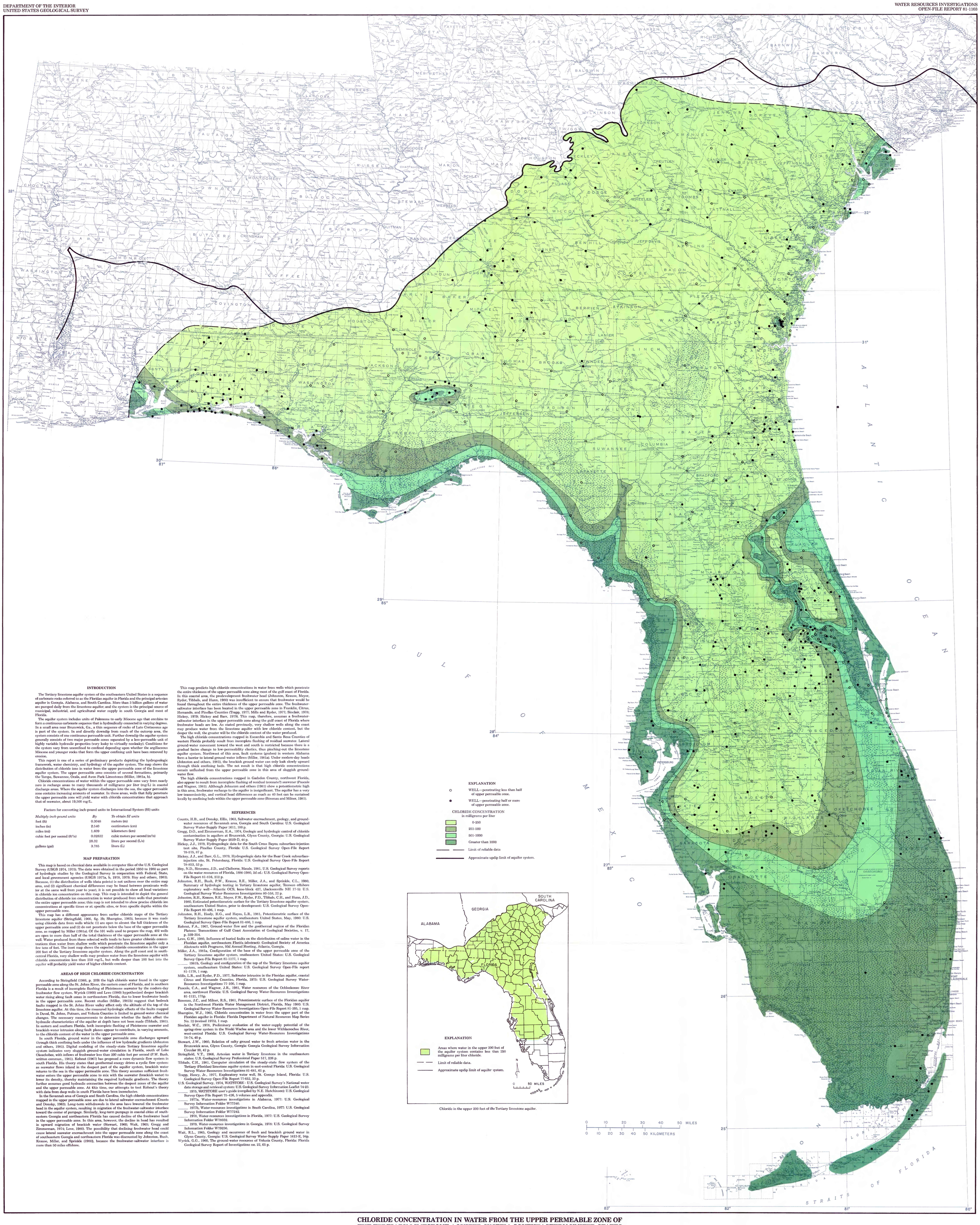

Chloride in the upper 200 feet of the Tertiary limestone aquifer.

INTRODUCTION

The Tertiary limestone aquifer system of the southeastern United States is a sequence of carbonate rocks referred to as the Floridan aquifer in Florida and the principal artesian aquifer in Georgia, Alabama, and South Carolina. More than 3 billion gallons of water are pumped daily from the limestone aquifer; and the system is the principal source of municipal, industrial, and agricultural water supply in south Georgia and most of Florida.

The aquifer system includes units of Paleocene to early Miocene age that combine to form a continuous carbonate sequence that is hydraulically connected in varying degrees. In a small area near Brunswick, Ga., a thin sequence of rocks of Late Cretaceous age is part of the system. In and directly downdip from much of the outcrop area, the system consists of one continuous permeable unit. Further downdip the aquifer system generally consists of two major permeable zones separated by a less-permeable unit of highly variable hydraulic properties (very leaky to virtually nonleaky). Conditions for the system vary from unconfined to confined depending upon whether the argillaceous Miocene and younger rocks that form the upper confining unit have been removed by erosion.

This report is one of a series of preliminary products depicting the hydrogeologic framework, water chemistry, and hydrology of the aquifer system. The map shows the distribution of chloride ions in water from the upper permeable zone of the limestone aquifer system. The upper permeable zone consists of several formations, primarily the Tampa, Suwannee, Ocala, and Avon Park Limestones (Miller, 1981a, b).

Chloride concentrations of water within the upper permeable zone vary from nearly zero in recharge areas to many thousands of milligrams per liter (mg/L) in coastal discharge areas. Where the aquifer system discharges into the sea, the upper permeable zone contains increasing amounts of seawater. In these areas, wells that fully penetrate the upper permeable zone will yield water with chloride concentrations that approach that of seawater, about 19,500 mg/L.

Factors for converting inch-pound units to International System (SI) units

Multiply inch-pound units	*By*	*To obtain SI units*
feet (ft)	0.3048	meters (m)
inches (in)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
	28.32	liters per second (L/s)
gallons (gal)	3.785	liters (L)

MAP PREPARATION

This map is based on chemical data available in computer files of the U.S. Geological Survey (USGS 1974, 1975). The data were obtained in the period 1950 to 1980 as part of hydrologic studies by the Geological Survey in cooperation with Federal, State, and local government agencies (USGS 1977a, b, 1978, 1979; Hoy and others, 1981). Because, (1) the distribution of wells (data points) is not uniform over the entire map area, and (2) significant chemical differences may be found between proximate wells (or at the same well from year to year), it is not possible to show all local variations in chloride ion concentration on this map. This map is intended to depict the general distribution of chloride ion concentration in water produced from wells that penetrate the entire upper permeable zone; this map is not intended to show precise chloride ion concentrations at specific times or at specific sites, or from specific depths within the upper permeable zone.

This map has a different appearance from earlier chloride maps of the Tertiary limestone aquifer (Stringfield, 1966, fig. 3b; Shampine, 1965), because it was made using chloride data from wells which: (1) are open to almost the full thickness of the upper permeable zone and (2) do not penetrate below the base of the upper permeable zone, as mapped by Miller (1981a). Of the 591 wells used to prepare the map, 402 wells are open to more than half of the total thickness of the upper permeable zone at the well. Water produced from these selected wells tends to have greater chloride concentrations than water from shallow wells which penetrate the limestone aquifer only a few tens of feet. The inset map shows the expected chloride concentration in the upper 200 feet of the Tertiary limestone aquifer system. Along the gulf coast and in south-central Florida, very shallow wells may produce water from the limestone aquifer with chloride concentration less than 250 mg/L, but wells deeper than 100 feet into the aquifer will probably yield water of higher chloride content.

AREAS OF HIGH CHLORIDE CONCENTRATION

According to Stringfield (1966, p. 209) the high chloride water found in the upper permeable zone along the St. Johns River, the eastern coast of Florida, and in southern Florida is a result of incomplete flushing of Pleistocene seawater by the modern-day freshwater flow system. Wyrick (1960) and Leve (1980) hypothesized deeper brackish water rising along fault zones in northeastern Florida, due to lower freshwater heads in the upper permeable zone. Recent studies (Miller, 1981b) suggest that bedrock faults mapped in the St. Johns River valley affect only the altitude of the top of the limestone aquifer. At this time, the measured hydrologic effects of the faults mapped in Duval, St. Johns, Putnam, and Volusia Counties is limited to ground-water chemical changes. The necessary measurements to determine whether the faults affect the hydraulic characteristics of the aquifer at depth have not been made (Tibbals, 1981). In eastern and southern Florida, both incomplete flushing of Pleistocene seawater and brackish-water intrusion along fault planes appear to contribute, in varying amounts, to the chloride content of the water in the upper permeable zone.

In south Florida, ground water in the upper permeable zone discharges upward through thick confining beds under the influence of low hydraulic gradients (Johnston and others, 1981). Digital modeling of the steady-state Tertiary limestone aquifer system indicates very sluggish ground-water circulation in Florida, south of Lake Okeechobee, with inflows of freshwater less than 200 cubic feet per second (P.W. Bush, written commun., 1981). Kohout (1967) has proposed a more dynamic flow system in south Florida. His theory states that geothermal energy drives a cyclic flow system: as seawater flows inland in the deepest part of the aquifer system, brackish water returns to the sea in the upper permeable zone. This theory assumes sufficient freshwater enters the upper permeable zone to mix with the seawater (brackish water) to lower its density, thereby maintaining the required hydraulic gradients. The theory further assumes good hydraulic connection between the deepest zones of the aquifer and the upper permeable zone. At this time, our attempts to test Kohout's theory with data from deep wells in south Florida have been inconclusive.

In the Savannah area of Georgia and South Carolina, the high chloride concentrations mapped in the upper permeable zone are due to lateral saltwater encroachment (Counts and Donsky, 1963). Long-term withdrawals in the area have lowered the freshwater head in the aquifer system, resulting in migration of the freshwater-saltwater interface toward the center of pumpage. Similarly, long-term pumpage in coastal cities of southeastern Georgia and northeastern Florida has caused decline of the freshwater head in the upper permeable zone. In this area, however, the decline in head has resulted in upward migration of brackish water (Stewart, 1960; Wait, 1965; Gregg and Zimmerman, 1974; Leve, 1980). The possibility that declining freshwater head could cause lateral seawater encroachment into the upper permeable zone along the coast of southeastern Georgia and northeastern Florida was discounted by Johnston, Bush, Krause, Miller, and Sprinkle (1980), because the freshwater-saltwater interface is more than 50 miles offshore.

This map predicts high chloride concentrations in water from wells which penetrate the entire thickness of the upper permeable zone along most of the gulf coast of Florida. In this coastal area, the predevelopment freshwater head (Johnston, Krause, Meyer, Ryder, Tibbals, and Hunn, 1980) was insufficient to ensure that freshwater would be found throughout the entire thickness of the upper permeable zone. The freshwater-saltwater interface has been located in the upper permeable zone in Franklin, Citrus, Hernando, and Pinellas Counties (Trapp, 1977; Mills and Ryder, 1977; Sinclair, 1978; Hickey, 1979; Hickey and Barr, 1979). This map, therefore, assumes a freshwater-saltwater interface in the upper permeable zone along the gulf coast of Florida where freshwater heads are low. As stated previously, very shallow wells along the coast may produce water from the limestone aquifer with low chloride content, but the deeper the well, the greater will be the chloride content of the water produced.

The high chloride concentrations mapped in Escambia and Santa Rosa Counties of western Florida probably result from incomplete flushing of residual seawater. Lateral ground-water movement toward the west and south is restricted because there is a gradual facies change to low-permeability clastics, thus pinching-out the limestone aquifer system. Northwest of this area, fault systems (graben) in western Alabama form a barrier to lateral ground-water inflows (Miller, 1981a). Under modern-day heads (Johnston and others, 1981), the brackish ground water can only leak slowly upward through thick confining beds. The net result is that high chloride concentrations remain unflushed from the upper permeable zone in this area of sluggish ground-water flow.

The high chloride concentrations mapped in Gadsden County, northwest Florida, also appear to result from incomplete flushing of residual (connate?) seawater (Pascale and Wagner, 1981). Although Johnston and others (1981) show a potentiometric high in this area, freshwater recharge to the aquifer is insignificant. The aquifer has a very low transmissivity, and vertical head differences as much as 40 feet can be sustained locally by confining beds within the upper permeable zone (Rosenau and Milner, 1981).

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CHLORIDE CONCENTRATION IN WATER FROM THE UPPER PERMEABLE ZONE OF THE TERTIARY LIMESTONE AQUIFER SYSTEM, SOUTHEASTERN UNITED STATES

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