Open-File Map Series 113, Plate 3
*See Open-File Report 110 for accompanying text

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Florida Department of Environmental Protection
Florida Geological Survey

OPEN-FILE MAP SERIES 113, Plate 3

GEOMORPHOLOGY OF THE USGS FORT PIERCE 30 X 60 MINUTE QUADRANGLE, SOUTH FLORIDA

2022

BY

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Barrier Island Sequence District

The Barrier Island Sequence District occurs along the Atlantic Coast. It extends from Georgia (Clark and Zisa, 1976) into Florida, and south to the vicinity of Lake Okeechobee (Figure 3). Pleistocene and Holocene coastal processes formed extensive barrier islands, beaches, lagoons, embayments, and shallow-water marine terraces in the district. Within the mapped area, the Barrier Island Sequence District is subdivided into four provinces: Allapattah Flats, Osceola Plain, Upper St. Johns River Valley, and Atlantic Coastal Complex (Figure 4). Elevations of the district within Florida range from sea level to about 235 feet (71.6 meters) above MSL. Within the study area, elevations in the district range from sea level along the Atlantic Coast in the Atlantic Coastal Complex Province, to approximately 90 feet (27.4 meters) above MSL in the Osceola Plain Province (Figure 1). The Barrier Island Sequence District in the mapped area is bounded to the south by the Everglades District and to the west by the Lakes District (Figure 3). Strand plains and shore-parallel dunes represent the preserved depositional features of former shorelines. The swales between beach ridges are often swampy and contain lakes, wetlands, linear swamps, and tributary streams in addition to the coast-parallel mangrove swamps landward of the barrier islands within the study area. The swales control the development of lakes in parts of the Osceola Plain Province and the extensive linear wetlands of the Atlantic Coastal Complex Province. Much of the river and stream drainage in the Barrier Island Sequence District is controlled by the relict ridges forming distinct, swale-induced, drainage patterns. The district includes two important coastal drainage systems within the study area, the North and South forks of the St. Lucie River, flowing toward the Atlantic Coast. The Indian River and Hobe Sound are estuarine lagoons that receive water from the St. Lucie River, numerous small streams, canals, and ditches that drain east toward the Atlantic Ocean. The St. Johns River Marsh, the headwater region of the St. Johns River, is in the Barrier Island Sequence District in the study area. Tertiary/Quaternary undifferentiated shelly sediments underlie the Barrier Island Sequence District within the mapped area. The Pleistocene Anastasia Formation, Quaternary beach ridge and dune deposits, Quaternary undifferentiated sediments, and Holocene sediments overlie the Tertiary/Quaternary undifferentiated shelly sediments. The Anastasia Formation occurs at and near the coast, where it is sporadically exposed along the barrier island coastlines within the mapped area. Holocene sediments exist along the Atlantic Coast (OFMS 113, Plate 1). Karst features in the district are mostly related to dissolution of shell and carbonate beds within the Tertiary/Quaternary undifferentiated shelly sediments and the Anastasia Formation. Shallow karst depressions, including cover-subsidence sinkholes and solutions pits, were formed by dissolution of shell and coquina (Schmidt and Scott, 1984). Cover-subsidence sinkholes often form wetlands. In areas where the Anastasia Formation crops out along the Atlantic Coast, microkarst surfaces have developed (Upchurch et al., 2019).

Osceola Plain Province

The Osceola Plain Province extends from Seminole County to Martin County. It includes most of the Kissimmee River valley in the western two-thirds of the province and a strand plain in the eastern third. The flat, undulating surface of the Osceola Plain Province has the topography of a marine terrace (White, 1970) or a shallow marine platform. There are significant accumulations of dune and beach sand on the western boundary of the province, continuing onto the eastern flank of the Lake Wales Ridge Complex Province. Some of the dune fields are well developed and have significant relief. Elevations of the Osceola Plain Province in the study area range from approximately 25 feet (7.6 meters) MSL along the boundary with the Upper St. Johns River Valley Province (Figure 1), to about 90 feet (27.4 meters) above MSL. The eastern boundary between the Osceola Plain Province and the Upper St. Johns River Valley Province is at the toe of a slope break marking a marine escarpment. The Osceola Plain Province is higher, has greater relief, and is better drained than the Allapattah Flats Province to the southeast (Figure 1). The boundary between these two provinces is placed at the base of the marine escarpment along the eastern boundary of the Osceola Plain Province. The Osceola Plain Province shares a short boundary with the Everglades Province (Everglades District) to the south (Figures 1 and 4). The boundary is placed at the transition from slightly higher elevations and relief of the Osceola Plain Province to the slightly lower elevations and relief of the Everglades Province. The southern boundary with the Okeechobee Plain Province (Everglades District) separates the lower end of the Kissimmee River valley and the lowlands surrounding the northern half of Lake Okeechobee. The strand plain in the eastern third of the Osceola Plain Province is well developed from southeastern Seminole and eastern Orange counties into eastern Osceola County, narrowing to a ridge ending in westernmost Indian River County and northeastern Okeechobee County (Figures 3 and 4). Drainage in the province includes swale-controlled streams and wetlands associated with the many streams that parallel the Atlantic Coast. Several creeks cut across the ridges and flow toward the St. Johns River. The Kissimmee River once meandered through a shallow, flood plain south to Lake Okeechobee. In the 1960s, the Kissimmee River was channelized for flood control, and the landscape was significantly altered. In the late 1990s, efforts began to restore the natural flow of the river system. Surficial geologic units exposed on the Osceola Plain include Tertiary/Quaternary undifferentiated shelly sediments, Quaternary undifferentiated sediments, and Quaternary beach ridge and dune sediments (OFMS 113, Plate 1). Tertiary/Quaternary undifferentiated shelly sediments underlie the surficial quartz sands in the province throughout the mapped area (OFMS 113, Plate 2). Large karst landforms are not common in the Osceola Plain Province. The shallow depressions and cover-subsidence sinkholes which are present are most likely due to dissolution of shell material in the shallow subsurface.

Upper St. Johns River Valley Province

The Upper St. Johns River Valley Province includes the fluvial/paludal valley from the headwaters of the St. Johns River, near the St. Lucie-Martin County boundary, northward to the outfall of Lake Monroe between Seminole and Volusia counties. The province follows a low-elevation drainage system that was an ancient embayment or lagoon between the Atlantic Coastal Complex Province to the east and the strand plain of the eastern Osceola Plain Province to the west (Figure 4). Most of the Upper St. Johns River Valley Province is very flat with a riverine floodplain, wetlands, and lakes. The southern part of the province is slightly higher in elevation and lacks the distinct river channel and fluvial landforms that are present in the northern part of the province. Sediment transport in the system is negligible, but wetland development and the lacustrine/paludal sediments influence the presence of distributaries, lakes, and other landforms. Elevations in the Upper St. Johns River Valley Province in the mapped area range from five feet (1.5 meters) MSL to about 45 feet (10.7 meters) above MSL. Elevations above 35 feet (13.7 meters) MSL are generally restricted to the border regions with the Atlantic Coastal Complex Province and the Osceola Plain Province. The eastern boundary with the Atlantic Coastal Complex Province follows the change from coastal ridges to the east, and the wetland and river complex to the west (Figure 1). The southern boundary between the Upper St. Johns River Valley Province and the Allapattah Flats Province is placed where the St. Johns River Marsh drains north into the St. Johns River (Figure 1). The boundary of the Upper St. Johns River Valley Province with the Osceola Plain Province is placed at the toe of a marine escarpment where elevations increase on to the Osceola Plain Province to the west (Figure 1). The concept that the province was once an embayment or lagoon is supported by the presence of coastal landforms on the margins of the Atlantic Coastal Ridge Complex Province to the east and the Osceola Plain Province to the west. Lakes are present along the course of the river in the northern part of the province, and there are many distributaries and oxbows, as is typical of a sediment-choked, low-gradient stream system. Anthropogenic alteration of the southern portion of the Upper St. Johns River Valley Province is extensive. The Upper St. Johns River Valley Province is a broad area where Tertiary/Quaternary undifferentiated shelly sediments and Quaternary undifferentiated sediments occur at or near the land surface. Holocene sediments overlie these deposits in many of the low-lying river and wetland areas. Regions that are relatively unaffected by ditching and drainage systems have common, but not abundant, shallow depressions that are cover-subsidence sinkholes. These formed as a result of dissolution of shell material in the underlying Tertiary/Quaternary shelly sediments.

Atlantic Coastal Complex Province

The Atlantic Coastal Complex Province extends along the Atlantic Coast from the St. Johns River in Duval County to central Palm Beach County. The province consists of Quaternary barrier islands and related features on, and inland from, the Atlantic Coast. Water bodies and wetlands landward of the barrier islands include lagoons and small embayments. Within the study area, tidal estuarine coastlines are dominated by mangrove swamps. Most of the Atlantic Coastal Complex Province is a Pleistocene strand plain. Many of the beach ridges and dunes in this province are coast parallel. Elevations of the province in the study area range from sea level along the Atlantic Coast to about 50 feet (15.2 meters) above MSL along the western boundary of the province. The ridge and dune topography of the Atlantic Coastal Complex Province transitions to slightly lower elevation and flatter topography along most of its western boundary with the Upper St. Johns River Valley Province within the mapped area (Figure 1). Open lagoons and small embayments, located landward of the barrier islands, are locally termed "rivers" because of their historic uses for navigation. Drainage patterns in the Atlantic Coastal Complex Province are swale-dominated and coast-parallel in nature, with streams and wetlands occupying the swales between ridges. Some streams flow toward the Atlantic Ocean through breaks in the beach ridges, such as the North and South forks of the St. Lucie River. The surficial lithostratigraphic units that affect the landforms in the Atlantic Coastal Complex Province include Tertiary/Quaternary undifferentiated shelly sediments, the Pleistocene Anastasia Formation, Quaternary undifferentiated sediments, and Quaternary beach ridge and dune sediments (Scott et al., 2001). Holocene undifferentiated sediments occur on many of the barrier islands and in the tidal mangrove estuaries. Sporadic exposures of the Anastasia Formation from St. Johns County to Palm Beach County create unique rocky coastlines. Cover-subsidence sinkholes occur in the province where the Tertiary/Quaternary undifferentiated shelly sediments and the Pleistocene Anastasia Formation are at or near the land surface. Dissolution features can be seen where the Anastasia Formation is exposed along the modern coast and in the Tertiary/Quaternary undifferentiated shelly sediments exposed in mines and borrow pits.

Allapattah Flats Province

The Allapattah Flats Province extends from southern St. Lucie County to northeastern Palm Beach County (Figure 4). The province includes the indistinct, low-elevation, drainage divide between the headwater wetlands of the St. Johns River and the northeastern Everglades. It is characterized by very little change in elevation, highly variable directions of surface water flow, and numerous shallow circular wetlands in undeveloped areas of the landscape. The Allapattah Flats Province north of the St. Lucie Canal has elevations between 25 feet and 30 feet (7.6 meters and 9.1 meters) MSL. The southern part of the province ranges from 15 feet to 25 feet (4.6 meters to 7.6 meters) MSL, with most elevations below 20 feet (6.1 meters) MSL in the headwaters of the local drainage systems to the south and east (Figure 4). The boundaries of the Allapattah Flats Province are largely based on drainage patterns. The boundary between the Allapattah Flats Province and the Upper St. Johns River Valley Province is placed where the St. Johns River Marsh drains north to the St. Johns River (Figure 1). The northern Allapattah Flats Province is separated from the Atlantic Coastal Complex Province by Green Ridge (White, 1970), a narrow, coastal ridge which largely isolates the coastal rivers of St. Lucie and Martin counties from the Allapattah Flats Province (Figure 1). The Allapattah Flats Province is slightly higher in elevation than the Everglades Province (Everglades District), but there is no definitive elevation break upon which a province boundary can be drawn. Therefore, the boundary approximates where the pre-development Everglades drainage system began. The boundary with the Osceola Plain Province to the west is at a distinct break in elevation on to the southern end of the strand plain that covers the eastern part of the Osceola Plain Province (Figure 1). Regions in the northern Allapattah Flats Province that have not been ditched and drained have wetlands that run north-northwest to south-southeast, parallel to the ancient coastal landforms. These landforms indicate that the northern Allapattah Flats Province was once a shallow marine shelf. The low ridges and swales within this area are likely either coast-parallel bedforms developed on this shelf, or poorly developed strand plains created as the sea retreated from the shelf. The southern portion of Allapattah Flats Province does not have obvious landforms indicative of coastal or shallow marine processes. The Allapattah Flats Province includes wetlands that historically drained north to the St. Johns River, west and south to the Everglades, or east to the Atlantic Ocean prior to construction of the St. Lucie Canal. Drainage is complex because surface-water drainage directions can change with water stage. Well-defined streams are rare, but strand-plain swales and interconnected, coalesced, cover-subsidence sinkholes exist. The depressions created by strand-plain formation control locally dominant paths of surface water flow. By the end of the 20th century, the St. Lucie Canal had been constructed and large areas of the province had been partly drained by shallow ditches, altering the historical drainage system. Undeveloped lands remain swampy. The Allapattah Flats Province is underlain by Tertiary/Quaternary undifferentiated shelly sediments. Karst landforms are limited to numerous, nearly circular, shallow, closed depressions. These depressions are cover-subsidence sinkholes formed on shell beds that occur near land surface in the Tertiary/Quaternary shelly sediments. Toward the edges of the province, these depressions become oriented in the general direction of surface water flow.

Everglades District

The Everglades District includes the southern part of peninsular Florida (Figure 3). Many areas are characterized by wetlands, but others include Pleistocene to Holocene carbonate islands and coastal ridges. The district has little topographic relief. The Everglades District is subdivided within the mapped area into two provinces: The Okeechobee Plain and Everglades provinces (Figures 1 and 4). Elevations within the Everglades District gradually decrease from north to south. Lowest elevations in the district are at sea-level along the coastlines. Highest elevations approach 50 feet MSL. Elevations of the district within the mapped area range from approximately five to 45 feet (1.5 to 13.7 meters) MSL. Nearshore marine and coastal processes have had limited impact on the dominant landforms in the northern part of the district. All the provinces within the Everglades District are related to a vast and complex drainage system that begins with the Kissimmee River and its tributaries in the Barrier Island Sequence District to the north. Lake Okeechobee has human-modified outlets to the west and east, but much of its natural flow is south toward Florida Bay. Drainage in much of the district is by way of sloughs, sheet flow in wetlands, and poorly defined stream systems predominantly flowing from north to south. Much of the district is covered by extensive wetlands. All the provinces within the district have relatively flat landscapes, and elevation changes of inches or a few feet often mark the differences between provinces. With few exceptions, pre-development drainage was as sheet flow and through sloughs (wetlands). The dominant flow of water through the central and eastern Everglades District has historically been north to south. Flow beginning in the Kissimmee River valley would discharge to Lake Okeechobee, then over the low, natural sills on the south side of the lake, and finally as sheet flow through the Everglades Province. During the 20th century, the St. Lucie Canal was constructed for navigation and as an eastern outlet for Lake Okeechobee. Near-surface sediments of the northern Everglades District include Tertiary/Quaternary undifferentiated shelly sediments (Scott et al., 2001). Karst landforms are geologically young, thus small, forming during the Pliocene to Holocene. They are subtle, and more common in the southern than northern part of the district. Karren on rock surfaces and sinkholes can be found throughout the Everglades District. Duricrusts, microkarst, and breccias are also common wherever limestone is exposed. Cover-subsidence sinkholes (Upchurch et al., 2019) are common in many of the regions where the Tertiary/Quaternary shelly sediments and Tamiami Formation (west of mapped area) are at or near the land surface. Cover collapse sinkholes are rare in the district.

Okeechobee Plain Province

The Okeechobee Plain Province is the northernmost province of the Everglades District encompassing parts of Highlands, Okeechobee, Glades, and Martin counties and small areas of St. Lucie and Hendry counties (Figure 4). The northern part of the province includes the lower Kissimmee River valley. This province includes Lake Okeechobee and the low-elevation plains and wetlands surrounding the northern half of the lake. The land surface of the Okeechobee Plain Province has low relief, with elevations as low as 5 feet (1.5 meters) MSL, increasing to 45 feet (13.7 meters) MSL within the study area. In the Kissimmee River valley, the boundary between the Okeechobee Plain Province and the Osceola Plain Province to the north is placed where the river valley begins to narrow relative to the southern part of the valley (Figure 4). The boundary is more distinct to the northeast as elevation rises to the ridge at the southern end of the Osceola Plain Province. On the east, the boundary with the Everglades Province diverges from Lake Okeechobee where historic southward overland flow of water to the Everglades occurred. The boundary with the Everglades Province is along the southern shore of Lake Okeechobee, the former location of a low sill that controlled flow to the Everglades (Figure 4). The sill has been replaced by the Herbert Hoover Dike. Coastal landforms are muted and indistinct in the Okeechobee Plain Province. The province is a broad, relatively flat marine terrace that has been modified by fluvial processes and wetland development. The dominant fluvial feature is the lower Kissimmee River valley. The natural river channel meanders, and the floodplain includes abandoned meanders and other fluvial landforms. In the 1960s, the Kissimmee River was channelized for flood control. In the late 1990s, restoration to the natural drainage began and can be observed in the northern part of the province. Elsewhere in the province wetlands are common in low areas. The Okeechobee Plain Province is underlain by Tertiary/Quaternary undifferentiated shelly sediments and Quaternary undifferentiated sediments (Scott et al., 2001). Surficial sediments include peat, muck, and marl associated with Holocene wetlands. Karst features are uncommon. Cover-subsidence sinkholes appear to be related to dissolution of the shell material, but they are less frequent than in the southern provinces of the Everglades District.

Everglades Province

The Everglades Province extends from the southern shore of Lake Okeechobee through Palm Beach, Broward, and Miami-Dade counties and parts of Glades, Martin, Hendry, Monroe, and Collier counties (Figure 4). The province constitutes the largest subtropical wetland in the United States. The Everglades Province is a broad plain, sloping gently from north to south in southern peninsular Florida. For the most part, the province was covered by sawgrass marsh with scattered tree islands that transition to mangroves to the south and pine flatwoods to the east and west. Today, parts of this drainage system have been interrupted by canals, agricultural areas, and other land uses, including the Everglades Agricultural Area in the north. Land-surface elevations in the Everglades Province range from sea level to 40 feet (12.2 meters) MSL. Within the study area, elevations in the Everglades Province range from about 10 to 40 feet (3.0 to 12.2 meters) MSL. The northern boundary of the Everglades Province with the Okeechobee Plain Province follows the southern shore of Lake Okeechobee where drainage is southward to the Everglades Province (Figure 4). The boundary of the Everglades Province with the Okeechobee Plain Province on the east side of Lake Okeechobee is near the St. Lucie Canal, the approximate location where historic overflow from Lake Okeechobee to the south began. The narrow boundary with the Osceola Plain Province follows a distinct increase in elevation at a low ridge at the southeastern end of the Osceola Plain Province, near Indiantown. The boundary of the province with the Allapattah Flats Province is based upon slightly higher elevations in the Allapattah Flats Province. The Everglades Province includes the historical drainage system from Lake Okeechobee toward the south and southwest. Historically, the Everglades Province was a sawgrass marsh dominated by sheet flow of water with scattered, tear-drop shaped tree islands, mostly south of Lake Okeechobee. The Pliocene Tamiami Formation underlies most of the Everglades Province outside of the mapped area. The northern part of the Everglades Province is underlain by Tertiary/Quaternary undifferentiated shelly sediments. Holocene peat and calcitic marl form a thin cover over the shelly sediments (Scott et al., 2001). Peat deposits were thickest to the north, in the Everglades Agricultural Area. Karst in the northern Everglades Province develops in response to dissolution of carbonate shell material within the Tertiary/Quaternary shelly sediments that are near the land surface. Where thick muck soils and peats bury the limestone and shelly sediments, karst landforms are not evident; although, they do occur beneath the organic sediments. Where the upper surface of limestone in the peatlands is exposed, small karren and microkarst are often evident. Duricrusts and breccias are also found on the surface of the limestone. Larger depressions (solution sinkholes; Upchurch et al., 2019) are also found on the limestone surface in the Everglades Province. These features are common under hammocks, ponds, and sloughs, and seem to be associated with regions of peat accumulation. The organic acids in the peats are thought to have dissolved the limestone surface.

*Note: See Open-File Report 110 for references

Figure 1. Geomorphic Provinces (modified from Williams et al., 2022).

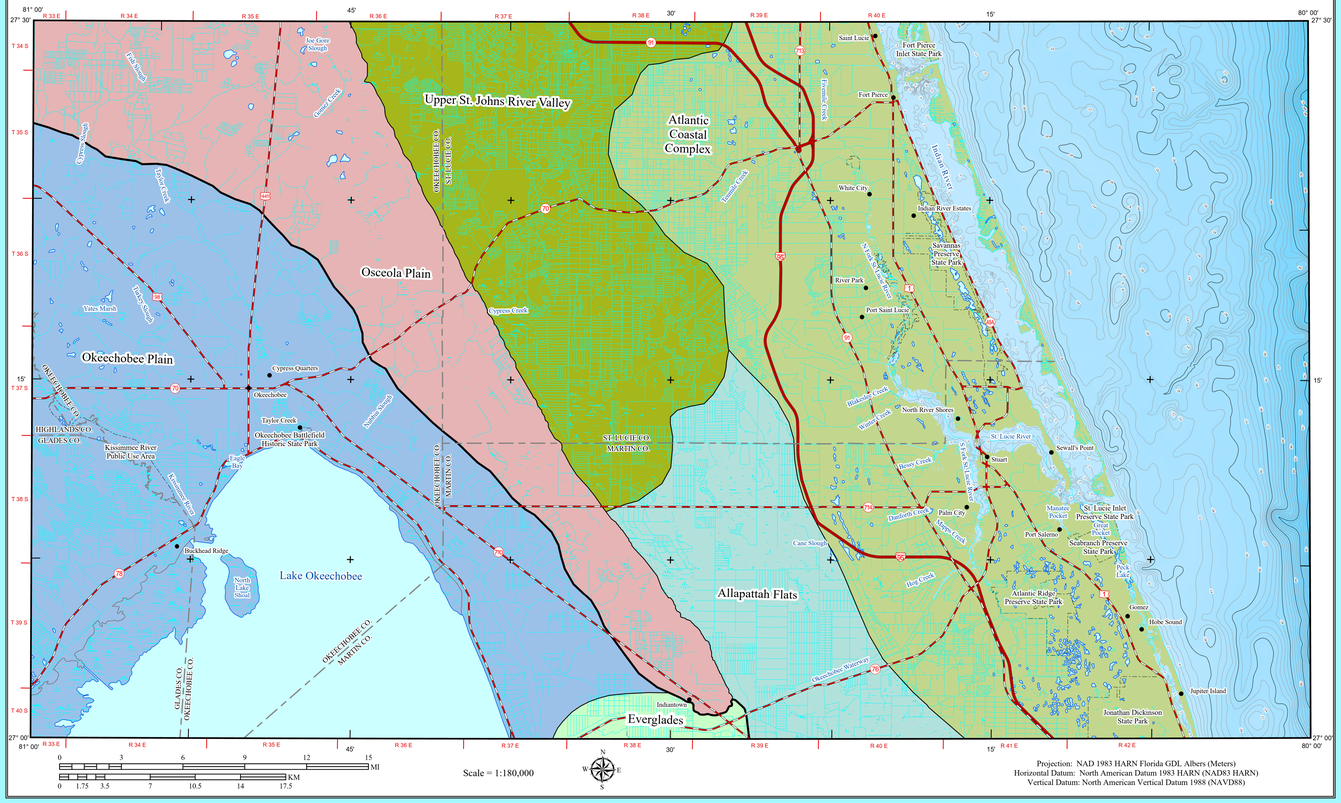


Figure 2. LiDAR (light detection and ranging) and DEM (digital elevation model) mosaic.

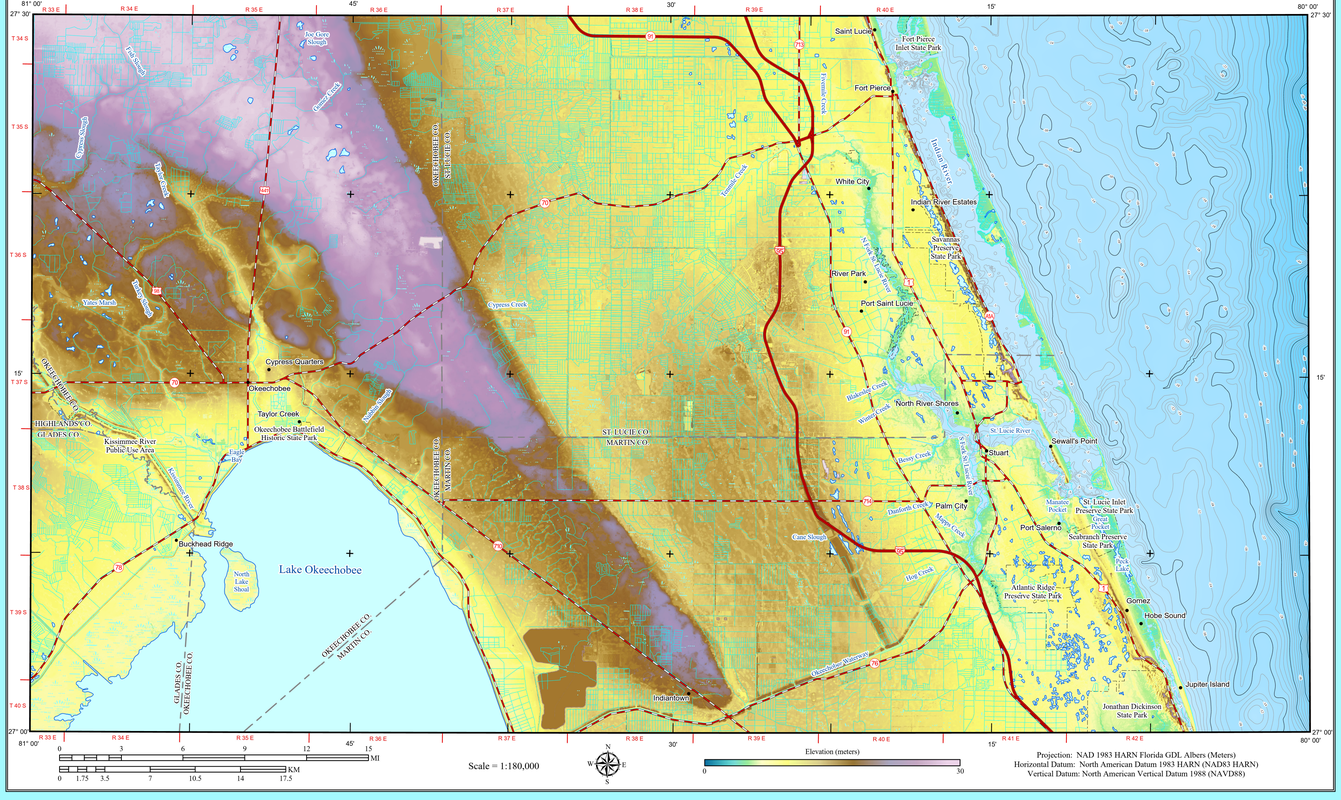


Figure 3. Geomorphic Districts (modified from Williams et al., 2022).

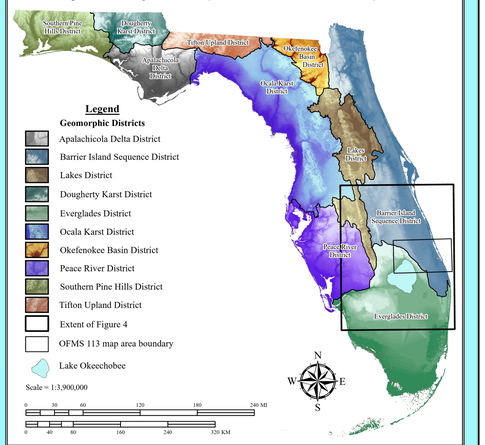
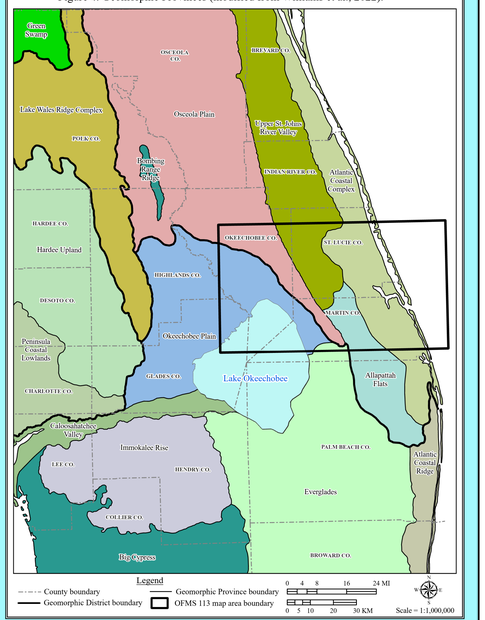


Figure 4. Geomorphic Provinces (modified from Williams et al., 2022).



Legend for Figures 1 & 2

City/town
County boundary
Primary highway
Secondary highway
USGS 1:24,000 Quadrangle tick mark
Geomorphic Province boundary
Geomorphic District boundary
State lands and parks
River or stream or canal
Waterbody
Wetland
Bathymetry (2m) Index
Intermediate

NOTE: Information regarding subsidence incident reports maintained by the FGS can be found at *https://floridadep.gov/fgs/sinkholes/content/subsidence-incident-reports*

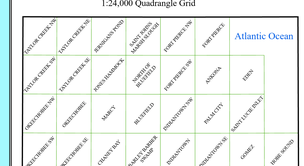
APPROXIMATE MEAN DECLINATION, 2022

1:24,000 Quadrangle Grid

ADJOINING MAPS

1	2	
3		
4	5	

1 Bartow (OFMS 111)
2 Vero Beach (OFMS 112)
3 Arcadia (OFMS 87/88)
4 Fort Myers (to be mapped in 2024)
5 West Palm Beach (to be mapped in 2023)



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Refer to Open-File Report 110, Appendix A for well information
Refer to OFMS 113, Plate 1 for Geologic Map
Refer to OFMS 113, Plate 2 for Cross-Sections

Disclaimer

This map was created using Florida Department of Environmental Protection (DEP) databases and data obtained by the Florida Geological Survey (FGS). It was completed August 31, 2022, by the DEP/FGS Geological Investigations Section. This document is prepared for the presentation of the geologic information shown and is not intended to replace site-specific or use-specific investigations. The FGS does not guarantee this document to be free from errors or inaccuracies and disclaims any responsibility or liability for inappropriate change of scale, interpretations, or decisions based thereon. Cooperatively funded by the DEP/FGS and the U.S. Geological Survey (USGS), National Cooperative Geologic Mapping Program, under USGS assistance award number G20AC00368. The views and conclusions in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government.

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