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OPEN-FILE REPORT 101

Text to accompany geologic map of the USGS Daytona Beach 30 x 60 minute quadrangle, northeast Florida (Open-File Map Series 105)

By

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ABSTRACT

The accompanying 1:100,000 scale geologic map (Open-File Map Series 105, Plate 1) depicts the areal distribution of bedrock and surficial geologic units for the U.S. Geological Survey (USGS) Daytona Beach 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, geophysical log analyses and analyses of various Geographic Information System (GIS) data sources. The resulting data were compiled in ESRI® ArcGIS® ArcMap™ 10 software for publication as part of the Florida Geological Survey Open-File Map Series. Mapped units range from Middle Miocene to Quaternary. Important resources in the mapped area include potable groundwater, springs, sand, clay, and coquina. Numerous springs, swallets (sinking streams), and other karst features are present in the study area. The geologic maps 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, energy production facilities, waste management and storage facilities, locating sources of mineable resources for aggregate supply, and protection of springs, surface and groundwater quality.

Keywords: Florida, geologic map, Avon Park Formation, Ocala Limestone, Hawthorn Group, Penney Farms Formation, Marks Head Formation, Coosawhatchie Formation, Cypresshead Formation, Anastasia Formation, geomorphology, hydrogeology, springs, swallets, karst, sinkholes, Floridan aquifer system, Flagler County, Lake County, Marion County, Putnam County, Volusia County, Daytona Beach.

INTRODUCTION

Florida Geological Survey (FGS) Open-File Report (OFR) 101 accompanies Open-File Map Series (OFMS) 105, which is comprised of three plates. Plate 1 depicts the near-surface geology of the USGS Daytona Beach 30 x 60 minute quadrangle on a digital elevation model (DEM). Plate 2 depicts five geologic cross-sections, a stratigraphic correlation chart, and representative photos for several of the lithologic units in the study area. Plate 3 is a geomorphology map on a DEM, showing locations of known springs, sinkholes and swallets, along with photographs of selected exposures within the study area.

The study area is located along the Atlantic coastline of Florida (Figure 1). It includes the communities of Daytona Beach, DeLand, Flagler Beach and Ormond Beach. The quadrangle, which includes portions of Flagler, Lake, Marion, Putnam and Volusia Counties, is bounded to the west by the USGS Ocala 30 x 60 minute quadrangle, recently mapped under the STATEMAP program (Green et al., 2009a; Green et al., 2009b; Green et al., 2010a; Green et al.,

2010b), to the north by the USGS Saint Augustine 30 x 60 minute quadrangle and to the south by the USGS Orlando 30 x 60 minute quadrangle (Figure 1). The Tomoka, St. Johns, and Ocklawaha Rivers, along with numerous creeks and springs, 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 105. Information provided by this report and the plates in OFMS 105 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 potential aquifer recharge and confinement, 3) aiding water-management decisions on groundwater flow and usage, 4) providing information on aquifer vulnerability to potential pollution, 5) ecosystem, wetlands and environmental characterization, and 6) recreational uses.

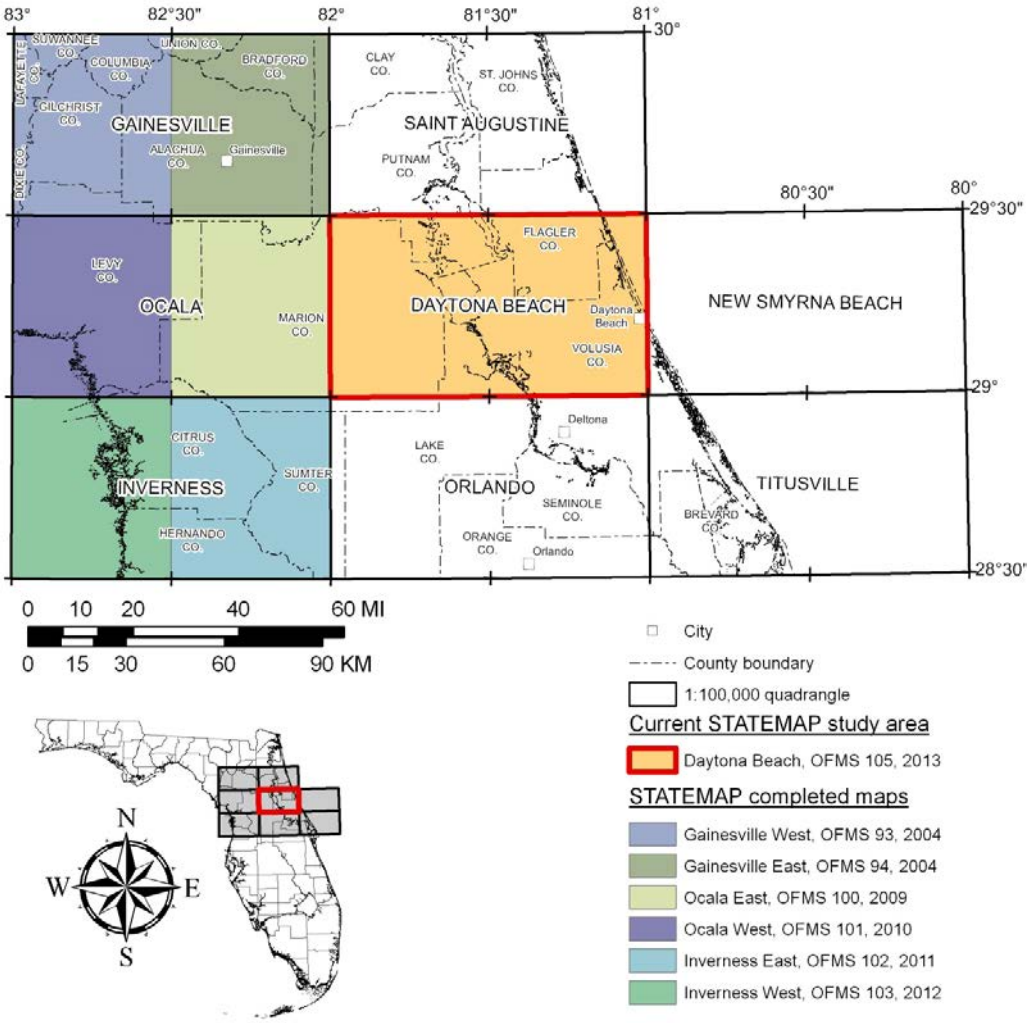

Figure 1. Nearby areas mapped under the FGS STATEMAP Program.

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) new core drilling, 5) collecting and describing outcrop samples, and 6) preparing a geologic map, geological cross-sections and geomorphic map of the area. Fieldwork, performed during the fall of 2012 through the summer of 2013, consisted of sampling and describing numerous outcrops, river and borrow pit exposures.

Forty-three new samples of geologic material were added to the FGS surface-sample archives (M-Series) and five cores (1,294 feet or 394.4 meters total) were drilled for the project. Approximately 100 outcrops and exposures were also examined during the project. In addition to new cores collected for this study, approximately 350 sets of cores and cuttings archived in the Florida Geological Survey well repository were examined and formation picks were made for mapped geologic units. Over four hundred formation picks derived from geophysical logs (see discussion beginning on page 21 for geophysical log interpretation), in addition to the data from the cores and cuttings, were utilized in developing various modeled surfaces. Figure 2 shows the locations of FGS cores and cuttings and St. Johns River Water Management District (SJRWMD) data points within the study area. Appendix A includes FGS wells with core and/or cuttings samples which were examined by the authors and used for the top of rock model or for determining the geologic surface and subsurface formations. An interpolated top of rock surface was developed using kriging along with a Digital Elevation Model (DEM) to generate an overburden thickness model. The map and accompanying plates were developed in ESRI® ArcGIS® ArcMap™ 10 software for publication as part of OFMS 105.

Due to a lack of complete LiDAR coverage in the study area, a custom elevation model was created for this product. Two products were used to create this elevation model: standard LiDAR elevation models with horizontal resolutions of five feet (1.5 meters); and a much coarser elevation model based off of topographic contours with a horizontal resolution of 100 feet (30.5 meters). LiDAR coverage currently exists for the entirety of Lake, Marion, and Volusia counties, in addition to a small portion of Putnam County along the St. John's River Corridor, and a swath of the coastal areas of Volusia County approximately three miles wide. The majority of both Volusia and Putnam counties lacked LiDAR coverage.

The hybrid elevation model was created by first combining all of the existing LiDAR elevation models into a single raster. The coarser 100 foot (30.5 meter) contour-based DEM was re-sampled and aligned to match the resolution of the five feet (1.5 meter) 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 coverage if available; where LiDAR was not available, elevation values were drawn from the coarser, contour based DEM.

As a preliminary step, points from each of the datasets (cores, cuttings and geophysical logs) were used to generate a Triangular Irregular Network (TIN) of the modeled surface. This TIN was then used as a method of examining and discarding any points that appeared anomalous compared to their surrounding values. During this step, any point which differed substantially from the surrounding points were indicated by a sharp depression or peak in the TIN surface; points found that differed by 75 or more feet from surrounding points were then removed from the dataset.

After this step was completed, an ordinary kriging method was used to generate a top of rock surface using the "stable" algorithm. Lag size was empirically calculated based on the total spatial extent of the combined datasets, and then adjusted slightly to improve model performance. The error values for all data were examined after each iteration of the model, and any points with a standardized error greater than five or less than negative five were discarded in order to improve the final model performance.

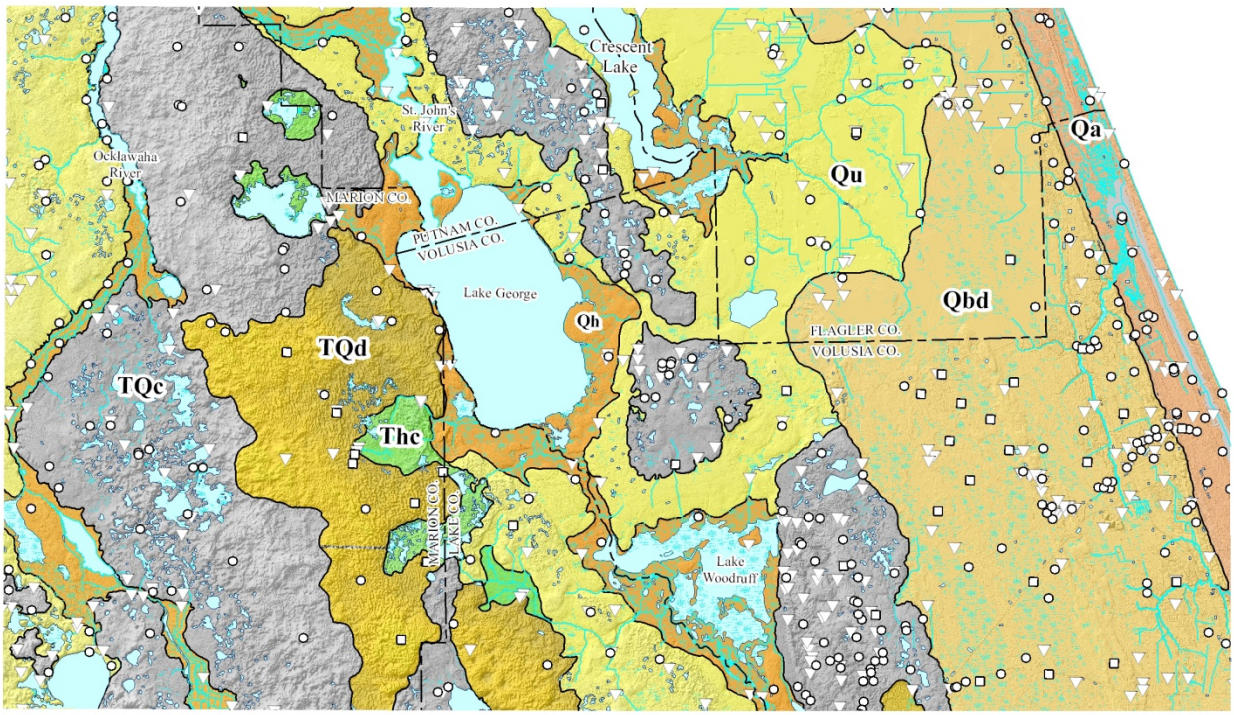

Figure 2. FGS cores (squares), cuttings (circles) and St. Johns River Water Management District geophysical logs (triangles) utilized for top of rock models. See discussion starting on page 14 for lithostratigraphic unit abbreviations and descriptions.

Much of the study area is blanketed by a veneer of undifferentiated Tertiary and Quaternary sediments and soils. 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 Tertiary/Quaternary dune (TQd), undifferentiated Quaternary (Qu), Holocene (Qh) or Quaternary beach ridge and dune (Qbd) sediments attain a thickness greater than 20 feet (6.1 meters), then they appear as the mapped unit. If these undifferentiated 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 105, Plate 1) and geologic cross sections (OFMS 105, 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 several large sections of the mapped area is hindered by the presence of numerous wetlands, farms, ranches and privately owned land. Additionally, much of the coastal area is heavily developed with sub-divisions,

many of which are gated communities. In instances where access was limited by these factors, the authors had to rely on existing well and core data. Fieldwork access was typically limited to public roads, State-owned lands and County-owned lands.

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 Flagler (Scott, 1992b), Lake (Scott, 1992d), Marion (Scott, 1992e), Putnam (Scott, 1992a), and Volusia (Scott, 1992c) counties at 1:126,720 scale were previously published by the FGS. However, each of these 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. 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 of this project. A statewide geologic map (Scott et al., 2001) also provided a framework for the current, more detailed mapping.

Scott (1988) published detailed descriptions, structure contour maps, and isopach maps for units of the Hawthorn Group. Huddlestun (1988) defined and discussed the Nashua and Cypresshead Formations. This study also benefited greatly from the work performed during geologic mapping of the eastern portion of the USGS Ocala 30 x 60 minute quadrangle (Green et al., 2009a; Green et al., 2009b). Some of the field relationships and stratigraphic problems were worked out during those projects and data gathered during work on them proved invaluable to the completion of this project.

GEOLOGIC SUMMARY

The near surface geology of the USGS 30 x 60 minute Daytona Beach quadrangle is composed of a complex mixture of Middle Eocene 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 Daytona Beach quadrangle is the Tertiary Coosawhatchie Formation of the Hawthorn Group (Thc). This unit is exposed in the vents of Marion Salt Spring, Juniper Spring and Alexander Spring (see OFMS 105, Plate 1).

Detailed description of the lithology of all units found in the study area begins on page 14 of this publication. Along with lithologic descriptions, several diagnostic foraminifera and echinoids aid in distinguishing Ocala Limestone from the Avon Park Formation. The Avon Park Formation contains *Cushmania* [*Dictyoconus*] *americana* and *Discorinopsis gunteri* which are not found in the Ocala Limestone. The occurrence of *Nummulites* spp. and *Lepidocyclina* spp. in the Ocala Limestone helps to distinguish it from the Avon Park Formation in the mapped area.

Much of the Daytona Beach quadrangle is located within the Ocklawaha, Tomoka, and St. Johns River Basins (Figure 3). There are numerous springs and spring-fed rivers within the study area, including two springs in Lake County, thirty-seven springs in Marion County, nine springs in Putnam County and one in Volusia County. These include twelve first magnitude springs and thirty-seven lesser magnitude springs (Scott et al., 2004). A first magnitude spring is defined as having a minimum average flow of at least 100 cubic feet per second (64.6 million gallons per day; Copeland, 2003).

Portions of the recharge areas for many of the aforementioned springs in Lake, Marion, Putnam and Volusia counties are located within the study area. Many of these springs have shown significant increases in pollutants in the last few decades, particularly nitrate (Phelps, 1994; Phelps, 2004; Jones et al., 1996; Scott et al., 2002; Upchurch et al., 2004; Copeland et al., 2009). Detailed geologic mapping of lithostratigraphic units in this area provides critical data needed for future assessments of the vulnerability of the aquifer systems and springs to contamination. Understanding the surficial geology of the map area is a key factor in developing management and protection plans, not only for the springs, but for the unconfined portions of the Floridan aquifer system.

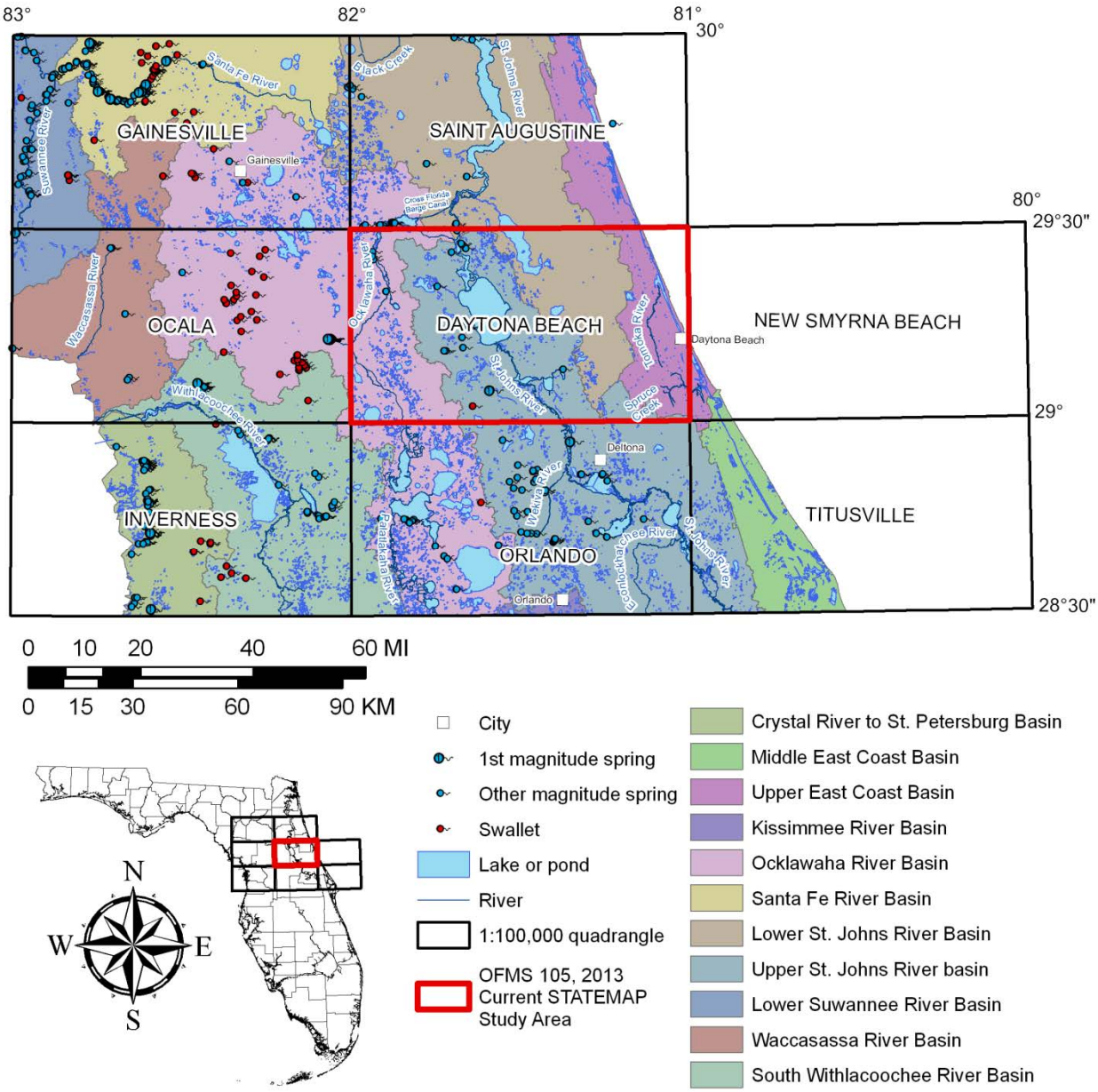

Figure 3. Location of selected river basins, springs, swallets and other water bodies.

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).

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

The study area can be divided into two main karst regions: the areas upon the Mt. Dora Ridge and the areas surrounding it. Generally, the overburden sediments are thickest and contain a higher percentage of clay and clayey sediments, resulting more frequently in the occurrence of cover-collapse sinkholes to the west and south of the Mt. Dora Ridge. To the east of the Mt. Dora Ridge, extending towards the St. Johns River valley, the overburden sediments are generally thinner (see OFMS 105, Plate 2) resulting in both cover-subsidence and cover-collapse sinkholes (Sinclair and Stewart, 1985). Several wells examined in this study located on the flanks of the Mt. Dora Ridge exhibited the effects of that increased karstification. The samples for those wells typically exhibited increased amounts of sand, organics and clayey sand interspersed with occasional bits of carbonate rock at depth followed by a correspondingly deeper-than-expected top of first carbonate rock unit. One well drilled for this project (W-19453; OFMS 105, Plate 2, cross-section C-C'), demonstrates this. The well had significantly thicker Cypresshead Formation and thinner Hawthorn Group sediments than expected. Possible explanations include karst or filling in of an erosional low in the top of the Hawthorn Group surface. Unfortunately, well control in this area was inadequate to determine the nature of the surface.

Structure

Several structural features have affected the geology of the region (Figure 4). 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 western 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 had Upper Cretaceous sediments deposited upon it (Applin, 1951). It formed a relatively stable base for Eocene carbonate deposition (Williams et al., 1977). The arch did not affect mid-Tertiary to Holocene sediment deposition (Williams et al., 1977; Scott, 1997).

The Sanford High, named by Vernon (1951), is a positive feature located in Volusia and Seminole counties. It is a prominent structure affecting the near surface depositional and post-depositional environments within the map area (Figure 4). Vernon (1951) described this feature as "a closed fold that has been faulted, the Sanford high being located on the upthrown side". The Ocala Limestone and Hawthorn Group are missing over this feature and post-Hawthorn Group sediments (undifferentiated Pliocene/Pleistocene shelly sediments) directly overlie the Avon Park Formation in the vicinity of the Sanford High (see OFMS 105, Plate 2).

The St. Johns Platform, introduced by Riggs (1979a, 1979b), extends northward from the Sanford High into St. Johns County. This platform, which is expressed on the erosional surface of the Ocala Limestone, dips gently north-northwest towards Jacksonville (Scott, 1983). This is evident throughout the map area (OFMS 105; Plate 2). Undifferentiated sediments, thickest on the flanks of the Mt. Dora, DeLand and Crescent City ridges, have subsequently been deposited on the exposed undifferentiated Pliocene/Pleistocene shelly sediments, Miocene Hawthorn Group and Eocene carbonates. These consist of residual clays, sands, and aeolian sands deposited during the Miocene to Holocene (Scott, 1997).

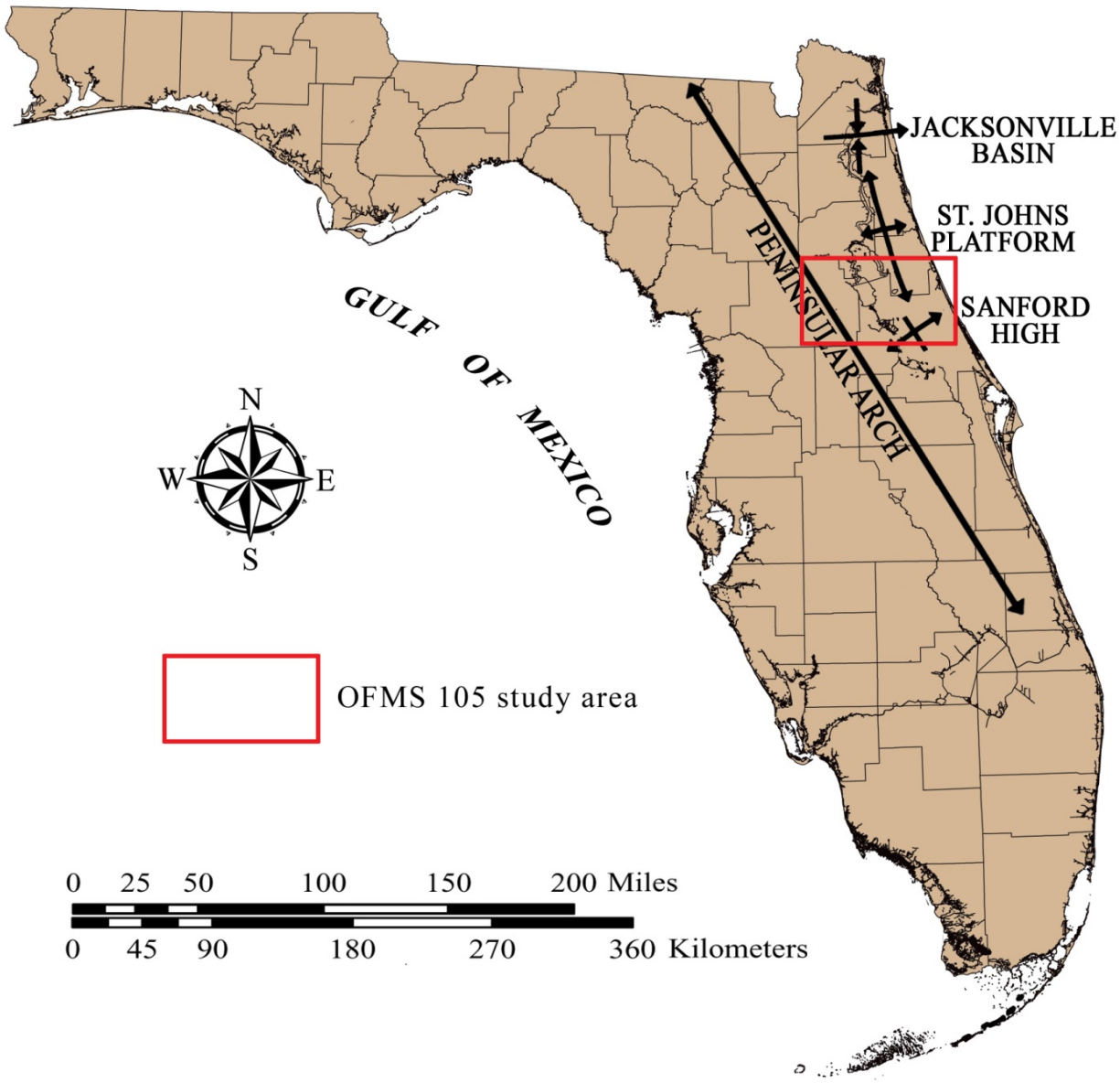

Figure 4. Principal subsurface structures of north Florida (modified from Scott, 1988).

Geomorphology

Healy (1975) recognized six possible marine terraces within the study area (Figure 5) based upon elevations above mean sea level (MSL): the Silver Bluff terrace at elevations between 1 and 10 feet (0.3 and 3 meters), the Pamlico terrace at elevations between 10 and 25 feet (3 and 7.6 meters), the Talbot terrace at elevations between 25 and 42 feet (7.6 and 12.8 meters), the Penholloway terrace at elevations between 42 and 70 feet (12.8 and 21.3 meters), the Wicomico terrace at elevations between 70 to 100 feet (21.3 to 30.5 meters) and the Sunderland/Okefenokee terrace at elevations between 100 and 170 feet (30.5 and 51.8 meters). Detailed discussions and correlations of these marine terraces and relict shorelines have been attempted by many authors, including Matson and Sanford (1913), Cooke (1931, 1939), Flint (1940, 1971), MacNeil (1950), Alt and Brooks (1965), Pirkle et al. (1970), Healy (1975), and Colquhoun et al. (1991).

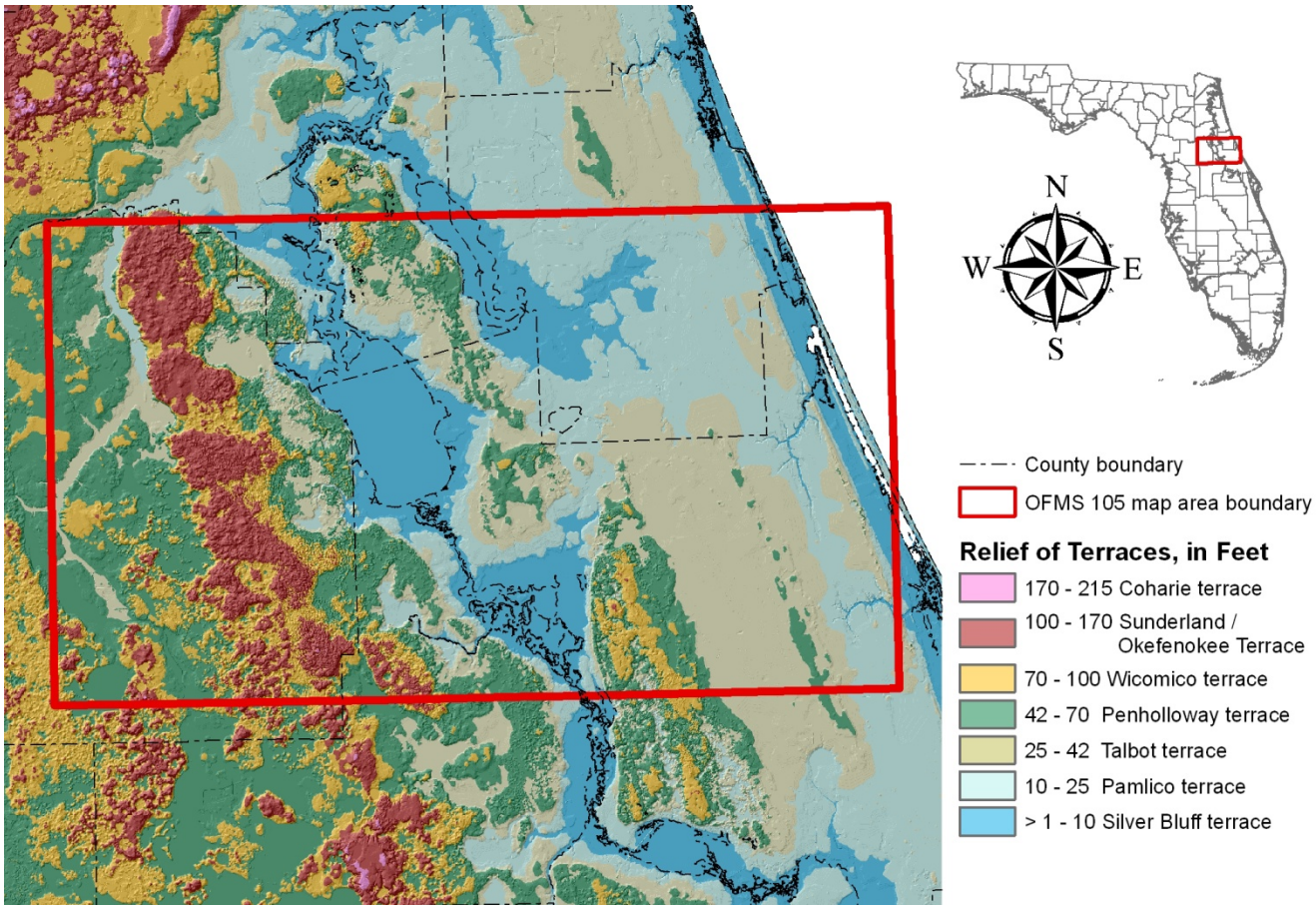

Figure 5. Terraces in the study area (after Healy, 1975).

According to Scott et al., (in preparation), the study area falls within three geomorphic districts: the Barrier Island Sequence District, the Central Lakes District and the Ocala Karst District (OFMS 105; Plate 3, Figure 2). These districts are further subdivided into terranes (OFMS 105; Plate 3, Figure 3) by Scott et al., (in preparation).

Barrier Island Sequence District

The Barrier Island Sequence District extends into Florida from Georgia. The district is characterized by beach ridges, dunes and paleo-lagoons. The district extends from the Florida-Georgia state line southward to the vicinity of Lake Okeechobee. It lies to the east of the Okeefenokee Basin District, the Ocala Karst District, the Central Lakes District, and the Sarasota River District. It lies north of the Everglades District (OFMS 105, Plate 3, Figure 2). Elevations within the District range from sea level to more than 145 feet (44.2 meters) above MSL. The surficial and shallow subsurface sediments of the district were deposited during the Plio-Pleistocene and lie unconformably on sediments ranging from the Middle Eocene Avon Park Formation to the Oligocene-Miocene Hawthorn Group.

Beach ridge plains occur in several areas of the Barrier Island Sequence District at elevations ranging from near sea level to more than 75 feet (22.9 meters) above MSL. In the study area, these occur on the Atlantic Coastal Complex and portions of the Lower St. Johns River Valley. Drainage patterns in these areas may be strongly controlled by the relict beach ridges forming, in some cases, a distinct trellis drainage pattern. The beach ridge swales are often swampy and control the development of lakes on portions of the Osceola Plain.

The Barrier Island Sequence District contains relict (or paleo) lagoons. The occurrence of the lagoonal features is most prominent in the southern portion of the district in the headwaters of the St. Johns River. White (1970) thought that this area was not a paleo-lagoon but a beach ridge plain that had been reduced in stature by dissolution of incorporated shell material. He stated that there were relict beach ridges in the area and that the ridges controlled the drainage. Modern topographic maps, however, do not show the beach ridges nor do they reveal a drainage pattern indicative of beach ridges.

This paleo-lagoon lies between the Atlantic coast on the east and a prominent erosional scarp on the west. The scarp toe occurs at approximately 30 feet (9.1 meters) above MSL and extends nearly continuously from the southern-most portion of the Barrier Island Sequence District northward to the Florida-Georgia state line. The paleo-lagoon extends uninterrupted from the southern end of the district to southern Volusia County. Northward from southern Volusia County the relict lagoon is either interrupted or partially covered by beach ridges. However, the lagoon can be recognized as far north as the vicinity of Jacksonville in Duval County.

Atlantic Coastal Complex

The Atlantic Coastal Complex extends from the Florida-Georgia line to northern Brevard County (OFMS 105, Plate 3, Figure 3). In the study area, the terrane consists of Pliocene through recent barrier beach ridges and dunes that are consistent with the terrane as a whole. Elevations range from sea level to 90 feet (27.4 meters) above MSL. Within the mapped area, elevations range from sea level to approximately 50 feet (15.2 meters) above MSL. There are multiple coast parallel creeks and swamps in the swales separated by ridges and broad scale development of trellis drainage. Some of the major water features include the Tomoka River, Spruce Creek, Graham Swamp and the Halifax River. The latter two, made more distinct by construction of the Intracoastal Waterway, separate the modern barrier island from the mainland to the west. In the study area, the terrane has varying thickness of undifferentiated Quaternary, undifferentiated Tertiary and Quaternary shelly sediments and outcrops of the Pleistocene Anastasia Formation near the Atlantic coast (OFMS 105, plate 2).

Lower St. Johns River Valley

The Lower St. Johns River Valley has been hypothesized by Scott (2013, personal communication) as part of a paleo-lagoon. The relict lagoon feature extends nearly continuously from the headwaters of the St. Johns River in Palm Beach County to central Duval County. In Volusia County, the paleo-lagoon is either partially interrupted or partially covered by beach ridges. In this area, the Atlantic Coastal Complex separates the Upper St. Johns River Valley from the Lower St. Johns River Valley (OFMS 105, Plate 3, Figure 3). The southern end of this interruption corresponds to the westward turn of the St. Johns River as it occupies the St. Johns River Offset. The southern end of the Lower St. Johns River Valley includes Crescent Lake and extends northward to central Duval County where the St. Johns River turns east toward the Atlantic Ocean and some beach ridge uplands separate the St. Johns River Valley from the drainages associated with the Nassau and St. Marys Rivers. Elevations of the terrane range from sea level to more than 80 (24.4 meters) above MSL. Within the study area, elevations range from sea level to 45 feet (13.7 meters) above MSL. Variable thicknesses of undifferentiated Quaternary sediments lie on undifferentiated Pliocene/Pleistocene shelly sediments or the Hawthorn Group in the terrane.

Central Lakes District

The Central Lakes District occupies most of the Central Highlands of Cooke (1939) in peninsular Florida. The district extends from eastern Alachua County, southeastern Bradford County and southern Clay County to southernmost Highlands County. The Central Lake District lies east and south of the Ocala Karst District, south of the Okefenokee District, west of the Barrier Island Sequence District and north of the Sarasota River District and the Everglades District (OFMS 105; Plate 3, Figure 2). A thick (up to 200 feet [61 meters]) sequence of siliciclastic and carbonate sediments of the Hawthorn Group, siliciclastic sediments of the Cypresshead Formation and undifferentiated siliciclastic sediments overlie the Ocala Limestone in the district. Dissolution of the limestone and subsequent subsidence or collapse has created the characteristic rolling hills, sinkhole lakes and dry sinks that dominate the landscape. Much of the terrane is internally drained due to the karst features and the permeable sand cover. District-wide elevations range from near sea level to over 300 feet (91.4 meters) above MSL. Within the mapped area, elevations vary from near sea level in the St. Johns River Offset to more than 200 feet (61 meters) above MSL on the Mt. Dora Ridge. In the study area, the Central Lakes District includes the Crescent City Ridge, the DeLand Ridge, the Fort McCoy Plain, the Mt. Dora Ridge, the Ocklawaha River Valley and the St. Johns River Offset. These ridge features were once part of a more extensive Cypresshead Formation upland that subsequently was erosionally altered leaving the remnant highs.

Crescent City Ridge

The Crescent City Ridge lies in northwestern Volusia County and southeastern Putnam County (OFMS 105, Plate 3, Figure 3). It is located between the St. Johns River Offset and the Lower St. Johns River Valley. Crescent Lake lies at the eastern toe of the ridge. The lake likely represents a portion of the paleo-course of the ancestral St. Johns River, abandoned when the river began to occupy the offset. Elevations vary from approximately 25 feet (7.6 meters) to 125 feet (38.1 meters) above MSL. Locally, relief on the ridge approaches 50 feet (15.2 meters). The

terrain is a rolling, karstic landscape with closed-basin lakes. A thin sequence of Quaternary sand overlies the Cypresshead Formation and undifferentiated Pliocene/Pleistocene shelly sediments. The Hawthorn Group is absent under the ridge within the mapped area.

DeLand Ridge

The DeLand Ridge occurs in western Volusia County extending north-south from near the Flagler County boundary to the Seminole County line (OFMS 105, Plate 3, Figure 3). Elevations on the DeLand Ridge vary from approximately 20 feet (6.1 meters) to more than 100 feet (30.5 meters) above MSL within the mapped area and statewide. Locally, relief on the ridge approaches 50 feet (15.2 meters). The terrain is a rolling karstic landscape with closed basin lakes. A paleo-sand dune field occurs in the south-central portion of the ridge. The DeLand Ridge lies on top of the Sanford High. In portions of Volusia County, the Hawthorn Group and the Ocala Limestone are absent due to erosion and Cypresshead Formation and undifferentiated Pliocene/Pleistocene shelly sediments lie on the Middle Eocene Avon Park Formation. Thin remnants of the Ocala Limestone are present under limited portions of the DeLand Ridge.

Fort McCoy Plain

The Fort McCoy Plain is a relatively flat, poorly to moderately drained area just east of the Ocala Karst Hills and southeast of the Hawthorne Lakes Region (OFMS 105; Plate 3, Figure 3). Scattered sinkholes are present within the terrane and elevations range from approximately 40 feet (12.2 meters) to approximately 90 feet (27.4 meters) above MSL within the study area. The Fort McCoy Plain is underlain by sediments of the Hawthorn Group, which are mantled with variable thicknesses of undifferentiated Quaternary sediments (Scott et al., 2001; Green et al., 2009a; Green et al., 2009b).

Mt. Dora Ridge

The Mt. Dora Ridge occurs in the western portion of the study area in Marion, Putnam and Lake counties. The terrain is a rolling karstic landscape with numerous lakes. Elevations on the Mt. Dora Ridge statewide and within the mapped area vary from 10 feet (3 meters) to more than 200 feet (61 meters) above MSL. Relief often exceeds 100 feet (30.5 meters). Karst processes acting through a thick sequence of siliciclastic sediments (deep-cover karst) created the landscape. Dissolution of the Ocala Limestone and carbonates within the Hawthorn Group is responsible for the development of the Mt. Dora Ridge's distinctive landscape. A paleo-sand dune field occurs in the eastern portion of the ridge in eastern Marion and northern Lake counties (OFMS 105, Plate 1). The area, known as the Big Scrub in the Ocala National Forest, is highly karstified. Tertiary/Quaternary dune sediments (TQd) overlie the Cypresshead Formation on part of the Mt. Dora Ridge. Elsewhere, the Cypresshead Formation lies on the Hawthorn Group.

Ocklawaha River Valley

The Ocklawaha River Valley is a narrow valley extending from near the Lake-Marion County line northward to the Marion-Putnam County line. To the south, the valley abuts the Tavares Lakes Region. To the north, it merges with the St. Johns River Offset. The headwaters of the Ocklawaha River occur in Lake Griffin, in the Tavares Lakes Region, a broader and more karstic portion of the Central Lakes Region. As it enters the Ocklawaha River Valley, the river becomes confined to a narrow valley bounded by the Ocala Karst Hills and the Fort McCoy Plain

on the west and the Mt. Dora Ridge on the east (OFMS 105; Plate 3, Figure 3). The terrane is underlain by Cypresshead Formation, Hawthorn Group sediments and undifferentiated Quaternary sediments. Elevations of the valley within the study area range from 40 feet (12.2 meters) to 70 feet (21.3 meters) above MSL.

St. Johns River Offset

The St. Johns River flows northward from the headwaters in Palm Beach County, flowing into the Atlantic Ocean in Duval County (OFMS 105; Plate 3, Figure 3). The upper and lower St. Johns River valleys follow a pathway that is closer to the Atlantic coastline than the middle reach of the river between Sanford and Palatka. At the approximate latitude of Sanford, Seminole County, the river jogs westward then northward in a narrow valley bounded in the study area by the Mt. Dora Ridge on the west and the DeLand Ridge and the Crescent City Ridge on the east. White (1970) named and described this as the St. Johns River Offset. Elevations in the terrane vary from less than 5 feet (1.5 meters) to 75 feet (22.9 meters) above MSL. White believed that this portion of the St. Johns River's course was first developed in the Pliocene or early Pleistocene by dissolution of the underlying Eocene carbonate sediments. Pirkle (1971) suggested that the dissolution along the west-to-east trend resulted from faulting and fracturing of the Eocene rocks. White (1970) believed that a complex geomorphic history was necessary to force the St. Johns River out of its coast-parallel course and into a more inland, older valley. Within the offset there are varying thicknesses of undifferentiated Quaternary sediments lying on the Ocala Limestone.

Ocala Karst District

The Ocala Karst District encompasses a broad area extending from Wakulla County in the panhandle to Hillsborough and Pinellas counties in west-central peninsular Florida (OFMS 105, Plate 3, Figure 2). Carbonate sediments ranging from the Middle Eocene Avon Park Formation to the Oligocene-Miocene Tampa Member of the Arcadia Formation (Hawthorn Group) lie near the land surface. Dissolution of these sediments has created distinct landforms that characterize the district, including caves, caverns numerous springs, sinking (swallets) and resurgent streams. The Ocala Karst District merges with the Central Lakes District with which it shares a karstic influence (OFMS 105; Plate 3, Figure 2). The southern terminus of the district occurs where the impermeable Hawthorn Group sediments retard the development of karst features in the Sarasota River District and streams and rivers become more common.

Elevations within the district range from sea level to over 300 feet (91.4 meters) above MSL. Only a small portion of the District occurs along the southwest corner of the mapped area (OFMS 105; Plate 3, Figure 3). Elevations range from 40 feet (12.2 meters) to 180 feet (54.9 meters) above MSL in the southeastern portion of the Ocala Karst Hills within the mapped area. The topography over much of the district is gently rolling with only minor relief.

Sinclair and Stewart (1985) delineated zones of similar karst development in Florida based on the thickness and type of sediment cover and on the sinkhole types. Carbonate sediments of the Ocala Karst District are overlain by siliciclastics of varying thickness ranging from a few feet (one meter) to as much as 200 feet (61 meters) over carbonate sediments. Cover subsidence and cover collapse sinkholes are the dominant sinkhole type in the district. Rock collapse sinks occur but are uncommon.

Regional geomorphic terranes are recognized within the Ocala Karst District based on elevation, abundance of karst features, drainage, and relief. One geomorphic terrane, the Ocala Karst Hills, is recognized within the Ocala Karst District within the mapped area based on elevation, abundance of karst features, drainage, and relief (OFMS 105, Plate 3, Figures 1 and 3).

Ocala Karst Hills

The Ocala Karst Hills terrane occurs from north-central Marion County southward to northeastern Sumter County (OFMS 105, Plate 3, Figure 3). Statewide, elevations in the terrane area range from 20 feet (6.1 meters) to 195 feet (59.4 meters) above MSL. Elevations of the terrane within the mapped area range from 40 feet (12.2 meters) to 180 feet (54.9 meters) above MSL.

Several springs are present in the Ocala Karst Hills, including Silver Springs, which occurs along the eastern edge of the terrane along the boundary with the Central Lakes District. Hawthorn Group sediments are thin to absent in the terrane. Cypresshead Formation sediments overlie Hawthorn Group in the area (Green, et al., 2009a). There is a small area in the Ocala Karst Hills along the southwestern boundary of the mapped area which has undifferentiated Quaternary sediments at the surface (OFMS 105, Plate 1).

LITHOSTRATIGRAPHIC UNITS

Tertiary System

Eocene Series

Avon Park Formation

The Middle Eocene Avon Park Formation (Tap), first described by Applin and Applin (1944), is entirely a subsurface unit within the USGS Daytona Beach 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 coverage existed (see OFMS 105, Plate 2).

Lithology of the Avon Park Formation can vary between limestone and dolostone. The limestones consist of cream to light brown to tan, poorly- to well-indurated, variably fossiliferous grainstone and wackestone, with rare mudstone. The limestones 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. Accessory minerals include chert, pyrite, celestine, gypsum and quartz (some as doubly-terminated euhedral crystals “floating” in vugs).

Fossils present in the unit include molluscs, foraminifera (*Spirolina* sp., *Lituonella floridana*, *Bolivina* spp., *Cushmania* [*Dictyoconus*] *americana*), *Cribrobulimina cushmani*, and *Fabiana cubensis*, 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.

Distinction 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, particularly in the vicinity of the Sanford High (where the Ocala Limestone is often thin to

missing). 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).

The top of the Avon Park ranges from approximately 5 feet (1.5 meters) below MSL in W-5611 (OFMS 105; Plate 2, cross-section D-D') to approximately 170 feet (51.8 meters) below MSL in W-18815 (OFMS 105; Plate 2, cross-sections E-E'). Due to graphical space constraints, as well as 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 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, molluscs, echinoids and bryozoans. The Ocala Limestone, which sits unconformably on the Avon Park Formation throughout most of the study area, is thin to absent in the vicinity of the Sanford High.

Based on lithologic differences, the Ocala Limestone can be informally subdivided into an upper and lower unit (Scott, 1991). 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 break out 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, bryozoans, molluscs, 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 (*Lepidocyclina ocalana*, *Amphistegina pinarensis*, *Nummulites* [*Camerina*] *vanderstoki*, *Nummulites* [*Operculinoides*] *ocalana*), bryozoans, algae, molluscs, echinoids, and crustaceans.

The Ocala Limestone occurs throughout most of the study area (except where missing on the Sanford High) and is near the surface along the northwestern portion of the map area (OFMS 105, Plate 2). The top of the Ocala Limestone ranges from 23 feet (7 meters) above MSL in W-10360, (OFMS 105; Plate 2, cross-section B-B') to 97 feet (29.6 meters) below MSL in W-4065 and W15133 (OFMS 105; Plate 2, cross-section A-A'). Approximately 60 percent of the wells utilized for geologic cross-sections penetrate the entire thickness of the Ocala Limestone. In these wells, the thickness of the Ocala Limestone ranges from 135 feet (41 meters) in W-11634 (OFMS 105; Plate 2, cross-section B-B') to 5 feet (1.5 meters) in W-15352 (OFMS 105; Plate 2, cross-section D-D'). The Ocala Limestone is generally thickest in the western portion of the study area away from the Sanford High. The Ocala Limestone forms part of the FAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Miocene Series

Hawthorn Group

Sediments of the Miocene Hawthorn Group are thought to have been deposited over the Peninsular Arch throughout much of the study area, but erosion and karstification have removed these sediments from the crest of the Ocala Platform (Cooke, 1945; Espenshade and Spencer, 1963; Scott, 1983). The unit is also missing in the vicinity of the Sanford High (Scott, 1988). Hawthorn Group sediments within the study area consist of phosphatic siliciclastics (sands, silts and clays) and carbonates (dolostone with minor limestone). Fossils in the Hawthorn Group are sparse but may include vertebrates, corals, and molluscs. Benthic foraminifera characteristic of the Hawthorn Group include *Archaias* spp. and *Sorites* sp. Williams et al. (1977) report that the most commonly found fossils are oysters and coral heads.

Within the mapped area, the Hawthorn Group is composed of the Penney Farms Formation (Thpf), the Marks Head Formation (Thmh) and the Coosawhatchie Formation (Thc; OFMS 105; Plate 2, Figure 2). While these formations can be identified and delineated in cores, they are often not readily differentiated in cuttings, particularly where cavings from above cause mixing of the sediments during drilling. In these instances, they are referred to as undifferentiated Hawthorn Group (Th) on the cross-sections. In instances where they can reliably be differentiated, the formations are shown on the cross-sections (OFMS 105; Plate 2, cross-sections B-B' and C-C'). Unit descriptions for the Hawthorn Group listed below are summaries and the reader is referred to Scott (1988) for a more complete discussion of lithologies, variability and relationships of these lithologically complex formations. Hawthorn Group sediments are unconformably overlain by Tertiary/Quaternary dune sediments, Cypresshead Formation (TQc) and undifferentiated Quaternary sediments (Qu).

In the mapped area, Hawthorn Group sediments occur primarily west of Lake George and the St. Johns River (OFMS 105, Plate 1). The top of the Hawthorn Group ranges between 70 feet (21.3 meters) above MSL in W-3886 (OFMS 105; Plate 2, cross-section B-B') to 56 feet (17 meters) below MSL in W-19453 (OFMS 105; Plate 2, cross-section C-C'). The Hawthorn Group sediments range in thickness from 78 feet (23.8 meters) in well W-19451 to 10 feet (3 meters) in well W-10360 (OFMS 105; Plate 2, cross-section B-B'). Sediments of the Hawthorn Group form the Intermediate aquifer system/Intermediate confining unit (IAS/ICU; Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Penney Farms Formation

The Penney Farms Formation (Thpf) consists of variable admixtures of dolostone, quartz sand, phosphatic sand and clay. The sand content is variable and at times the unit becomes a dolomitic sand. Phosphatic sand is common and may be present in amounts exceeding 25 percent with an average of 5 to 10 percent (Scott, 1988). Clay percentages are generally minor (less than 5 percent) and often increase towards the top of the unit in the dolostones. The dolostones are medium-gray to pale-yellowish brown and are generally moderately- to well-indurated. Mollusc molds are common in the dolostones. Intraclasts are common in the hard, finer-grained dolostones in the lower portion of the unit. These intraclasts are composed of dolomite similar to the rest of the unit, but they often have rims of phosphate replacement along the edges of the clasts (see OFMS 105; Plate 2, Figure 2, Photo 2). Limestone, which occurs sporadically in the lower portion of the unit, is generally dolomitic, phosphatic, and quartz sandy. The Penney

Farms Formation unconformably overlies the Ocala Limestone within the mapped area. Where present in the mapped area, it is overlain unconformably by the Marks Head Formation (Hawthorn Group). The base of the Marks Head Formation is placed at the contact between the darker-colored sands and clays of the upper Penney Farms and the generally lighter-colored interbedded sands, clays, and dolostone of the Marks Head Formation (OFMS 105; Plate 2, cross-sections B-B' and C-C').

Marks Head Formation

The Marks Head Formation (Thmh) consists of interbedded sands, clays and dolostones. Limestone, while uncommon, does occur within the unit (Scott, 1988). Dolostones are generally quartz sandy, phosphatic and clayey. Colors of the dolostones range from yellowish-gray to olive gray. Induration, which varies inversely with the clay content, ranges from poorlyconsolidated to well indurated. Phosphate content typically ranges up to five percent but may occasionally be significantly higher. Quartz sand content ranges from five percent to greater than 50 percent. The unit is overlain unconformably by the Coosawhatchie Formation (Hawthorn Group), although this unconformity is often not readily apparent. In general, the contact between the Coosawhatchie and Marks Head formations is placed at the top of the first hard carbonate bed or light-colored clay unit below the darker-colored, clayey, dolomitic quartz sands and dolostones of the basal Coosawhatchie Formation (Scott, 1988).

Coosawhatchie Formation

The Miocene Coosawhatchie Formation (Thc) consists of quartz sands, dolostones and clays. The unit ranges in color from greenish-gray and light gray to olive gray. The most common lithology in the upper section of the unit is characteristically a sandy to very sandy dolostone which may be interbedded with quartz sands and clays (Scott, 1988). Quartz sands and clays dominate and dolostones become subordinate in the lower portion of the section. The quartz sands are fine- to medium-grained, generally phosphatic, clayey and dolomitic. In many instances, the sands grade into dolostones and clays. Clay content is variable and may range from five to more than 30 percent (Scott, 1988). Phosphate content is highly variable, ranging from a trace to more than 20 percent. Coarse phosphate sands and pebbles are present but not common in the unit. The unit is unconformably overlain by the Pliocene/Pleistocene Cypresshead Formation (TQc) in the vicinity of the Mt. Dora Ridge (OFMS 105, Plate 2, cross-sections B-B' and C-C').

Hawthorn Group (Undifferentiated)

In the areas between the Sanford High and the Peninsular Arch, sediments of the Coosawhatchie, Marks Head and Penney Farms formations often become difficult to break out lithologically. In these areas, sediments of the Hawthorn Group are mapped as Hawthorn Group, undifferentiated (Th; Scott, 1988).

Where exposed west of the mapped area, the undifferentiated Hawthorn Group is light olive gray and blue gray in unweathered sections and reddish-brown to reddish-gray in weathered sections (Green et al., 2009a). It consists of poorly- to moderately-consolidated,

clayey sands to silty clays and relatively pure clays with little-to-no phosphate due to leaching and transport (Scott, 2001). It is typically deeply weathered.

Where present, the undifferentiated Hawthorn Group unconformably overlies the Ocala Limestone (Scott et al., 2001). It is unconformably overlain by the Cypresshead Formation (TQc) and undifferentiated Quaternary and Holocene sediments (OFMS 105, Plate 2).

Due to the karstic nature of the Mt. Dora Ridge, elevations of the Hawthorn Group are highly variable. Within the study area, the top of the unit may exceed 70 feet (21.3 meters) above MSL as in well W-3886 (OFMS 105; Plate 2, cross-section B-B') or be at a depth of more than 55 feet (16.8 meters) below MSL (OFMS 105; Plate 2, cross-section C-C', W-19453). Along the flanks of the ridge, thin beds of the undifferentiated Hawthorn Group were penetrated in various wells (OFMS 105, Plate 2). In these, the top of the undifferentiated Hawthorn Group ranges from 33 feet (10 meters) above MSL in W-10360 (OFMS 105; Plate 2, cross-section B-B') to 34 feet (10.4 meters) below MSL well W-8415 (OFMS 105; Plate 2, cross-section A-A’). Thickness of the undifferentiated Hawthorn Group varies between 10 to 45 feet (3 to 13.7 meters). Undifferentiated Hawthorn Group sediments are often clayey sands and only rarely consist of relatively pure clays. The Hawthorn Group generally has low permeability and forms part of the IAS/ICU (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Tertiary/Quaternary Systems

Pliocene/Pleistocene Series

Cypresshead Formation

The Pliocene/Pleistocene Cypresshead Formation (TQc), named by Huddlestun (1988), 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 are common within this formation. Discoid quartzite pebbles, mica, and ghosts of nearshore marine molluscs are often present. The Cypresshead Formation is present throughout much of the study area and forms the core of the various ridges present in the region (see geomorphology section for more discussion). East of the St. Johns River, it typically 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.

Elevations range from near sea level to over 180 feet (54.9 meters) above MSL in the mapped area. The Cypresshead Formation thickness ranges between 90 feet to 35 feet (27.4 to 10.7 meters) in study area wells.

These sediments sit unconformably on the undifferentiated Hawthorn Group (Th) or Coosawhatchie Formation (Hawthorn Group; Thc) west of the St. Johns River and undifferentiated Pliocene/Pleistocene shelly sediments (TQsu) in the eastern portion of the mapped area (OFMS 105; Plate 2). 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).

Pliocene/Pleistocene Shelly Sediments

A sequence of undifferentiated Pliocene/Pleistocene shelly sediments lies east of the St. Johns River and occupies the section where the Hawthorn Group is missing around the Sanford High. 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. Efforts were made by the authors to locate the type section of the Nashua Formation, as defined by Huddlestun (1988), to no avail. Since we did not have adequate core control and could not locate the type section, these authors have decided to utilize the convention of the Scott, et al. (2001) and map these sediments as undifferentiated Pliocene/Pleistocene shelly sediments (TQsu). The unit sits unconformably on the Ocala Limestone or, in the vicinity of the Sanford High, the Avon Park Formation (OFMS 105; Plate 2, cross-sections A-A', B-B' and D-D'). Huddlestun (1988) indicated that the unit grades laterally into the Cypresshead Formation (TQc) in the vicinity of the Trail Ridge (northwest of the mapped area). Evidence from this study, however, indicates that the unit is, at least in part, older than the Cypresshead Formation. This may be a result of prograding of deltaic Cypresshead Formation sediments over TQsu marine sediments during changes in sea level. Work currently underway at the Florida Museum of Natural History indicates that some of these shelly sands just north of the study area are Pliocene (Roger Portell, personal communication). These undifferentiated shelly sands are overlain by the Cypresshead Formation in the Crescent City and DeLand ridges (OFMS 105, Plate 2, cross-section D-D'). Elsewhere, the unit is unconformably overlain by undifferentiated Quaternary sediments, Quaternary beach ridge and dune sediments (Qbd) or the Anastasia Formation (Qa).

Undifferentiated Pliocene/Pleistocene shelly sediments (TQsu) typically consist of fine-to-medium quartz sand with variable amounts of calcilutite, shell and clay. Shells may vary from whole to fragments and may occasionally become the dominant lithology. Other accessory minerals may include calcite, aragonite, clay, mica, heavy minerals and minor phosphate. Colors range from light gray to light olive gray.

The top of the undifferentiated Pliocene/Pleistocene shelly sediments ranges from 50 feet (15.2 meters) above MSL in W-5611, (OFMS 105; Plate 2, cross-section D-D') to 45 feet (13.7 meters) below MSL in W-15667 (OFMS 105; Plate 2, cross-section E-E'). The thickness of the undifferentiated Pliocene/Pleistocene shelly sediments in the cross-section wells varies from 95 feet (28.9 meters) in W-15133 (OFMS 105; Plate 2, cross-section A-A') to 15 feet (4.6 meters) in W-18282 (OFMS 105; Plate 2, cross-section A-A'). Permeable sediments of the undifferentiated Pliocene/Pleistocene 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 Mt. Dora Ridge where elevations of these dune sands can be lower. Sands forming these dunes are thought to be derived from re-working of sediments from the

Cypresshead Formation (TQc) and undifferentiated Quaternary sediments (Qu). There are large portions of the Mt. Dora Ridge in the Ocala National Forest and sections of the DeLand Ridge which have Tertiary/Quaternary dune sediments mapped (OFMS 105, 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

Anastasia Formation

The Anastasia Formation (Qa) is present within the Atlantic Coastal Complex in a narrow band along the eastern edge of the study area. The formation, named by Sellards (1912), is composed of interbedded coquinoid limestone and quartz sands. It typically occurs as an orangish-brown, unindurated to moderately indurated coquina consisting of whole and broken mollusc shells in a quartz sand matrix. The coquina is commonly cemented by sparry calcite. The sands occur as light gray to tan and orangish-brown, unconsolidated to moderately indurated, unfossiliferous to very fossiliferous beds. The unit sits unconformably on undifferentiated Pliocene/Pleistocene shelly sediments (TQsu; OFMS 105, Plate 2, cross-section E-E'). The top of the Anastasia Formation ranges from 5 feet (1.5 meters) above MSL in wells W-3473 and W-11047 (OFMS 105; Plate 2, cross-section E-E'), to 12 feet (3.7 meters) below MSL in W-3976 (OFMS 105; Plate 2, cross-section A-A'). The thickness of the Anastasia Formation in the cross-section wells varies from 45 feet (13.7 meters) in W-15667 to 10 feet (3 meters) in W-18815 (OFMS 105; Plate 2, cross-section E-E'). This formation is considered part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Undifferentiated Quaternary Sediments

Undifferentiated Quaternary sediments (Qu) in the study area lie unconformably on the Hawthorn Group, undifferentiated Pliocene/Pleistocene shelly sediments or Cypresshead Formation (OFMS 105, Plate 2, cross-sections). The undifferentiated Quaternary sediments present in the mapped area may be highly variable in thickness.

Generally, these undifferentiated Quaternary sediments consist of white to gray to orange to blue-green, fine- to coarse-grained, clean to clayey 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 noted on the basis of surficial expression of relict beach ridges and dunes. While not a formally recognized lithostratigraphic unit, it is mapped following the convention of Scott et al., (2001) in order to facilitate a better understanding of Florida’s geology. This unit unconformably overlies undifferentiated Pliocene/Pleistocene shelly

sediments (TQsu), or the Anastasia Formation (Qa) in the eastern part of the study area (OFMS 105; Plates 1 and 2).

Beach ridge and dune sediments are dominantly siliciclastic sands 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).

Holocene Sediments

Sediments mapped as Holocene (Qh) may include quartz sands, marls, organics, and minor carbonate sands and mud. They may also include fresh-water molluscs. Within the study area, they occur as floodplain deposits in the vicinity of Lake George, the St. Johns River and the Ocklawaha River. These sediments are considered part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

HYDROGEOLOGY

Hydrostratigraphic units within the map area, in ascending order, consist of the Floridan aquifer system (FAS), the Intermediate aquifer system/Intermediate confining unit (IAS/ICU), and the Surficial aquifer system (SAS; Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). The FAS, the primary source for springs and drinking water in the region, is generally comprised of carbonate units of the Avon Park Formation and the Ocala Limestone. The sands, silts, clays and carbonates 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 the Cypresshead Formation, undifferentiated Pliocene/Pleistocene shelly sediments (TQsu), Tertiary/Quaternary dune sediments (TQd), undifferentiated Quaternary sediments (Qu), beach ridge and dune sediments (Qbd), and Holocene sediments (Qh).

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. Several of these are found in the Crescent City and DeLand ridges.

GEOPHYSICAL LOGGING

As part of this project, the St. Johns River Water Management District (SJRWMD) conducted geophysical logging on new wells drilled in the study area by the Florida Geological Survey. Boreholes were logged with a variety of geophysical tools, including Gamma (natural gamma log), Caliper, and Induction logs (Fluid Resistivity and Fluid Conductivity). The geophysical log of particular interest in this study was the gamma log for its usefulness in differentiating the various lithostratigraphic units by recording the naturally occurring gamma-ray activity in the lithology of the borehole wall.

By comparing gamma-ray activity between lithostratigraphic units it is often possible to differentiate them. This log is particularly useful for differentiating between Hawthorn Group units and subjacent and superjacent formations. Kwader (1982) and Scott (1988) discuss the

gamma-ray response from clay minerals and phosphate typical to the formations in the Hawthorn Group. Development of high gamma activity occurs when minerals incorporate high percentages of potassium, uranium or thorium in their lattice structures. Potassium-rich sources include potassium feldspar, mica, and illitic clay. Uranium and thorium tend to be found in phosphorite, apatite, organic material and dolomite.

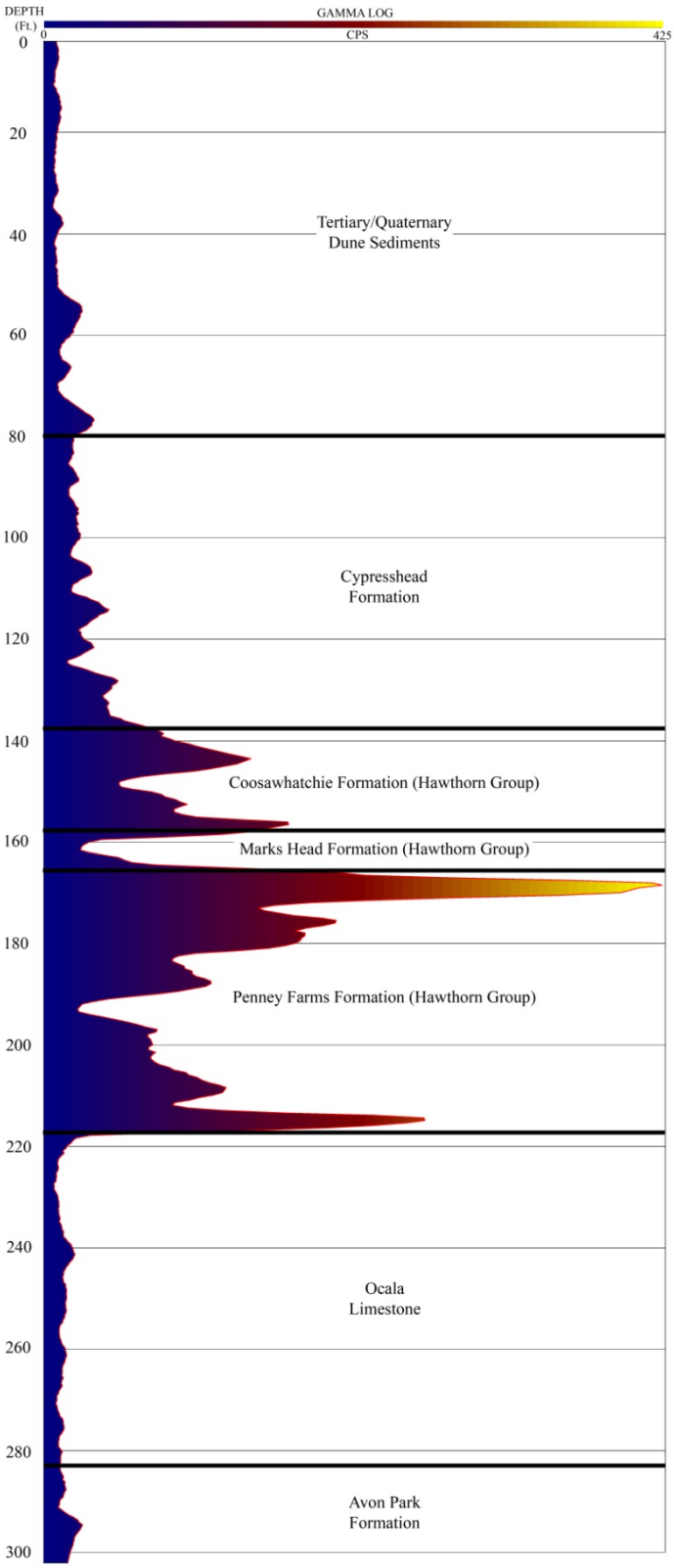

Figure 6. Gamma Log of W-19451 (see OFMS 105, plate 2, B-B')

Gamma-ray intensity units were measured in counts per second (CPS). In Figure 6, gamma-ray intensity units are shown on the log horizontal axis in CPS for W-19451 (see OFMS 105, Plate 2, cross-section B-B'). Carbonates of the Ocala Limestone and Avon Park Formation have the lowest intensity gamma peaks in contrast to the high intensity radioactivity of the Hawthorn Group. Formations above the Hawthorn Group, such as the Cypresshead Formation and Tertiary-Quaternary dune sediments (TQd), typically have much lower intensity signatures. In the study area, elevated radioactivity primarily results from the inclusion of phosphate grains. Medium intensity gamma-ray signatures are from moderately radioactive clay-minerals and from organic material or peat (Davis et. al., 2001).

Stratigraphy and Gamma-Ray Log Interpretation

Avon Park Formation

Logs from the Avon Park Formation typically show a combination of low gamma-ray intensity dolostone with distinct beds of relatively higher gamma-ray intensity lignite or organic layers. The top of the Avon Park Formation characteristically ranges from a yellow-gray dolomitic wackestone to a yellow-brown recrystallized dolostone. Below this initial lithology, but usually at or near the top of the unit, there can be variable amounts of black to dark brown, finely particulate to fibrous, partially decomposed organic material or lignite.

The organic matter can occur as finely disseminated particles, sand to pebble sized blebs, identifiable leaf or sea-grass fossils, laminations or as discrete beds. One such bed of organic-rich material can be seen in Figure 6, the top of the Avon Park Formation at approximately 295 feet (89.9 meters) below land surface (BLS).

Ocala Limestone

In contrast to the higher intensity gamma-ray signature of the Hawthorn Group, the Ocala Limestone is easily identified on the gamma-ray log. This unit characteristically produces the lowest gamma-ray intensity in the Eocene stratigraphic sequence and can be used as a low baseline for relative gamma-ray intensity (Davis et. al., 2001).

In general, the Ocala Limestone has lower gamma-ray intensity than the underlying Avon Park Formation. In the study area, however, dolomitization of the Avon Park Formation and recrystallization of the lowermost Ocala Limestone has significantly altered the original rock lithology and fabric making the distinction of the gamma-ray signatures between these units more difficult. The presence of organics when at or near the top of Avon Park Formation (e.g., Figure 6) can assist in determining the contact between these two formations. One such organic-rich zone occurs at 295 feet (89.9 meters) BLS.

Hawthorn Group

The Hawthorn Group consists of a complex sequence of siliciclastics and carbonates with varying percentages of phosphate minerals. The resulting gamma-ray peaks are, in general, significantly higher than those of the formations above and below the Hawthorn Group which makes this unit easily discernible on geophysical logs (Figure 6).

The Hawthorn Group in the western portion of the study area consists of the Penney Farms, Marks Head and Coosawhatchie formations. The gamma-ray logs from the cores drilled for this study show a pattern of three generalized zones corresponding with these formations. However, the pattern shows a variation in the intensities and thickness of peak groups dependent on the lithologic variation of the sample. For example, in W-19451 (OFMS 105; Plate 2, cross-section C-C') the higher gamma-ray intensity zones at approximately 138-158 feet (42-48.2 meters) BLS correlate with the Coosawhatchie Formation. The Coosawhatchie Formation in this well consists primarily of siliciclastics with varying amounts of dolomitic clay and fine to pebble sized phosphate ranging in content between three and fifteen percent. The second zone is a low intensity gamma-ray zone of the Marks Head Formation (between 158-167 feet [48.2-50.9 meters] BLS) consisting of a well-indurated, light gray recrystallized dolosilt with one to three percent fine-to-medium phosphate. The third zone correlates with the Penney Farms Formation showing a drop in the gamma-ray intensity at approximately 167 feet (50.9 meters) BLS at an unconformity, followed by a significant peak at about 168 feet (51.2 meters) BLS where the lithology is a phosphatic, clayey sand with burrows and intraclasts.

The Penney Farms Formation in this core is highly variable in lithology and phosphate content as reflected in the gamma-ray log. The Penney Farms Formation unconformably overlies the Ocala Limestone. At this contact, the gamma-ray log intensity drops significantly and the delineation of these two formations is readily apparent (Figure 6).

Pliocene/Pleistocene shelly sediments

In the study area east of the St. Johns River, undifferentiated Pliocene/Pleistocene shelly sediments (TQsu) lie unconformably over the Hawthorn Group, and below the undifferentiated Quaternary sediments or Cypresshead Formation (OFMS 105, Plate 2). Undifferentiated Pliocene/Pleistocene shelly sediments present in the mapped area may be highly variable in thickness and typically consist of fine to medium quartz sand with variable amounts of calcilutite, shell, phosphate and clay. Other accessory minerals may include calcite, aragonite, clay, mica, and heavy minerals. The presence of phosphate and heavy minerals can cause spikes in the gamma-ray log making this unit readily distinguishable from the overlying Cypresshead Formation or undifferentiated Quaternary sediments.

Cypresshead Formation and Tertiary/Quaternary dune sediments

The Cypresshead Formation (TQc) is typically composed of variably clayey quartz sand, silt and gravel characteristic of a fluvio-deltaic deposit. The sediments of the Tertiary/Quaternary dune sediments (TQd) are fine to medium quartz sand with varying amounts of disseminated organic matter. Often, the Cypresshead Formation cannot be readily distinguished from the overlying TQd by the gamma-ray log due to their similar lithologies. Because these units lack phosphate, they are easily distinguishable from the underlying Hawthorn Group (Figure 6).

DERIVATIVE PRODUCTS

Several derivative products will come from this project. During the mapping project, data from over 400 wells with samples were analyzed. Formation picks, made on all available wells with cores and cuttings samples, allow creation of a structure contour map of the top of the FAS, along with the construction of structure contour and isopach maps of the IAS/ICU in the area. Additional derivative data 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).

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APPENDIX A: FGS WELLS UTILIZED FOR STUDY

This table lists FGS wells within the boundaries of the USGS Daytona Beach 30 x 60 minute quadrangle utilized for the top of rock model and/or geologic mapping. Due to graphical constraints, not all wells will appear on Plate 1 of OFMS 105. The first 40 wells in the table were utilized for geologic cross-sections and appear on Plates 1 and 2 of OFMS 105.

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft)	Total Depth (ft)
1	W-657	FGS	Cuttings	29.057207	81.284507	DELAND	72	511
2	W-1118	FGS	Cuttings	29.037454	81.166793	DAYTONA BEACH SW	40	5958
3	W-3473	FGS	Cuttings	29.348867	-81.088452	ORMOND BEACH	10	147
4	W-3886	FGS	Cuttings	29.061175	-81.633026	FARLES LAKE	112	114
5	W-3957	FGS	Cuttings	29.328611	-81.771944	LAKE KERR	74	131
6	W-3976	FGS	Cuttings	29.279701	-81.062553	ORMOND BEACH	8	207
7	W-4065	FGS	Cuttings	29.33066	-81.329785	CODYS CORNER	13	188
8	W-4069	FGS	Cuttings	29.442638	-81.538192	CRESCENT CITY	65	115
9	W-5039	FGS	Cuttings	29.320232	-81.392224	SEVILLE	13	107
10	W-5573	FGS	Cuttings	29.012656	-81.645593	FARLES LAKE	57	200
11	W-5611	FGS	Cuttings	29.121674	-81.315836	DELAND	80	225
12	W-6136	FGS	Cuttings	29.050833	-81.755278	LAKE MARY	144	240
13	W-6137	FGS	Cuttings	29.2666	-81.030356	ORMOND BEACH	12	160
14	W-7842	FGS	Cuttings	29.298333	-81.835277	LAKE KERR	90	280
15	W-8134	FGS	Cuttings	29.035346	-81.289603	DELAND	86	390
16	W-8415	FGS	Cuttings	29.322472	-81.966477	FORT MCCOY	66	145
17	W-10360	FGS	Cuttings	29.025462	-81.962674	LAKE WEIR	98	520
18	W-10935	FGS	Cuttings	29.036371	-81.465068	LAKE WOODRUFF	42	310
19	W-11047	FGS	Cuttings	29.243591	-81.046165	DAYTONA BEACH	5	210
20	W-11634	FGS	Cuttings	29.053629	-81.880195	LAKE WEIR	89	295
21	W-12371	FGS	Cuttings	29.05537	-81.018042	SAMSULA	25	250
22	W-13594	FGS	Cuttings	29.146102	-81.031728	DAYTONA BEACH	31	200
23	W-14318	FGS	Core	29.384685	-81.512155	CRESCENT CITY	54	158
24	W-14752	FGS	Core	29.211111	-81.728888	JUNIPER SPRINGS	68	93
25	W-15118	FGS	Cuttings	29.274364	-81.09203	ORMOND BEACH	23	200
26	W-15133	FGS	Cuttings	29.287264	-81.159063	FAVORETTA	23	205
27	W-15352	FGS	Cuttings	29.136797	-81.334614	LAKE DIAS	64	240
28	W-15667	FGS	Cuttings	29.433963	-81.114219	FLAGLER BEACH EAST	0	120
29	W-15729	FGS	Cuttings	29.061527	-81.348229	DELAND	72	450
30	W-15921	FGS	Cuttings	29.310377	-81.494339	SEVILLE	39	170
31	W-17567	FGS	Cuttings	29.471388	-81.809999	LAKE DELANCY	81	200
32	W-17571	FGS	Cuttings	29.142777	-81.704999	JUNIPER SPRINGS	118	71
33	W-18282	FGS	Cuttings	29.321666	-81.539444	WELAKA SE	20	170
34	W-18815	FGS	Core	29.200555	-81.039444	DAYTONA BEACH	6	1001
35	W-19022	FGS	Cuttings	29.325832	-81.079722	ORMOND BEACH	6	86
36	W-19444	FGS	Core	29.0335	-81.09509	SAMSULA	43	200
37	W-19448	FGS	Core	29.227563	-81.362112	LAKE DIAS	28	200
38	W-19451	FGS	Core	29.049766	-81.675616	FARLES LAKE	178	303
39	W-19452	FGS	Core	29.406833	-81.806416	LAKE DELANCY	123	318
40	W-19453	FGS	Core	29.254066	-81.7698	LAKE KERR	114	273
41	W-153	FGS	Cuttings	29.030308	-81.911444	LAKE WEIR	58	350
42	W-177	FGS	Cuttings	29.485565	-82.016519	CITRA	69	95
43	W-181	FGS	Cuttings	29.375246	-81.899592	EUREKA DAM	21	65
44	W-183	FGS	Cuttings	29.23577	-81.964577	LYNNE	69	133
45	W-194	FGS	Cuttings	29.485162	-81.186782	FLAGLER BEACH WEST	20	70
46	W-195	FGS	Cuttings	29.459726	-81.262505	BUNNELL	14	65
47	W-196	FGS	Cuttings	29.435251	-81.31732	BUNNELL	5	65
48	W-197	FGS	Cuttings	29.409561	-81.367767	BUNNELL	11	120

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft)	Total Depth (ft)
49	W-198	FGS	Cuttings	29.353407	-81.510599	WELAKA SE	45	100
50	W-199	FGS	Cuttings	29.270276	-81.645293	SALT SPRINGS	38	80
51	W-200	FGS	Cuttings	29.313234	-81.771858	LAKE KERR	50	120
52	W-201	FGS	Cuttings	29.182203	-81.890483	LYNNE	62	100
53	W-202	FGS	Cuttings	29.156872	-81.955242	LYNNE	64	75
54	W-245	FGS	Cuttings	29.029765	-81.293389	DELAND	57	264
55	W-939	FGS	Cuttings	29.035512	-81.326351	DELAND	84	290
56	W-1129	FGS	Cuttings	29.492157	-81.913262	EUREKA DAM	18	55
57	W-1131	FGS	Cuttings	29.448032	-81.91754	EUREKA DAM	76	56.7
58	W-1132	FGS	Cuttings	29.432991	-81.934441	EUREKA DAM	18	69
59	W-1133	FGS	Cuttings	29.432991	-81.934441	EUREKA DAM	18	55.4
60	W-1134	FGS	Cuttings	29.416018	-81.921456	EUREKA DAM	19	68
61	W-1135	FGS	Cuttings	29.404321	-81.917402	EUREKA DAM	19	75
62	W-1136	FGS	Cuttings	29.375268	-81.900744	EUREKA DAM	33	85
63	W-1137	FGS	Cuttings	29.375268	-81.900744	EUREKA DAM	33	97
64	W-1139	FGS	Cuttings	29.317171	-81.899779	FORT MCCOY	25	78
65	W-1140	FGS	Cuttings	29.302207	-81.916158	FORT MCCOY	30	54.8
66	W-1141	FGS	Cuttings	29.28741	-81.932539	FORT MCCOY	29	62.3
67	W-1142	FGS	Cuttings	29.274113	-81.955438	FORT MCCOY	45	77.5
68	W-1143	FGS	Cuttings	29.259654	-81.955344	FORT MCCOY	30	82.5
69	W-1144	FGS	Cuttings	29.244925	-81.978438	LYNNE	33	96
70	W-1147	FGS	Cuttings	29.182281	-82.016943	OCALA EAST	56	100
71	W-1148	FGS	Cuttings	29.182281	-82.016943	OCALA EAST	56	69
72	W-1149	FGS	Cuttings	29.182281	-82.016943	OCALA EAST	56	70
73	W-1150	FGS	Cuttings	29.185918	-82.012733	OCALA EAST	57	92
74	W-1151	FGS	Cuttings	29.182281	-82.016943	OCALA EAST	56	81
75	W-1152	FGS	Cuttings	29.171454	-82.029134	OCALA EAST	39	112
76	W-1153	FGS	Cuttings	29.162065	-82.039221	OCALA EAST	67	91.9
77	W-1491	FGS	Cuttings	29.470614	-81.302613	BUNNELL	14	117
78	W-1520	FGS	Cuttings	29.363512	-81.342814	CODYS CORNER	9	130
79	W-1707	FGS	Cuttings	28.982555	-82.041749	OXFORD	86	165
80	W-1712	FGS	Cuttings	28.987422	-82.018405	OXFORD	76	111
81	W-1717	FGS	Cuttings	29.230913	-81.265922	LAKE DIAS	33	150
82	W-1746	FGS	Cuttings	29.230913	-81.265922	LAKE DIAS	33	5418
83	W-1762	FGS	Cuttings	28.987222	-82.018611	OXFORD	76	141
84	W-1966	FGS	Cuttings	29.069711	-81.976674	LAKE WEIR	108	141
85	W-2216	FGS	Cuttings	29.184444	-81.881666	LYNNE	65	125
86	W-2444	FGS	Cuttings	29.474951	-81.248174	FLAGLER BEACH WEST	19	80
87	W-2944	FGS	Cuttings	29.210536	-81.043388	DAYTONA BEACH	9	282
88	W-2951	FGS	Cuttings	29.211925	-81.043945	DAYTONA BEACH	9	167
89	W-3059	FGS	Cuttings	29.492539	-81.151525	FLAGLER BEACH WEST	10	7077
90	W-3060	FGS	Cuttings	29.492658	-81.155062	FLAGLER BEACH WEST	10	70
91	W-3183	FGS	Cuttings	29.000774	-81.300398	DELAND	32	400
92	W-3291	FGS	Cuttings	29.054688	-81.929566	LAKE WEIR	59	210
93	W-3292	FGS	Cuttings	29.040086	-81.929522	LAKE WEIR	51	160
94	W-3472	FGS	Cuttings	29.349634	-81.087677	ORMOND BEACH	11	147
95	W-3476	FGS	Cuttings	29.162756	-81.100615	DAYTONA BEACH	24	496
96	W-3477	FGS	Cuttings	29.191839	-81.07104	DAYTONA BEACH	27	505
97	W-3479	FGS	Cuttings	29.48909	-81.147133	FLAGLER BEACH WEST	13	81
98	W-3527	FGS	Cuttings	29.102162	-81.213429	DAYTONA BEACH SW	40	351
99	W-3528	FGS	Cuttings	29.15803	-81.098204	DAYTONA BEACH	29	235
100	W-3532	FGS	Cuttings	29.158755	-81.107694	DAYTONA BEACH	27	235
101	W-3534	FGS	Cuttings	29.158596	-81.103186	DAYTONA BEACH	28	234
102	W-3535	FGS	Cuttings	29.162735	-81.096405	DAYTONA BEACH	25	211
103	W-3540	FGS	Cuttings	29.180526	-81.079953	DAYTONA BEACH	28	498

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft)	Total Depth (ft)
104	W-3569	FGS	Cuttings	29.199703	-81.040054	DAYTONA BEACH	6	200
105	W-3573	FGS	Cuttings	29.199703	-81.040054	DAYTONA BEACH	6	160
106	W-3574	FGS	Cuttings	29.199981	-81.033668	DAYTONA BEACH	7	160
107	W-3651	FGS	Cuttings	29.433462	-81.149946	FLAGLER BEACH WEST	10	114
108	W-3653	FGS	Cuttings	29.279948	-81.070545	ORMOND BEACH	8	182
109	W-3697	FGS	Cuttings	29.064752	-81.300456	DELAND	82	138
110	W-3888	FGS	Cuttings	29.106998	-81.619507	ALEXANDER SPRINGS	52	35
111	W-3889	FGS	Cuttings	29.180555	-81.890277	LYNNE	61	171
112	W-3975	FGS	Cuttings	29.474993	-81.672301	WELAKA	20	483
113	W-4057	FGS	Cuttings	29.308011	-81.316391	CODYS CORNER	23	146
114	W-4059	FGS	Cuttings	29.492423	-81.673809	WELAKA	21	80
115	W-4062	FGS	Cuttings	29.496287	-81.589353	CRESCENT CITY	64	176
116	W-4067	FGS	Cuttings	29.333713	-81.342141	CODYS CORNER	13	180
117	W-4223	FGS	Cuttings	29.192808	-81.066501	DAYTONA BEACH	27	205
118	W-4226	FGS	Cuttings	29.173609	-80.983332	PORT ORANGE	14	170
119	W-4227	FGS	Cuttings	29.225639	-81.006629	DAYTONA BEACH	17	185
120	W-4228	FGS	Cuttings	29.194704	-81.059776	DAYTONA BEACH	31	225
121	W-4580	FGS	Cuttings	29.35134	-81.087898	ORMOND BEACH	9	93
122	W-4581	FGS	Cuttings	29.35134	-81.087898	ORMOND BEACH	9	93
123	W-4582	FGS	Cuttings	29.35134	-81.087898	ORMOND BEACH	9	93
124	W-4583	FGS	Cuttings	29.35134	-81.087898	ORMOND BEACH	9	93
125	W-4584	FGS	Cuttings	29.35134	-81.087898	ORMOND BEACH	9	90
126	W-4591	FGS	Cuttings	29.35134	-81.087898	ORMOND BEACH	9	93
127	W-4619	FGS	Cuttings	29.270812	-81.068115	ORMOND BEACH	5	198
128	W-4622	FGS	Cuttings	29.290667	-81.090834	ORMOND BEACH	38	201
129	W-5021	FGS	Cuttings	29.476337	-81.673419	WELAKA	21	87
130	W-5029	FGS	Cuttings	29.47379	-81.182468	FLAGLER BEACH WEST	23	115
131	W-5037	FGS	Cuttings	29.409352	-81.305411	BUNNELL	13	76
132	W-5038	FGS	Cuttings	29.384937	-81.188446	FLAGLER BEACH WEST	28	103
133	W-5040	FGS	Cuttings	29.353809	-81.252695	CODYS CORNER	18	171
134	W-5309	FGS	Cuttings	29.20207	-81.050299	DAYTONA BEACH	30	275
135	W-5430	FGS	Cuttings	29.016345	-81.637199	FARLES LAKE	46	147
136	W-5489	FGS	Cuttings	29.184116	-81.006367	DAYTONA BEACH	5	148
137	W-5607	FGS	Cuttings	29.035671	-81.282938	DELAND	85	110
138	W-5613	FGS	Cuttings	29.021047	-81.290983	DELAND	41	190
139	W-5614	FGS	Cuttings	29.041225	-81.283379	DELAND	75	315
140	W-5743	FGS	Cuttings	29.248311	-81.455902	PIERSON	68	250
141	W-5745	FGS	Cuttings	29.053055	-82.039166	BELLEVIEW	84	124
142	W-5746	FGS	Cuttings	29.474653	-81.741353	WELAKA	12	200
143	W-5758	FGS	Cuttings	29.246366	-81.456459	PIERSON	70	250
144	W-5784	FGS	Cuttings	29.20207	-81.050299	DAYTONA BEACH	30	210
145	W-5789	FGS	Cuttings	29.005555	-82.010277	BELLEVIEW	71	112
146	W-6016	FGS	Cuttings	29.034722	-82.043333	BELLEVIEW	89	800
147	W-6110	FGS	Cuttings	29.037668	-81.319483	DELAND	71	304
148	W-6273	FGS	Cuttings	29.138611	-81.849999	HALFMOON LAKE	54	141
149	W-6326	FGS	Cuttings	29.01506	-81.372187	DELAND	18	101.5
150	W-6328	FGS	Cuttings	29.190259	-81.075889	DAYTONA BEACH	28	210
151	W-6353	FGS	Cuttings	29.0383	-81.302922	DELAND	65	220
152	W-7172	FGS	Cuttings	29.011171	-81.346062	DELAND	49	95
153	W-7173	FGS	Cuttings	29.011171	-81.346062	DELAND	49	198
154	W-7383	FGS	Cuttings	29.226329	-82.049686	OCALA EAST	55	110
155	W-7697	FGS	Cuttings	29.011111	-82.045555	BELLEVIEW	95	230
156	W-7781	FGS	Cuttings	29.429444	-81.859194	LAKE DELANCY	139	328
157	W-7835	FGS	Cuttings	29.040086	-81.929522	LAKE WEIR	51	180
158	W-7871	FGS	Cuttings	29.172836	-81.084388	DAYTONA BEACH	22	200

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft)	Total Depth (ft)
159	W-7917	FGS	Cuttings	29.175255	-82.008141	OCALA EAST	54	180
160	W-8075	FGS	Cuttings	28.987222	-82.043611	OXFORD	70	285
161	W-8108	FGS	Cuttings	29.027097	-81.292974	DELAND	46	253
162	W-8132	FGS	Cuttings	29.127777	-81.888611	LYNNE	108	105
163	W-8407	FGS	Cuttings	29.201016	-81.929977	LYNNE	59	125
164	W-8411	FGS	Cuttings	29.191922	-82.030363	OCALA EAST	39	192
165	W-8412	FGS	Cuttings	29.266919	-81.916475	FORT MCCOY	73	165
166	W-8413	FGS	Cuttings	29.322472	-81.966477	FORT MCCOY	66	173
167	W-8414	FGS	Cuttings	29.141922	-81.977586	LYNNE	55	219
168	W-8453	FGS	Cuttings	29.115539	-81.186447	DAYTONA BEACH SW	41	305
169	W-8455	FGS	Cuttings	29.047492	-81.003929	SAMSULA	25	700
170	W-8458	FGS	Cuttings	29.079998	-81.148306	DAYTONA BEACH SW	40	310
171	W-8503	FGS	Cuttings	29.0522	-81.304741	DELAND	72	407
172	W-8562	FGS	Cuttings	29.21535	-82.045555	OCALA EAST	38	105
173	W-8593	FGS	Cuttings	29.145259	-81.145889	DAYTONA BEACH NW	43	100
174	W-8594	FGS	Cuttings	29.026103	-81.187168	DAYTONA BEACH SW	38	91
175	W-10259	FGS	Cuttings	29.325168	-81.114834	ORMOND BEACH	29	440
176	W-10304	FGS	Cuttings	29.433462	-81.149946	FLAGLER BEACH WEST	10	88
177	W-10307	FGS	Cuttings	29.505803	-81.884531	KEUKA	40	180
178	W-10332	FGS	Cuttings	29.279948	-81.070545	ORMOND BEACH	8	228
179	W-10395	FGS	Cuttings	29.214941	-82.012677	OCALA EAST	62	160
180	W-10430	FGS	Cuttings	29.433462	-81.149946	FLAGLER BEACH WEST	10	66
181	W-10578	FGS	Cuttings	29.069308	-82.012274	BELLEVIEW	99	158
182	W-10728	FGS	Cuttings	28.996786	-81.716047	UMATILLA	51	130
183	W-10788	FGS	Cuttings	29.274505	-81.832016	LAKE KERR	132	125
184	W-11046	FGS	Cuttings	29.240535	-81.045608	DAYTONA BEACH	12	220
185	W-11099	FGS	Cuttings	29.279948	-81.070545	ORMOND BEACH	8	300
186	W-11175	FGS	Cuttings	29.060342	-81.264904	DELAND	70	550
187	W-11261	FGS	Cuttings	29.422538	-81.733387	WELAKA	31	190
188	W-11301	FGS	Cuttings	29.137546	-81.343747	LAKE DIAS	52	150
189	W-11329	FGS	Cuttings	29.199448	-81.119452	DAYTONA BEACH	25	160
190	W-11394	FGS	Cuttings	29.326639	-81.773417	LAKE KERR	87	140
191	W-11512	FGS	Cuttings	29.21535	-82.045555	OCALA EAST	38	110
192	W-11520	FGS	Cuttings	29.146102	-81.031728	DAYTONA BEACH	31	205
193	W-11569	FGS	Cuttings	28.991614	-81.298574	ORANGE CITY	61	210
194	W-11648	FGS	Cuttings	29.083072	-81.877976	LAKE WEIR	70	210
195	W-11694	FGS	Cuttings	29.235221	-81.031039	DAYTONA BEACH	3	205
196	W-11696	FGS	Cuttings	29.243867	-81.463401	PIERSON	75	200
197	W-11730	FGS	Cuttings	29.171666	-81.837777	HALFMOON LAKE	65	160
198	W-11776	FGS	Cuttings	29.336033	-81.131173	FAVORETTA	52	160
199	W-11828	FGS	Cuttings	29.094752	-81.303576	DELAND	64	230
200	W-11848	FGS	Cuttings	29.389014	-81.086141	FLAGLER BEACH EAST	15	155
201	W-11861	FGS	Cuttings	29.406891	-81.158442	FLAGLER BEACH WEST	27	220
202	W-11929	FGS	Cuttings	29.119536	-81.512696	ALEXANDER SPRINGS	3	114
203	W-11934	FGS	Cuttings	29.164231	-81.534035	ASTOR	8	163
204	W-12014	FGS	Cuttings	29.133777	-81.028007	DAYTONA BEACH	31	160
205	W-12021	FGS	Core	29.233569	-81.17645	DAYTONA BEACH NW	27	71
206	W-12022	FGS	Core	29.207202	-81.195617	DAYTONA BEACH NW	35	48
207	W-12023	FGS	Core	29.163871	-81.21228	DAYTONA BEACH NW	39	57
208	W-12024	FGS	Core	29.191925	-81.22895	DAYTONA BEACH NW	38	73
209	W-12025	FGS	Core	29.218591	-81.219505	DAYTONA BEACH NW	33	71
210	W-12026	FGS	Core	29.185258	-81.180335	DAYTONA BEACH NW	36	84
211	W-12027	FGS	Core	29.020818	-81.204223	DAYTONA BEACH SW	39	74
212	W-12028	FGS	Core	29.239147	-81.235336	DAYTONA BEACH NW	35	75
213	W-12029	FGS	Core	29.141927	-81.238395	DAYTONA BEACH NW	41	57.5

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft)	Total Depth (ft)
214	W-12031	FGS	Core	29.09165	-81.160614	DAYTONA BEACH SW	41	92
215	W-12032	FGS	Core	29.025817	-81.148117	DAYTONA BEACH SW	41	82
216	W-12034	FGS	Core	29.225257	-81.252281	LAKE DIAS	37	92
217	W-12058	FGS	Cuttings	29.377145	-81.131955	FLAGLER BEACH WEST	34	180
218	W-12059	FGS	Cuttings	29.373439	-81.139285	FAVORETTA	21	260
219	W-12060	FGS	Cuttings	29.38338	-81.131826	FLAGLER BEACH WEST	26	200
220	W-12061	FGS	Cuttings	29.389809	-81.144256	FLAGLER BEACH WEST	23	120
221	W-12142	FGS	Cuttings	29.007156	-81.342233	DELAND	56	230
222	W-12154	FGS	Cuttings	29.090555	-81.068138	SAMSULA	21	100
223	W-12166	FGS	Cuttings	29.26748	-81.077278	ORMOND BEACH	27	180
224	W-12228	FGS	Cuttings	29.250531	-81.439074	SEVILLE	59	190
225	W-12340	FGS	Cuttings	29.431675	-81.214119	FLAGLER BEACH WEST	23	325
226	W-12385	FGS	Cuttings	29.136231	-81.145109	DAYTONA BEACH NW	43	150
227	W-12409	FGS	Cuttings	29.201388	-81.913263	LYNNE	69	192
228	W-12632	FGS	Cuttings	29.237521	-81.097118	DAYTONA BEACH	26	200
229	W-12633	FGS	Cuttings	29.259533	-81.108549	ORMOND BEACH	20	200
230	W-12796	FGS	Cuttings	29.19996	-81.061095	DAYTONA BEACH	29	150
231	W-12797	FGS	Cuttings	29.146599	-81.153515	DAYTONA BEACH NW	42	140
232	W-12801	FGS	Cuttings	29.170149	-81.169047	DAYTONA BEACH NW	38	200
233	W-12808	FGS	Cuttings	29.170149	-81.169047	DAYTONA BEACH NW	38	220
234	W-12809	FGS	Cuttings	29.170149	-81.169047	DAYTONA BEACH NW	38	222
235	W-12810	FGS	Cuttings	29.170149	-81.169047	DAYTONA BEACH NW	38	210
236	W-12811	FGS	Cuttings	29.170149	-81.169047	DAYTONA BEACH NW	38	210
237	W-12904	FGS	Cuttings	28.99751	-80.966672	EDGEWATER	29	210
238	W-12950	FGS	Cuttings	29.083639	-81.067998	SAMSULA	22	120
239	W-13086	FGS	Cuttings	29.360588	-81.966944	FORT MCCOY	73	103
240	W-13102	FGS	Cuttings	29.491375	-81.951944	EUREKA DAM	64	160
241	W-13235	FGS	Cuttings	29.065145	-81.250656	DELAND	50	120
242	W-13236	FGS	Cuttings	29.263173	-81.110494	ORMOND BEACH	16	80
243	W-13414	FGS	Cuttings	29.446626	-81.296821	BUNNELL	11	90
244	W-13415	FGS	Cuttings	29.446626	-81.296821	BUNNELL	11	100
245	W-13416	FGS	Cuttings	29.279948	-81.070545	ORMOND BEACH	8	200
246	W-13417	FGS	Cuttings	29.279948	-81.070545	ORMOND BEACH	8	130
247	W-13426	FGS	Cuttings	29.25944	-81.125108	FAVORETTA	8	100
248	W-13427	FGS	Cuttings	29.162259	-81.01886	DAYTONA BEACH	9	80
249	W-13431	FGS	Cuttings	29.431372	-81.230577	FLAGLER BEACH WEST	23	140
250	W-13440	FGS	Cuttings	29.445797	-81.262863	BUNNELL	13	8856
251	W-13456	FGS	Cuttings	29.145091	-81.145551	DAYTONA BEACH NW	44	270
252	W-13461	FGS	Cuttings	29.145091	-81.145551	DAYTONA BEACH NW	44	270
253	W-13513	FGS	Cuttings	29.431372	-81.230577	FLAGLER BEACH WEST	23	80
254	W-13546	FGS	Cuttings	29.03224	-81.337657	DELAND	67	400
255	W-13595	FGS	Cuttings	29.146102	-81.031728	DAYTONA BEACH	31	200
256	W-13596	FGS	Cuttings	29.146102	-81.031728	DAYTONA BEACH	31	200
257	W-13678	FGS	Cuttings	29.446626	-81.296821	BUNNELL	11	140
258	W-13689	FGS	Cuttings	29.016896	-81.223145	DAYTONA BEACH SW	43	200
259	W-13695	FGS	Cuttings	29.167776	-81.299602	LAKE DIAS	35	160
260	W-13837	FGS	Cuttings	29.197252	-81.599341	ASTOR	0	320
261	W-13864	FGS	Cuttings	29.188051	-81.049559	DAYTONA BEACH	30	190
262	W-14180	FGS	Cuttings	29.371822	-81.558277	WELAKA SE	24	157
263	W-14187	FGS	Cuttings	29.446532	-81.197911	FLAGLER BEACH WEST	23	160
264	W-14188	FGS	Cuttings	29.446532	-81.197911	FLAGLER BEACH WEST	23	170
265	W-14189	FGS	Cuttings	29.446532	-81.197911	FLAGLER BEACH WEST	23	170
266	W-14190	FGS	Cuttings	29.446532	-81.197911	FLAGLER BEACH WEST	23	115
267	W-14264	FGS	Cuttings	29.188051	-81.049559	DAYTONA BEACH	30	185
268	W-14315	FGS	Core	29.181644	-81.713966	JUNIPER SPRINGS	48	280

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft)	Total Depth (ft)
269	W-14316	FGS	Core	29.147061	-81.664883	JUNIPER SPRINGS	110	140
270	W-14327	FGS	Core	29.175	-81.715555	JUNIPER SPRINGS	72	112
271	W-14353	FGS	Core	29.514721	-81.662585	SATSUMA	89	162
272	W-14432	FGS	Cuttings	29.242616	-81.046075	DAYTONA BEACH	5	210
273	W-14623	FGS	Cuttings	29.14277	-81.035394	DAYTONA BEACH	29	210
274	W-14625	FGS	Cuttings	29.14277	-81.035394	DAYTONA BEACH	29	200
275	W-14751	FGS	Core	29.105277	-81.655	FARLES LAKE	60	102
276	W-14763	FGS	Cuttings	29.483917	-81.527712	CRESCENT CITY	0	157
277	W-14965	FGS	Cuttings	29.505542	-81.291653	ESPANOLA	28	220
278	W-14966	FGS	Cuttings	29.511425	-81.287819	ESPANOLA	28	220
279	W-14967	FGS	Cuttings	29.500002	-81.27917	BUNNELL	27	220
280	W-14968	FGS	Cuttings	29.504171	-81.266708	ESPANOLA	28	210
281	W-15109	FGS	Cuttings	29.287264	-81.159063	FAVORETTA	23	200
282	W-15141	FGS	Cuttings	29.112307	-81.053498	SAMSULA	25	180
283	W-15201	FGS	Cuttings	28.965459	-81.655433	UMATILLA	68	368
284	W-15312	FGS	Cuttings	29.083836	-82.012291	BELLEVIEW	104	240
285	W-15362	FGS	Cuttings	29.207384	-81.409683	PIERSON	42	370
286	W-15635	FGS	Cuttings	29.020728	-81.299304	DELAND	49	400
287	W-15651	FGS	Cuttings	29.140633	-81.14964	DAYTONA BEACH NW	44	300
288	W-15772	FGS	Cuttings	29.100462	-81.143198	DAYTONA BEACH SW	41	300
289	W-15780	FGS	Cuttings	29.186469	-81.152616	DAYTONA BEACH NW	29	300
290	W-15835	FGS	Cuttings	29.094613	-81.362092	DELAND	52	315
291	W-15862	FGS	Cuttings	29.222891	-81.468786	PIERSON	41	200
292	W-15863	FGS	Cuttings	29.222891	-81.468786	PIERSON	41	200
293	W-15994	FGS	Cuttings	29.143395	-81.129309	DAYTONA BEACH NW	43	818
294	W-15995	FGS	Cuttings	29.185305	-81.072731	DAYTONA BEACH	26	820
295	W-16007	FGS	Core	29.103013	-81.315333	DELAND	90	90
296	W-16008	FGS	Core	29.174972	-81.452546	PIERSON	32	90
297	W-16009	FGS	Core	29.257553	-81.12047	ORMOND BEACH	21	75
298	W-16164	FGS	Cuttings	29.164925	-81.153526	DAYTONA BEACH NW	36	350
299	W-16174	FGS	Cuttings	29.375061	-81.917222	EUREKA DAM	68	190
300	W-16175	FGS	Cuttings	29.145091	-81.145551	DAYTONA BEACH NW	44	330
301	W-16217	FGS	Cuttings	29.313542	-81.105587	ORMOND BEACH	17	104
302	W-16219	FGS	Cuttings	29.336666	-81.709166	SALT SPRINGS	1	200
303	W-16227	FGS	Cuttings	29.27645	-81.684166	SALT SPRINGS	41	200
304	W-16278	FGS	Cuttings	29.020929	-81.299259	DELAND	48	370
305	W-16280	FGS	Cuttings	29.462172	-81.934722	EUREKA DAM	37	264
306	W-16557	FGS	Cuttings	29.17212	-81.96295	LYNNE	70	300
307	W-16563	FGS	Cuttings	28.967222	-81.979252	LADY LAKE	79	426
308	W-16801	FGS	Cuttings	29.281447	-81.066859	ORMOND BEACH	7	195
309	W-16823	FGS	Cuttings	29.257109	-81.114031	ORMOND BEACH	25	130
310	W-16831	FGS	Cuttings	29.029145	-81.260806	DELAND	70	150
311	W-17060	FGS	Cuttings	29.104148	-81.308952	DELAND	83	460
312	W-17154	FGS	Cuttings	29.141944	-81.364999	LAKE DIAS	19	460
313	W-17175	FGS	Cuttings	29.377782	-81.526741	CRESCENT CITY	43	400
314	W-17255	FGS	Cuttings	29.390277	-81.967777	EUREKA DAM	47	44.5
315	W-17274	FGS	Cuttings	29.363333	-81.684722	SALT SPRINGS	23	460
316	W-17475	FGS	Cuttings	29.465833	-81.651666	WELAKA	51	16
317	W-17476	FGS	Cuttings	29.463888	-81.651666	WELAKA	45	41
318	W-17477	FGS	Cuttings	29.464722	-81.653055	WELAKA	30	15
319	W-17531	FGS	Cuttings	29.179166	-81.0625	DAYTONA BEACH	28	970
320	W-17532	FGS	Cuttings	29.097777	-81.273888	DELAND	49	140
321	W-17537	FGS	Cuttings	29.097777	-81.273888	DELAND	49	66
322	W-17561	FGS	Cuttings	29.429693	-81.858975	LAKE DELANCY	140	136
323	W-17562	FGS	Cuttings	29.091944	-81.708611	FARLES LAKE	92	81

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft)	Total Depth (ft)
324	W-17563	FGS	Cuttings	29.268333	-81.82	LAKE KERR	140	96
325	W-17564	FGS	Cuttings	29.282499	-81.770833	LAKE KERR	67	76
326	W-17565	FGS	Cuttings	29.360833	-81.856944	LAKE KERR	131	81
327	W-17566	FGS	Cuttings	29.105277	-81.813055	LAKE MARY	112	101
328	W-17568	FGS	Cuttings	29.298055	-81.696666	SALT SPRINGS	41	126
329	W-17569	FGS	Cuttings	29.471111	-81.860277	LAKE DELANCY	163	91
330	W-17659	FGS	Cuttings	28.968055	-82.011666	OXFORD	68	101
331	W-17660	FGS	Cuttings	29.354429	-81.46245	SEVILLE	27	25
332	W-17686	FGS	Cuttings	29.032202	-81.556458	ALEXANDER SPRINGS	46	91
333	W-17764	FGS	Core	29.3208	-81.179199	FAVORETTA	23	151
334	W-18061	FGS	Cuttings	29.499166	-81.958333	EUREKA DAM	81	141
335	W-18250	FGS	Cuttings	29.284722	-81.126388	FAVORETTA	25	90
336	W-18267	FGS	Cuttings	29.386111	-81.972777	EUREKA DAM	56	180
337	W-18279	FGS	Cuttings	29.428611	-81.856388	LAKE DELANCY	139	380
338	W-18281	FGS	Cuttings	29.321666	-81.539444	WELAKA SE	20	110
339	W-18284	FGS	Cuttings	29.251666	-81.507222	WELAKA SE	12	170
340	W-18287	FGS	Cuttings	29.431944	-81.513888	CRESCENT CITY	37	160
341	W-18297	FGS	Cuttings	29.499166	-81.958333	EUREKA DAM	81	210
342	W-18814	FGS	Core	29.176666	-81.116666	DAYTONA BEACH	28	1006
343	W-18825	FGS	Cuttings	29.508055	-81.161944	BEVERLY BEACH	18	290
344	W-18863	FGS	Core	29.211111	-81.086944	DAYTONA BEACH	28	1000
345	W-18998	FGS	Core	29.068058	-81.289174	DELAND	72	870
346	W-19036	FGS	Core	29.169166	-81.641943	JUNIPER SPRINGS	67	195
347	W-19060	FGS	Core	29.411361	-81.305111	BUNNELL	13	92
348	W-19213	FGS	Core	29.431916	-81.513911	CRESCENT CITY	37	112
349	W-19240	FGS	Core	29.091389	-81.044167	SAMSULA	23	810