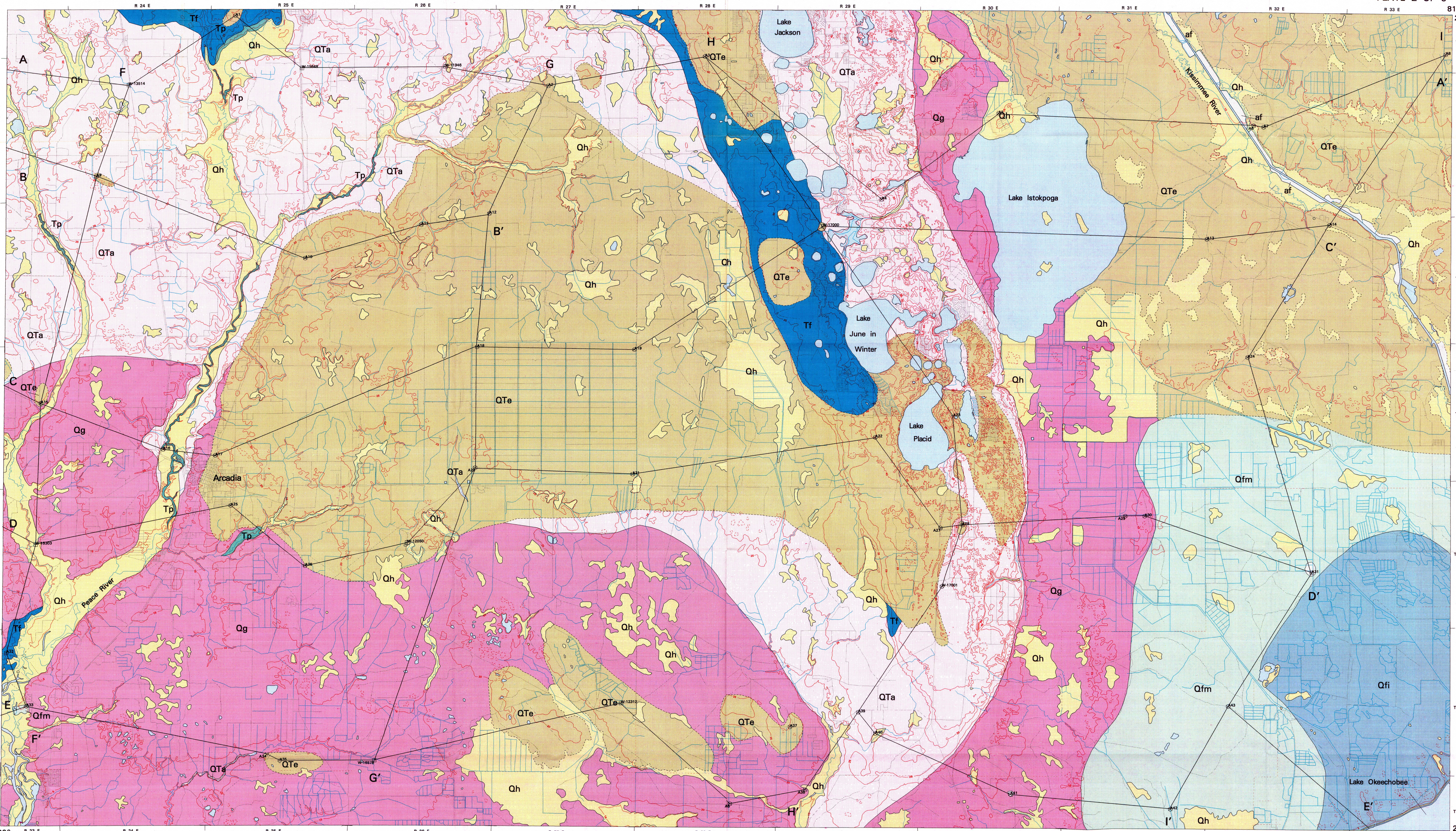

INTRODUCTION

The goal of mapping the Sarasota and Arcadia quadrangles in west central peninsular Florida (fig. 1)was to provide a detailed geologic framework for understanding the geologic history of the area, and for applied studies such as land use planning and modeling of ground-water availability and quality. Surficial geology, which includes units at the surface and generally within 15-30 m of the surface and is the subject of these maps, is important for studies of the unconfined (surficial) aquifer system. The quadrangles were mapped from 1987 to 1992.

The map area is underlain by siliciclastic deposits whose sources outside the depositional area were crystalline rocks in Georgia, Alabama, and South Carolina, and deposits of shallow marine and river sediments in northern Florida and adjacent areas.

Phosphatic deposits and shell beds formed in shallow marine waters within the depositional basin. In the subsurface and the uplands, older shelly deposits are represented by limestone, dolomite, or calcareous or dolomitic silt, sand and clay. Rivers that originate mainly in the Georgia piedmont carry large volumes of quartz gravel, sand, silt, and minor amounts of clay to the Atlantic and Gulf coasts; the sediment is transported to the map area by southward-moving intertidal and shallow subtidal marine currents. The Florida platform, of which the peninsula is the emerged eastern half, consists of a sequence of detrital and biogenic sediment that accumulated on igneous, metamorphic, and sedimentary bedrock that lies as much as 8 km below the present land surface (Miller, 1986).

Geomorphology

The map area is a broad, flat, southward-dipping plain that is bounded on the west by bays and barrier islands adjacent to the Gulf of Mexico in the Sarasota quadrangle; it is interrupted by a 5-km to 16-km wide south-southeast-trending ridge in the Arcadia quadrangle. The ridge, which contains the highest elevations on the peninsula and reaches 64 m near its southern terminus in the Arcadia quadrangle, consists of beach ridge and dune complexes deposited during two high sea level stands during the late Pliocene and earliest Pleistocene by southward-moving longshore currents.

In the Sarasota quadrangle, there are three main rivers: the Myakka River, which drains southward into Charlotte Harbor south of the Sarasota quadrangle, and the Manatee and Braden rivers, which drain northward and westward into the Gulf of Mexico. The Manatee River system includes a reservoir, Lake Manatee. In the Arcadia quadrangle, the Peace River, near the western edge of the map, flows southward towards Charlotte Harbor, and the Kissimmee River, just east of the ridge, flows southward towards Lake Okeechobee, which is located in the extreme southeast corner of the quadrangle. The Kissimmee River was straightened by dredging but is now undergoing reengineering to recreate its original meandering path.

Most of the lakes in the map area are shallow and have sinkhole origins. Large sinkhole lakes are prevalent in the central valley of the ridge, where they are concentrated in the area underlain by muddy sand of the backbarrier facies of the younger beach ridge complex. The largest lakes, Okeechobee and Istokpoga, which are both in the lowlands east and southeast of the central ridge, are probably underlain by many sinkholes, but are more directly related to tidal scour associated with the sea level high stand at about 20 m (early to middle Pleistocene).

GEOLOGIC MAPPING TECHNIQUES

Mapping was conducted mainly by correlating subsurface core and auger samples (table 1 and fig. 2); some borehole geophysical logs, especially gamma logs, were used to assist in correlation. A few shell pits, particularly the APAC and Quality Aggregates pits near Fruitville in the western part of the Sarasota quadrangle and the Desoto Shell Company pits south of Arcadia in the Arcadia quadrangle, yielded important biostratigraphic information that gave age estimates for several of the units (see "Age estimates" below). Samples from canal spoil piles were also examined for lithologic and biostratigraphic information. Side Looking Airborne Radar (SLAR) and satellite images, aerial photographs, and County Soil Surveys were used to interpolate between drill sites and pits. SLAR and satellite images were helpful mainly east of the ridge, where high-energy erosional and depositional processes left distinctive linear features. In contrast, the low-energy Gulf coastal processes resulted in more subtle features that are less visible from the ground or the air.

Nine geologic units were distinguished on the basis of stratigraphic position, lithology, and mineralogic weathering profiles (table 2). Units deposited in the middle Pliocene through the end of the Pleistocene have in common many depositional lithofacies, but the degree of weathering and the elevations of the upper and lower surfaces are fairly distinct for each unit. Each of these units is intended to contain all the preserved lithofacies that appear to have accumulated during a single depositional cycle (rise and fall of sea level, transgression and regression). The one exception is the Fruitville Formation, which may contain deposits from two cycles, but which could not be divided over most of the map area. The lower boundaries of the units are in all cases unconformities; upper boundaries are either the modern land surface, or an unconformity, where the unit is overlain by a subsequent unit. The units, called "formations" and "members" on this map, are in fact hybrids consisting of lithostratigraphic units, in the sense of the North American Code of Stratigraphic Nomenclature (NACSN, 1983) and unconformity-bounded units, in the sense of the International Stratigraphic Guide (ISSC, 1976; Poag and Ward, 1993). The terms formation and member are used because the units are mappable, using a combination of lithologic, mineralogic, geomorphic and other criteria presented below.

The unit contacts shown on the maps were drawn on the basis of abrupt geomorphologic or lithologic changes. Linear features such as abrupt changes in surface elevation of 5 m or more over a distance of a kilometer or so, discerned on topographic maps (5 foot, about 1.5 m, contour interval), or changes in vegetation, moisture, surface reflectance, or surface roughness, as seen on Side-Looking Airborne Radar (SLAR) and satellite images and aerial photographs were interpreted in many cases as erosional shorelines or beach ridges. Contacts between soil types on soils maps and distinct lateral changes noted in surface exposures, such as tan, fine, loose quartz sand adjacent to white, shelly quartz sand, calcareous clayey sand, or greenish, phosphatic clay were interpreted as nongradational lithofacies that were juxtaposed by successive depositional cycles separated by times of subaerial exposure. In the subsurface, the contacts are determined by features such as yellow, orange, or red oxidation zones at the tops of depositional clay or clayey sand beds; residual clay in the tops of carbonate deposits; and pebble beds, mainly quartz and phosphate, at the base of many units.

The geologic maps were constructed from all surface information and from subsurface data projected to the surface (fig. 2). After compilation of cross sections (A through G for Sarasota quadrangle and A through I for Arcadia quadrangle) from subsurface data, contour maps (figs. 3-8) were constructed from unit boundary depths depicted on cross sections. Structure contour maps include maps of the base of the Fort Thompson Formation, undivided (fig. 3); the base of the Fort Ogden Formation (fig. 4); the base of an unnamed sheet of windborne sand (QTe) deposited after the Archbold Formation but mainly prior to the Fort Ogden Formation (fig. 5); the base of the Archbold Formation (fig. 6); the base of the Fruitville Formation (fig. 7); and a combined map of the base of the Peace River Formation and the top of the Arcadia Formation (fig. 8). An isopach (equal thickness) map was prepared for highly permeable sand at the surface for which hydraulic conductivities of (10)-7 to (10)-4 were estimated (fig. 9; see discussion in "Hydrogeology of the surficial aquifer").

Mineralogic weathering profiles

The use of mineralogic weathering profiles as indicators of relative age of surficial sedimentary deposits was first established in the central Atlantic Coastal Plains (Owens and others, 1983). The technique has been used successfully in other areas (Soller, 1988; McCartan and others, 1990) and is here applied to a mixed siliciclastic and carbonate terrane for the first time. A typical mineralogic weathering profile contains a lower percentage of iron-bearing heavy minerals such as epidote and garnet in the upper part of the section compared with the lower part (table 2). Percent of feldspar also increases downward. Detrital iron minerals dissolve most rapidly above the water table where they are in contact with oxygenated meteoric water. Secondary iron oxides and hydroxides precipitate when the moisture content of the zone above the water table is lower, during dry weather. Feldspar alters to clay minerals in the same zone.

Epidote and garnet are present in surficial deposits throughout the Florida map area and therefore provide a standard for applying the mineralogic weathering profile technique developed farther north. In Florida, as in the Atlantic Coastal Plain, younger and older surficial units have younger and older fossil assemblages and also have thinner (younger) or thicker (older) weathering profiles. In addition to iron mineral loss with age, in shelly quartz sand deposits 200 thousand years (Ka) old or younger in the map area, aragonite has been leached or converted to calcite in the top few meters, but most of it is retained below the weathering zone. In Holocene deposits, aragonite and iron minerals do not vary appreciable with depth. The relationship between age and the presence of aragonite is based on the composition of shells in beds dated by uranium-thorium (U/Th) disequilibrium series, amino acid racemization, and biostratigraphy in the map area and the adjacent region. It may not be useful elsewhere. Primary calcite (in shells) and secondary calcite (which replaces aragonite in shells and is precipitated as cement) persists longer, but is also eventually lost by dissolution in meteoric water, starting in the upper part of the section.

Calcium carbonate and iron minerals are retained longer in clayey or very shelly beds where acidic, oxygenated water flow is restricted or chemically buffered. Dissolution and alteration are enhanced in well-sorted sand beds where meteoric water is free flowing. Relative age of surficial depositional units can be established by comparing thicknesses of mineralogic weathering profiles in complete sections that have similar textures. Eroded (stripped) or muddy sections may contain relatively fresh minerals near the surface and so might be mistakenly considered younger than a more complete or sandier section deposited at the same time. Mineralogic weathering profiles are useful only as relative age indicators, within a region that has only one landscape and deposits with the same general depositional origin. Weathering profiles in each region must be calibrated by traditional estimates of age such as isotopic ratios or biostratigraphy. The mineralogy of clay fractions and whole rock samples was determined by X-ray diffraction; optical microscopy was used to determine the composition of fine sand, which was first separated into light and heavy mineral fractions in bromoform (specific gravity = 2.85).

Age estimates

The age of each lithostratigraphic unit (formation and member) was estimated based on the fossil assemblages or by numerical analysis such as carbon 14 on wood, peat, or humate, U/Th disequilibrium series on corals, molluscs, or other calcite or aragonite samples, 87Sr/86Sr on shells, and amino-acid racemization on shells. Some of the evidence used to date the units was found outside the map area (Osmond and others, 1965; Karrow and Belknap, 1990; Muhs and others, 1992). None of the age estimates is absolute or precise, but relative ages are probably reliable. In the text, ages noted as "100 Ka" and "200 Ka" are generalized; the true depositional ages in this example are likely to be in the ranges 80-140 Ka and 200-260 Ka.

GEOLOGIC HISTORY

The Florida peninsula is the emergent eastern half of the Florida platform, which is roughly delineated by the 200-m depth contour on the sea floor. The platform was created during the late Paleozoic during a collision between sedimentary, igneous, and metaigneous rocks of the North American and African plates (see Plate 1 in Chowns and Williams, 1983; Gohn, 1988). Mesozoic and Cenozoic deposits of the Florida platform are composed of siliciclastic sediment derived from the north interspersed with local biogenic carbonate and phosphate accumulations. Silt and sand size quartz, feldspar, heavy minerals, and some of the clay was transported by longshore drift from rivers to the north down both sides of the Florida peninsula (fig. 1A). The original source for most of the detritus were the Piedmont, Blue Ridge, and Valley and Ridge Provinces of Georgia and adjacent states. Most of the material moved along the higher energy east coast rather than along the lower energy west coast. This is true today as well; very little sand travels east and southward by longshore drift around the northeast Gulf of Mexico (Tanner, 1960; Gorsline, 1966). Shoals outlined by the bathymetric contours between 10 and 90 m depths in that area suggest that larger volumes of sand moved southward along the Gulf coast in the past, when sea level was lower (fig. 1A). Two source areas are also reflected in heavy mineral assemblages dominated by garnet, which is mainly from the western source, and epidote, which is derived from both source terranes (M.W. Higgins, USGS, oral communication, 1990; McCartan and Owens, 1991) (fig. 1A). Most of the surficial deposits contain a significant amount of epidote in their less weathered beds; garnet is abundant in a few places in the western part of the peninsula.

Mesozoic and Cenozoic deposits of the Florida platform accumulated on a surface that was deformed episodically into broad basins and arches. The deepest basin is in southwest Florida (Miller, 1986), south of the map area, and the main uplift area is north and northwest of the map area (the Ocala arch; see Vernon and Puri, 1965, and Miller, 1986). The "bullseye" distribution of stratigraphic units around the Ocala arch, with older deposits closer to the center, indicates that warping occurred during or after the deposition of Miocene sediment. There is also evidence that the basement has continued to warp in the Quaternary (tide gage data, Richard Stumpf, USGS, oral communication, 1992, and Okeechobee embayment, Thomas Scott, Florida Geological Survey, oral communication, 1991), and this may be part of the cause for the irregular distribution of the deposits shown on these maps and cross sections. The low angle of southward surface decline, less than 1 degree, is difficult to see in bedding planes that typically have steeper angles due to local hydrodynamic factors, but can be seen in the regional distribution of stratigraphic units. Other factors that significantly affected the distribution of Miocene to Holocene deposits include the elevation of sea level, timing and volume of precipitation, the depth of the ground-water table, the volume of sediment supplied by longshore drift from the rivers of northern Florida and Georgia, wind direction and strength, the availability of local sand sources without vegetative cover, air and ocean temperatures, and the duration of subaerial erosion between periods of deposition. Of these factors, the position of sea level has had the greatest influence on the distribution of depositional units, and most contacts between surficial geologic units in the map area are associated with highstands of sea level.

The oldest unit delineated on the Arcadia and Sarasota maps is the Arcadia Formation of the Hawthorn Group (Scott, 1988). It was deposited over four discrete time periods, the latest of which ended about 16.7 Ma, in the earliest late Miocene (Sugarman and others, 1994). The depositional lithofacies represented by sediment of the Arcadia Formation in the map area include carbonate banks, mainly molluscan, and intertidal and subtidal mud and quartz sand and beds that have a large proportion of fine-to coarse-grained phosphate grains. The phosphate reflects periods in which siliciclastic and carbonate deposition was slow and biologic and biochemical processes enhanced the precipitation of phosphatic minerals, mainly as replacement for carbonate shells, grains, and as early postdepositional cement. Polished phosphate grains are ubiquitous and indicate that during and after each hiatus, currents and waves locally eroded and reworked some of the phosphate.

There is no record of marine deposition in the map area for the next 11 m.y., although deposits of this age interval are found in northern Florida (Jones and others, 1993) and elsewhere on the Atlantic coast (Sugarman and others, 1994). Fossil vertebrates from this time interval(16.7-11 Ma), from both land and estuarine environments, have been found north of the map area (Webb, 1990). It seems likely, therefore, that younger Miocene deposits were once present in the map area and were eroded prior to deposition of the earliest Pliocene unit. This erosion removed both the younger Miocene units and parts of

[illegible]

NEW STRATIGRAPHIC UNITS

[illegible]

modern appearance (G.L. Wingard, USGS, written and oral communications, 1991-1993). The age is believed to be about 450 Ka to 1.25 Ma on the basis of fossil content and correlation with one or the other of two units in South Carolina and North Carolina. Correlation is on the basis of mineralogic weathering profiles, fossil assemblages, and stratigraphic position. The Fort Ogden Formation includes some deposits that were previously assigned to the Bermont Formation (Willard and others, 1993) and to "undifferentiated Pliocene and Pleistocene deposits" (Johnson, 1986).

Two new members of the Fort Thompson Formation (Sellards, 1919) are delineated in the map area. The older is the Manatee College Member, named for Manatee Community College, which is located on Route 41 in the southeast corner of the Sarasota Quadrangle. The Manatee College Member includes sand deposits, locally shelly, that are locally cemented by calcite. There is a slightly deeper mineralogic weathering profile in this member than in the stratigraphically younger member. The age is 260-206 Ka on the basis of a U/Th age estimates on a coral from a pit southeast of Orlando (Muhs and others, 1992), and a mollusc shell from Oldsmar, north of Tampa (Karrow and others, 1990). The dated fossils are in beds that are stratigraphically correlative with the Manatee College Member.

The Indian Prairie Member of the Fort Thompson Formation is named for the Indian Prairie Canal which enters Lake Okeechobee in the southeast part of the Arcadia Quadrangle. Fossil oyster reefs in that area extend into adjacent quadrangles and are in a brackish water facies of the Indian Prairie Member. Sand, mud, and shell beds that are inferred to have been deposited in beach, open bay, and shallow marine environments at the same time as the oyster reefs are present beneath modern barrier deposits along the Gulf of Mexico and the Atlantic Ocean, as well as in shell pits southwest of the town of Okeechobee, which is just east of the Arcadia map area, at the head of Lake Okeechobee. Shells, heavy minerals, and feldspar are fresh throughout the member, and fossil mollusc assemblages (G.L. Wingard, oral communication, 1993) are indistinguishable from modern assemblages; both lines of evidence indicate a relatively young age of deposition. U/Th disequilibrium series age estimates on corals and oolitic limestone suggest that stratigraphically correlative units on Merritt Island and in south Florida were deposited about 100 Ka (Osmond and others, 1965; Karrow and Belknap, 1990; Muhs and others, 1992).

HYDROGEOLOGY OF THE SURFICIAL AQUIFER

The surficial aquifer consists primarily of the hydraulically unconfined permeable lithologies in Holocene beach and stream deposits, older windborne deposits (map symbol QTe), and the beach, dune, and shelf sands of the Fort Thompson, Fort Ogden, Archbold, and Fruitville Formations (fig. 2; permeable lithologies are noncarbonates shown full column width and some full-column carbonates). Duerr and Wolansky (1986) discussed the surficial aquifer in part of Sarasota County using previously accepted stratigraphic terms. Figure 9 shows the thickness of the uppermost permeable quartz sand deposits in the map area, without regard to which allostratigraphic unit the sand belongs. This derived "hydrogeologic" sand unit is the most vulnerable to pollution and, in the lowlands, is locally a path for recharge of the intermediate aquifer system. On the central ridge, the surficial sand is connected directly to the intermediate and Upper Floridan aquifers through sinkholes (Adams and Stoker, 1985; Belles and Martin, 1985). The confining layer that marks the base of the surficial aquifer is typically a bed within 15 m of the surface that contains enough clay, silt, or calcite or dolomite cement to significantly impede downward infiltration of meteoric (rain) water (fig. 2; confining lithologies are shown as less than full column width; some full-column width carbonate lithologies also impede water). This confining layer is laterally discontinuous and quite leaky in the vertical direction, so surface water and pollutants can penetrate into the underlying intermediate aquifer system in many places.

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GEOLOGIC MAP OF THE ARCADIA, FLORIDA 30 X 60-MINUTE QUADRANGLE

by
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1995

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