johns River run perpendicular to the ridges, but some segments and tributaries exhibit trellis drainage.

Karst features are not common in the part of the province present in the Bartow quadrangle, although shallow sag ponds occur. These are cover-settlement features and likely exist due to dissolution of thinly buried concentrations of shell material, primarily mollusks, within the Tertiary/Quaternary shelly sediments that underlie the majority of the Osceola Plain. In the eastern part of the province, many of these features become elongated parallel to the beach ridge strand plain. Their genesis may be related to the origin of wetlands and swamps in swales, in addition to the dissolution of shell material of the undifferentiated Tertiary/Quaternary shelly sediments.

Bombing Range Ridge

Bombing Range Ridge, which is entirely within the Bartow quadrangle, is surrounded by the Osceola Plain (OFMS 111, Plate 3, Figure 1). It consists of, and is surrounded by, a large region of undifferentiated Quaternary sediments (Scott et al., 2001). The Tertiary/Quaternary shelly sediments are deep enough under the ridge that they do not appear to have a strong influence on surface landforms. Elevations of the province vary from about 75 feet (22.9 meters) to over 145 feet (44.2 meters) above MSL. Bombing Range Ridge is distinct from the surrounding Osceola Plain due to its higher elevation and linear form, the latter parallel to many of the Pliocene and Pleistocene beach ridges in the region.

Bombing Range Ridge appears to have a littoral origin being parallel to the trend of the paleo-ridges throughout northern and central peninsular Florida. The sediments of Bombing Range Ridge are presently mapped as undifferentiated Quaternary sediments, not Cypresshead Formation as in the Lake Wales Ridge Complex six to eight miles (9.7 to 12.9 kilometers) to the west. This suggests Bombing Range Ridge is the result of Pleistocene coastal processes, post-deposition to the Plio-Pleistocene Cypresshead Formation. Further work will be required to determine the origin and age of this feature due to limited core and cuttings control and active military operations in the area.

Bombing Range Ridge has weakly developed surface drainage to the east and west. Fluvial processes and the development of drainage on the surrounding Osceola Plain is affected by the location of Bombing Range Ridge. Arbuckle Creek and Morgan Hole Creek separate Bombing Range Ridge from the Lake Wales Ridge in the Lake Wales Ridge Complex. Morgan Hole Creek has its headwaters in a swampy region between the two lobes in the northern portion of Bombing Range Ridge and follows the south-southeast trend of the ridge before turning southwest to join Arbuckle Creek. Arbuckle Creek and Morgan Hole Creek drain south into Lake Istokpoga in the northwest portion of the Okeechobee Plain.

A series of karst lakes at the eastern toe of the Lake Wales Ridge proper, including Lake Weohyakapka and Lake Arbuckle, occur to the west of Bombing Range Ridge, creating separation between it and the Lake Wales Ridge Complex. These karst lakes have a similar pattern and size to many of the karst lakes found within the Lake Wales Ridge Complex, including the probable karst formation of Lake Istokpoga to the south in the Okeechobee Plain. The karst formation of these lakes appears to be related to dissolution of the shell beds in the Tertiary/Quaternary shelly sediments that underlie the surficial undifferentiated Quaternary sediments.

Lakes District

The Lakes District occupies most of the Central Highlands of Cooke (1939) in peninsular Florida. The district lies east of the Ocala Karst and Peace River districts, west of the Barrier Island and Everglades districts, and south of the Okefenokee Basin District (OFMS 111, Plate 3, Figure 3). A thick sequence of up to 200 feet (61 meters) of siliciclastic and carbonate sediments of the Hawthorn Group, siliciclastic sediments of the Cypresshead Formation, and undifferentiated Tertiary/Quaternary sediments overlie the Ocala Limestone in the Lakes District, except from central Polk County and southward, where Suwannee Limestone is present, and where the Ocala Limestone and the Hawthorn Group are locally absent (Arthur et al., 2008).

Dissolution of carbonate and subsequent subsidence or collapse has created the characteristic rolling hills, sinkhole lakes, and dry sinks that dominate the landscape. Portions of the district are internally drained due to the presence of karst features and permeable sand cover. Elevations in the Lakes District vary from less than five feet (1.5 meters) above MSL to nearly 315 feet (96 meters) above MSL. In the study area, the only province within Lakes District is the Lake Wales Ridge Complex (OFMS 111, Plate 3, Figure 4). Elevations of the district within the Bartow quadrangle range from 45 feet (13.7 meters) to 310 feet (94.5 meters) above MSL. The higher elevation regions were once part of an extensive Cypresshead Formation upland that subsequently eroded, leaving remnant highs. The boundaries of the district generally follow the outcrop belt of the Cypresshead Formation in Florida. Topographic relief between the sandy ridges and the karst lakes and depressions can be over 100 feet (30.5 meters) in the hillier regions.

Sea-level fluctuations have influenced landform development of the Lakes District, evident by its coast-parallel orientation, and many of its provinces are relict beach ridges associated with deposition of the Cypresshead Formation. In some areas, the distribution of karst lakes is controlled by the beach ridges, with many of the lakes occurring in the ancient swales or on the flanks or toes of the ridges. Drainage in the district is mostly interior with few surface streams other than those draining to the local karst lakes, or occasionally connecting a chain of lakes.

Distinctive circular to sub-circular lakes are visible in aerial photographs, LiDAR, maps, and satellite imagery, revealing the individual sinkholes and coalescing sinkholes which give the Lakes District its name. Dissolution of limestone and subsequent subsidence or collapse of the overlying siliciclastic sediments has formed karst lakes of varying size and depth, and some exist as wetlands or dry depressions. Swallets (stream-to-sink features) are present in the district, but most are small and few are documented. Springs are also common in the Lakes District, but they are much more abundant in the northern portion than in the Bartow quadrangle.

Lake Wales Ridge Complex

The Lake Wales Ridge Complex is a remnant of a once broader upland which has a coastal depositional history (OFMS 111, Plate 3, Figure 4). It is underlain by the Cypresshead Formation.

This province has been eroded and lowered by sea-level fluctuations, fluvial erosion, aeolian redistribution of sediments, and karst processes. Elevations range from 50 feet (15.2 meters) to more than 310 feet (94.5 meters) above MSL. Within the mapped area, elevations range from 50 feet (15.2 meters) to 300 feet (91.4 meters) above MSL.

The area is well drained via the numerous karst features present. Aeolian dune fields are present in many regions. Sediment in these areas often lacks some of the clay that may be present where the Cypresshead Formation is at or near the surface, and water rapidly infiltrates the ground.

The most common features of the Lake Wales Ridge Complex are numerous karst lakes. The location of the lakes in the province appear to be strongly related to swale locations. Concentrated linearly and largely following the north-northwest to south-southeast trend of the beach ridges, these swales create a trellis drainage pattern of streams and wetlands. Springs are not common except in the northern part of the province. The upper Peace River valley contains several swallets, some in-channel, and others only capturing water during high flow conditions. Mapped and documented swallet features are not common in the remainder of the Lake Wales Ridge Complex.

Peace River District

The Peace River District covers much of west-central peninsular Florida, extending from Hillsborough and Pinellas counties southward to the Caloosahatchee valley in Lee and Glades counties. The district lies south of the Ocala Karst District, west of the Lakes District, and northwest of the Everglades District (OFMS 111, Plate 3, Figure 3). Of the three provinces in the district, only the Hardee Upland is present within the mapped area. Elevations in the district range from sea level to more than 190 feet (57.9 meters) above MSL in the hills near the headwaters of the Alafia River. Within the Bartow quadrangle, elevations in the Peace River District range from 10 feet (3.1 meters) to 190 feet (57.9 meters) above MSL.

Low permeability siliciclastic sediments of the Hawthorn Group underlie the Peace River District allowing the development of numerous rivers and streams, including the Alafia, Little Manatee, Manatee, Myakka, Peace, and their tributaries (Scott et al., 2001). Drainage in the district is predominantly dendritic.

The Peace River District has limited karst development due to the thick cover of Hawthorn Group sediments over most of the region. Karst is limited to sag ponds and swampy areas that develop above shell beds, typically within the undifferentiated Tertiary/Quaternary shelly sediments. Springs occur, but almost all are located near the coastline. Karst features become more common in the north where the Tampa Member of the Arcadia Formation and the Suwannee Limestone approach land surface and the Hawthorn Group clayey sediments thin. Cover-collapse sinkholes occur in the northern part of the district.

The transition from the Peace River District to the Lakes District occurs where the low permeability sediments of the Hawthorn Group either become more permeable due to facies changes, or where Hawthorn Group sediments are eroded and no longer retard the development of karst features. The landscape of the Peace River District is relatively flat, with limited relief outside of areas incised by local rivers and hills in the eastern part of the district in the Hardee Upland.

Hardee Upland

Sand and clayey sand of weathered Hawthorn Group, reworked Cypresshead Formation sediments, and undifferentiated Quaternary siliciclastic sediments overlie the Hawthorn Group

throughout the Hardee Upland (Scott et al., 2001). Hawthorn Group sediments (usually the Peace River Formation) consisting of phosphatic sand, clay, and carbonate, overlie the Suwannee Limestone (Arthur et al., 2008). Carbonates of the Tampa Member of the Arcadia Formation and Suwannee Limestone appear near the surface, and karst becomes more prevalent in the northern part of the province. Much of the northern Hardee Upland has been terraformed due to phosphate mining throughout the 20th and into the 21st century.

The Hardee Upland is a broad, south-southeasterly sloped plain (OFMS 111, Plate 3, Figure 1). Elevations vary from about 10 feet (3 meters) in the incised river valleys, toward the Gulf of Mexico and Tampa Bay, to over 190 feet (57.9 meters) above MSL. Elevations range from 120 feet (36.6 meters) to 155 feet (47.2 meters) above MSL in the portion of the province in the mapped area.

The Hardee Upland includes the headwaters and most of the tributaries of the Alafia, Little Manatee, Manatee, and Myakka rivers. Although there are isolated wetland features, most of the region is drained by overland flow, though river corridors can be swampy. Most of the drainage is dendritic, primarily developed on the siliciclastic sediments of the Peace River Formation. The remnant trellis drainage in the upper Peace River may have been inherited from the ridges and swales of the western Lake Wales Ridge Complex to the north, but the ridges and swales are no longer evident in the northeastern Hardee Upland.

Due to the thick cover of Hawthorn Group sediments over much of the province, very few karst features are present on the Hardee Upland. Springs are present mostly in the northwestern province in the Alafia River valley and near the coastline. In the northern portion of the province, the overlying clayey sediments of the Hawthorn Group thin, and limestones of the Tampa Member of the Arcadia Formation and the Suwannee Limestone are near the surface. Cover collapse sinkholes occur in this portion of the Hardee Upland.

LITHOSTRATIGRAPHIC UNITS

Tertiary System

Eocene Series

Avon Park Formation

The middle Eocene Avon Park Formation (Tap), first named by Applin and Applin (1944), is entirely a subsurface unit within the USGS Bartow 30 x 60 minute quadrangle. It was encountered in many of the wells utilized for this study and efforts were made to include it in the geologic cross sections where suitable well coverages existed (see OFMS 111, Plate 2).

The lithology of the Avon Park Formation can vary between limestone and dolostone. The limestones are cream to light brown to tan, poorly to well-indurated, variably fossiliferous grainstone and wackestone, with rare mudstone. They are often interbedded with tan to brown, very-poorly to well-indurated, very fine to medium crystalline, fossiliferous (molds and casts), vuggy dolostones. Minor clay beds and organic-rich laminations may occur, especially at or near the top of the unit. Although not common, sedimentary structures include cross-beds and burrows. The burrows generally occur in the uppermost thinly bedded up-dip part of the formation (e.g., where the unit crops out in Citrus and Levy counties; Green et al., 2010; Williams et al., 2010). Accessory minerals include chert, pyrite, celestine, gypsum, and quartz (some as doubly-

terminated euhedral crystals “floating” in vugs).

Fossils present in the unit include mollusks, foraminifera (*Spirolina* sp., *Lituonella floridana*, *Fabiana cubensis*, and *Cushmania* [*Dictyoconus*] *americana*), echinoids (*Neolaganum* [*Peronella*] *dalli*), algae, and carbonized plant remains. Porosity in the Avon Park Formation is generally intergranular in the limestone section. Fracture porosity occurs in the more densely recrystallized dolostone, and intercrystalline porosity is characteristic of sucrosic textures. Pinpoint vugs and fossil molds are present to a lesser extent.

Distinguishing between the middle Eocene Avon Park Formation and the unconformably overlying unit, the upper Eocene Ocala Limestone, can at times be difficult in the study area. Dolomitization of the Avon Park Formation and common recrystallization of the lowermost Ocala Limestone has significantly altered the original rock lithology and fabric. Fossil indicators are only somewhat helpful because the latest deposits of the Avon Park Formation and the earliest deposits of the Ocala Limestone are both bank assemblages, consistent with deposition in a shallow-water limestone bank or plateau, not unlike the present-day Bahama Banks (Bryan, 2004). In the mapped area, the transition from the Ocala Limestone to the Avon Park Formation was typically picked based on textural changes from a yellowish-gray grainstone, often containing *Lepidocyclina ocalana* and *Nummulites ocalanus*, to a less chalky, more recrystallized, carbonate with an increase in grainsize, color change, and the appearance of organics. There is also a change in fossil fauna where common Ocala Limestone benthic foraminifera give way to *Fallotella* sp. and *Cushmania* [*Dictyoconus*] *americana*. Increases in fossil molds and Avon Park Formation fossils generally become apparent below the contact.

The top of the Avon Park Formation ranges from approximately 220 feet (67.1 meters) below MSL in W-341 (OFMS 111; Plate 2, cross-sections A-A' and E-E') to approximately 740 feet (225.6 meters) below MSL in W-9070 (OFMS 111; Plate 2, cross-section D-D'). Due to limited coverage of deeper wells, the total thickness of the Avon Park Formation was not investigated in this study. The Avon Park Formation forms part of the Floridan aquifer system (FAS; Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Ocala Limestone

The upper Eocene Ocala Limestone (To), first described by Dall and Harris (1892), is a biogenic marine limestone comprised largely of foraminifera, mollusks, echinoids, and bryozoans. The Ocala Limestone, which sits unconformably on the Avon Park Formation, is recrystallized to varying degrees within the study area.

Based on lithologic differences, the Ocala Limestone, in some areas, can be informally subdivided into an upper and lower unit (Scott, 1991b). This subdivision, while often apparent in cores and quarries, is not readily apparent in cuttings. As a consequence of this, the geologic cross-sections do not depict the upper and lower Ocala Limestone. The upper unit is typically a white to cream, fine- to coarse-grained, poorly- to well-indurated, moderately- to well-sorted, very fossiliferous limestone (wackestone, packstone, and grainstone). Fossils commonly include foraminifera (*Lepidocyclina ocalana* and *Sphaerogypsina globulus*), bryozoans, mollusks, and a rich diversity of echinoids. The lower unit is typically a white to cream, fine- to medium-grained, poorly- to moderately- indurated, moderately- to well-sorted limestone (grainstone to packstone). Fossils include foraminifera (*Amphistegina pinarensis*, *Nummulites* [*Camerina*] *vanderstoki*, and *Nummulites* [*Operculinoides*] *ocalanus*), bryozoans, algae, mollusks, echinoids, and crustaceans.

The Ocala Limestone occurs throughout the study area (OFMS 111, Plate 2). The top of the Ocala Limestone ranges from 10 feet (3.1 meters) below MSL in W-16307, (Appendix A) to 500 feet (152.4 meters) below MSL in W-9142 (Appendix A). The thickness of the Ocala Limestone ranges from 360 feet (109.7 meters) in W-4190 (Appendix A) to 20 feet (6.1 meters) in W-9147 (Appendix A).

The Ocala Limestone is generally thickest in the southern portion of the study area towards the South Florida Basin. The Ocala Limestone forms part of the FAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Oligocene Series

Suwannee Limestone

The lower Oligocene Suwannee Limestone (Ts), named by Cooke and Mansfield (1936), consists of limestone (grainstone and packstone) in the study area. The unit is typically gray, tan, and yellowish gray, moderately to very well-indurated, finely to coarsely crystalline, with limited occurrences of fossiliferous beds. Chert is occasionally present in the unit in minor amounts. Porosity types include intergranular and moldic. Sedimentary features include bioturbation and cross-bedding (Budd, 2002). Fossils present in the unit include mollusks, corals, echinoids (including the index fossil *Rhyncholampas gouldii*), as well as abundant miliolids, and other benthic foraminifera such as *Discorinopsis gunteri*, *Fallotella* [*Dictyoconus*] *cookei*, and *Fallotella* [*Coskinolina*] *floridana*.

The Suwannee Limestone unconformably overlies the Ocala Limestone throughout the western and central portions of the study area (OFMS 111, plate 2). It is absent from the eastern portion of the mapped area (Arthur et al., 2008; OFMS 111, plate 2). The Suwannee Limestone may be conformably overlain by the Nocatee Member of the Arcadia Formation (Hawthorn Group) in the western part of the mapped area and the undifferentiated Arcadia Formation in the central portion of the mapped area (OFMS 111, plate 2).

In the subsurface, the Suwannee Limestone and Ocala Limestone can be difficult to distinguish in the study area because both units may be dominated by packstones and often contain no diagnostic fossils. Brewster-Wingard et al. (1997) studied these units further south in the Florida peninsula and state: "...the delineation of the formational boundary [between the Ocala Limestone and the Suwannee Limestone] is often difficult, and foraminifera frequently provide the most reliable means for identifying the units." The present authors agree with this statement for the current map area.

The Suwannee Limestone is entirely a subsurface unit in the mapped area (OFMS 111, Plate 2). The top of the Suwannee Limestone ranges from approximately 45 feet (13.7 meters) above MSL in W-3604 (Appendix A) to 370 feet (112.8 meters) below MSL in W-12992 (Appendix A). The thickness of the Suwannee Limestone ranges from 215 feet (65.5 meters) in W-9063 (Appendix A) to zero feet (meters) as it thins and disappears towards the eastern portion of the mapped area (OFMS 111; Plate 2). The Suwannee Limestone makes up part of the FAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Oligocene-Pliocene Series

Hawthorn Group

Sediments of the upper Oligocene to Pliocene Hawthorn Group are thought to have been deposited over the Ocala Platform throughout the study area, but post-Pliocene erosion and karstification have removed sediments from the crest of the Ocala Platform, exposing Oligocene carbonates in portions of the peninsula (Cooke, 1945; Espenshade and Spencer, 1963; Scott, 1981b). Hawthorn Group sediments within the study area consist of phosphatic siliciclastics (sands, silts, and clay) and carbonates.

Within the mapped area, the Hawthorn Group is composed of sediments from the Arcadia Formation (including the Tampa and Nocatee members), and the Peace River Formation (including the Bone Valley Member). Sediments of the Arcadia Formation lie unconformably over the Suwannee Limestone where it is present and the Ocala Limestone where the Suwannee Limestone is missing (OFMS 111, Plate 2, cross-sections). The various Hawthorn Group sediments are, at times, unconformably overlain by the Tertiary/Quaternary Cypresshead Formation, undifferentiated Tertiary/Quaternary shelly sediments, and/or reworked Cypresshead Formation sediments.

Arcadia Formation

The upper Oligocene to middle Miocene (Brewster-Wingard et al., 1997) Arcadia Formation (Tha) is a yellowish gray to white, variably sandy (quartz and phosphorite) carbonate, intercalated with beds of siliciclastic-dominant sediments. Phosphate content can be highly variable and range up to 25 percent but is more commonly in the 10 percent range (Scott, 1988). The unit is exposed in various places along the banks of the Peace River (OFMS 111, Plate 1). Although limestone is present, dolostones are most common, ranging in grain size from microcrystalline to medium, with the coarser material being sucrosic. Minor clay and chert beds (some composed of silicified clay) also occur (Upchurch et al., 1982; Scott, 1988). Porosity types include intergranular and moldic. In places, the Arcadia Formation can be further subdivided into the Nocatee Member and Tampa Member. See below for further discussion of these units.

Undifferentiated Arcadia Formation sediments range from approximately 145 feet (44.2 meters) above MSL (Appendix A, W-11096) to more than 245 feet (74.7 meters) below MSL (Appendix A, W-9134). The unit is thickest in the southwestern portion of the study area and ranges from 355 feet (108.2 meters) thick in W-18675 (Appendix A) to approximately five feet (1.5 meters) thick in W-6510 (Appendix A). In general, the Arcadia Formation forms part of the IAS/ICU in the study area (Arthur et al., 2008).

Nocatee Member

The upper Oligocene (Brewster-Wingard et al., 1997) Nocatee Member of the Arcadia Formation (Than) is predominantly a siliciclastic unit consisting primarily of quartz sand and clay beds with occasional phosphate, silt, limestone, and dolomite (Scott, 1988). The Nocatee Member is entirely a subsurface unit in Florida. Where present, it forms the base of the Arcadia Formation. The Nocatee Member was recognized in several wells along the western and central parts of the study area (OFMS 111; Plate 2, cross-section A-A', B-B', C-C', D-D', and E-E'). The Nocatee Member is differentiated from the overlying Tampa Member and underlying Suwannee Limestone

by a significant increase in quartz sand content and lower percentage of calcareous matrix. This unit is also marked by an increase in light olive-gray to light greenish-gray clay beds. In the mapped area, the top of the unit ranges from approximately 65 feet (19.8 meters) above MSL in W-1864 (OFMS 111; Plate 2, cross-section A-A') to 340 feet (103.6 meters) below MSL in W-9067 (Appendix A). The unit ranges in thickness from 288 feet (87.8 meters) in W-11038 (Appendix A) to five feet (1.5 meters) in W-9276 (Appendix A). The Nocatee Member of the Arcadia Formation, where present, generally forms part of the IAS/ICU (Arthur et al., 2008).

Tampa Member

The upper Oligocene to lower Miocene (Brewster-Wingard et al., 1997) Tampa Member of the Arcadia Formation (That) varies from white to yellowish gray in color and ranges from a wackestone to packstone with varying amounts of quartz sand, silt, and clay (Scott, 1988). Phosphate is often absent in the Tampa Member, making this one of the characteristics that aid in distinguishing it from undifferentiated Arcadia Formation sediments. Phosphate can be present, though in amounts less than three percent. Dolomite, silt, and clay are occasionally present though rare. Dolomite is mostly observed near contacts with overlying and/or underlying units such as the Arcadia Formation or dolomitized sections of the Suwannee Limestone. Occasional thin clay beds were observed in core, and less notably in cuttings, throughout the area. Quartz sand content in the carbonate sections varies from two percent to thirty percent. Sand beds can be found intermittently within the unit. Chert, silicified limestone, and silicified corals are not uncommon in the Tampa Member. Fossil molds of foraminifera, mollusks, and gastropods are all common within the Tampa Member. Porosity of the unit is generally intergranular and moldic.

In the western and southwestern portion of the study area, the Tampa Member overlies the Arcadia Formation (undifferentiated), or the Nocatee Member of the Arcadia Formation. In limited regions of the study area, the Tampa Member overlies the Suwannee Limestone and the contact appears to be locally conformable. In many wells, the transition between the Tampa Member and the overlying undifferentiated Arcadia Formation is marked by a transition from phosphatic dolostone (Arcadia Formation) to a limestone with little to no phosphate content (Tampa Member, Arcadia Formation). Toward the east and south, the Tampa Member facies grades laterally into the Arcadia Formation. The top of the FAS generally coincides with the uppermost carbonate unit occurrence, where the Tampa Member occurs along the updip erosional pinchout and forms an irregular subcrop contact with the Suwannee Limestone (Arthur et al., 2008).

In the study area, the top of the Tampa Member ranges from approximately 75 feet (22.9 meters) above MSL in W-1864 (OFMS 111; Plate 2, cross-section A-A') to approximately 175 feet (53.3 meters) below MSL in W-13712 (OFMS 111; Plate 2, cross-sections C-C'). The maximum observed thickness of the Tampa Member is 250 feet (76.2 meters) in W-4006 Appendix A). The Tampa Member is thinnest at 10 feet (3 meters) in W-1864 near the eastern limit of the unit (OFMS 111; Plate 2, cross-sections A-A') where it grades into the undifferentiated Arcadia Formation.

Peace River Formation

The middle Miocene to lower Pliocene (Scott, 1988; Covington, 1993) Peace River Formation (Thp) is comprised of yellowish gray to olive gray, interbedded sands, clays, and carbonates with the siliciclastic component being dominant (Scott, 1988). Phosphate sand and gravel are most common in the uppermost beds, although they are generally interspersed

throughout the unit. The Peace River Formation contains a diverse fossil assemblage of marine and terrestrial fauna (e.g., shark teeth, ray spines, horse teeth, dugong, and whale ribs), particularly within the Bone Valley Member. Porosity types in the formation are generally intergranular.

The Peace River Formation unconformably overlies the Arcadia Formation throughout the mapped area (OFMS 111, Plate 2). Identifying the contact between the Peace River Formation and Arcadia Formation can be problematic in some localities. The two units may appear to be conformable, with phosphate-rich siliciclastics grading with depth into more siliciclastic-interbedded carbonates containing generally finer-grained and less abundant phosphate (Arthur et al., 2008). In such cases, the lower contact of the Peace River Formation is estimated based on sedimentary structures as well as a best approximation of where the overall lithologic sequence becomes more carbonate dominant (Scott, 1988). In most of the study area, the contact is readily recognized at the first occurrence of a light colored, phosphatic and quartz sandy dolostone.

The Peace River Formation ranges from approximately 200 feet (61 meters) above MSL to 165 feet (50.3 meters) below MSL in W-11036 (Appendix A). Thicknesses range from 195 feet (59.4 meters) in W-16539 (Appendix A) to zero feet (meters) in the Peace River valley where the Arcadia Formation crops out.

The Peace River Formation is within the upper portion of the Intermediate Aquifer System/Confining Unit (IAS/ICU) and regionally is a confining to semi-confining lithostratigraphic unit. The Peace River Formation sediments comprise a low-permeability confining to semi-confining facies within the IAS/ICU within the study area. (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Bone Valley Member

The middle Miocene to lower Pliocene (Webb and Crissinger, 1983) Bone Valley Member of the Peace River Formation (Thpb) is lithologically very similar to the Peace River Formation. The lithology of the Bone Valley Member differs in that it contains higher concentrations of coarse-grained phosphate (more than 30 percent by volume), ranging up to gravel-size. Some pebble-sized grains show evidence of reworking, boring structures, and multiple stages of phosphatization. Phosphate coloration ranges from black and brown to cream and white. The non-phosphorite component of the Bone Valley Member is comprised of quartz sand and clay (e.g. palygorskite and sepiolite; Scott, 1988), occasionally with minor amounts of dolomite. Carbonate beds are not present; however, limestone and dolostone cobbles may be present (Dr. Thomas M. Scott, personal communication, 2005). According to Scott (1988, p. 87), “the occurrence of phosphate gravels in the Bone Valley Member is the most lithologically important factor in the separation of the member from the remainder of the Peace River Formation.” Scott (1988) also notes that the contact between the Bone Valley Member and the Peace River Formation is gradational, both laterally and vertically. While the Bone Valley Member can often be separated from the remainder of the Peace River Formation in cores and in mines, it is rarely possible to differentiate in cuttings.

After looking at hundreds of sets of cuttings and dozens of cores throughout the study area the authors have determined that the Bone Valley Member, as defined by Scott (1988), could not be reliably mapped at this scale. This is due to a combination of several factors including the gradational nature of the contacts, lithological similarities between the Bone Valley Member and the Peace River Formation, poor core control, and significant phosphate mining activity during the last century.

Of the 329 boreholes located in the area historically mapped as the Bone Valley Member

in the region, only a small fraction of the wells had sediment matching the lithostratigraphic definition of the Bone Valley Member of Scott (1988). Arthur et al. (2008) only had seventeen wells within the current map area which identified the Bone Valley Member as being present. It should be noted that the areas mapped as Bone Valley Member in Arthur et al. (2008) and Scott (1988) were based on a very limited number of wells, and the boundaries of the unit were heavily influenced by the presence of phosphate mines. Mining in the phosphate district is largely driven by economics and thus the mining companies historically mined phosphate-rich zones, not necessarily the Bone Valley Member lithostratigraphic unit as defined by Scott (1988).

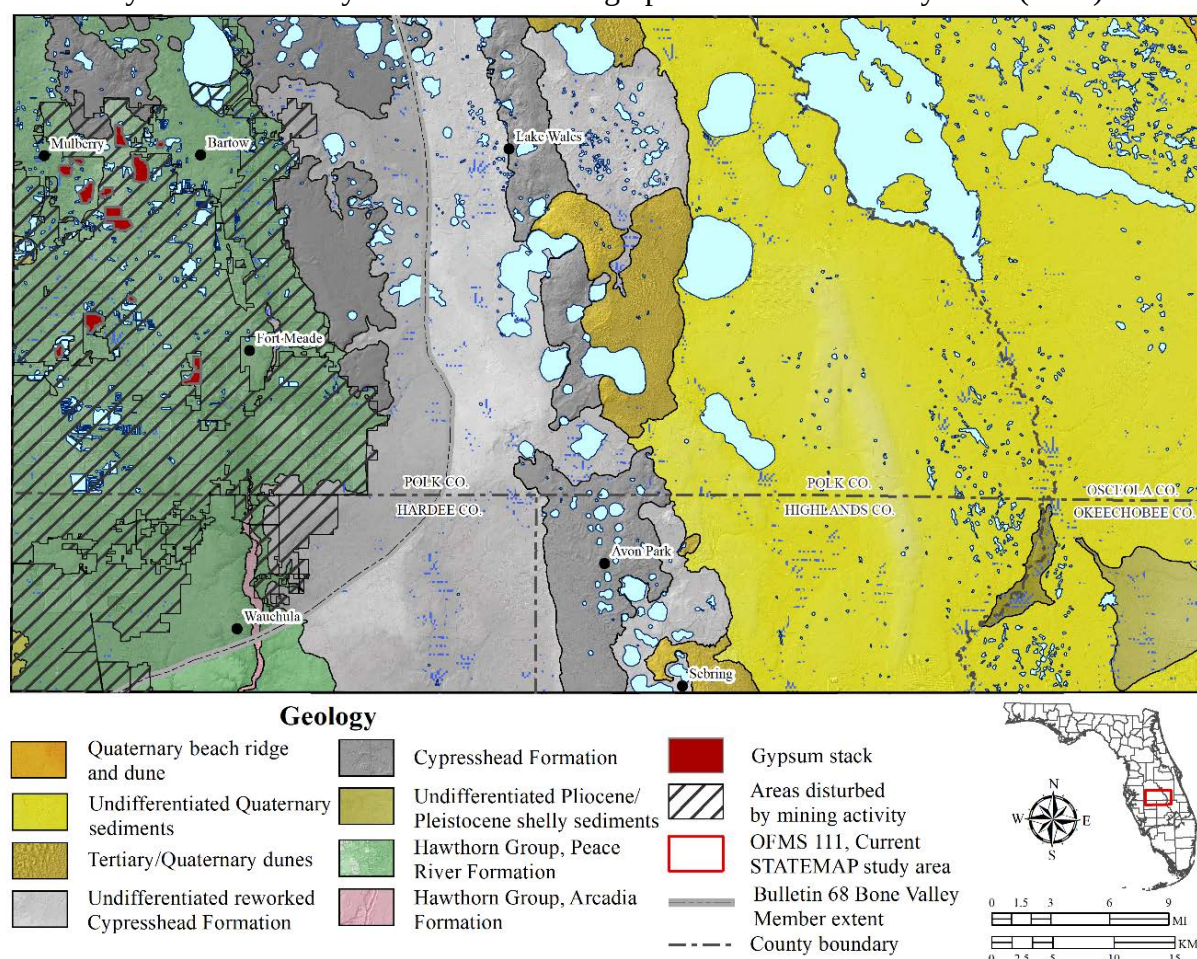


Figure 7. Areas affected by phosphate mining with extents of Bone Valley Member from Arthur et al. (2008).

The western part of the mapped area has been extensively mined for phosphate (Figure 7) going as far back as 1890 (Sellards, 1915). As a result, much of the area formerly mapped as Bone Valley Member by Scott (1988) and Arthur et al. (2008) has been removed and/or reclaimed, and the surficial sediments no longer truly represent the original lithology. This also proved to be an issue when working with core and cuttings samples that have been collected over the span of the past 100 years. These samples often had incomplete location and elevation information, making the determination of the top of the Bone Valley Member problematic at best. Without reliable information and specific locations and elevations on boreholes located in mined areas, the authors

were unable to determine if the various samples examined were collected pre- or post-mining in many instances. After much discussion with various staff geologists (including Dr. Thomas M. Scott), it was determined that it was best to map the area as Peace River Formation and forego attempts to delineate the Bone Valley Member at this scale. The reader is referred to Scott (1988) and Arthur et al. (2008) for the former extents and additional discussion of the Bone Valley Member.

Tertiary/Quaternary Systems

Pliocene/Pleistocene Series

Cypresshead Formation

The Pliocene/Pleistocene Cypresshead Formation (TQc), is a mottled reddish-brown to reddish-orange to white, unconsolidated to poorly consolidated, fine- to very-coarse grained, variably clayey to clean quartz sand. Cross-bedded sands and bimodal sand-size distributions are common within this formation. Discoid quartzite pebbles, heavy mineral grains, and mica are often present. Ghosts of nearshore marine mollusks and burrows are rare. The Cypresshead Formation is present throughout much of the western portion of the study area and forms the core of the various ridges present in the region. The lower portion of the Cypresshead Formation frequently becomes a more weathered, finer-grained, well-sorted sand and silt. In cores, the unit is often characterized by beds of fine-grained, well-sorted sand with thin layers of clay dispersed through the sand. Occasional coarse sand beds may occur.

The Cypresshead Formation sits unconformably on the Peace River Formation (Hawthorn Group) in the western part of the mapped area (OFMS 111; Plate 2). In the east-central portion of the mapped area, the Cypresshead Formation sits on, and likely interfingers with, the undifferentiated Tertiary/Quaternary shelly sediments (OFMS 111; Plate 2, cross-sections A-A', B-B', C-C', and E-E').

Elevations of the top of the unit range from over 295 feet (89.9 meters) above MSL to 45 feet (13.7 meters) above MSL (Appendix A, W-12896) in the mapped area. Cypresshead Formation thickness ranges between 265 feet (80.8 meters) in W-14884 (Appendix A) to five feet (1.5 meters) in W-9245 (Appendix A).

Permeable sediments of the Cypresshead Formation form part of the surficial aquifer system (SAS; Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Undifferentiated reworked Cypresshead Formation

Sediments mapped as undifferentiated reworked Cypresshead Formation (TQuc) in the study area are the result of post-depositional reworking of Cypresshead Formation sediments. The reworked Cypresshead Formation sediments can range from white to gray to orange to light brown to grayish brown. They are fine to coarse quartz sands with scattered quartz gravel and varying percentages of clay in the matrix (Scott, 2001). They are generally lower in elevation and have less relief than Cypresshead Formation sediments. They are primarily present along the flanks of the Lake Wales Ridge Complex in the mapped area (OFMS 111, Plate 2, cross sections A-A', B-B', C-C', D-D', and E-E'). Several relict ridges exist parallel to the Lake Wales Ridge Complex extending into the Hardee Upland. Based on limited field exposures, pits, and borehole data, the

authors of this study believe that these ridges were likely originally deposited as Cypresshead Formation and have been subsequently reworked during sea-level fluctuations and modified by karst processes.

Elevations of the top of the reworked Cypresshead Formation range from approximately 175 feet (53.3 meters) above MSL (Appendix A, W-3852) to 50 feet (15.2 meters) above MSL (Appendix A, W-9257) in the mapped area. Thickness of these sediments range from approximately 200 feet (61.0 meters) in W-930 (Appendix A) to five feet (1.5 meters) in W-15346 (Appendix A).

Permeable sediments of the reworked Cypresshead Formation form part of the surficial aquifer system (SAS; Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Undifferentiated Tertiary/Quaternary shelly sediments

A sequence of undifferentiated Tertiary/Quaternary shelly sediments (TQsu) lies east of the Lake Wales Ridge Complex. Huddlestun (1988) named this unit the Nashua Formation. Much of the evidence listed by Huddlestun (1988) was based on biostratigraphic correlation and not lithologic distinction. Sediments located along the Econlockhatchee River were investigated during fieldwork for mapping in the Orlando quadrangle (Green et al., 2015a; Green et al., 2015b) project and were determined to be very young (late Pleistocene-Holocene, Roger Portell, personal communication). Given the age uncertainty of these units, lack of adequate core control and lack of access to the type section, the authors decided to utilize the convention of Scott et al. (2001) and map these sediments informally as undifferentiated Tertiary/Quaternary shelly sediments. Where present, these sediments lie unconformably on the Peace River Formation (OFMS 111; Plate 2, cross-sections A-A', B-B', C-C', E-E', and F-F'). Huddlestun (1988) indicated that the unit grades laterally into the Cypresshead Formation in the vicinity of the Trail Ridge (north of the mapped area). Evidence from mapping in the Orlando quadrangle (Green et al., 2015a; Green et al., 2015b), however, indicated that the unit is, at least in part, older than the Cypresshead Formation. This may be a result of prograding of Cypresshead Formation sediments over Tertiary/Quaternary shelly marine sediments during changes in sea level. Some of these fossiliferous sands north of the study area (in the Daytona Beach quadrangle) are Pliocene (Roger Portell, personal communication). The Tertiary/Quaternary shelly sediments present in the study area are generally below 50 feet (15.2 meters) MSL.

The elevation of the Tertiary/Quaternary shelly sediments is highest (48 feet [14.6 meters]) in the southeastern corner of the mapped area in Okeechobee county. It is postulated that these instances of higher elevation Tertiary/Quaternary shelly sediments are indicative of paleo-shorelines that have been “stranded” due to sea-level fluctuation and the influence of dynamic topography. Additional studies are needed to determine the exact nature and relationships of these units in the region.

These undifferentiated Tertiary/Quaternary shelly sands are overlain by reworked Cypresshead Formation and Tertiary/Quaternary dunes on the eastern flank of the Lake Wales Ridge Complex in the central portion of the mapped area (OFMS 111, Plate 2, cross-sections A-A', B-B' and E-E'). In the eastern portion of the mapped area, the unit is unconformably overlain by reworked Cypresshead Formation, undifferentiated Quaternary sediments, or Quaternary beach ridge and dune sediments.

Undifferentiated Tertiary/Quaternary shelly sediments disconformably overlie the Peace River Formation throughout the study area east of the Lake Wales Ridge Complex. There are

problems in mapping these sediments as separate units because their historical definition is based on biostratigraphic, not lithostratigraphic, criteria (Scott and Allmon, 1990; Scott and Wingard 1995). Scott and Campbell (1993) informally applied the name Okeechobee formation to these sediments in an effort to provide a lithostratigraphic framework. McCartan and Moy (1995) mapped several units southwest of this area (Sarasota quadrangle) based upon inferred ages from fossils, stratigraphic position, and isotope age dates. Due to the similar lithologies of these units, difficulties encountered in attempting to differentiate them in drill cuttings, and the fact that the Okeechobee formation was never formalized, they are placed within the undifferentiated Tertiary/Quaternary shelly sediments on this map.

Undifferentiated Tertiary/Quaternary shelly sediments typically consist of fine-to-medium quartz sand with variable amounts of calcilutite, silt, marine mollusk shells, and clay. Colors range from light-gray to light-olive gray. Shells, which may vary from whole to fragments, are normally highly weathered and abraded and may occasionally become the dominant lithology. Other accessory minerals may include calcite, aragonite, mica, heavy minerals, and minor phosphate sand and gravel. A basal phosphate lag is often present. In the study area, Tertiary/Quaternary shelly sediments occur predominantly in the form of unconsolidated sands with varying percentages of shell fragments. Calcite cemented Tertiary/Quaternary shelly sediments were encountered, albeit less frequently than unconsolidated material.

The top of the undifferentiated Tertiary/Quaternary shelly sediments ranges from approximately 60 feet (18.3 meters) above MSL in the vicinity of Kissimee Prairie Preserve State Park to 35 feet (10.7 meters) below MSL east of the Lake Wales Ridge in W-9259 (OFMS 111; Plate 2, cross-section A-A'). The thickness of the undifferentiated Tertiary/Quaternary shelly sediments in the cross-section wells varies from 180 feet (54.9 meters) in W-9134 (Appendix A) to 10 feet (3.1 meters) in W-9254 (Appendix A).

Permeable sediments of the undifferentiated Tertiary/Quaternary shelly sediments form part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Tertiary/Quaternary dunes

Tertiary/Quaternary dunes (TQd), while not a formally recognized lithostratigraphic unit, are mapped following the convention of Scott et al. (2001) in order to facilitate a better understanding of Florida's geology. Where LiDAR is available, these dunes are readily differentiated from other units by their distinct topographic expression. These dune sediments are fine-to-medium quartz sand with varying amounts of disseminated organic matter. They are generally found at elevations above 100 feet (30.5 meters) MSL, although there are areas along the flanks of the Lake Wales Ridge where elevations of these dune sands can be lower. Sands forming these dunes are derived from re-working of sediments from the Cypresshead Formation (TQc) and undifferentiated Quaternary sediments (Qu). There are several areas along the eastern flank of the Lake Wales Ridge which have Tertiary/Quaternary dune sediments mapped (OFMS 111, Plate 1). These sediments are considered part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Pleistocene to Holocene Series

Undifferentiated Quaternary sediments

While not a formally recognized lithostratigraphic unit, undifferentiated Quaternary sediments (Qu), are mapped following the convention of Scott et al. (2001), in order to facilitate a better understanding of Florida's geology. The undifferentiated Quaternary sediments in the mapped area may be highly variable in thickness. Undifferentiated Quaternary sediments (Qu) in the study area lie unconformably on Cypresshead Formation, reworked Cypresshead Formation, or undifferentiated Tertiary/Quaternary shelly sediments (OFMS 111, Plate 2).

Generally, undifferentiated Quaternary sediments consist of white to gray to orange to brown, fine- to coarse-grained, clean to clayey (usually) unfossiliferous sands, sandy clays and clays with variable admixtures of organics. The undifferentiated Quaternary sediments form part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Quaternary beach ridge and dune

Quaternary beach ridge and dune sediments (Qbd) are a subdivision of the undifferentiated Quaternary sediments that are mapped on the basis of having a surficial expression of relict beach ridges and dunes. While not a formally recognized lithostratigraphic unit, the unit is mapped following the convention of Scott et al. (2001) in order to facilitate a better understanding of Florida's geology. The unit unconformably overlies undifferentiated Tertiary/Quaternary shelly sediments (TQsu) in the extreme northeastern corner of the study area (OFMS 111; Plates 1 and 2).

Beach ridge and dune sediments are dominantly siliciclastic sands with occasional shells and are unconsolidated to poorly consolidated. Organics typically occur as disseminated organic matrix, roots and plant debris, carbonized remains, or charcoal. The unit is considered part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

MINING EFFECTS

Figure 7 depicts areas subjected to phosphate mining in the mapped quadrangle. Mining activities in the central Florida phosphate district have created numerous gypsum stacks or "gypstacks", which are mounds of phosphogypsum derived as byproduct from phosphate processing. These "gypstacks" represent significant thicknesses of recent, man-made materials. Because the Florida Department of Environmental Protection maintains a GIS coverage of these "gypstack" footprints, it was decided to delineate them on the current maps (OFMS 111, Plates 1 and 2).

The geologic map and cross-sections associated with this product (OFMS 111, plates 1 and 2) are based on field work and borehole data from the FGS Geological Sample Repository. Areas shown as Peace River Formation (Thp), Cypresshead Formation, and undifferentiated Quaternary (Qu) in the phosphate mining zones on OFMS 111 (plates 1 and 2) reflect data which are primarily derived from boreholes and historic data. As such, the reader should note that there are differences between the geology as mapped and the surficial geology inside of some of these mined areas. In some of the mined areas, undifferentiated Quaternary sediments, Cypresshead Formation

sediments (dominated by quartz sand), and (portions of) the Peace River Formation have been removed/disturbed during mining, in some cases multiple times, during the last century. Mining processes in these areas have mixed the undifferentiated Quaternary sediments, Cypresshead Formation sediments, along with quartz sand, unmined phosphate grains, clays, and carbonate materials from the Peace River Formation.

Unfortunately, staff were denied access to the phosphate mines and mining company data which would be needed to attempt to delineate these areas better and therefore had to rely on existing historical data in this area. As such, it was not possible to accurately apply the same mapping rules in these mined areas since, without access to mining data it is not always clear where areas represent original (undisturbed) ground or areas of reclaimed land. The phosphate mining processes are quite disruptive to the area and the general process involves replacing the sediments once the phosphate has been removed. These reclaimed lands are often terraformed back into a topography which approximates original topography. In some instances, the mined areas are obvious, but in others it is not. Therefore, the authors have elected to show the geology of the region based on historic data and cores/cuttings information.

HYDROGEOLOGY

Hydrostratigraphic units within the map area, in ascending order, consist of the FAS, the IAS/ICU, and the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). A graphic representation of the hydrostratigraphic units, and their relationship to lithostratigraphic units, can be seen on OFMS 111, Plate 2, Figure 2. The FAS, the primary source for springs and drinking water in the region, is generally comprised of carbonate units of the Avon Park Formation, the Ocala Limestone, the Suwannee Limestone, and the Tampa Member of the Arcadia Formation (Hawthorn Group). Arthur et al. (2008) provide a more detailed discussion of the FAS in the region. The sands, silts, clays and carbonates of the remainder of the Hawthorn Group comprise the IAS/ICU. The IAS/ICU is highly localized and laterally discontinuous in the study area. The SAS is comprised of TQsu, TQd, Qu, Qbd, and Qh sediments.

Where clayey siliciclastic sediments of the Hawthorn Group and younger units are thick and continuous, they provide confinement for the FAS, but where the clayey siliciclastic sediments of the Hawthorn Group and younger units are thin, missing or lack significant clay component, karst features often occur.

DERIVATIVE PRODUCTS

Several derivative products were developed in the process of completing this project. During the mapping efforts, data from 262 wells with samples were analyzed and used (Appendix A). Formation picks made on these cores and cutting samples will allow creation of structure contour and isopach maps for the top of several units in the area. Additional derivative products anticipated to come from this mapping effort include aquifer vulnerability assessment maps. Data derived from prior STATEMAP products have often been used to augment other Florida Geological Survey and Florida Aquifer Vulnerability Assessment (FAVA) projects in the state (Arthur et al., 2007; Baker et al., 2007). These geologic maps will also be compiled and published as part of the Statewide Surficial Geologic Map in the next decade.

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APPENDIX A: FLORIDA GEOLOGICAL SURVEY WELLS UTILIZED FOR STUDY

This table lists FGS wells within the boundaries of the USGS Bartow 30 x 60 minute quadrangle utilized for the project. Due to graphical constraints, not all wells will appear on Plate 1 of OFMS 111. The first 38 wells in the table were utilized for geologic cross-sections and appear on Plates 1 and 2 of OFMS 111.

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
1	W-341	FGS	Cuttings	27.95002	-81.57536	LAKE WALES	219	732
2	W-437	FGS	Cuttings	27.66639	-81.36558	LAKE ARBUCKLE NE	61	1000
3	W-623	FGS	Cuttings	27.83677	-81.52614	BABSON PARK	159	967
4	W-952	FGS	Cuttings	27.95836	-81.67952	ELOISE	141	663
5	W-1008	FGS	Cuttings	27.79738	-81.81398	HOMELAND	124	802
6	W-1710	FGS	Cuttings	27.80417	-81.25500	LAKE WEOHYAKAPKA	63	364
7	W-1864	FGS	Cuttings	27.97917	-81.88556	MULBERRY	123	619
8	W-1887	FGS	Cuttings	27.71025	-81.53633	FROSTPROOF	150	1113
9	W-2842	FGS	Cuttings	27.65778	-81.49124	LAKE ARBUCKLE	116	1238
10	W-4123	FGS	Cuttings	27.75888	-81.80526	HOMELAND	140	836
11	W-4503	FGS	Cuttings	27.81141	-81.33035	LAKE WEOHYAKAPKA	100	976
12	W-5464	FGS	Cuttings	27.89074	-81.56940	LAKE WALES	242	1056
13	W-9048	FGS	Cuttings	27.64167	-81.60111	FROSTPROOF	85	760
14	W-9049	FGS	Cuttings	27.64424	-81.63583	BEREAH	111	720
15	W-9070	FGS	Cuttings	27.56198	-81.77282	WAUCHULA	69	830
16	W-9144	FGS	Cuttings	27.70524	-81.12538	FORT KISSIMMEE NW	59	640
17	W-9150	FGS	Cuttings	27.79251	-81.12362	LAKE MARIAN SE	61	490
18	W-9259	FGS	Cuttings	27.93260	-81.42296	HESPERIDES	54	530
19	W-9264	FGS	Cuttings	27.73143	-81.79963	BOWLING GREEN	116	780
20	W-9277	FGS	Cuttings	27.83861	-81.75694	HOMELAND	198	664
21	W-9348	FGS	Cuttings	27.81284	-81.68740	ALTURAS	142	620
22	W-11179	FGS	Cuttings	27.83150	-81.44332	LAKE WEOHYAKAPKA	86	422
23	W-13712	FGS	Cuttings	27.63959	-81.82805	BOWLING GREEN	115	1218
24	W-14137	FGS	Cuttings	27.63833	-81.76972	BOWLING GREEN	113	1052
25	W-14503	FGS	Cuttings	27.96069	-81.79697	BARTOW	112	667
26	W-14884	FGS	Cuttings	27.60450	-81.48008	LAKE ARBUCKLE SW	148	400
27	W-15336	FGS	Cuttings	27.94308	-81.17395	LAKE MARIAN NW	67	860
28	W-16308	FGS	Core	27.82438	-81.59804	BABSON PARK	132	405
29	W-16539	FGS	Cuttings	27.50726	-81.12868	FORT KISSIMMEE	54	782
30	W-17022	FGS	Cuttings	27.68127	-81.19490	FORT KISSIMMEE NW	59	1043
31	W-17141	FGS	Cuttings	27.80197	-81.19840	LAKE MARIAN SW	52	880
32	W-18535	FGS	Core	27.50272	-81.41964	LAKE ARBUCKLE SW	129	1877
33	W-18629	FGS	Core	27.65871	-81.13458	FORT KISSIMMEE NW	49	397
34	W-18805	FGS	Core	27.89333	-81.81208	BARTOW	95	505.5
35	W-18807	FGS	Core	27.84278	-81.81091	HOMELAND	86	585
36	W-19735	FGS	Core	27.58456	-81.14675	FORT KISSIMMEE	44	400
37	W-19748	FGS	Core	27.89133	-81.17392	LAKE MARIAN NW	58	350
38	W-19749	FGS	Core	27.95500	-81.36908	LAKE WEOHYAKAPKA	60	385
39	W-345	FGS	Cuttings	27.97965	-81.61499	LAKE WALES	129	545
40	W-381	FGS	Cuttings	27.65361	-81.35194	LAKE ARBUCKLE NE	61	1035
41	W-449	FGS	Cuttings	27.57083	-81.82083	WAUCHULA	122	660
42	W-592	FGS	Cuttings	27.52143	-81.73091	GRIFFINS CORNER	97	515
43	W-667	FGS	Cuttings	27.66541	-81.35556	LAKE ARBUCKLE NE	60	540
44	W-668	FGS	Cuttings	27.66849	-81.35201	LAKE ARBUCKLE NE	62	1055
45	W-672	FGS	Cuttings	27.95086	-81.78369	BARTOW	126	601
46	W-904	FGS	Cuttings	27.91833	-81.60290	LAKE WALES	132	1155
47	W-911	FGS	Cuttings	27.61889	-81.47167	LAKE ARBUCKLE SW	152	1285
48	W-928	FGS	Cuttings	27.85528	-81.69217	ALTURAS	166	658
49	W-930	FGS	Cuttings	27.50778	-81.44167	LAKE ARBUCKLE SW	131	475

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Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
50	W-965	FGS	Cuttings	27.71289	-81.52508	FROSTPROOF	142	1023
51	W-967	FGS	Cuttings	27.73611	-81.60000	FROSTPROOF	164	963
52	W-978	FGS	Cuttings	27.78888	-81.58011	BABSON PARK	120	628
53	W-981	FGS	Cuttings	27.69958	-81.49132	LAKE ARBUCKLE	104	1060
54	W-1111	FGS	Cuttings	27.88197	-81.70953	ELOISE	162	824
55	W-1476	FGS	Cuttings	27.85142	-81.98592	BRADLEY JUNCTION	138	889
56	W-1726	FGS	Cuttings	27.80028	-81.23102	LAKE MARIAN SW	50	930
57	W-1754	FGS	Cuttings	27.86643	-81.56287	BABSON PARK	121	1080
58	W-1760	FGS	Cuttings	27.89510	-81.97473	MULBERRY	112	764
59	W-1801	FGS	Cuttings	27.90283	-81.78342	BARTOW	97	1085
60	W-1997	FGS	Cuttings	27.95306	-81.57548	LAKE WALES	198	1100
61	W-2044	FGS	Cuttings	27.87526	-81.78028	HOMELAND	177	775
62	W-2098	FGS	Cuttings	27.92536	-81.90311	MULBERRY	215	768
63	W-2131	FGS	Cuttings	27.98721	-81.73324	ELOISE	135	650
64	W-2304	FGS	Cuttings	27.75591	-81.88849	BRADLEY JUNCTION	141	912
65	W-2413	FGS	Cuttings	27.86162	-81.77272	HOMELAND	187	812
66	W-2431	FGS	Cuttings	27.87576	-81.84434	BARTOW	129	186
67	W-2538	FGS	Cuttings	27.86475	-81.93147	BRADLEY JUNCTION	177	788
68	W-2732	FGS	Cuttings	27.64371	-81.90371	BAIRD	117	1010
69	W-2742	FGS	Cuttings	27.89694	-81.92370	MULBERRY	197	600
70	W-2843	FGS	Cuttings	27.59377	-81.50842	AVON PARK	166	1301
71	W-2846	FGS	Cuttings	27.55667	-81.45556	LAKE ARBUCKLE SW	96	120
72	W-3007	FGS	Cuttings	27.90094	-81.91794	MULBERRY	207	826
73	W-3459	FGS	Cuttings	27.89889	-81.95333	MULBERRY	127	650
74	W-3559	FGS	Cuttings	27.52649	-81.79997	WAUCHULA	76	250
75	W-3604	FGS	Cuttings	27.96308	-81.88581	MULBERRY	132	130
76	W-3649	FGS	Cuttings	27.85955	-81.72611	ALTURAS	159	738
77	W-3747	FGS	Cuttings	27.88611	-81.71960	ELOISE	157	720
78	W-3780	FGS	Cuttings	27.91917	-81.62250	LAKE WALES	115	420
79	W-3852	FGS	Cuttings	27.74944	-81.95917	BAIRD	179	970
80	W-3874	FGS	Cuttings	27.88308	-81.70203	ELOISE	146	750
81	W-4006	FGS	Cuttings	27.60694	-81.97500	FT. GREEN	126	810
82	W-4185	FGS	Cuttings	27.86167	-81.93083	BRADLEY JUNCTION	182	832
83	W-4190	FGS	Cuttings	27.89158	-81.49541	HESPERIDES	114	802
84	W-4255	FGS	Cuttings	27.96197	-81.91731	MULBERRY	255	845
85	W-4364	FGS	Cuttings	27.80806	-81.55395	BABSON PARK	120	600
86	W-4389	FGS	Cuttings	27.97173	-81.92972	MULBERRY	217	778
87	W-4895	FGS	Cuttings	27.63333	-81.65556	BEREAH	111	1018
88	W-5351	FGS	Cuttings	27.75625	-81.56940	BABSON PARK	131	370
89	W-5826	FGS	Cuttings	27.99368	-81.94160	MULBERRY	126	474
90	W-5982	FGS	Cuttings	27.95222	-81.90616	MULBERRY	183	498
91	W-6510	FGS	Cuttings	27.94625	-81.72376	ELOISE	127	530
92	W-6621	FGS	Cuttings	27.61781	-81.88592	FT. GREEN	101	887
93	W-7060	FGS	Cuttings	27.86216	-81.84524	HOMELAND	130	700
94	W-7091	FGS	Cuttings	27.69852	-81.95816	BAIRD	134	302
95	W-7307	FGS	Cuttings	27.97928	-81.75974	BARTOW	171	690
96	W-8869	FGS	Core	27.90674	-81.85361	BARTOW	111	128
97	W-8879	FGS	Core	27.94722	-81.86444	BARTOW	106	122
98	W-9046	FGS	Cuttings	27.56957	-81.65804	GRIFFINS CORNER	75	830
99	W-9047	FGS	Cuttings	27.58970	-81.56820	AVON PARK	97	740
100	W-9050	FGS	Cuttings	27.59889	-81.64139	GRIFFINS CORNER	68	710
101	W-9051	FGS	Cuttings	27.61722	-81.60552	AVON PARK	97	720
102	W-9059	FGS	Cuttings	27.61972	-81.92028	FT. GREEN	117	980
103	W-9063	FGS	Cuttings	27.51151	-81.96000	FT. GREEN	90	820
104	W-9067	FGS	Cuttings	27.54028	-81.92222	FT. GREEN	105	820
105	W-9069	FGS	Cuttings	27.57083	-81.70139	GRIFFINS CORNER	123	790
106	W-9089	FGS	Cuttings	27.59111	-81.78889	WAUCHULA	81	770
107	W-9091	FGS	Cuttings	27.51778	-81.60833	AVON PARK	68	850

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Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
108	W-9092	FGS	Cuttings	27.50167	-81.63528	GRIFFINS CORNER	71	830
109	W-9093	FGS	Cuttings	27.53972	-81.64222	GRIFFINS CORNER	55	740
110	W-9096	FGS	Cuttings	27.54167	-81.67576	GRIFFINS CORNER	98	850
111	W-9102	FGS	Cuttings	27.53177	-81.84424	WAUCHULA	115	650
112	W-9119	FGS	Cuttings	27.79280	-81.01839	LAKE MARIAN SE	71	660
113	W-9120	FGS	Cuttings	27.82511	-81.01449	LAKE MARIAN SE	71	660
114	W-9130	FGS	Cuttings	27.72714	-81.01745	FORT KISSIMMEE NE	68	634
115	W-9131	FGS	Cuttings	27.74901	-81.07517	FORT KISSIMMEE NE	70	626
116	W-9132	FGS	Cuttings	27.71286	-81.10025	FORT KISSIMMEE NE	62	680
117	W-9133	FGS	Cuttings	27.67688	-81.13299	FORT KISSIMMEE NW	46	600
118	W-9134	FGS	Cuttings	27.68945	-81.02601	FORT KISSIMMEE NE	60	610
119	W-9136	FGS	Cuttings	27.73818	-81.10406	FORT KISSIMMEE NE	64	710
120	W-9137	FGS	Cuttings	27.69040	-81.10882	FORT KISSIMMEE NE	59	650
121	W-9138	FGS	Cuttings	27.66851	-81.10807	FORT KISSIMMEE NE	59	600
122	W-9139	FGS	Cuttings	27.66817	-81.05958	FORT KISSIMMEE NE	64	615
123	W-9141	FGS	Cuttings	27.74370	-81.12728	FORT KISSIMMEE NW	63	710
124	W-9142	FGS	Cuttings	27.74132	-81.13109	FORT KISSIMMEE NW	63	710
125	W-9143	FGS	Cuttings	27.68111	-81.03471	FORT KISSIMMEE NE	66	718
126	W-9145	FGS	Cuttings	27.74972	-81.05862	FORT KISSIMMEE NE	70	510
127	W-9147	FGS	Cuttings	27.87796	-81.03995	LAKE MARIAN NE	66	710
128	W-9148	FGS	Cuttings	27.77898	-81.11647	LAKE MARIAN SE	56	473
129	W-9149	FGS	Cuttings	27.82694	-81.09159	LAKE MARIAN SE	65	660
130	W-9151	FGS	Cuttings	27.81141	-81.14145	LAKE MARIAN SW	61	610
131	W-9156	FGS	Cuttings	27.73475	-81.10806	FORT KISSIMMEE NE	64	690
132	W-9210	FGS	Cuttings	27.88583	-81.75272	BARTOW	132	560
133	W-9212	FGS	Cuttings	27.67870	-81.96119	BAIRD	141	740
134	W-9214	FGS	Cuttings	27.67875	-81.88757	BAIRD	140	700
135	W-9215	FGS	Cuttings	27.78770	-81.77325	HOMELAND	112	680
136	W-9216	FGS	Cuttings	27.70083	-81.93656	BAIRD	175	800
137	W-9217	FGS	Cuttings	27.84721	-81.90375	BRADLEY JUNCTION	305	640
138	W-9218	FGS	Cuttings	27.83261	-81.92012	BRADLEY JUNCTION	169	640
139	W-9223	FGS	Cuttings	27.73672	-81.63417	BEREAH	140	641
140	W-9224	FGS	Cuttings	27.78233	-81.74667	ALTURAS	145	717
141	W-9227	FGS	Cuttings	27.73677	-81.90387	BAIRD	124	730
142	W-9228	FGS	Cuttings	27.80980	-81.94455	BRADLEY JUNCTION	133	620
143	W-9230	FGS	Cuttings	27.77332	-81.89566	BRADLEY JUNCTION	164	663
144	W-9231	FGS	Cuttings	27.82387	-81.84710	HOMELAND	169	650
145	W-9232	FGS	Cuttings	27.73673	-81.67417	BEREAH	131	703
146	W-9233	FGS	Cuttings	27.78753	-81.69968	ALTURAS	157	480
147	W-9237	FGS	Cuttings	27.79884	-81.99787	BRADLEY JUNCTION	145	686
148	W-9238	FGS	Cuttings	27.79569	-81.53472	BABSON PARK	192	724
149	W-9245	FGS	Cuttings	27.83385	-81.89616	BRADLEY JUNCTION	145	622
150	W-9249	FGS	Cuttings	27.76599	-81.85417	HOMELAND	152	670
151	W-9250	FGS	Cuttings	27.82510	-81.43799	LAKE WEOHYAKAPKA	59	570
152	W-9251	FGS	Cuttings	27.84258	-81.35848	LAKE WEOHYAKAPKA	67	670
153	W-9252	FGS	Cuttings	27.86806	-81.38725	LAKE WEOHYAKAPKA	70	530
154	W-9253	FGS	Cuttings	27.88293	-81.42007	HESPERIDES	63	460
155	W-9254	FGS	Cuttings	27.85360	-81.40375	LAKE WEOHYAKAPKA	62	540
156	W-9255	FGS	Cuttings	27.84638	-81.37908	LAKE WEOHYAKAPKA	64	570
157	W-9257	FGS	Cuttings	27.90192	-81.37467	LAKE WEOHYAKAPKA	49	500
158	W-9258	FGS	Cuttings	27.90194	-81.40765	HESPERIDES	61	500
159	W-9260	FGS	Cuttings	27.88301	-81.44483	HESPERIDES	112	485
160	W-9263	FGS	Cuttings	27.79516	-81.90278	BRADLEY JUNCTION	158	600
161	W-9265	FGS	Cuttings	27.82416	-81.78984	HOMELAND	119	580
162	W-9266	FGS	Cuttings	27.70028	-81.83806	BOWLING GREEN	119	742
163	W-9271	FGS	Cuttings	27.85495	-81.69321	ALTURAS	163	220
164	W-9273	FGS	Cuttings	27.86048	-81.73185	ALTURAS	115	430
165	W-9275	FGS	Cuttings	27.91604	-81.71833	ELOISE	120	614

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Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
166	W-9276	FGS	Cuttings	27.90111	-81.71944	ELOISE	118	618
167	W-9278	FGS	Cuttings	27.76750	-81.66456	ALTURAS	124	648
168	W-9279	FGS	Cuttings	27.76783	-81.61528	BABSON PARK	151	600
169	W-9351	FGS	Cuttings	27.75854	-81.72406	ALTURAS	187	785
170	W-10420	FGS	Cuttings	27.96357	-81.87601	MULBERRY	113	102
171	W-10440	FGS	Cuttings	27.94172	-81.79634	BARTOW	108	129
172	W-10498	FGS	Cuttings	27.52139	-81.45306	LAKE ARBUCKLE SW	141	90
173	W-10501	FGS	Cuttings	27.74765	-81.83437	BOWLING GREEN	105	823
174	W-10579	FGS	Cuttings	27.83465	-81.64152	ALTURAS	137	200
175	W-10808	FGS	Cuttings	27.76866	-81.19373	LAKE MARIAN SW	55	854
176	W-10877	FGS	Cuttings	27.97451	-81.78778	BARTOW	139	171
177	W-10946	FGS	Cuttings	27.97895	-81.65710	ELOISE	134	306
178	W-11036	FGS	Cuttings	27.96227	-81.95197	MULBERRY	214	828
179	W-11038	FGS	Cuttings	27.72528	-81.80111	BOWLING GREEN	124	1215
180	W-11323	FGS	Cuttings	27.59698	-81.70536	GRIFFINS CORNER	113	1160
181	W-11333	FGS	Cuttings	27.52146	-81.76778	WAUCHULA	96	1080
182	W-11365	FGS	Cuttings	27.93473	-81.77919	BARTOW	104	275
183	W-11366	FGS	Cuttings	27.98599	-81.20292	LAKE MARIAN NW	68	540
184	W-11689	FGS	Cuttings	27.90306	-81.75569	BARTOW	129	166
185	W-11866	FGS	Cuttings	27.89793	-81.88767	MULBERRY	154	255
186	W-11885	FGS	Cuttings	27.92201	-81.79026	BARTOW	112	525
187	W-12235	FGS	Core	27.51167	-81.84861	WAUCHULA	118	118
188	W-12268	FGS	Cuttings	27.90441	-81.65870	ELOISE	117	160
189	W-12462	FGS	Cuttings	27.91353	-81.82641	BARTOW	104	200
190	W-12481	FGS	Cuttings	27.94059	-81.97695	MULBERRY	134	742
191	W-12640	FGS	Cuttings	27.88394	-81.86414	BARTOW	118	1390
192	W-12655	FGS	Cuttings	27.76583	-81.94465	BRADLEY JUNCTION	153	828
193	W-12780	FGS	Cuttings	27.80424	-81.75519	HOMELAND	173	221
194	W-12896	FGS	Cuttings	27.89984	-81.47152	HESPERIDES	107	725
195	W-12992	FGS	Cuttings	27.58046	-81.97893	FT. GREEN	115	1702
196	W-13078	FGS	Core	27.57517	-81.80709	WAUCHULA	69	202
197	W-13233	FGS	Cuttings	27.57187	-81.85923	WAUCHULA	114	1027
198	W-13234	FGS	Cuttings	27.64615	-81.91981	BAIRD	135	360
199	W-13238	FGS	Core	27.58889	-81.93611	FT. GREEN	120	202
200	W-13245	FGS	Core	27.68306	-81.82333	BOWLING GREEN	84	201
201	W-13269	FGS	Core	27.66667	-81.98806	BAIRD	129	200
202	W-13491	FGS	Core	27.96188	-81.96694	MULBERRY	156	49
203	W-13589	FGS	Cuttings	27.67326	-81.93778	BAIRD	144	482
204	W-13603	FGS	Cuttings	27.78408	-81.94875	BRADLEY JUNCTION	121	1083
205	W-14120	FGS	Cuttings	27.59806	-81.92056	FT. GREEN	107	867
206	W-14431	FGS	Cuttings	27.82180	-81.96854	BRADLEY JUNCTION	152	812
207	W-14504	FGS	Cuttings	27.87238	-81.93278	BRADLEY JUNCTION	166	709
208	W-14722	FGS	Cuttings	27.66639	-81.76972	BOWLING GREEN	122	1400
209	W-14726	FGS	Cuttings	27.66720	-81.76397	BOWLING GREEN	127	1200
210	W-14831	FGS	Cuttings	27.65694	-81.99833	BAIRD	127	520
211	W-14883	FGS	Cuttings	27.90358	-81.62254	LAKE WALES	127	635
212	W-15346	FGS	Core	27.64170	-81.86508	BOWLING GREEN	96	394
213	W-15938	FGS	Core	27.75655	-81.51077	BABSON PARK	82	444
214	W-16027	FGS	Core	27.95639	-81.81389	BARTOW	99	402
215	W-16149	FGS	Core	27.93977	-81.85246	BARTOW	97	50
216	W-16150	FGS	Core	27.99576	-81.83035	BARTOW	100	83
217	W-16300	FGS	Core	27.84040	-81.53647	BABSON PARK	123	349
218	W-16305	FGS	Core	27.79145	-81.56041	BABSON PARK	121	1200
219	W-16307	FGS	Core	27.91981	-81.59393	LAKE WALES	145	504
220	W-16309	FGS	Core	27.89766	-81.56861	LAKE WALES	153	345
221	W-16324	FGS	Cuttings	27.56690	-81.71902	GRIFFINS CORNER	118	730
222	W-16401	FGS	Core	27.93327	-81.55404	LAKE WALES	124	205
223	W-16405	FGS	Core	27.81405	-81.50630	BABSON PARK	91	263

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Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
224	W-16408	FGS	Cuttings	27.85736	-81.53108	BABSON PARK	133	65
225	W-16409	FGS	Cuttings	27.81389	-81.53926	BABSON PARK	285	150
226	W-16410	FGS	Cuttings	27.84684	-81.56204	BABSON PARK	165	89
227	W-16411	FGS	Cuttings	27.78444	-81.55556	BABSON PARK	131	105
228	W-16412	FGS	Cuttings	27.76939	-81.50214	BABSON PARK	94	40
229	W-16413	FGS	Cuttings	27.80246	-81.52022	BABSON PARK	116	55
230	W-16415	FGS	Cuttings	27.98322	-81.57865	LAKE WALES	152	80
231	W-16417	FGS	Cuttings	27.96197	-81.56202	LAKE WALES	148	71
232	W-16422	FGS	Cuttings	27.84306	-81.53353	BABSON PARK	151	60
233	W-16424	FGS	Cuttings	27.75486	-81.65440	FORT KISSIMMEE SE	141	35
234	W-16425	FGS	Cuttings	27.83164	-81.52600	BABSON PARK	144	58
235	W-16426	FGS	Cuttings	27.84244	-81.57111	BABSON PARK	176	70
236	W-16669	FGS	Core	27.50028	-81.20000	FORT KISSIMMEE	35	29.5
237	W-16956	FGS	Cuttings	27.89669	-81.04034	LAKE MARIAN NE	67	625
238	W-17004	FGS	Core	27.81444	-81.80500	HOMELAND	111	24
239	W-17042	FGS	Cuttings	27.51114	-81.27840	LAKE ARBUCKLE SE	61	1183
240	W-17342	FGS	Core	27.76306	-81.78472	HOMELAND	115	71
241	W-17424	FGS	Cuttings	27.50365	-81.12229	FORT KISSIMMEE SE	55	158
242	W-17448	FGS	Core	27.80279	-81.19670	LAKE MARIAN SW	63	92
243	W-17453	FGS	Core	27.50111	-81.19631	FORT KISSIMMEE	38	90
244	W-17467	FGS	Core	27.74417	-81.96889	BAIRD	158	51
245	W-17677	FGS	Core	27.95417	-81.36889	LAKE WEOHYAKAPKA	60	74
246	W-17768	FGS	Cuttings	27.80755	-81.01917	LAKE MARIAN SE	72	235
247	W-17852	FGS	Cuttings	27.80755	-81.01917	LAKE MARIAN SE	72	390
248	W-18395	FGS	Core	27.58356	-81.58850	AVON PARK	97	1120
249	W-18496	FGS	Cuttings	27.94278	-81.35500	LAKE WEOHYAKAPKA	52	31
250	W-18571	FGS	Cuttings	27.81444	-81.86694	HOMELAND	166	900
251	W-18675	FGS	Core	27.59778	-81.84194	WAUCHULA	123	1640
252	W-18725	FGS	Cuttings	27.66048	-81.13273	FORT KISSIMMEE NW	46	1980
253	W-18784	FGS	Cuttings	27.65833	-81.13297	FORT KISSIMMEE NW	48	1220
254	W-18803	FGS	Core	27.79586	-81.88719	BRADLEY JUNCTION	167	200
255	W-18806	FGS	Core	27.86611	-81.80529	HOMELAND	94	308
256	W-19523	FGS	Core	27.68317	-81.66226	BEREAH	143	76.5
257	W-19524	FGS	Core	27.68314	-81.66228	BEREAH	143	600
258	W-19556	FGS	Cuttings	27.72038	-81.98878	BAIRD	144	2850
259	W-19712	FGS	Core	27.86446	-81.56600	BABSON PARK	118	147
260	W-19713	FGS	Core	27.96389	-81.74277	ELOISE	152	61
261	W-19714	FGS	Core	27.74708	-81.53643	FROSTPROOF	113	102
262	W-19744	FGS	Core	27.58750	-81.02344	FORT KISSIMMEE SE	65	40