

INTRODUCTION

Ground-water withdrawals in southwest Florida are increasing because of urban growth, industrial expansion, and increased agricultural irrigation. As a result, the potentiometric surface of the Floridan aquifer has been lowered in some areas, allowing seawater to encroach into the aquifer and threaten the freshwater resource of the area. Effective management of ground water is needed to control this encroachment and protect the freshwater aquifer.

Because of increased interest in the occurrence and changes of chloride concentration in ground water along the coast, the U.S. Geological Survey, in cooperation with the Southwest Florida Water Management District, began a program in 1977 to study the saltwater-freshwater transition zone along coastal southwest Florida from Levy County southwest to Charlotte County (fig. 1). The continuing program includes evaluation of various methods used for locating the saltwater-freshwater transition zone and selection of monitor sites to determine location and movement of the transition zone.

All elevations in this report are referenced to NGVD of 1929 (National Geodetic Vertical Datum of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

The purpose of this report is to show the general location of the 250-milligram-per-liter (mg/L) line of equal chloride concentration in that part of the Floridan aquifer tapped by the majority of wells along the coast. This zone, referred to as the upper producing zone of the Floridan aquifer, produces most of the water used in coastal southwest Florida. The zone occurs near the top of the Floridan aquifer and increases in depth and thickness from north to south. The 250-mg/L line of equal chloride concentration in 1979 (fig. 1) is used in this report to represent the transition from saltwater to freshwater in the upper part of the Floridan aquifer.

The line was mapped from results of previous investigations and interpretation of chloride concentration data in the files of the U.S. Geological Survey. The 250-mg/L line is used because the U.S. Environmental Protection Agency (1977) recommends that chloride concentrations not exceed 250 mg/L in public water supplies in areas where more suitable supplies are available.

HYDROGEOLOGY

Southwest Florida is underlain by a thick sequence of sedimentary rocks that are generally grouped into four hydrogeologic units (fig. 2): (1) surficial aquifers composed predominantly of fine sand and clayey sand with extensive areas of shell beds, marl, and limestone. Along the coast, the aquifer ranges in thickness from zero in the north to 80 feet in the south. Water in the aquifer is generally unconfined. The surficial aquifer is usually a minor source of freshwater for private domestic or small irrigation wells. However, in the southern part of the study area, the aquifer is a major source of water because in many places the water is more readily available and less mineralized than water from the Floridan aquifer.

The upper confining bed for the Floridan aquifer consists of relatively impermeable, interbedded limestone, dolomite, sand, and clay. The upper confining bed for the Floridan aquifer is hydraulically continuous. Thickness of the confining bed increases from 25 feet in Pasco County to 400 feet in southern Sarasota County (Buono and others, 1979). The major and lowermost unit of the upper confining bed is the Hawthorn Formation, which contains limestone and sand strata that are generally related to the deepest part of the aquifer to which the well is open, based on the assumption that most yield to the wells originates from the deepest zones penetrated. The depths below sea level at which the 250-mg/L line of equal chloride concentration occurs are approximately 400 to 600 feet in Manatee County, 600 feet in Sarasota County, and 600 to 800 feet in Charlotte County.

The Floridan aquifer, most productive and widely used aquifer in southwest Florida, was originally defined by Parker and others (1956) to include, in descending order, the permeable zones of the Hawthorn Formation of middle Miocene age that are in hydraulic connection with the underlying formation, the Tampa Limestone of early Miocene age, the Suwannee Limestone of Oligocene age, the Ocala Limestone of late Eocene age, and all or parts of the Avon Park and Lake City Limestones of middle Eocene age. The Floridan aquifer extends downward from the top of the persistent limestone sequence to the top of the persistent evaporite. It consists of a thick sequence of limestone and dolomite that dips and thickens southward (fig. 3). The aquifer yields water from permeable zones in the carbonates. The transition zone typically slopes landward with the result that saltwater wedges beneath freshwater and extends farther landward with increasing depth. Seawater moving inland from the sea floor introduces salt ions into the overlying freshwater system. Upon leaving these ions, the seawater becomes less dense and rises. The flow of freshwater carries salt back to the sea. This process limits the extent to which saltwater can infiltrate the aquifer (Cooper and others, 1964).

Both convection and molecular diffusion are important parts of this dispersion process. Convection is the mechanical process responsible for transferring one fluid into the other as a result of ocean tides and the rise and fall of the potentiometric surface. The potentiometric map of the Floridan aquifer can be used to indicate the general direction of flow within the aquifer. Freshwater in the aquifer moves from areas of high potential where recharge occurs through percolation, sinks, and streambeds to areas of low potential where discharge occurs through wells, springs, seeps, and direct flow to the sea. In southwest Florida, this movement is generally westward toward the coast where the potentiometric surface approaches sea level.

The likelihood of seawater intrusion is greatest in the dry season when water levels are low and pumping rates are high. High pumping rates often reverse the hydraulic gradient. The potentiometric surface in May (fig. 5) generally depicts aquifer conditions near the end of the dry season when the aquifer is under maximum stress. Overdevelopment of coastal aquifers by pumping water in excess of recharge reduces the freshwater head and induces inland migration of seawater.

FRESHWATER-SALT-WATER RELATION

Freshwater in the Floridan aquifer is underlain by saltwater throughout the peninsula of Florida. In coastal parts of the aquifer, chloride concentrations grade from less than 25 mg/L to 19,000 mg/L, forming a zone of transition between the freshwater and saltwater as opposed to a sharp contact between the two fluids. The size and shape of this zone of transition is influenced by variations in thickness and permeability of stratified beds forming the aquifer and by the hydraulic gradient. The transition zone typically slopes landward with the result that saltwater wedges beneath freshwater and extends farther landward with increasing depth.

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POSITION OF THE 250-MILLIGRAM-PER-LITER LINE OF EQUAL CHLORIDE CONCENTRATION

The transition zone between freshwater and saltwater in the upper part of the Floridan aquifer is bounded on the coastal side by chloride concentrations of 19,000 mg/L and on the landward side by chloride concentrations of 25 mg/L (fig. 6). The zone is depicted in this report as the approximate position of the 250-mg/L line of equal chloride concentration. The purpose of this line is intended to depict the position of the line where it intersects the base of the upper producing zone of the Floridan aquifer. In this report, the upper producing zone is described as being that part of the aquifer which contains most of the production wells (fig. 3). Thus, the bottom of the zone is defined by us, in the form of production well depth, and not by descriptive hydrogeologic characteristics.

The position of the 250-mg/L line of equal chloride concentration (fig. 1) was determined by the interpretation of chloride concentration data for wells (table 1) open within the upper producing zone of the Floridan aquifer (fig. 3). In areas where data were minimal, the position of the line was interpolated on the basis of available hydrogeologic data for the aquifer. In previous studies where the chloride concentration line has been determined, these interpretations were used as a basis for determining the present position, using current data to adjust the position of the line.

Chloride concentration values for wells were assumed to represent water from the base of the well unless data specified that samples were taken from some other point in the well. Wells that terminated within or near the upper producing zone or wells that were sampled within or near that zone were plotted on a 1:50,000 scale map. A line of equal concentration was drawn between points and weighted toward the deeper wells or deeper sampling points, with heavier resource being placed on more precise values. Data from wells in the northern counties is generally of better quality because of a better knowledge of the sampling zone and more current data than in the south. The 250-mg/L chloride concentration line was then transferred to the 1:500,000 scale map.

Actually, the 250-mg/L line is located less than 3 miles inland along most of coastal southwest Florida. It lies off the coast in parts of southern Hillsborough, Manatee, and Sarasota Counties. In northern Pinellas County, the line turns southward into Hillsborough County; a closed line shows that freshwater extends in the upper part of the Floridan aquifer in southern Pinellas County. In Hillsborough County, the line extends northward along the tidal part of the Hillsborough River. In southern Sarasota County, the line turns eastward and extends inland through Charlotte and De Soto Counties.

The top of the Floridan aquifer lies near land surface in coastal areas of Levy, Citrus, Hernando, and Pasco Counties. In these counties, the location of the 250-mg/L line of equal chloride concentration for the upper producing zone of the aquifer was determined by interpolating chloride concentration data collected in 1978 (table 1) from wells having depths ranging from 30 to 525 feet below sea level. Data were sparse in some areas and the position of the line was partially based on Mills and Ryder (1977) for Citrus and Hernando Counties and on Reichenbaugh (1972) for Pasco County. The depth represented by the 250-mg/L line in Levy and Citrus Counties is approximately 100 feet below sea level, which places it in the Avon Park Limestone or Ocala Limestone (fig. 3).

In Hernando and Pasco Counties, the line ranges from near 100 feet below sea level in the north to greater than 200 feet below sea level in the south, which places it predominantly in the Suwannee Limestone. The upper producing zone of the Floridan aquifer in Hillsborough and Pinellas Counties falls predominantly within the Tampa Limestone, although part of the underlying Suwannee Limestone may be in this zone (J.J. Hickey, written commun., 1979). The top of the zone lies near land surface in the northern part of the counties and extends to a depth of 200 feet below sea level in southern Hillsborough County. Chloride concentration data collected in the mid-1970's at wells open within the upper 250 feet of the Floridan aquifer were used to define the position of the 250-mg/L line of equal chloride concentration. The depth below sea level represented by the line is approximately 250 feet in northern Pinellas and Hillsborough Counties and increases to approximately 400 feet in southern Hillsborough County.

The upper producing zone of the Floridan aquifer in Manatee, Sarasota, Charlotte, and De Soto Counties consists of the Tampa Limestone and the lower part of the Hawthorn Formation. The top of the producing zone lies about 200 feet below sea level in northern Manatee County, 400 feet below sea level in northern Sarasota County, 300 feet below sea level in southern Sarasota County, and dips to 700 feet below sea level along the Charlotte-De Soto county line. Chloride concentration data used to define the position of the 250-mg/L line were collected during 1964-76 from wells open to the Tampa Limestone, or the lower part of the Hawthorn Formation, or both. In some cases, the only well-construction information available was well depth. Hence some samples may represent water from shallower zones as well as the upper Floridan aquifer (D.P. Brown, written commun., 1979).

The depth represented by the 250-mg/L line is considered to be related to the deepest part of the aquifer to which the well is open, based on the assumption that most yield to the wells originates from the deepest zones penetrated. The depths below sea level at which the 250-mg/L line of equal chloride concentration occurs are approximately 400 to 600 feet in Manatee County, 600 feet in Sarasota County, and 600 to 800 feet in Charlotte County.

SUMMARY

The U.S. Geological Survey began a program in 1977 in cooperation with the Southwest Florida Water Management District to determine the location of the transition zone between freshwater and saltwater in the upper part of the Floridan aquifer.

The approximate position of the 250-mg/L line of equal chloride concentration within the upper 200 feet of the Floridan aquifer is shown in this report to show the general location of the zone of transition. The position of the line is based on currently available chloride concentration data and results of previous Geological Survey investigations. Segment of the line were interpolated from nearby data because of sparse information in many areas. Chloride data for the line were taken at wells having known depths, but many wells are probably open to more than one producing zone.

In the northern counties, the 250-mg/L line is 100 to 200 feet below sea level in the Ocala Limestone and Avon Park Limestone, the major producing units of the area. The line is within the Suwannee Limestone in Pasco County. In Hillsborough and Pinellas Counties, the line is in the upper 200 feet of the Floridan aquifer where the upper producing zone falls predominantly within the Tampa Limestone. In the southern counties, the line is in the Tampa Limestone or the lower part of the Hawthorn Formation.

SELECTED REFERENCES

- Buono, Anthony, and Rutledge, A.T., 1978, Configuration of the top of the Floridan aquifer, Southwest Florida Water Management District and adjacent areas: U.S. Geological Survey Water-Resources Investigations 78-34.
- Buono, Anthony, Specier, R.M., Barr, G.L., and Wolansky, R.M., 1979, Generalized thickness of the confining bed underlying the Floridan aquifer, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations 79-117.
- Cooper, H.H., Jr., Kohout, F.A., Henry, H.R., and Glover, R.E., 1964, Sea water in coastal aquifers: U.S. Geological Survey Water-Supply Paper 1813-C, 84 p.
- Heath, R.C., and Smith, P.C., 1964, Ground water resources of Pinellas County, Florida: Florida Geological Survey Report of Investigations 12, 139 p.
- Joyner, B.F., and Sutcliffe, Horace, Jr., 1976, Water resources of the Myakka River basin area, southwest Florida: U.S. Geological Survey Water-Resources Investigations 76-58, 87 p.
- Mills, L.R., and Ryder, P.D., 1977, Saltwater intrusion in the Floridan aquifer, coastal Citrus and Hernando Counties, Florida: U.S. Geological Survey Water-Resources Investigations 77-100.
- Parker, G.G., Ferguson, G.E., Love, S.K., and others, 1955, Water resources of southeastern Florida, with special reference to the geology and ground water of the Miami area: U.S. Geological Survey Water-Supply Paper 1255, 965 p.
- Reichenbaugh, R.C., 1972, Sea-water intrusion in the upper part of the Floridan aquifer in coastal Pasco County, Florida, 1969: Florida Bureau of Geology Map Series 47.
- Stringfield, V.T., 1966, Artesian water in Tertiary limestone in the Suwannee River basin, state: U.S. Geological Survey Professional Paper 517, 226 p.
- U.S. Environmental Protection Agency, 1977, National secondary drinking water regulations: Federal Register, v. 42, no. 42, Thursday, March 31, 1977, Part 1, p. 17143-17147.
- Vernon, R.O., 1961, Geology of Citrus and Levy Counties, Florida: Florida Geological Survey Bulletin 33, 256 p.
- Wolansky, R.M., Barr, G.L., and Specier, R.M., 1979, Configuration of the bottom of the Floridan aquifer, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations 79-1490.
- , 1980, Configuration of the top of the highly permeable dolomite zone of the Floridan aquifer, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations 80-433.
- Yobbi, D.R., Woodman, W.M., and Schiner, G.R., 1980, Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District: May 1980: U.S. Geological Survey Open-File Report 80-587.

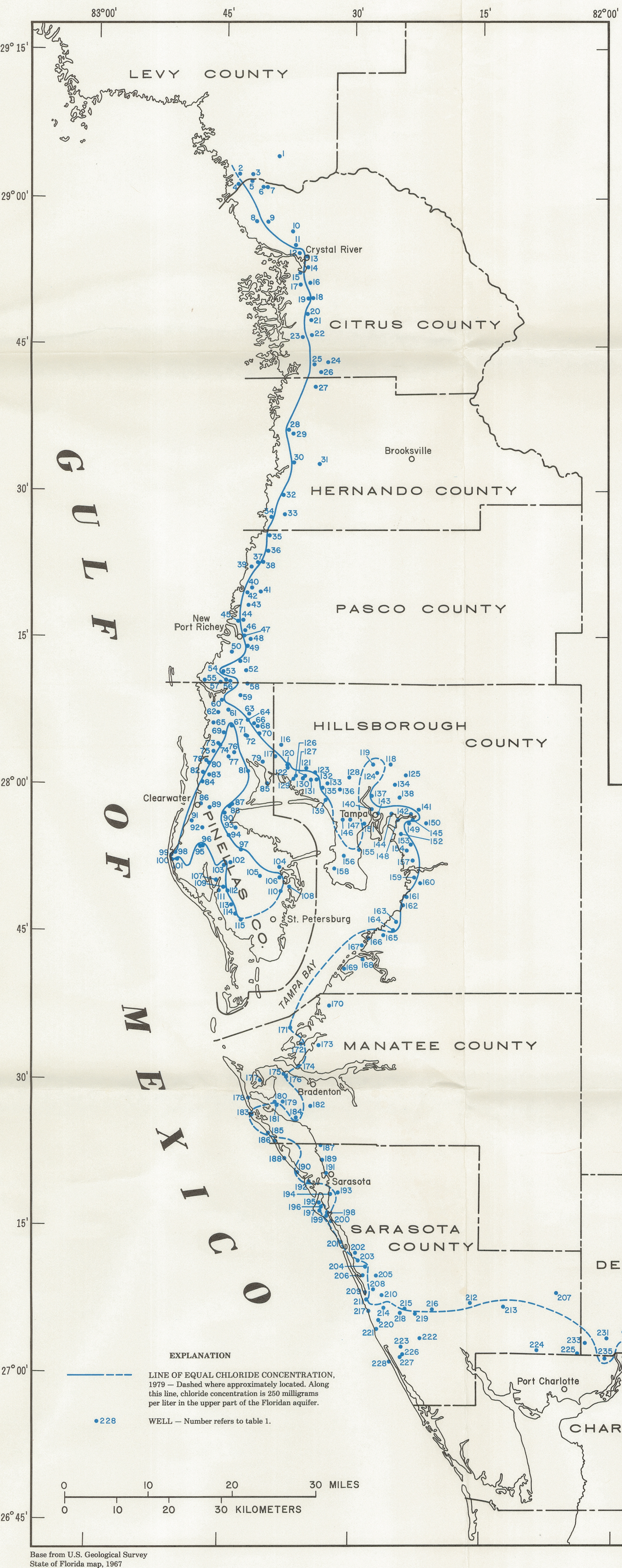


Figure 1.—Position of 250-milligram-per-liter line of equal chloride concentration in the upper part of the Floridan aquifer along the southwest coast of Florida.

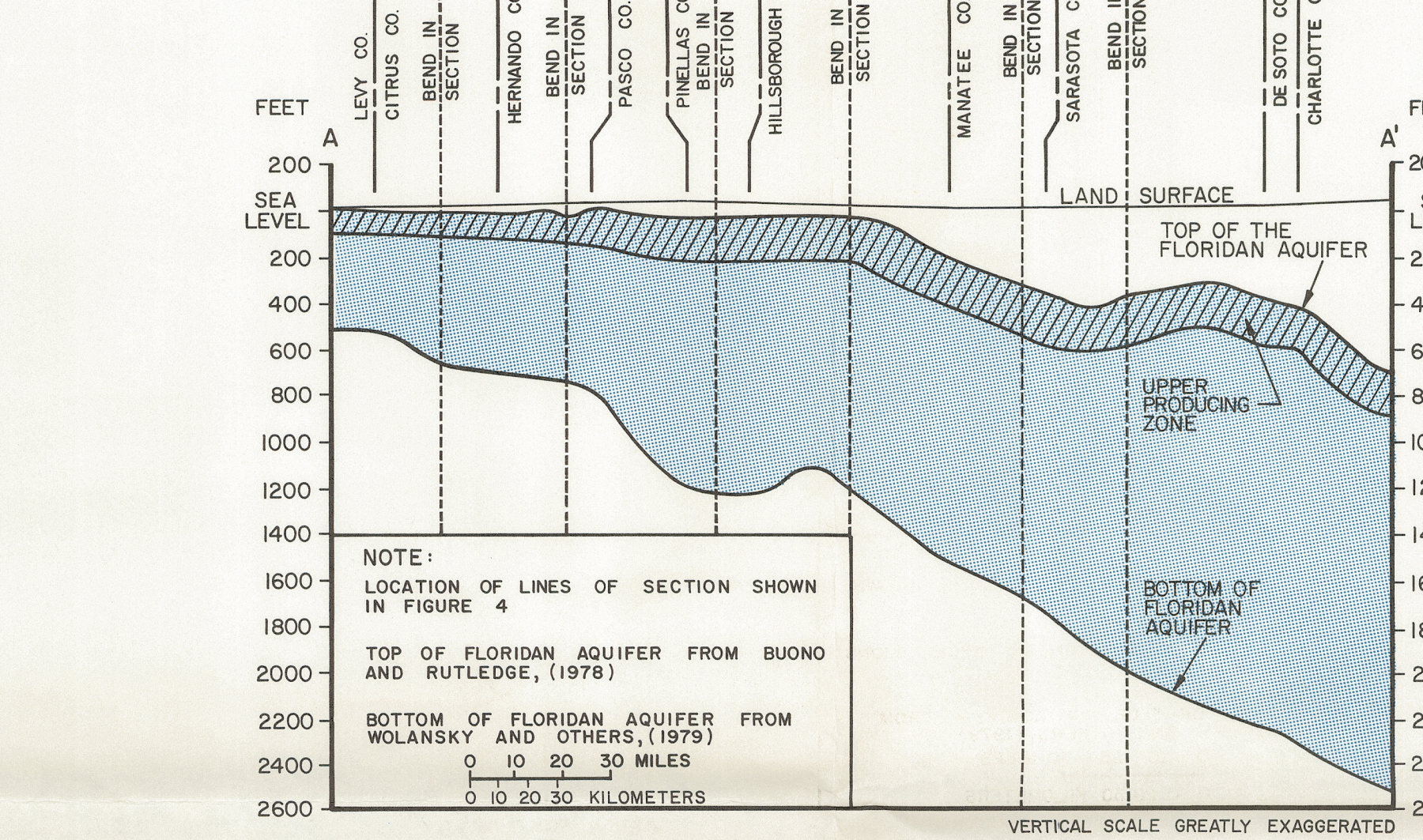


Figure 3.—Generalized geologic section along coastal southwest Florida.

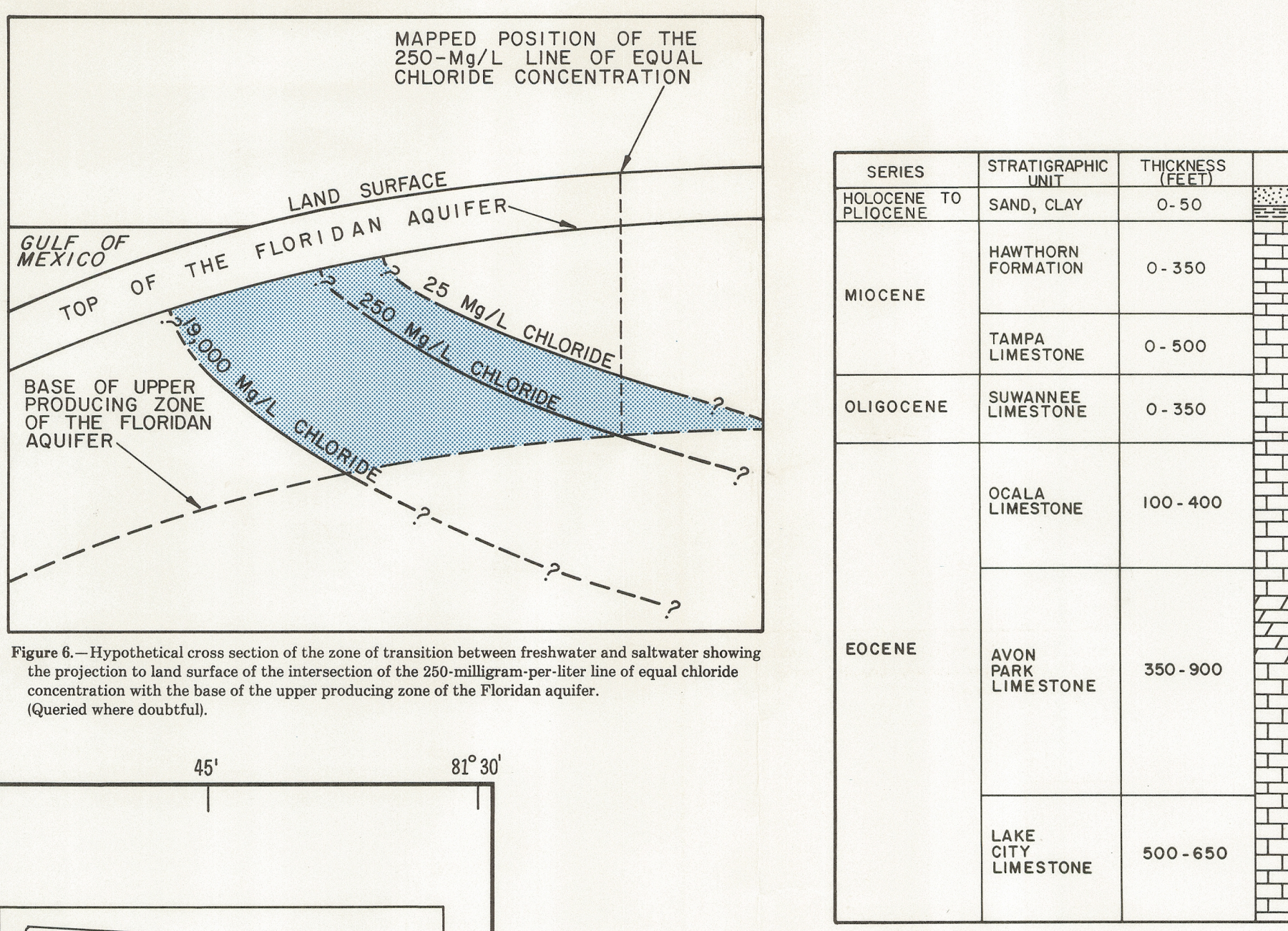


Figure 6.—Hypothetical cross section of the zone of transition between freshwater and saltwater showing the projection to land surface of the intersection of the 250-mg/L line of equal chloride concentration with the base of the upper producing zone of the Floridan aquifer.

SERIES	STRATIGRAPHIC UNIT	THICKNESS	HYDROLOGIC UNIT
HOLOCENE TO PLEISTOCENE	SAND, CLAY	0-50	SURFICIAL AQUIFER
	HAWTHORN FORMATION	0-350	UPPER CONFINING BED
MIOCENE	TAMPA LIMESTONE	0-500	UPPER PRODUCING ZONE
OLIGOCENE	SUWANNEE LIMESTONE	0-350	FLORIDAN AQUIFER
	OCALA LIMESTONE	100-400	
Eocene	AVON PARK LIMESTONE	350-900	LOWER CONFINING BED
	LAKE LIMESTONE	500-850	

Figure 2.—Generalized hydrogeologic column along coastal southwest Florida.

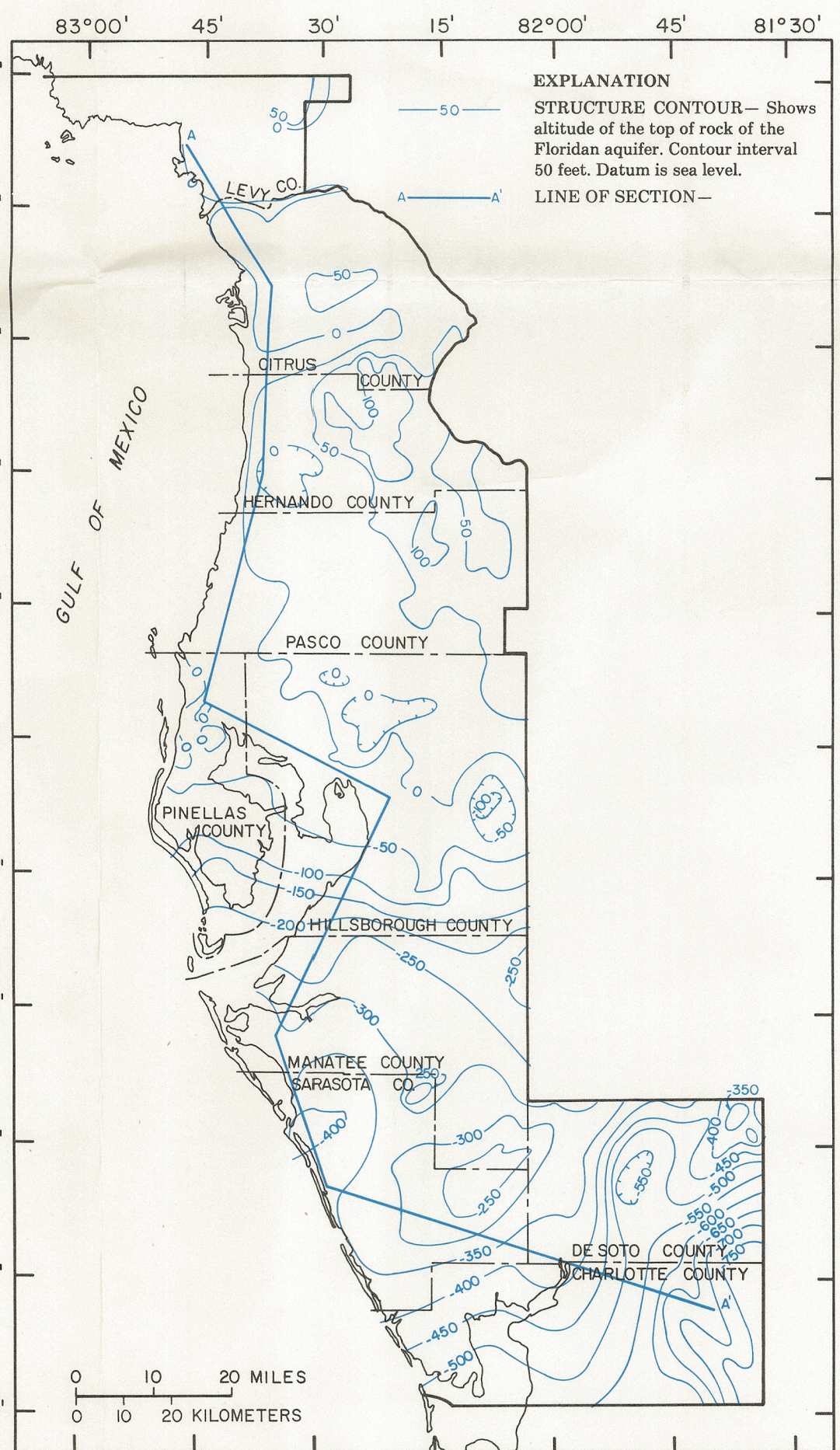


Figure 4.—Configuration of the top of the Floridan aquifer from Buono and Rutledge, 1978.

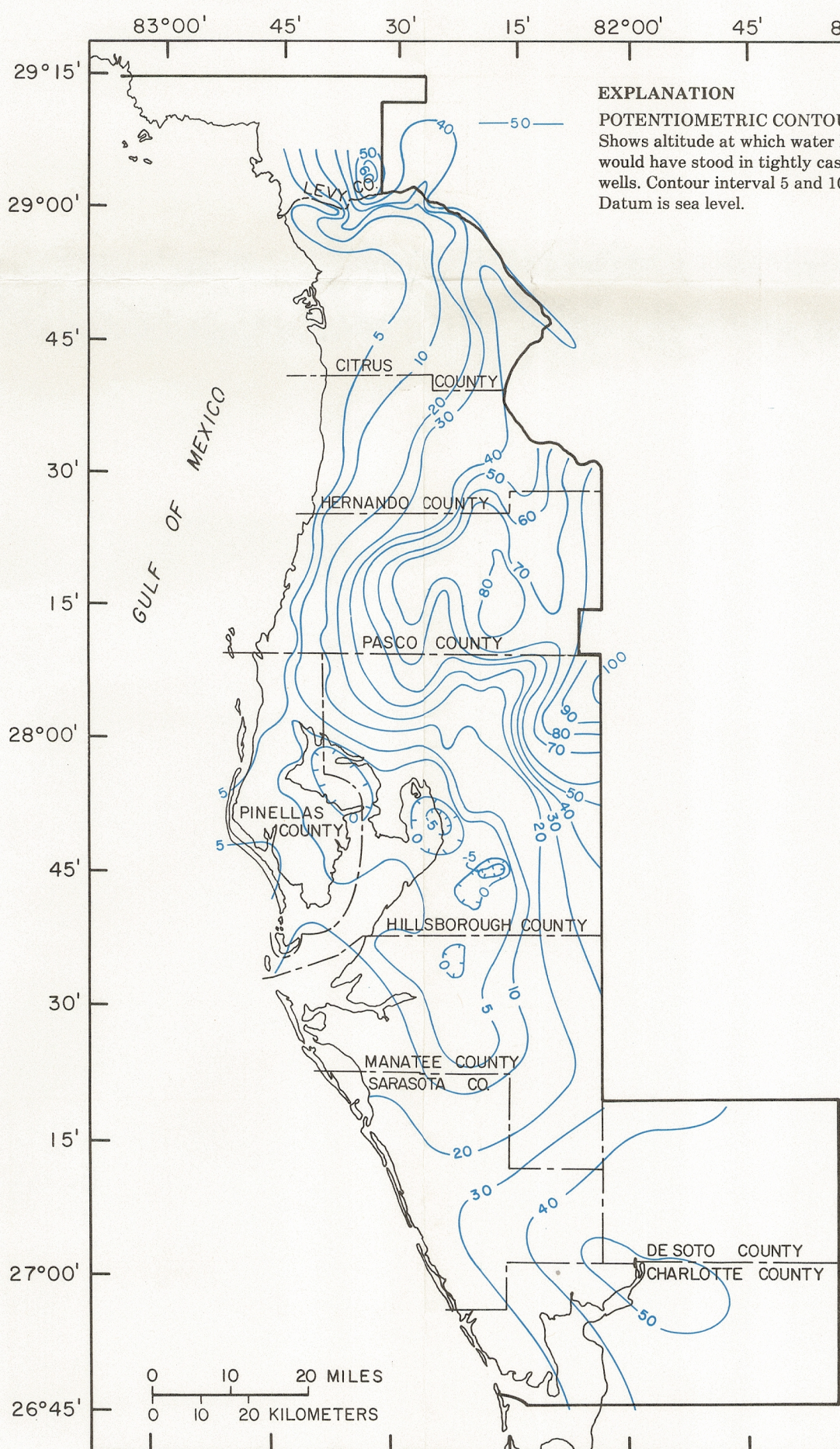


Figure 5.—Potentiometric surface of the Floridan aquifer, May 1980 from Yobbi and others, 1980.

POSITION OF THE SALTWATER-FRESHWATER INTERFACE IN THE UPPER PART OF THE FLORIDAN AQUIFER, SOUTHWEST FLORIDA, 1979

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