

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

By CRAIG L. SPRINKLE

REGIONAL AQUIFER-SYSTEM ANALYSIS—FLORIDAN AQUIFER SYSTEM

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ABSTRACT

The chemical quality of the ground water in the Floridan aquifer system is determined primarily by mineral-water interaction. However, some changes in water quality have been imposed by development, particularly near coastal pumping centers. A total of 601 chemical analyses, all from different wells, most completed in the upper part of the aquifer system, were used to describe the variations in water chemistry and to study the processes responsible for observed changes.

The Floridan aquifer system is a vertically continuous sequence of Tertiary carbonate rocks that are of generally high permeability and are hydraulically connected in varying degrees. The rocks are principally limestone and dolomite, but they grade into limy sands and clays near the aquifer system's updip limits. Major minerals in the aquifer system are calcite, dolomite, and, locally, gypsum or quartz; minor minerals include apatite, glauconite, and clay minerals such as kaolinite and montmorillonite. Trace amounts of metallic oxides or sulfides are present in some areas.

The aquifer system consists of the Upper and Lower Floridan aquifers, separated in most places by a less permeable confining unit that has highly variable hydraulic properties. Only the Upper Floridan aquifer is present throughout the study area. Freshwater enters the aquifer system in outcrop areas located primarily in central Georgia and north-central Florida. Discharge occurs chiefly to streams and springs and, to a lesser extent, directly into the sea. Most of the flow into and out of the system takes place where it is unconfined or where the upper confining unit is thin. Secondary permeability developed by dissolution of aquifer material is most prominent in these areas of dynamic flow.

Dissolved-solids concentrations in water from the Upper Floridan aquifer generally range from less than 25 milligrams per liter near outcrops to more than 25,000 milligrams per liter along the coasts. The dominant cations in the ground water are Ca^{2+} , Mg^{2+} , and Na^+ ; the dominant anions are HCO_3^- , Cl^- , and SO_4^{2-} . The concentration of Ca^{2+} is controlled primarily by calcite saturation. Concentrations of Mg^{2+} , Na^+ , and Cl^- are highest where mixing of freshwater and saltwater occurs. Concentrations of HCO_3^- reflect the control of calcite solubility. The concentration of SO_4^{2-} is highest where gypsiferous rock units are present in the aquifer system.

The major geochemical processes that occur in the Upper Floridan aquifer, based on water-quality maps and computations using a geochemical model, are (1) dissolution of aquifer minerals toward equilibrium, (2) mixing of ground water with recharge, leakage, or seawater, (3) sulfate reduction, and (4) cation exchange between water and aquifer minerals.

Similar processes apparently control minor dissolved constituents, although quantification is difficult with the available data. Statistical tests of available nutrient data indicate that concentrations of N (nitrogen) species in unconfined recharge areas may be increasing over time; more detailed studies of all N species are needed to test this hypothesis, however. Data on trace metals, radionuclides, and man-made organic contaminants are limited. Available data indicate that most freshwater within the Upper Floridan is potable, but detection of pesticides in a few samples indicates that the system is susceptible to contamination from the land surface in some areas, particularly where its upper confining unit is thin or absent.

Geochemical models were used to examine changes in major chemical elements along selected ground-water paths within the Upper Floridan aquifer. Water in the Upper Floridan aquifer can be categorized into four hydrochemical facies, whose exact distribution is determined by confined or unconfined conditions of the aquifer and by chloride concentrations. The reaction models are considered plausible based on available chemical, isotopic, and hydrologic information, and they clearly reveal the dominant effects of aquifer confinement on ground-water chemistry. In unconfined areas, large volumes of dilute water recharge the system and dissolve minerals contained in the aquifer, thus enhancing the aquifer's permeability. In coastal areas, geochemical-model results indicate that the mixing of freshwater and seawater leads to carbonate dissolution or precipitation, depending in part on the ratio of freshwater to seawater. The geochemical models also indicate that significant sulfate reduction may occur in confined areas; this suggests that there is some flux of carbon into the aquifer system, a factor that must be considered when using ^{14}C measurements to determine ground-water-flow velocities.

INTRODUCTION

The Floridan aquifer system in the Southeastern United States is one of the most productive aquifer systems in the world. It is an areally extensive (fig. 1) sequence of carbonate rocks previously described as the

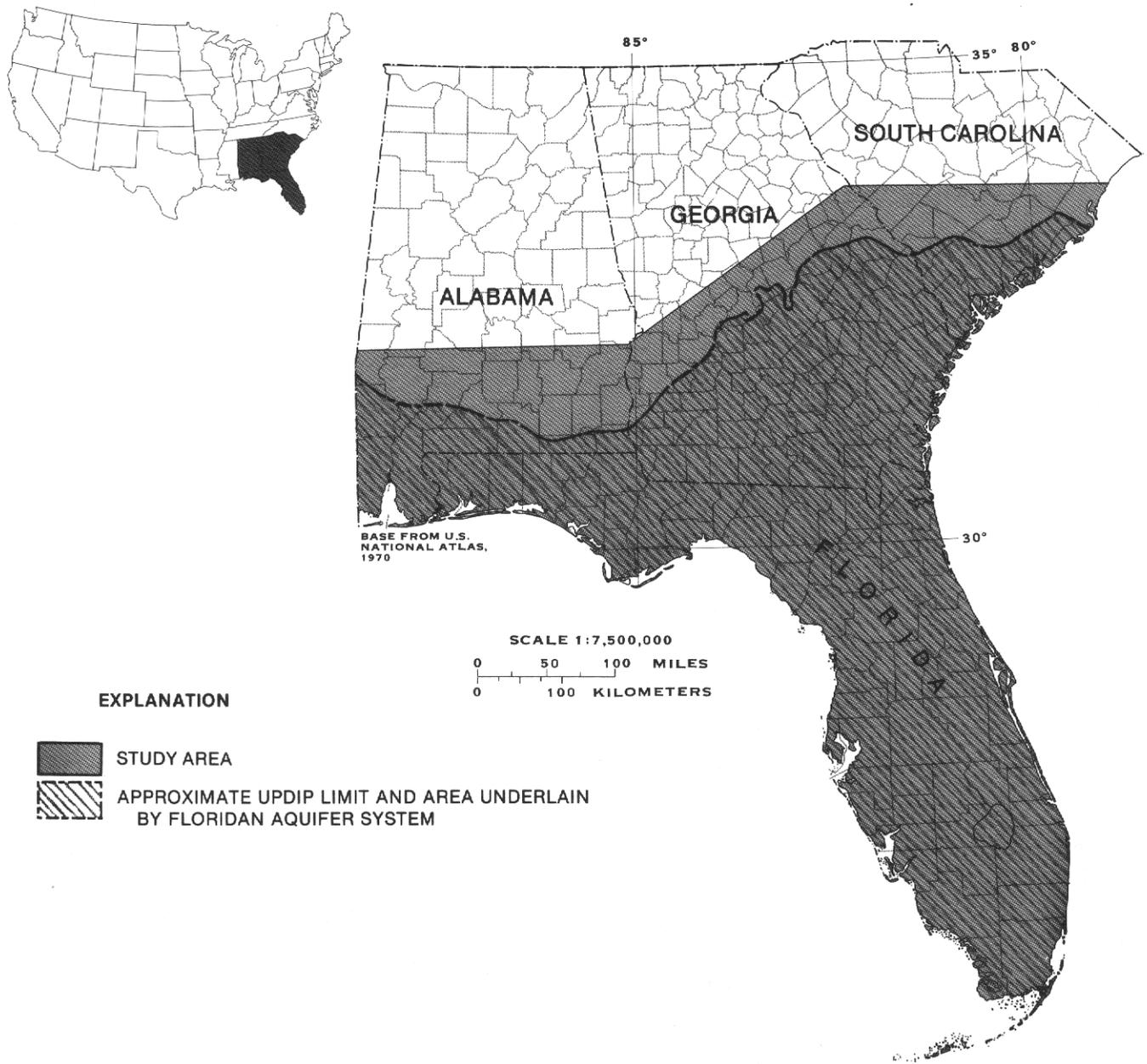


FIGURE 1.—Areal extent of the Floridan aquifer system.

Floridan aquifer in Florida (Parker and others, 1955) and the principal artesian aquifer in Florida, Georgia, Alabama, and South Carolina (Stringfield, 1966). More than 3 billion gallons of water are pumped from the aquifer system daily, making it the principal source of water for municipal, industrial, and agricultural use in southern Georgia and most of Florida. In large areas of Georgia and Florida, tremendous untapped reserves of freshwater are stored in the Floridan aquifer system. However, near some urban centers intensive development has led to declining water levels and localized degradation of water quality.

The chemical quality of ground water in the Floridan aquifer system is an important aspect to be considered in managing the aquifer. Specific information required for management includes a description of (1) the natural chemical character of both the aquifer and its water, (2) the processes that control the natural ground-water chemistry, (3) changes that have been imposed on water quality by development, and (4) actual or potential degradation of water quality which might limit future use.

In 1978, the U.S. Geological Survey began a study (Johnston, 1978) to describe the hydrogeologic frame-

work, geochemistry, and regional ground-water flow of the Floridan aquifer system. The Floridan study is one of several such studies in the Geological Survey's Regional Aquifer-System Analysis (RASA) program, which is a systematic effort to investigate aquifer systems that supply a major part of the Nation's water supply. The results of the Floridan RASA study are reported in U.S. Geological Survey Professional Paper 1403, which consists of the following chapters: A, summary (Johnston and Bush, 1988); B, hydrogeologic framework (Miller, 1986); C, hydraulics and regional flow (Bush and Johnston, 1988); D through H, subregional descriptions, including simulation of local water-supply problems; and I, geochemistry (this report).

PURPOSE AND SCOPE

The purposes of this report are to (1) summarize the available information on the mineralogy of the rocks and the quality of the water in the Floridan aquifer system and (2) describe the principal processes that have produced the present water chemistry.

One constraint of the RASA program was to use available data to the extent possible, in order to minimize costs and shorten time of study. Therefore, this report contains the published and unpublished results of many previous investigations. New chemical and isotopic data were collected in some areas, but a comprehensive program of water and rock sampling for chemical or isotopic analysis was not within the scope of the project. This report contains descriptions of climate, geological framework, hydrology, mineralogy, and chemistry of the Floridan aquifer system. The report concludes with a discussion of conceptual geochemical models and results of mass-transfer modeling of major chemical constituents in the Upper Floridan aquifer.

PREVIOUS REPORTS

A comprehensive bibliography of studies of the Floridan aquifer system published prior to 1965 is given in Stringfield (1966). A brief list of papers that discuss aspects of Floridan aquifer system geochemistry includes Back (1963), Hsu (1963), Hanshaw and others (1966), Kaufman and others (1969), Back and Hanshaw (1970), Hanshaw and others (1971), Rightmire and others (1974), Osmond and others (1974), Plummer (1975), Briel (1976), Kaufmann and Bliss (1977), Plummer (1977), Dalton and Upchurch (1978), Randazzo and Hickey (1978), Hanshaw and Back (1979), Rye and others (1981), Steinkampf (1982), and Plummer and others (1983). The other chapters of Professional Paper 1403 and interim reports by Ryder (1982), Tibbals (1981), and Krause (1982) should be consulted for more detailed

descriptions of the geology and hydrology of the Floridan aquifer system.

ACKNOWLEDGMENTS

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HYDROGEOLOGIC SETTING

CLIMATE AND RECHARGE

The study area (fig. 1) has a climatic range from temperate in the north to subtropical in the south and along the Gulf Coast. Mean annual temperatures range from about 18.6 °C in east-central Georgia to about 25.4 °C in the Florida Keys. These moderate air temperatures are partially reflected in ground-water temperatures measured in the Upper Floridan aquifer (fig. 2).

Precipitation is the primary source of recharge to the Floridan aquifer system. Annual precipitation (mostly rainfall) ranges from 40 inches (in) in Key West, Fla., to more than 65 inches in the Florida Panhandle and in southern Alabama. Most of the rainfall in Florida and the coastal areas of Alabama, Georgia, and South Carolina occurs as thunderstorms during the summer months. A significant part of the average annual rainfall in coastal areas may also be produced by tropical storms and hurricanes. In central Georgia, annual rainfall is more evenly divided between summer thunderstorms and cyclonic (frontal) storm systems that occur during winter and spring.

Stable isotope chemistry of the water that recharges the aquifer system is affected by the seasonal distribution of rainfall. As discussed by Gat (1980, p. 30), rainfall during the winter months is lighter in isotopes of ^{18}O and ^2H than during the summer months. Because evapo-