Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina

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REGIONAL AQUIFER-SYSTEM ANALYSIS

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For the most part, there are more clastic rocks and low-permeability limestone within these grabens than there are to the northwest and southeast of the normal or gravity faults that bound them. Because of the greater amount of clastic material in the grabens, the aquifer system is much thinner within them. For example, near Moultrie in Colquitt County, Ga., the aquifer system is less than 200 ft thick within one of the grabens but is more than 500 ft thick to the northwest, in an upbasin direction where the aquifer system would normally be expected to be thinner.

Movement along the faults of the graben system has downdropped low-permeability clastic rocks within the grabens opposite permeable limestone on either side of them. This juxtaposition has restricted the flow of ground water across the grabens and down the hydraulic gradient from them. Throughout the shaded area shown on plate 27 (southeast of the graben system and extending from Gadsden County, Fla., northeast to Berrien County, Ga.), the aquifer system is thin and consists of only a few hundred feet of permeable limestone underlain by gypsiferous limestone. The ground-water flow across this area, restricted by the grabens to the northwest, has not been sufficient to completely dissolve the gypsum contained in the limestone.

In southwestern Alabama, the arcuate faults shown on plate 27, like those in central Georgia, bound a series of grabens. Gulfward of these grabens (except in southern Mobile County, Ala.), there is very little limestone; thick sequences of clastic rocks in the grabens and seaward of them are the Floridan aquifer system's equivalent.

An oval-shaped northeast-trending thick pod of limestone in Clinch and Echols Counties, Ga., possibly represents the Suwannee Strait, a poorly understood channel-like feature that was once thought to separate predominantly clastic rocks to the northwest from predominantly carbonate rocks to the southeast. Because the feature as mapped on plate 27, is closed to the northeast and southwest, it is obviously not a channel. Its exact origin is not known, however.

There are several local, flat, shelflike features shown on plate 27 in southern Florida. The most prominent are just south of Miami in Dade County, north of Fort Pierce in St. Lucie County, and in Lee County. These shelflike areas are apparent, not real, and are the result of differences in elevation of the evaporite deposits that comprise the base of the aquifer system in southern Florida. These low-permeability evaporites occur at different altitudes in different wells because they interfinger with carbonate rocks as a series of discrete large lenses. Regionally, the lenses are mapped as if they were a single horizon, and their interfingering nature creates the illusion of irregular topography. The anhydrite that represents the base of the Floridan aquifer system is high under all these shelflike areas, and the aquifer system above these high spots is accordingly thin.

MAJOR HYDROLOGIC UNITS WITHIN THE FLORIDAN AQUIFER SYSTEM

The Floridan aquifer system is extremely complex because (1) the rocks that comprise it were originally laid down in highly variable depositional environments, and their texture and mineralogy accordingly vary considerably; (2) diagenesis has produced much change in the original sediments in places, and (3) large- to small-scale karst features are developed at several levels in the aquifer system owing to modern and ancient dissolution of the limestone. These factors, alone or in combination, create much local variability in the aquifer system's lithology and permeability characteristics. It is necessary, therefore, to generalize greatly both the geology and the hydraulic parameters of the aquifer system to present a regional view of each. Also, to simulate regional ground-water flow with a digital computer model, the complexities of local variations in geology and hydraulic properties must be simplified. Regionally, as mentioned earlier (section "Floridan Aquifer System"), the Floridan aquifer system generally consists of an Upper and a Lower Floridan aquifer separated by a middle confining unit. Neither the separate aquifers nor the middle confining unit is everywhere the same thickness or age or necessarily consists of the same type of rock. In places, no middle confining unit exists, and the entire aquifer system is more or less permeable. In other places, such as southern Florida, most of the aquifer system consists of low-permeability rocks separating thin zones of high permeability. Within regionally extensive aquifers or confining units, there may be from one to several local zones of contrasting permeability (see, for example, section E-E', pl. 21); these local zones, however, do not usually affect the overall character of the given aquifer or confining unit, even though a given zone may locally have an important hydraulic influence.

The upper major permeable zone of the aquifer system, herein called the Upper Floridan aquifer, yields large volumes of water nearly everywhere, and the water is usually of good chemical quality. As a result, few water-supply wells penetrate the aquifer system's middle confining unit and the Lower Floridan aquifer, which lie at considerable depth. The hydrologic character of these deeper parts of the aquifer system is therefore known from only a few scattered deep wells, most of which were constructed to test their potential for waste injection. Because all the numerous oil test wells in the study area completely penetrate both the Floridan aquifer system and its lower confining unit, however, the geologic character of the aquifer system's deep zones is better defined. Accordingly, the hydraulic properties of the deeper parts of the aquifer system are inferred in large part from their geologic character. The major high- and low-permeability zones within the aquifer system that are of regional extent are discussed in order from shallowest to deepest.

Upper Floridan Aquifer

The configuration and character of the top of the Upper Floridan aquifer are discussed in the section describing the top of the system. The time-stratigraphic units that compose the Upper Floridan aquifer at various places are shown in figure 9. Hydraulic head and water-quality data show that, where the Upper and Lower Floridan aquifers are in contact (that is, where there is no appreciable thickness of low-permeability rock between them), they behave as a single hydraulic unit. Where the aquifer system's middle confining unit is absent, the base of the Upper Floridan aquifer is actually the base of the entire aquifer system, and, likewise, the thickness of the Upper Floridan aquifer equals the thickness of the entire system.

The Upper Floridan aquifer generally consists of all or part of rocks of Oligocene age (mostly the Suwannee Limestone), rocks of late Eocene age (mostly the Ocala Limestone), and rocks of middle Eocene age (mostly the upper part of the middle Eocene). Locally, (for example, near Gainesville, Fla. column 13, fig. 9), all rocks of middle Eocene age, rocks of early Eocene age (mostly the Oldsmar Formation), and the upper part of strata of Paleocene age (mostly the Cedar Keys Formation) are included in the Upper Floridan aquifer in those places where the aquifer system's middle confining unit is not present. At a few locations (for example, column 16, fig. 9), rocks of early Miocene age (Tampa Limestone and equivalents) are permeable enough to be considered part of the Upper Floridan aquifer. Data collected during this study show that the permeability of the rocks included in the Upper Floridan aquifer is much higher than that of those comprising the Lower Floridan aquifer, with the exception of southern Florida's Boulder Zone, a zone of cavernous permeability encompassed within the Lower Floridan.

The thickness of the Upper Floridan aquifer as shown on plate 28 (modified from a map by Miller (1982d)) represents all strata that lie between the top of the highest vertically continuous permeable limestone (top of the Floridan aquifer system) and the base of either the Upper Floridan aquifer, where a regionally extensive middle confining unit exists, or the base of the entire aquifer system, where no appreciable thickness of low-permeability rock is present. This single aquifer condition (no separation of the aquifer system into upper and lower major permeable zones) exists in the patterned area shown on plate 28. The thickness values contoured on plate 28 were obtained primarily from well data, but, in areas of sparse control, the contouring has been supplemented by estimates obtained by subtracting contoured elevations of the top of the aquifer system (pl. 26) and the base of the Upper Floridan aquifer (pl. 29).

It is important to reiterate that the Upper Floridan aquifer, like the other major high- and low-permeability zones within the Floridan aquifer system, is delineated on the basis of permeability characteristics. Thus, neither the top nor the base of the Upper Floridan necessarily conforms to formation or time-stratigraphic boundaries. This situation is particularly true of the base of the Upper Floridan (fig. 9). The lithologic character of the rocks comprising the base of the Upper Floridan varies greatly, and accordingly, the rocks vary in their effectiveness as a confining unit. The vertical hydraulic conductivity of the rocks that comprise the base of the Upper Floridan, however, is everywhere at least two orders of magnitude less than that of the aquifer material itself. Because plate 28 represents the thickness of rocks of similar (high) permeability, interpretation of the map is different from that of the usual isopachous map. For example, thick sequences of rocks shown on plate 28 do not necessarily lie in downbasin positions, the situation commonly encountered on an ordinary thickness map. Rather, because sediments ordinarily become finer grained and correspondingly less permeable in a downbasin direction, greater thicknesses of permeable rock may occur in updip areas.

The altitude of the low-permeability rocks that mark the base of the Upper Floridan aquifer is the major factor affecting the thickness values shown on plate 28. Where the base occurs at shallow depths, the Upper Floridan is thin; where the base is deep, the aquifer is thick. The lines of equal thickness are irregular and, where they are closed, delineate numerous small, isolated thick or thin spots in places where the Upper Floridan as a whole is less than 400 ft thick. These small features are the result of erosion and (or) karst topography developed on the aquifer system's surface.

Plate 28 shows that the Upper Floridan aquifer is thin (1) in and near those places where the aquifer system crops out, (2) throughout roughly the western half of panhandle Florida, and (3) in a wide band parallel to the Atlantic coastline. Near the outcrop area, the limestone that comprises the aquifer thins and grades into clastic rocks in an updip direction. The two other widespread thin areas represent places where the aquifer system's middle confining unit (base of the Upper Floridan aquifer) lies at shallow depths. The greatest thickness of the Upper Floridan is along the north-central part of Florida's Gulf Coast and is part of the area where all of the rocks included in the aquifer system are permeable (the Upper and Lower Floridan aquifers merge). Areas of intermediate thickness adjacent to peninsular Florida's Gulf Coast and straddling the central part of the Florida-Georgia border reflect different altitudes of the aquifer system's middle confining unit.

In some places, the Floridan aquifer system contains two or more regionally extensive middle confining units, which lie at different depths and are separated by permeable rocks. An example of this situation occurs in the central part of peninsular Florida and is shown on plate 28; dashed contact lines show places where a deeper low-permeability zone is overlain by a shallower overlapping confining unit. Here, a band of low-permeability rock parallel to the Atlantic Ocean lies at an altitude several hundred feet higher than that of a western low-permeability zone that extends to the Gulf of Mexico. Where such an overlap occurs. the top of the shallower low-permeability unit is considered to be the base of the Upper Floridan aquifer. Geohydrologic cross section G-G' (pl. 23) shows this overlap in the third dimension. Farther north, the same two confining units are present (cross section F-F', pl. 22) but do not overlap.

Several major structural features are known to exist in the mapped area, but not all of them appear on plate 28. The area in Gilchrist and Lafayette Counties in northern Florida where the Upper Floridan aquifer is thin may represent the Peninsular arch. The thick area in southern Wakulla County, Fla., is probably part of the Southwest Georgia embayment. Aside from these two examples, no other major structures appear to coincide with variations in the Upper Floridan's thickness. Several small faults reflected by local anomalies in regional thickening trends of the Upper Floridan include the Gulf Trough graben system in central Georgia and a small-displacement normal fault in southern peninsular Florida. The faults shown in southwestern Alabama cut, displace, and in part mark the updip limit of the Upper Floridan aquifer.

Preliminary results from a digital model of the aquifer system (Bush, 1982) show that most of the ground-water circulation in the system takes place in the Upper Floridan aquifer. The water in the Upper Floridan is nearly everywhere less mineralized than that from deeper zones in the aquifer system (Sprinkle, 1985), largely because of more vigorous circulation of water in the Upper Floridan. The high permeability that permits this vigorous circulation results from high intergranular or moldic porosity in the Suwannee, Ocala, and Avon Park rocks comprising the Upper Floridan, coupled with much secondary porosity (mostly large dissolution cavities).

Middle confining unit

There are eight low-permeability units of subregional extent that lie within the Floridan aquifer system in the study area. Seven of these units separate the Upper Floridan aquifer from the Lower Floridan aquifer. The remaining unit lies within the Lower Floridan aquifer and is discussed in the following section describing that aquifer. Any or all of the subregional low-permeability units may locally contain thin zones of moderate to high permeability. Overall, however, the units act as a single confining unit within the main body of permeable limestone that constitutes the aquifer system. In much of southern Florida, several thick low-permeability units occur within the aquifer system—so many, in fact, that in places the strata that constitute the system are mostly low-permeability rocks containing a few high-permeability zones (see, for example, sections B'-B″ and H-H', pls. 17, 24). These zones show hydraulic head differences, contain water of somewhat different quality, and behave differently in response to natural and pumping (or injection) stresses. In places where two or more of the subregional low-permeability units occur, the base of the shallower low-permeability unit is considered to be the top of the Lower Floridan aquifer.

The areal extent and altitude of the top of each of the seven confining units separating the Upper and Lower Floridan aquifers are shown on plate 29, which was modified from a map by Miller (1982b). Because, by definition, the middle confining unit of the aquifer separates the Upper and Lower Floridan aquifers, the contours shown represent the base of the Upper Floridan aquifer, which varies greatly in altitude from place to place. For convenience and because the confining units are not necessarily a part of the same formation and do not consist of the same rock type everywhere, each confining unit has been designated by a roman numeral on plate 29. Each unit will be referred to by its particular numeral in the text of this report, on a fence diagram (pl. 30) that shows the three-dimensional relations of the various high- and low-permeability units within the aquifer, and in figure 9, which shows the relative ages of each unit. Because none of the low-permeability units mapped on plate 29 crop out, the extent and character of the units have been determined solely on the basis of well control.

Where no middle confining unit is present, the Upper and Lower Floridan aquifers merge vertically and are mapped as part of the Upper Floridan aquifer. In such places, because no low-permeability rocks exist above the base of the aquifer system, that base is synonomous with the bottom of the Upper Floridan aquifer. The white area on plate 29 shows this condition. The contours shown in this area are thus the same as those shown on a map of the base of the aquifer system (pl. 33). Over the northern two-thirds of this area, the base of the Upper Floridan aquifer is marked by calcareous glauconitic sand and clay beds that are the equivalents of the outcropping middle Eocene Lisbon and Tallahatta Formations of Alabama and western Georgia. Farther southeast, the base of the Upper Floridan consists of calcareous clastic rocks that are the equivalent of the lower Eocene Oldsmar Formation of Florida; in north-central Florida, anhydrite beds that are part of the Cedar Keys Formation underlie the Upper Floridan aquifer. The extent of each unit is shown on plate 33, and the units are discussed in more detail in the section of this report that describes the base of the aquifer system. In much of South Carolina (Colleton County and northward), the Upper Floridan aquifer pinches out, and the middle confining unit merges with the upper confining unit of the aquifer system. Accordingly, no middle confining unit is mapped north of the pinchout of the Upper Floridan.

Along the Atlantic Coast, an extensive band of low-permeability rocks (middle confining unit I, pl. 29) extending from southeastern South Carolina to the Florida Keys marks the base of the Upper Floridan aquifer. The strata that comprise unit I lie in the middle and upper parts of rocks of middle Eocene age (fig. 9). Very locally (for example, in the Jacksonville, Fla., area), the lower part of rocks of late Eocene age is included in unit I. From the Florida Keys northward to Liberty County, Ga., unit I consists of soft, micritic limestone and fine-grained dolomitic limestone, both of low porosity. North of Liberty County, these carbonate rocks grade laterally by facies change through calcareous sand and clay in northeastern Georgia northward into sandy clay in South Carolina. Figure 11 shows the approximate areal extent of the clastic and carbonate facies and the general configuration of the top of unit I throughout its known extent. Because the Upper Floridan aquifer pinches out in South Carolina, unit I merges with the aquifer system's upper confining unit north of this pinchout (fig. 12); the only permeable limestone in the extreme northeastern part of the mapped area is a thin bed that is part of the Lower Floridan aquifer. The contrast in permeability between the rocks of unit I and the permeable rocks above and below it is less than that for any other middle confining unit mapped. Accordingly, unit I is the leakiest confining unit known in the study area. The lithology of unit I is not much different from that of the permeable zones vertically adjacent to it, and the unit's original porosity has not been greatly affected by pore-filling secondary mineralization. There are minor variations in hydraulic head (Lichtler and others, 1968; Snell and Anderson, 1970) and water quality across unit I; these variations, together with flowmeter data (see, for example, Leve, 1970) from scattered wells, show that the unit acts as a confining bed. Unit I separates the Upper and Lower Floridan aquifers everywhere in east-central Florida, the area discussed by Tibbals (1985), and throughout roughly half of the contiguous area to the north that is discussed by Krause and Randolph (1985). In a narrow northwest-trending band in central peninsular Florida (pl. 29), unit I overlaps gypsiferous dolomite that comprises middle confining unit II, described below, and is separated from unit II by a few hundred feet of permeable rock (see cross section G-G', pl. 23). The areal extent of the overlap shown by the dashed contact line on plate 29 is approximate because it is based on well control.

In west-central peninsular Florida, the middle confining unit of the aquifer system consists of low-permeability gypsiferous dolomite and dolomitic limestone. This unit, labeled unit II on plate 29, occurs approximately in the middle of rocks of middle Eocene age. As mentioned earlier, unit II is overlapped by unit I in part of central Florida. The altitude of unit II throughout its known extent, including this area of overlap, is shown in figure 13. The gypsum that is responsible for the low permeability of unit II is largely intergranular and appears to fill preexisting pore spaces in the rock. Lenses, stringers, pods, and thin beds of gypsum are also present, however. The gypsiferous dolomite probably represents an extensive middle Eocene sabkha or tidal flat environment, although some of the intergranular gypsum may have been emplaced by gypsum-rich interstitial waters. Hydraulic data (Guyton and Associates, 1976) show that unit II forms an essentially nonleaky confining bed. Data from oil and deep injection test wells show that permeable rock everywhere underlies unit II. The highly mineralized water contained in this rock, which is part of the Lower Floridan aquifer, suggests poor interconnection with the freshwater of the overlying Upper Floridan. Figure 14 shows the thickness of unit II. Anamolously thick areas, such as those shown in Polk County, Fla., are thought to have been caused by incomplete dissolution of gypsum and anhydrite in places where the deep flow system is very sluggish. Thinner areas represent places where more vigorously circulating waters have dissolved much of unit II's

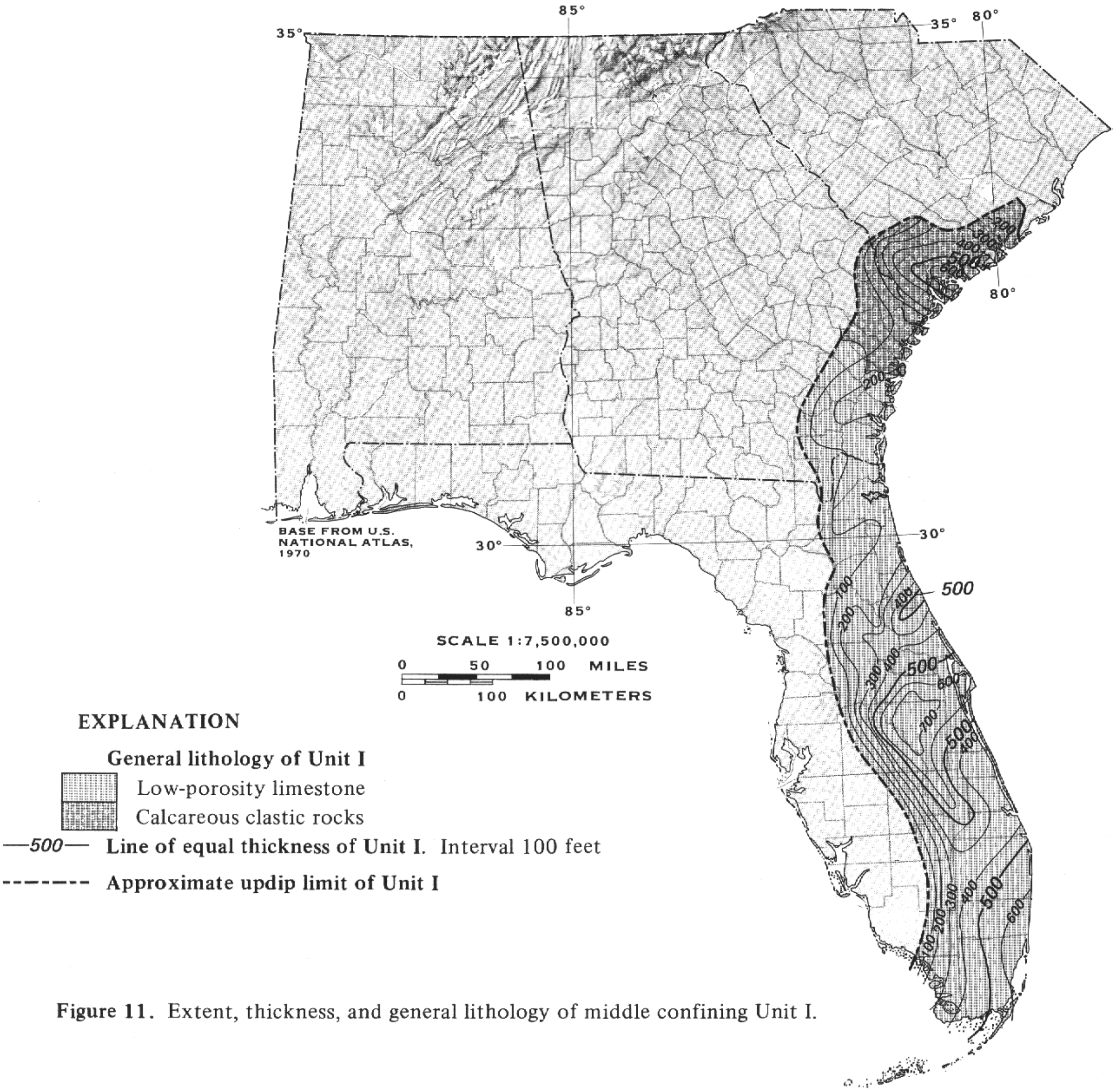


Figure 11. Extent, thickness, and general lithology of middle confining Unit I.

interstitial evaporitic material and thereby increased porosity and permeability. Unit II is treated as the base of the aquifer system in the subregional ground-water flow model discussed in by Ryder (1985) because (1) the unit is present throughout practically the entire area covered by the subregional model, (2) the unit has an extremely low permeability, and (3) the Lower Floridan aquifer below unit II is of relatively low permeability and contains poor-quality water. For the regional simulation described by Bush and Johnston (1985), however, the Lower Floridan aquifer that lies below unit II is treated as a high-permeability zone and is included as part of the ground-water flow system in west-central Florida, as it is elsewhere.

Along the central part of the Georgia-Florida border, the aquifer system's middle confining unit (unit III, pl. 29) consists of low-permeability, dense, fossiliferous, gypsiferous, dolomitic limestone that occurs in the lower or middle parts of rocks of middle Eocene age. The gypsum, like that found in unit II, is mostly intergranular, although it occurs rarely as layers and lenses within the limestone. Although small amounts of water can be obtained from unit III, the water is of poor quality owing to high sulfate concentrations that result from dissolution of the gypsum (see Sprinkle's (1985) map of sulfate concentration.) Concentrations of sulfate as high as 2,600 mg/L have been reported in ground water from unit II in Valdosta, Ga. (Krause,

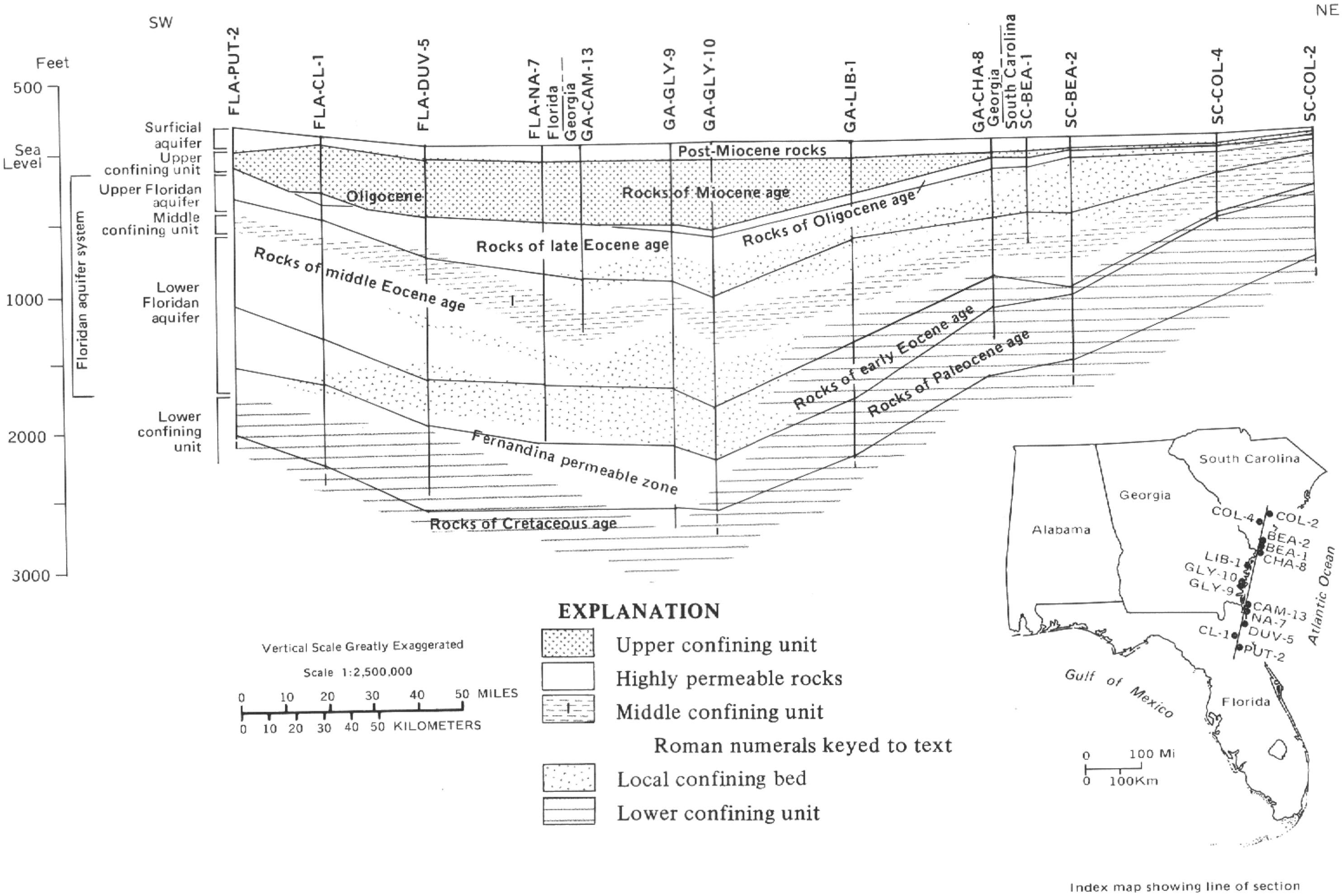


Figure 12. Generalized geohydrologic cross section from Putnam County, Fla. to Colleton County, S.C.

1979). Meyer (1962) recorded a sulfate concentration of about 1,100 mg/L in water from the same rocks near Lake City, Fla. Unit III is considered to be a slightly leaky confining bed. The extent and thickness of unit III are shown in figure 15. Where the thickness values shown in this figure exceed 200 ft, there are no permeable rocks below unit III; the gypsiferous rocks of the unit grade downward, without a break, into low-permeability clastic rocks that are part of the aquifer system's lower confining unit. This gradation is shown in cross section in figure 16. Elsewhere, especially near the edges of unit III, the gypsiferous limestone is underlain by permeable strata that are part of the Lower Floridan aquifer. No hydraulic or water-quality data exist for the Lower Floridan beneath unit III. Because the rock and permeability framework of the area underlain by unit III are similar to those underlain by unit II, the Lower Floridan aquifer under both areas is assumed to be similar: that is, under unit III the Lower Floridan is assumed to contain poor-quality water that is part of a slow-moving flow system. The subregional model that encompasses part of unit III (Krause and Randolph, 1985) does not consider the Lower Floridan aquifer under unit III to be a part of the ground-water flow system, for the same reasons that the Lower Floridan is excluded from the subregional model of Ryder (1985). In the regional simulation, however, the Lower Floridan, where it exists under unit III, is included as part of the flow system.

The rocks designated as middle confining unit IV (pl. 29) are deep-lying calcareous sand and clay, which in part grade northwestward into clastic rocks that are equivalents of the middle Eocene Lisbon and Tallahatta Formations, and the upper part of rocks of early Eocene age. Where unit IV is mapped, the Lower Floridan aquifer is present beneath the unit. Updip, the aquifer system consists of only one permeable zone that is treated as the Upper Floridan aquifer. Unit IV

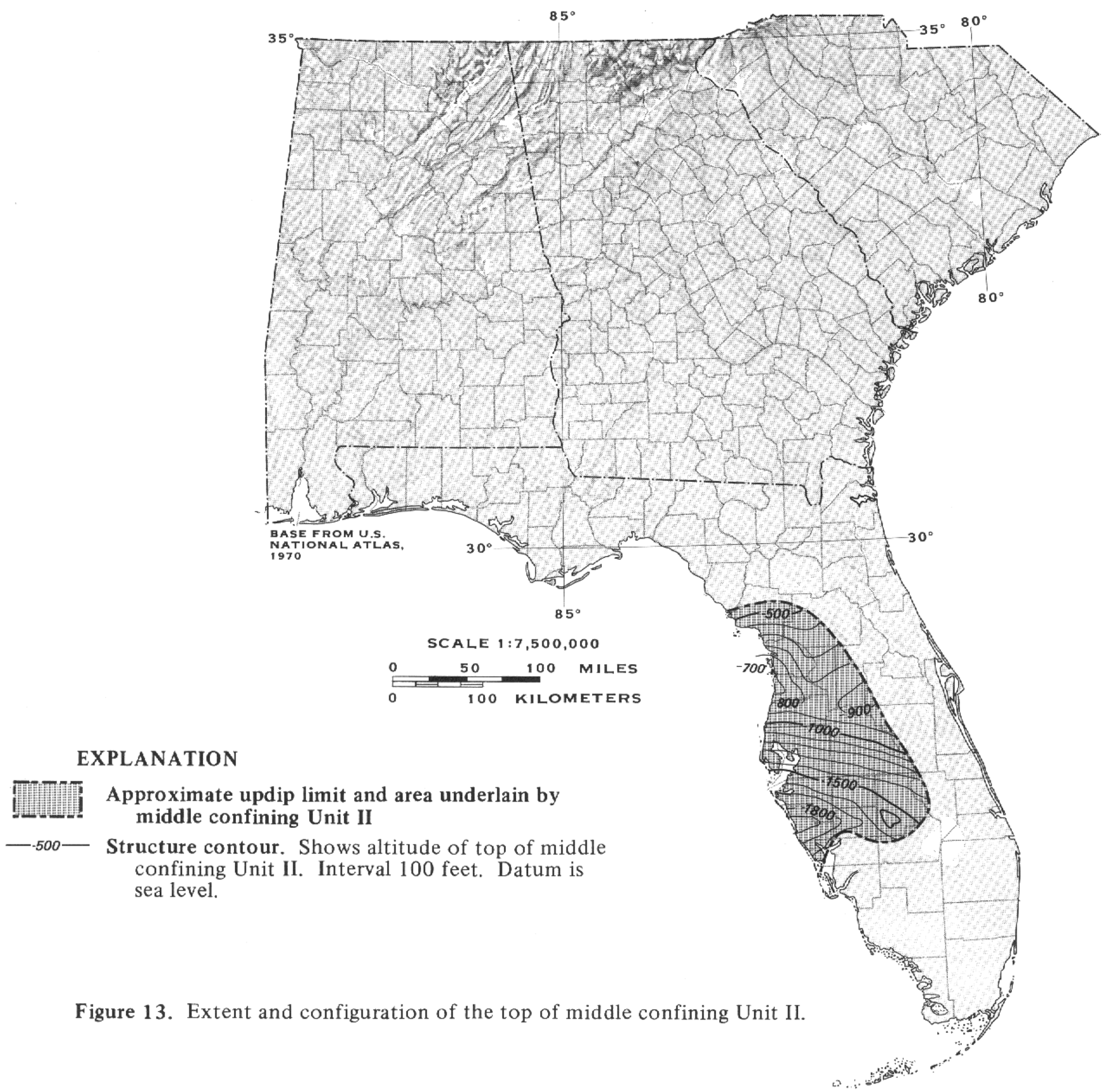


Figure 13. Extent and configuration of the top of middle confining Unit II.

represents a tongue of low-permeability rock extending into the aquifer system's permeable limestone, and locally dividing it into two discrete zones (cross section A-A, pl. 15). As figure 17 shows, the areal extent of unit IV is limited to a few counties in eastern panhandle Florida. There are no hydraulic head data available from which to determine the effectiveness of unit IV as a confining unit. The unit's lithologic character indicates that it is a relatively leaky confining unit whose ability to transmit water vertically is probably exceeded only by that of unit I. The Upper Floridan aquifer is very thick in the area underlain by unit IV (pl. 28). In fact, the greatest measured thickness of the Upper Floridan is from well FLA-GF-8, located in Gulf County, Fla., in this area. The maximum projected thickness of the Upper Floridan, however, is in southwestern Florida in the area underlain by middle confining unit VI.

The Floridan aquifer system is youngest in Florida's western panhandle (fig. 9) and in contiguous parts of southern Alabama. Here, the rocks that make up the Upper Floridan aquifer are mostly Oligocene (Chickasawhay Formation) in age and in places include lower Miocene strata (Tampa Limestone). The middle confining unit in this part of the study area, in contrast with the other units mapped on plate 29, corresponds to a single geologic unit—the Bucatunna Formation of Oligocene age. The Bucatunna Formation, mapped as unit V on plate 29, is a massive, dark gray, calcareous soft clay that contains up to 40 percent sand as dis-

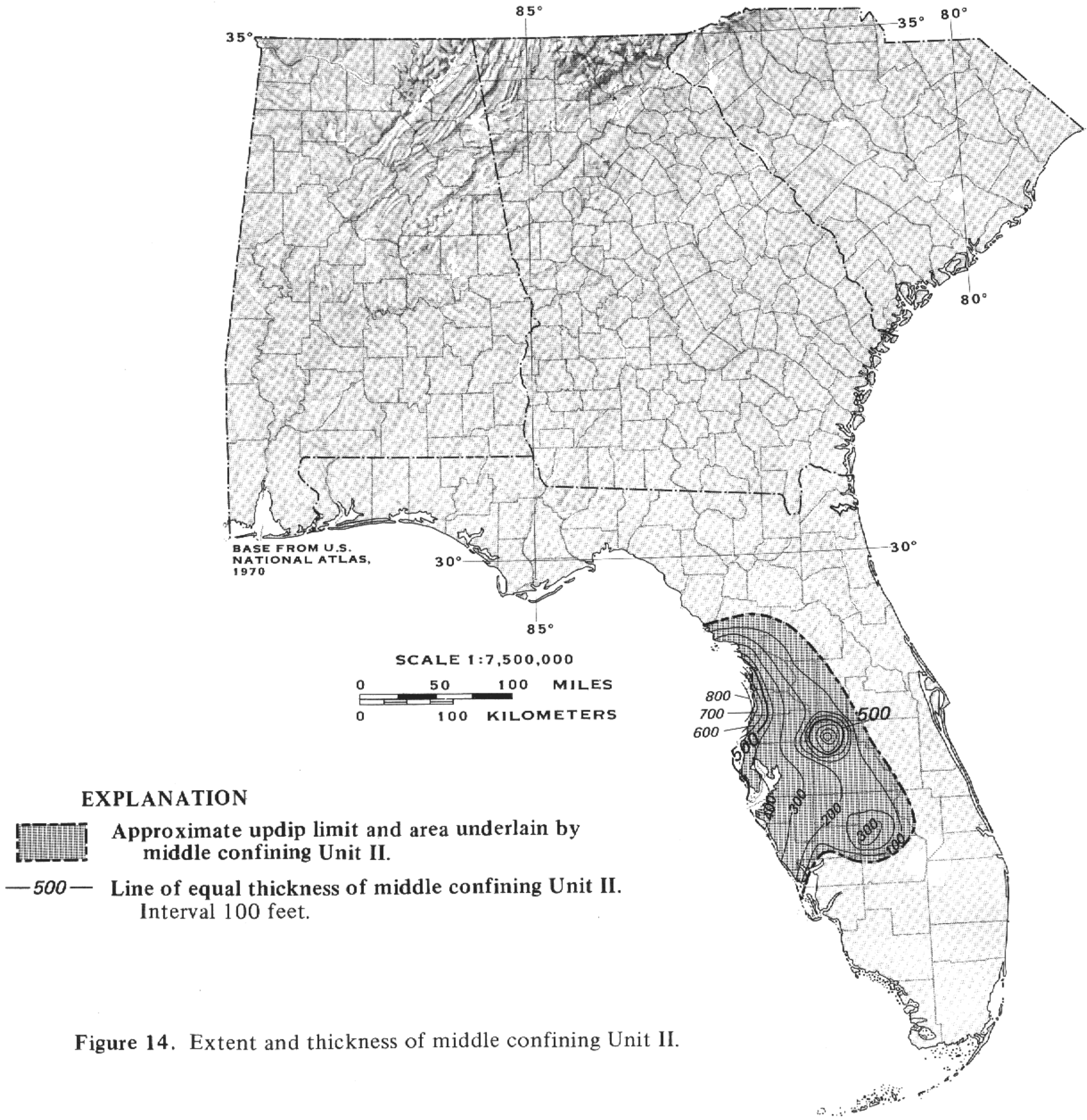
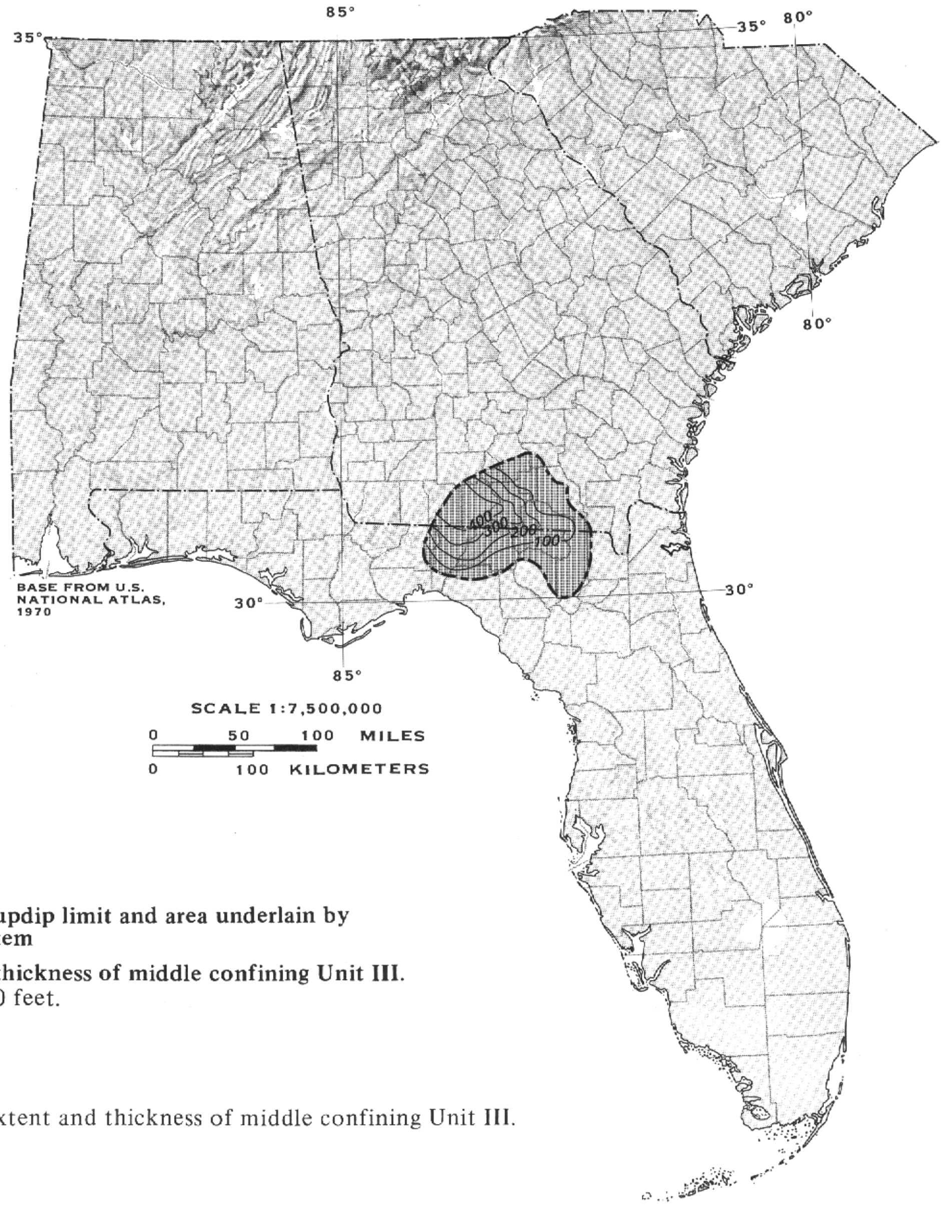


Figure 14. Extent and thickness of middle confining Unit II.

seminated grains and, near its northern and eastern pinchouts, as discrete beds. The thickness of the Bucatunna (fig. 18) is more uniform than that of most of the other middle confining units. The Bucatunna Formation can be readily identified on electric logs because of its extremely low resistivity, and it has been mapped primarily on the basis of this distinctive log pattern. The Lower Floridan aquifer underlies the Bucatunna (unit V) everywhere. Unit V is a virtually nonleaky confining unit. Hydraulic head data from southern Okaloosa County, Fla. (L. R. Hayes, personal commun., 1982), show that the Bucatunna Formation effectively isolates the Upper and Lower Floridan aquifers there. The faults shown in western Alabama on plate 29 disrupt the lateral continuity of unit V in the same manner that they affect the aquifer system's permeable zones—downdropping the grabens bounded by the faults has juxtaposed rocks of contrasting permeability.

The rocks that form the base of the Upper Floridan aquifer in southwestern peninsular Florida (middle confining unit VI, pl. 29) are a sequence of interbedded finely to coarsely crystalline dolomite and finely pellet-al, micritic limestone that is commonly argillaceous. The extent of unit VI is shown in figure 19. Over approximately the western half of the area underlain by unit VI, much of the intergranular pore space in the rocks assigned to the unit is filled with gypsum, which also occurs rarely as thin beds and coarse pods. The thickness of unit VI is shown in figure 20. Unit VI is



EXPLANATION

Approximate updip limit and area underlain by aquifer system

—300— Line of equal thickness of middle confining Unit III. Interval 100 feet.

Figure 15. Extent and thickness of middle confining Unit III.

usually found in the lower part of rocks of middle Eocene age, but in places it extends downward to include the upper part of rocks of early Eocene age (see figs. 9, 21). In northern Charlotte County and southern DeSoto and Highlands Counties, Fla., unit VI extends under middle confining unit II, as the dashed contact line on plate 29 shows . Southward, in Dade County and most of Monroe County, Fla., and eastward, in Broward County and part of Palm Beach County, Fla., unit VI is overlapped by unit I (see pl. 29). In both areas, unit VI is separated from the shallower low-permeability unit by a thin to moderately thick sequence of permeable rock. Because of sparse well control, the extent of the overlap shown on plate 29 is approximate. In those places where no shallower confining units overlap unit VI, the Upper Floridan aquifer is considerably thicker than it is where overlap occurs. No hydraulic head data are available across middle confining unit VI, but the unit is considered to be an effective confining bed because of its lithologic character.

A narrow northeast-trending strip of low-permeability rocks in west-central Georgia (middle confining unit VII, pl. 29) marks the base of the Upper Floridan aquifer there. Unit VII partly borders on and in places is gradational into unit III (fig. 16). The rocks that constitute unit VII are micritic to finely crystalline limestone that is often partially dolomitized and contains lenses, pods, beds, and intergranular pore fillings of gypsum. Figure 22 shows the extent and thickness

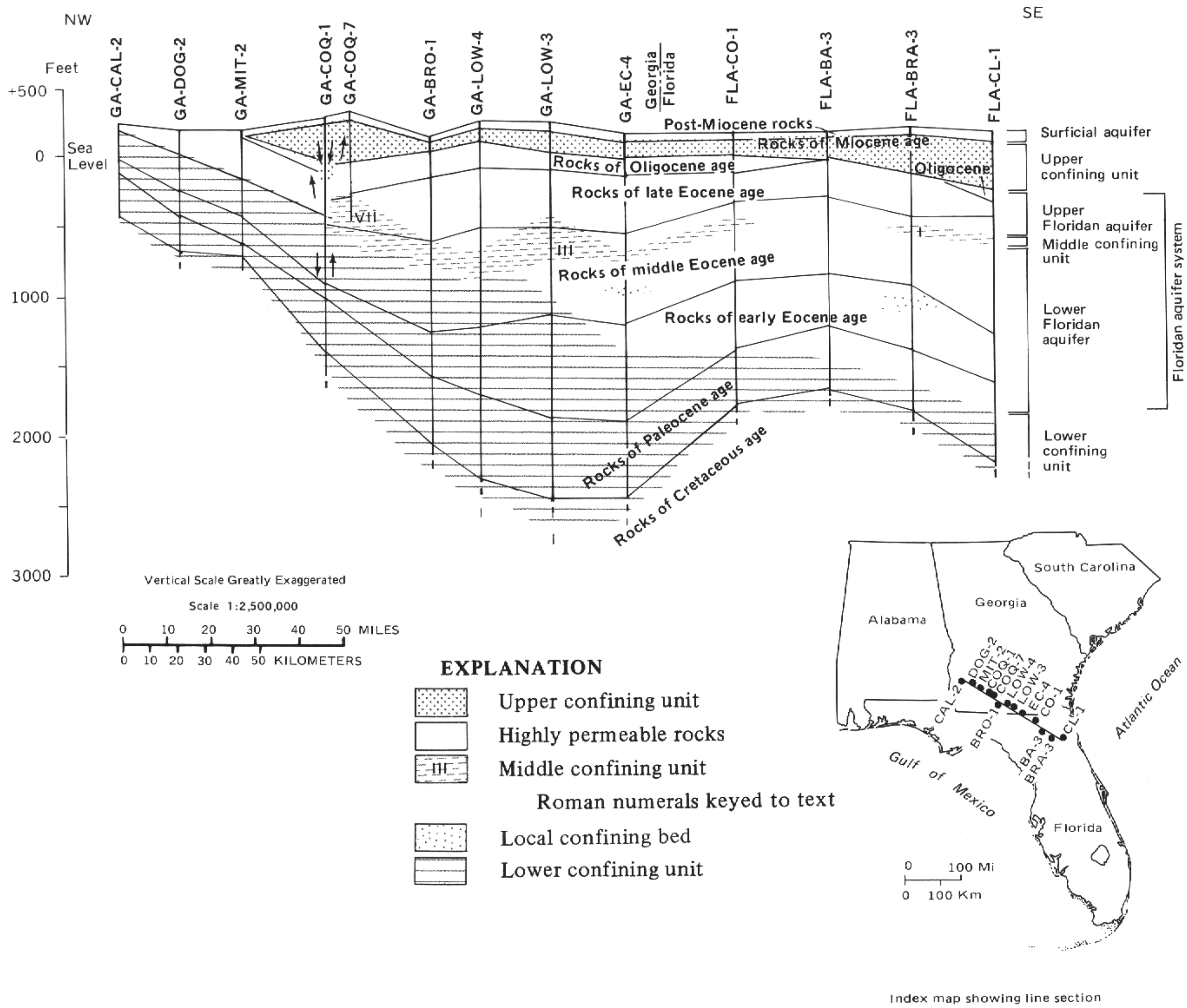


Figure 16. Generalized geohydrologic cross section from Calhoun County, Ga. to Clay County, Fla.

of unit VII. Near its southwestern border, the unit lies in the upper part of rocks of middle Eocene age; in its central part, it is composed of rocks of middle and late Eocene age; toward its northeastern limit, it is restricted to rocks of late Eocene age. Over the southern two-thirds of its extent, middle confining unit VII grades vertically downward into calcareous, glauconitic clastic rocks that are part of the Floridan aquifer system's lower confining unit. In this area, the Lower Floridan aquifer is absent. Farther northward, as the low-permeability rocks of unit VII thin and become younger, the unit is underlain by permeable limestone that is part of the Lower Floridan. The extent of the Lower Floridan aquifer under unit VII is only approximately known because of sparse well control. Unit VII is contiguous with, and just southeast of the Gulf Trough graben system. This author suggests that unit VII exists because it is adjacent to this structural feature. Juxtaposition of low-permeability rocks in the grabens opposite permeable limestone to the northwest (fig. 16) creates a damming effect on groundwater flow through the Floridan aquifer system, as described earlier. The restricted flow downgradient of the Gulf Trough (to the southeast) was not sufficient to dissolve the gypsum from the rocks of unit VII. To the northeast and southwest of the mapped extent of unit VII, either the faults that bound the Gulf Trough are discontinuous or the throw on them is not great. In

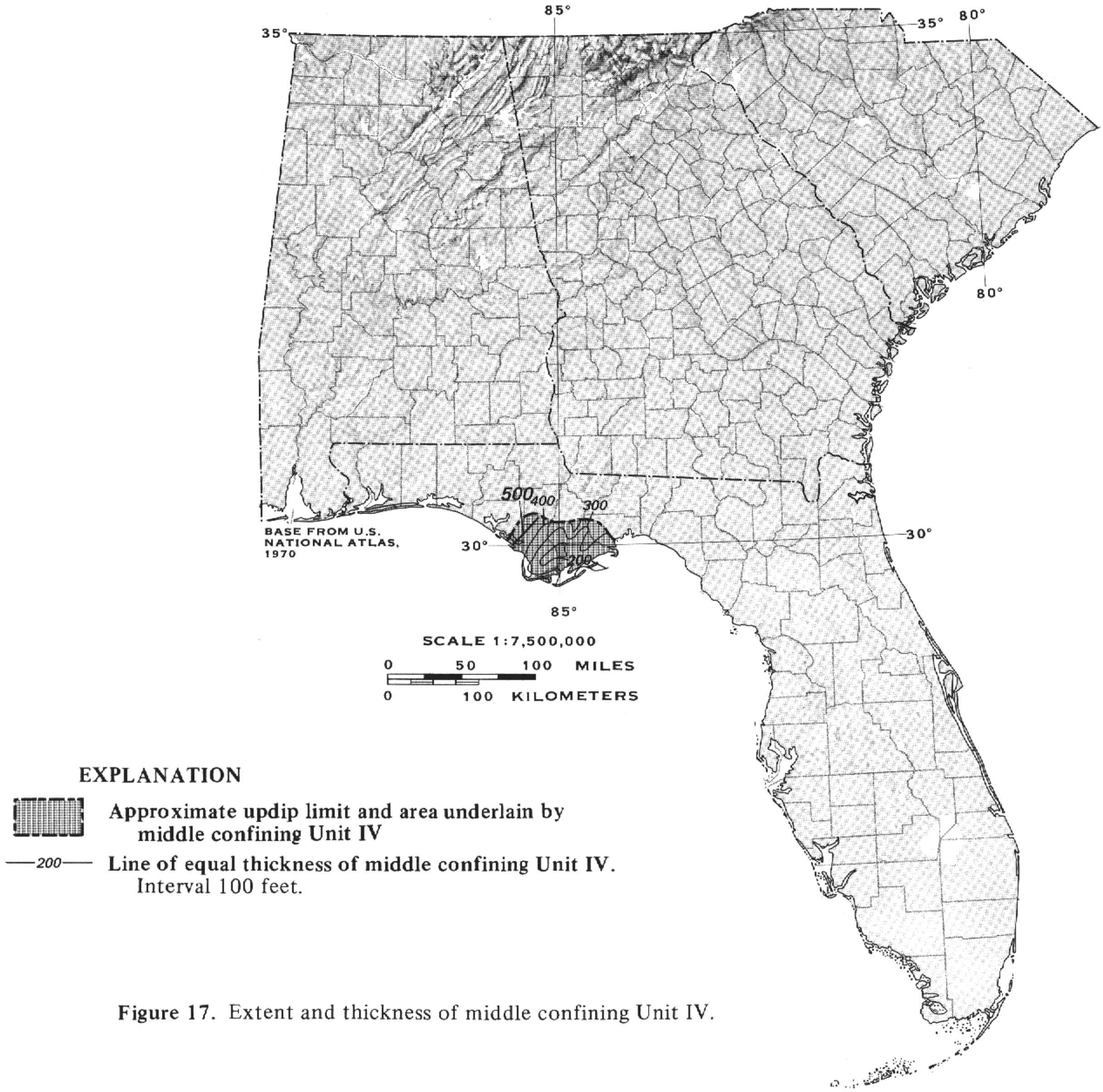


Figure 17. Extent and thickness of middle confining Unit IV.

these places, the rocks equivalent to unit VII are not gypsiferous, possibly because a more vigorous flow system has removed the gypsum by dissolution. On the basis of its lithology, unit VII is thought to be an effective confining unit, but hydraulic head data to quantify its effectiveness are lacking.

Lower Floridan Aquifer

All beds in the Floridan aquifer system that lie below the base of one of the middle confining units and above the base of the aquifer system are included in the Lower Floridan aquifer. Because it is deeply buried and in many places contains poor-quality water, the Lower Floridan has not been intensively drilled or tested, and its hydraulic character is therefore not well known. Scattered hydraulic data show large to small head differences between the Upper and Lower Floridan aquifers. The magnitude of these differences is directly related to the character of the middle confining unit that separates the aquifers; greater differences are found where the confining unit is virtually nonleaky. Ground-water flow in the Lower Floridan aquifer is sluggish except in those places where it is directly connected to the Upper Floridan aquifer. In the regional model discussed by Bush and Johnston (1985), active regional ground-water flow is thought to