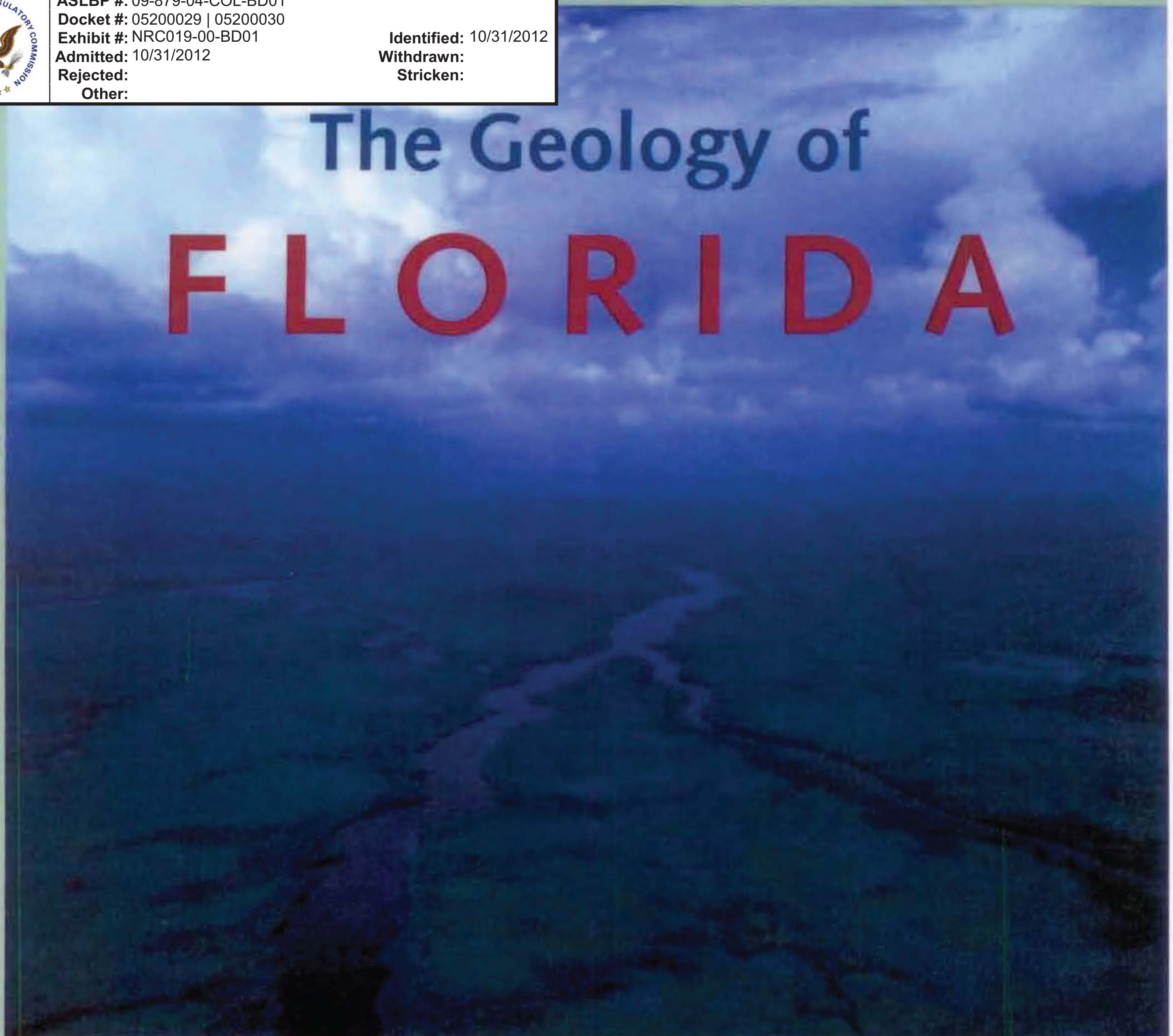

The Geology of FLORIDA

EDITED BY

Anthony F. Randazzo and Douglas S. Jones

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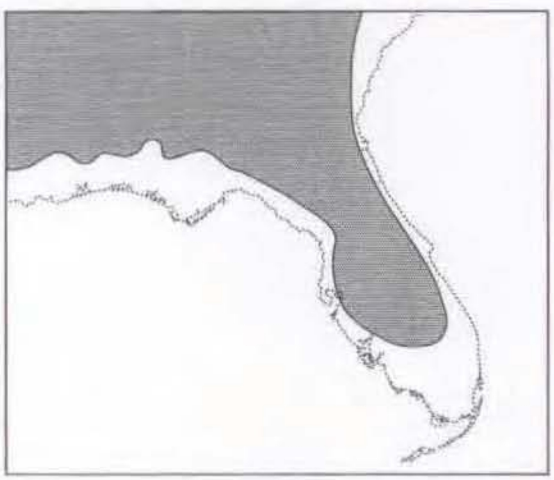

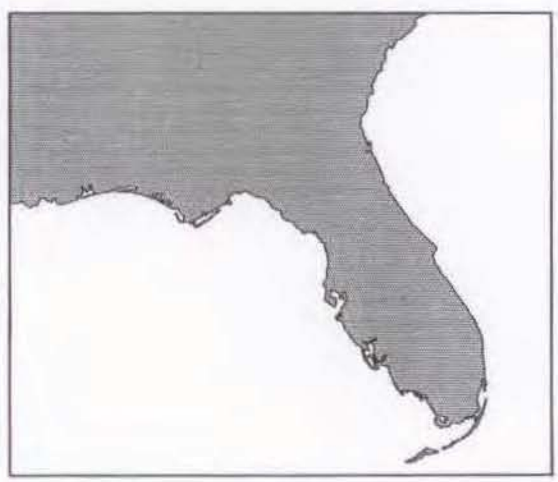

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Front cover, clockwise from top: Everglades National Park, photo by Thomas M. Scott; brain coral from the Florida Keys, photo by Douglas Cook; Winter Park sinkhole, photo by Thomas M. Scott; clay lens-occurring in a massive dolomite sequence, Citrus-County, photo by Thomas M. Scott; *Ecphora bradleyae* fossil, photo courtesy of Florida Museum of Natural History; deformation in Hawthorn Group sediments, Alapaha River, photo by-Thomas M. Scott; drag-line operation for phosphate mining, Polk County, photo by Anthony-F.-Randazzo.

Back cover, top: Geologist Gene Shinn demonstrating-sediment-core extraction in Florida Bay, photo by-Anthony F. Randazzo; *bottom:* sinkhole developed-in a gypstack, Polk County, photo courtesy-of Michael Graves, Richard Fountain, and-the *Lakeland Ledger.*

Transmissivity values reported for the aquifer system are 10,000 ft^2/d or less.

The quality of water in the shallower parts of the intermediate aquifer system generally makes it suitable for most uses. In the deeper parts of the aquifer system, dissolved-solids and chloride concentrations may be excessive, especially near the coast. Chloride concentrations greater than 1,800 mg/L were measured locally in water from wells completed in the intermediate aquifer system in Manatee County (Healy 1982).

Of the 298 Mgal/d of water withdrawn from the intermediate aquifer system during 1985, almost 80%, or 233 Mgal/d, was used for agricultural purposes (fig. 6.27). About 10%, or 31 Mgal/d, was withdrawn for public supply. Domestic and commercial uses accounted for withdrawals of about 19 Mgal/d (some 6%), and about 15 Mgal/d (5%) was pumped for industrial and mining uses.

Floridan Aquifer System

The highly productive Floridan aquifer system underlies all of Florida, but contains water with high concentrations of dissolved solids in many areas (fig. 6.28). The aquifer system also extends over a large part of the coastal plain of Georgia, and smaller areas of coastal Alabama and South Carolina. Many cities in Florida—including Jacksonville, Gainesville, Tallahassee, Orlando, Clearwater, Tampa, and St. Petersburg—depend on the Floridan for water supplies. This aquifer system also is the source of water for many smaller communities and rural households. Total withdrawals from the Floridan aquifer system in Florida were more than 2.5 billion gallons per day during 1985 (U.S. Geological Survey 1990). Even though withdrawals are extremely large, hydraulic heads in the aquifer system have declined very little, except in the vicinity of pumping centers, or where the permeability of the aquifer system is uncommonly low.

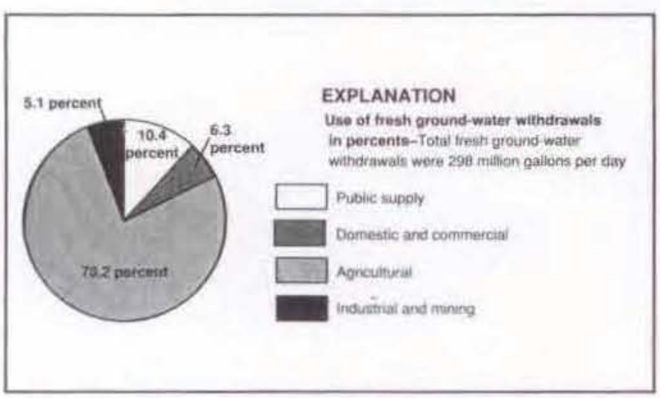

Figure 6.27. Withdrawals of freshwater from the intermediate aquifer system, by category of use, 1985 (U.S. Geological Survey 1990).

Where the Floridan aquifer system contains freshwater, it is the principal source of water supply; however, where the Floridan contains saltwater, the aquifer system also has been used as a repository for treated sewage and industrial wastes emplaced by injection wells. Drainage wells have been used in several counties in central Florida to divert excess surface runoff into the Floridan aquifer system. More than 17 Mgal/d of saltwater was withdrawn from the aquifer system during 1985, mostly for desalinization, mixing with potable water, or cooling purposes (U.S. Geological Survey 1990).

In Florida, the Floridan aquifer system consists of a thick sequence of carbonate rocks of Tertiary age. The strata composing the aquifer system can be assigned to several formations or parts of formations (fig. 6.29). The most permeable formations in the aquifer system are the Ocala Limestone and the upper part of the Avon Park Formation. Where present, the Suwannee Limestone is a principal aquifer; however, it is thinner and less extensive than the Ocala Limestone and the Avon Park Formation (see chapter 4). Where it is highly permeable, the Tampa Member of the Arcadia Formation is included in the aquifer system. Erosion has completely removed both the Suwannee and Tampa limestones in places. Where they are sufficiently permeable, beds in the lower part of the Avon Park Formation, the Oldsmar Formation, and the upper part of the Cedar Keys Formation are included in the aquifer system. Some researchers consider limestone beds in the lower part of the Hawthorn Group to be part of the Floridan, but this author (Miller 1986) excluded those limestones from the aquifer system.

The Floridan aquifer system is defined on the basis of its permeability. The permeability of the carbonate rocks that compose the aquifer system is at least an order of magnitude higher than that of the confining units that

Figure 6.28. Extent of the Floridan aquifer system and saline water in the system (Sprinkle 1989; Miller 1990).

overlie and underlie the system. Accordingly, the top and base of the aquifer system do not coincide everywhere with the top or base of rocks of any single geologic formation, or strata of any single geologic age (fig. 6.30). The permeability contrasts that define the aquifer system also can occur within rocks of a certain age. For example, in places the top of the aquifer system is within the Oligocene sequence, rather than at the top or base of these beds. Likewise, the base of the aquifer system does not coincide with any single stratigraphic boundary everywhere, but rather is the base of high-permeability rocks. Regionally, the top of the aquifer system in Florida is at the top of the Late Eocene Ocala Limestone, and the base of the system is marked by massively bedded anhydrite in the Paleocene Cedar Keys Formation. In panhandle Florida, low-permeability siliciclastic Eocene rocks form the base of the aquifer system.

In most places, the Floridan aquifer system can be divided into the Upper Floridan and Lower Floridan aquifers (Miller 1986), separated by a less-permeable middle confining unit (fig. 6.30). The Upper Floridan aquifer is the best-known, most permeable, and most productive part of the aquifer system, and consists mostly of the Suwannee and Ocala limestones and the upper part of the Avon Park Formation; locally, the Tampa Member of the Arcadia Formation also is included. Unnamed middle confining units separate the Upper and Lower Floridan aquifers in most places. These confining units vary in stratigraphic position (fig. 6.30) and lithology. They may consist of clay, micritic limestone, or anhydrous dolomite (Miller 1986), and they range in age from Oligocene to Early Eocene. Regardless of their stratigraphic position or lithology, the rocks of the confining units retard the movement of water between the two aquifers. The Lower Floridan aquifer

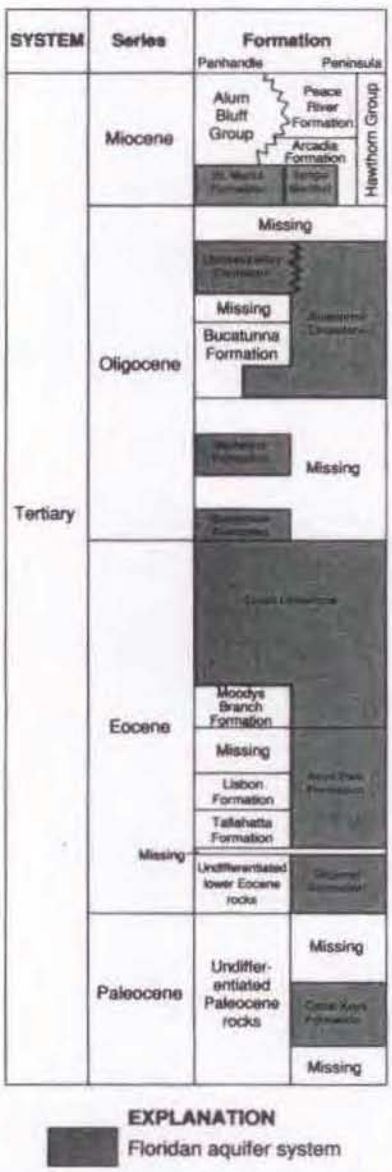

Figure 6.29. Stratigraphic units included in the Floridan aquifer system (Miller 1986).

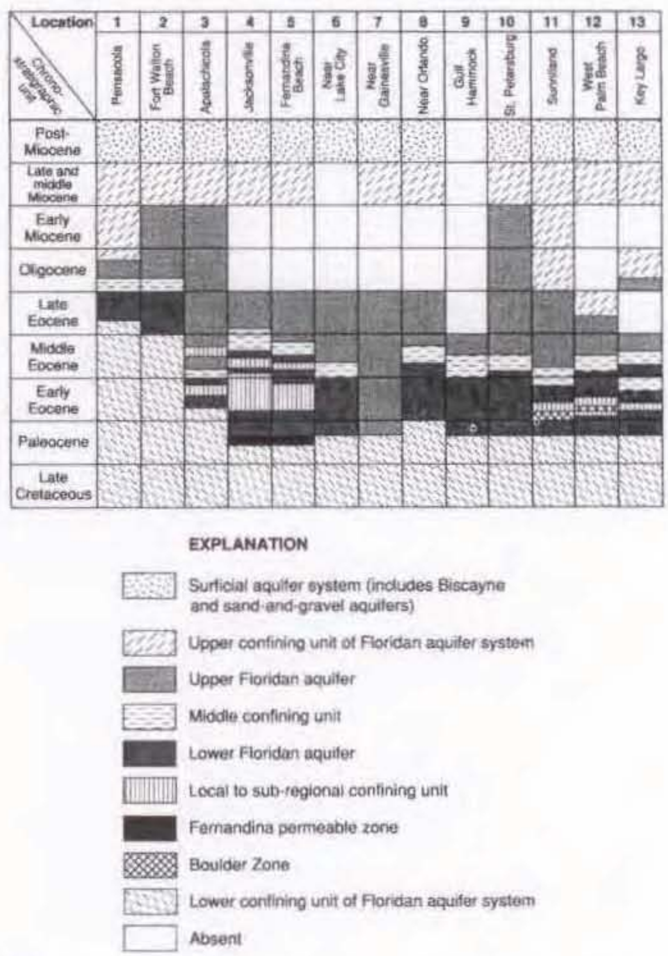

Figure 6.30. Relation of time-stratigraphic units to subdivisions of the Floridan aquifer system (Miller 1986). Location numbers refer to figure 6.28.

mostly consists of the lower part of the Avon Park Formation, the Oldsmar Formation, and the upper part of the Cedar Keys Formation.

In panhandle Florida, the Late Eocene Ocala Limestone is part of the Lower Floridan aquifer in places (fig. 6.30). Because it is deeply buried in most places and commonly contains saltwater, the Lower Floridan aquifer is not well known; however, an important, highly permeable zone occurs in the Lower Floridan in two areas. One of these is in the Fernandina Beach–Jacksonville area, and is called the Fernandina permeable zone (Krause and Randolph 1989). This zone is the source of a large volume of fresh to brackish water that leaks upward through the middle confining unit and provides part of the recharge to the Upper Floridan aquifer. The second area, southeast of a line from Cocoa Beach, in Brevard County, to Port Charlotte, in Charlotte County (Miller 1986), contains an extremely permeable and cavernous zone called the "Boulder Zone" (see chapter 4). The Boulder Zone is overlain by a confining unit and everywhere contains saltwater. The zone is used to receive treated sewage and other wastes emplaced by large-diameter injection wells, chiefly in the Miami–West Palm Beach area.

The Floridan aquifer system ranges from less than 200 feet thick in places along the Alabama/Florida border to more than 3,400 feet thick locally in central and southern peninsular Florida (fig. 6.31). The mapped thickness shown in figure 6.31 is the total for the upper and lower Floridan aquifers and all confining units within the aquifer system, including those areas where the aquifer system contains saltwater. Some of the thinning and thickening trends shown on figure 6.31 are related to geologic structures. For example, the aquifer system is thick in Gulf and Franklin counties along or near the axis of the Southwest Georgia Embayment, and in Nassau and Duval counties on the flank of the Southeast Georgia Embayment. The aquifer system thins along the axis of the Peninsular Arch of Florida (see figure 5.1). In western panhandle Florida, the aquifer system thins because of a facies change from highly permeable carbonate rocks to low-permeability clastic rocks. In Leon and Gadsden counties, the aquifer system is only about 600 feet thick (fig. 6.31), because gypsum has filled the original pore space in the rocks that compose the Lower Floridan aquifer. These low-permeability, gypsiferous rocks grade downward without a break into the siliciclastic rocks that form the lower confining unit of the Floridan aquifer system.

Some of the complexity of the Floridan aquifer system is shown on a cross section drawn from northwest to southeast approximately along the center of the Florida peninsula (fig. 6.32). The entire aquifer system thins over the Peninsular Arch, and thickens greatly to the southeast. The number of regional confining units increases to the southeast: for example, near the southeastern end of

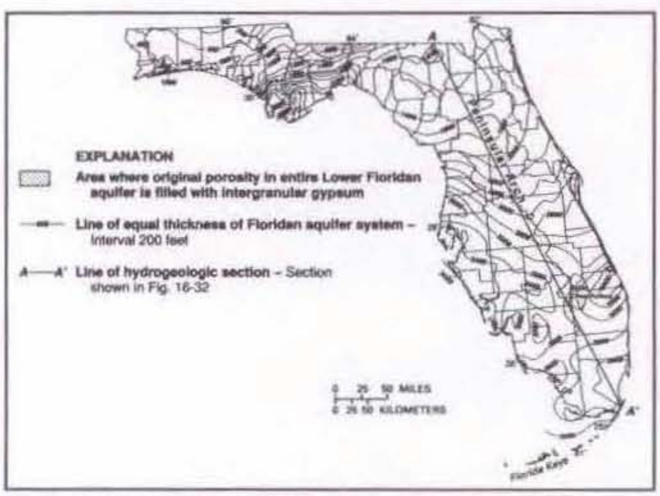

Figure 6.31. Thickness of the Floridan aquifer system (Miller 1986).

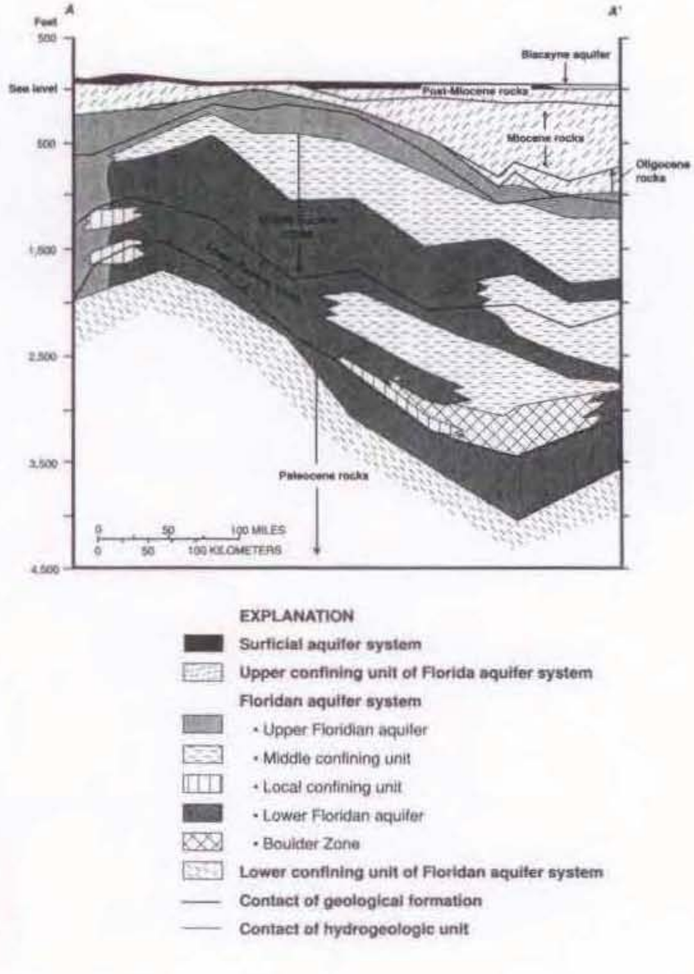

Figure 6.32. Hydrogeologic cross-section from Columbia County to Dade County (Miller 1990).

the section there are three regional confining units separating four permeable zones within the aquifer system. These confining units consist of low-permeability carbonate rocks, and the shallowest of the three separates the Upper Floridan aquifer from the Lower Floridan aquifer, whereas the two deeper confining units are within the Lower Floridan. The Boulder Zone and its overlying confining unit also are shown in the cross section. The regional confining units pinch out to the northwest and all are absent at the extreme northwest end of the cross section, where all the carbonate rocks are part of the Upper Floridan aquifer; however, local confining units may be present in the Upper Floridan.

The carbonate rocks of the Floridan aquifer system are generally soluble in slightly acidic groundwater. Dissolution begins as the water moves through original pore spaces and along joints and bedding planes in the rocks, and it may proceed until some of these openings are enlarged to caverns. These enlarged solution openings and other types of karst features form more readily where groundwater circulation is most vigorous. In the case of the Floridan aquifer system, groundwater enters, flows through, and discharges from the aquifer system more rapidly where the clayey upper confining unit of the system is absent or less than 100 feet thick (fig. 6.33). Sinkholes (see chapter 13) are more common where the aquifer system is unconfined or thinly confined. The distribution of large springs that issue from the Floridan aquifer system (fig. 6.34) is likewise directly related to the thickness of the upper confining unit, and in Florida all of the first-magnitude springs—those discharging 100 cubic feet per second or more—issue from the Floridan aquifer system (Rosenau et al. 1977). Comparison of figures 6.33 and 6.34 shows that these

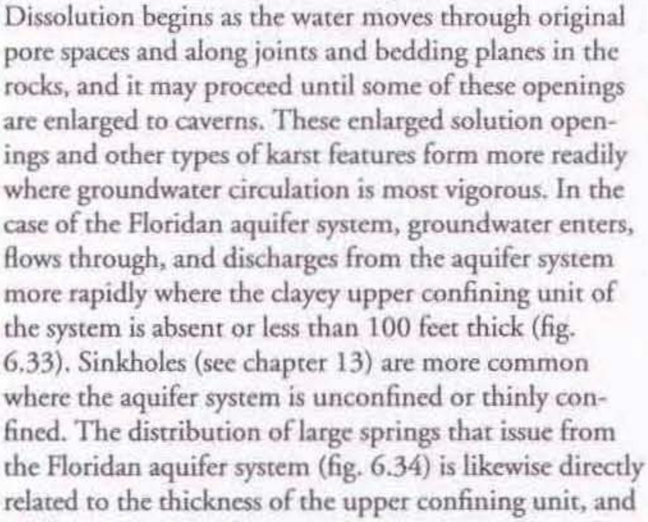

Figure 6.33. Thickness of the upper confining unit of the Floridan aquifer system (Miller 1986).

springs occur where the upper confining unit of the Floridan is thin or absent. In contrast, where the upper confining unit is thick, little dissolution of the aquifer system has occurred, except for deeply buried zones of paleokarst, such as the Boulder Zone.

The sinkholes, springs, and other karst features in central and northern Florida are the result of several intervals of dissolution. Some of the caverns from which first-magnitude springs issue are thought to be very old, and to have formed by downward-percolating water when the hydraulic head in the Floridan aquifer system was much lower than at present. It is possible that some of the major karst features are reactivated, and some may predate the clayey upper confining unit of the Floridan, which is composed mostly of sediments of the Hawthorn Group (see chapters 1, 4, 5, and 13).

The distribution of transmissivity values estimated for the Upper Floridan aquifer is shown in figure 6.35. All areas having transmissivity values greater than 1 million ft^2/d, and most of the areas having values greater than 250,000 ft^2/d, are where the aquifer system is unconfined or the upper confining unit is less than 100 feet thick (fig. 6.33). Where the aquifer system is thickly confined, transmissivity values are lower. However, transmissivity values also are directly related to the thickness of the aquifer system, and where it is thin in western panhandle Florida transmissivity values are less than 10,000 ft^2/d (fig. 6.35).

The major features of groundwater flow in the Floridan aquifer system are shown on a map of the potentiometric surface of the Upper Floridan aquifer (fig. 6.36). In May 1980 there were four prominent high areas on the potentiometric surface of the Upper Floridan, two in central peninsular Florida from which water moved outward in all directions, and two in panhandle Florida from which water moved toward the Gulf of Mexico. Water also moved into the aquifer as lateral flow from

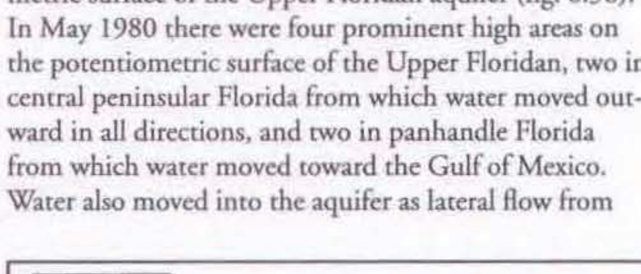

Figure 6.34. Locations of first-magnitude springs of Florida (Rosenau et al. 1977).

adjacent areas in Alabama and Georgia that are not shown in figure 6.36. Most of the water moved generally coastward or toward major streams and springs, which are low areas on the potentiometric surface; however, some of the water moved toward major pumping centers, including those at Fort Walton Beach, Fernandina Beach, Daytona Beach, New Smyrna Beach, and Clearwater.

Intense pumping in some areas has lowered the potentiometric surface to the point that the prepumping, coastward groundwater flow has been reversed, and water is moving from coastal areas toward pumping centers. This reversal creates the potential for saltwater encroachment. Pumping has lowered the potentiometric surface of the Upper Floridan aquifer more than 80 feet at Fort Walton Beach, where withdrawals are mainly for public supply, and at Fernandina Beach, where withdrawals are mostly for industrial (paper mill) uses (fig. 6.37). Withdrawals in west-central peninsular Florida for combined public-supply, agricultural, and mining uses have lowered the potentiometric surface by 10 to 50 feet or more over a broad area (fig. 6.37). Water-level data collected during 1985 (Bush et al. 1987) showed little change in the potentiometric surface from the 1980 maps presented here. Although large volumes of water were pumped from the Floridan aquifer system during 1980, springflow and discharge to streams remained the dominant means of discharge from the aquifer system.

Development of water from the Floridan aquifer system began in Florida during the 1880s, when wells were constructed for municipal supply in Jacksonville. By the early 1900s, several other Florida cities began withdrawing water from the Floridan. Many of the early wells flowed, because heads in the aquifer system were high, but the heads declined with increased withdrawals, requiring installation of pumps. During the 1930s, withdrawals for phosphate mining, citrus processing, and pulp and paper manufacture began, and these withdrawals soon became large. During 1985, withdrawals from the Floridan aquifer system in Florida were more than 2,500 Mgal/d (fig. 6.38). About 47% (1,181

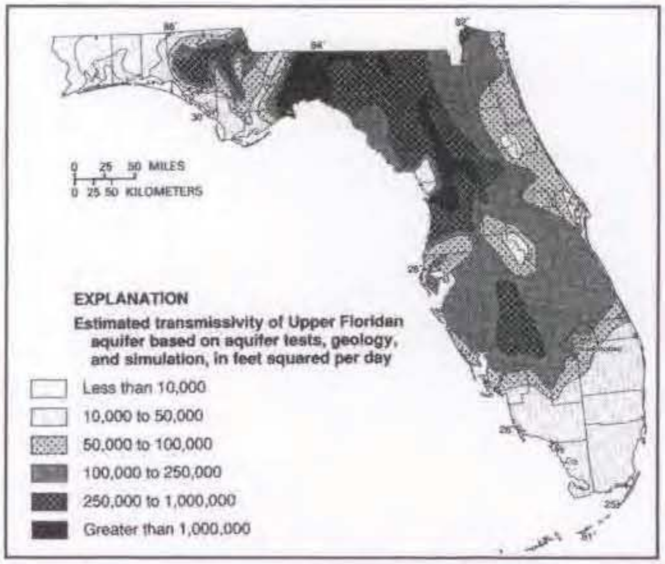

Figure 6.35. Estimated transmissivity of the Upper Floridan aquifer (Bush and Johnston 1988).

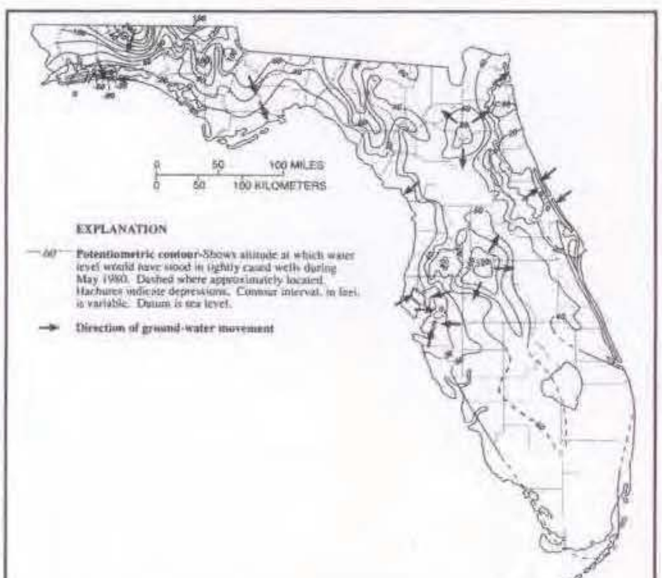

Figure 6.36. Potentiometric surface of the Upper Floridan aquifer in May 1980 (Bush and Johnston 1988).

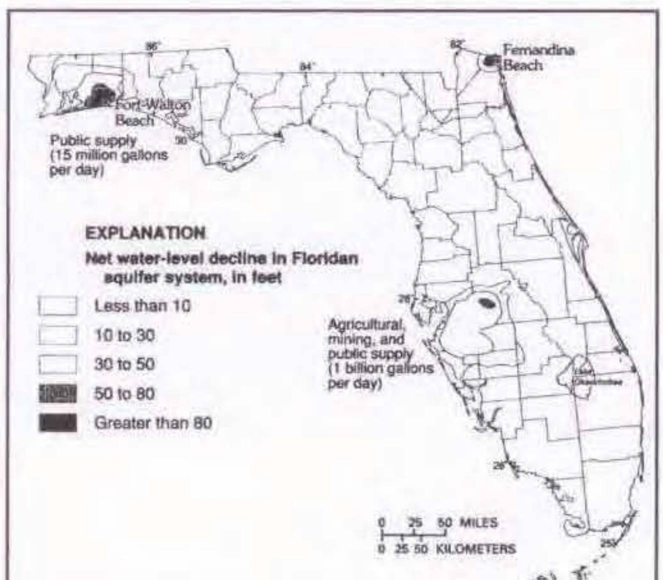

Figure 6.37. Net decline between estimated predevelopment potentiometric surface and observed potentiometric surface in May 1980 for the Upper Floridan aquifer (Bush and Johnston 1988).