

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

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REGIONAL AQUIFER-SYSTEM ANALYSIS—FLORIDAN AQUIFER SYSTEM

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zone. Studies cited in the "Mineralogy" section of this paper indicate that dolomite in upper Eocene rocks of the Gulf Coast of Florida formed in a mixing zone where salinity was lower than the salinity of seawater. Whether or not dolomite is actively forming in coastal mixing zones of the Floridan aquifer system needs further study.

TOTAL HARDNESS

Total hardness is a water-quality property of limited geochemical significance, but it is important for certain water uses; high levels of total hardness may cause excessive scale in pipes and boilers. Figure 19 shows the total hardness of water from the Upper Floridan aquifer. "Hardness" is a term that has long described certain chemical properties of water, yet it is a term that is difficult to define exactly. For years, the hardness of water was defined by the reaction of water with soap ("hard" water tended to form an encrustation or curd). Because all multivalent cations (especially the commonly found alkaline-earth cations—calcium, magnesium, strontium, and barium) can contribute to the soap reaction, a practical definition of hardness is "the effect of alkaline-earth cations" (Hem, 1985, p. 158). Today, hardness can be measured by titrating a water sample with a reagent that reacts with multivalent metal cations (alkaline earths, plus iron, manganese, zinc, copper, lead, and others, if present). More routinely, however, total hardness (as CaCO_3) is calculated by multiplying by 50.05 the sum of milliequivalents per liter of the alkaline earths (Skougstad and others, 1979, p. 281). Because most metal cations are present in only trace amounts, the total hardness of ground water in the Upper Floridan aquifer is due primarily to calcium and magnesium ions.

The total hardness of water in the Upper Floridan aquifer varies from less than 50 to more than 5,000 mg/L as calcium carbonate (CaCO_3). Generally, where the aquifer system is composed only of limestone, the total hardness is equivalent to carbonate hardness and is less than 120 mg/L. Ground water with higher total hardness usually results from (1) dissolution of other aquifer minerals, primarily dolomite and gypsum, (2) mixing of freshwater with residual saline ground water, (3) encroachment and mixing of modern-day seawater, or (4) contamination. Natural softening of the ground water by cation exchange may be responsible for the low hardness in Escambia and Santa Rosa Counties, Fla. (fig. 19).

The noncarbonate hardness of water in the Upper Floridan aquifer ranges from less than 10 to more than 4,000 mg/L as CaCO_3 (fig. 20). Noncarbonate hardness is the difference between total hardness and alkalinity (Skougstad and others, 1979, p. 283). Noncarbonate hardness is due to alkaline-earth salts other than carbon-

ates and bicarbonates; in the Upper Floridan aquifer, the noncarbonate hardness in freshwater areas results primarily from dissolution of gypsum. As discussed previously, deep wells in the Upper Floridan are likely to yield highly mineralized water. Because the gypsum content of the Floridan aquifer system generally increases with depth, total hardness (and noncarbonate hardness) of the ground water also increases with depth. In coastal areas, the salts in seawater may also contribute to noncarbonate hardness in the Upper Floridan aquifer.

The U.S. Geological Survey classifies water on the basis of total hardness (in milligrams per liter as CaCO_3) as follows (Hem, 1970, p. 225):

0–60	Soft
61–120	Moderately hard
121–180	Hard
More than 180	Very hard

Much of the water in the Floridan aquifer system that is very hard may be unsuitable for industrial uses without treatment. For domestic use, there is a higher level of tolerance, apparently through decreased consumer sensitivity after continual use (National Academy of Sciences/National Academy of Engineering, 1972, p. 68). Medical studies (Muss, 1962; Schroeder, 1966; Sauer, 1974; Marier and others, 1979) have found a significant correlation between increased levels of hardness in drinking water and a decreased risk of cardiovascular disease in humans.

BICARBONATE AND CARBONATE

The principal anion in most of the ground water in the Upper Floridan aquifer is bicarbonate (HCO_3^-). Plate 3 shows that HCO_3^- concentrations range from 2 to 4 mmol/L (122 to 244 mg/L) throughout most of the region. Sources of HCO_3^- in ground water are (1) dissolution of CO_2 gas in recharge water, principally within the soil zone, (2) dissolution of carbonate minerals, and (3) biochemical oxidation of organic materials. Many of the papers cited in previous sections discuss carbonate equilibria in natural waters; within the Upper Floridan aquifer the carbonate system is the strongest natural buffer, tending to maintain ground-water pH within the range 7.0 to 8.5. In this range the predominant carbonate species is HCO_3^- . At a pH of about 10.3, HCO_3^- and CO_3^{2-} are equal in concentration, and at a pH of about 6.3, H_2CO_3 (aqueous CO_2) and HCO_3^- are equal in concentration (Hem, 1970, fig. 19).

Many papers attempt to relate the total CO_2 dissolved in ground water to the CO_2 of the soil zone in recharge areas because of the effects CO_2 equilibria exert on both rock dissolution (for example, Thrailkill, 1968; Langmuir, 1971; Shuster and White, 1972; Long and Saleem, 1974; Drake and Wigley, 1975; Harmon and others, 1975;

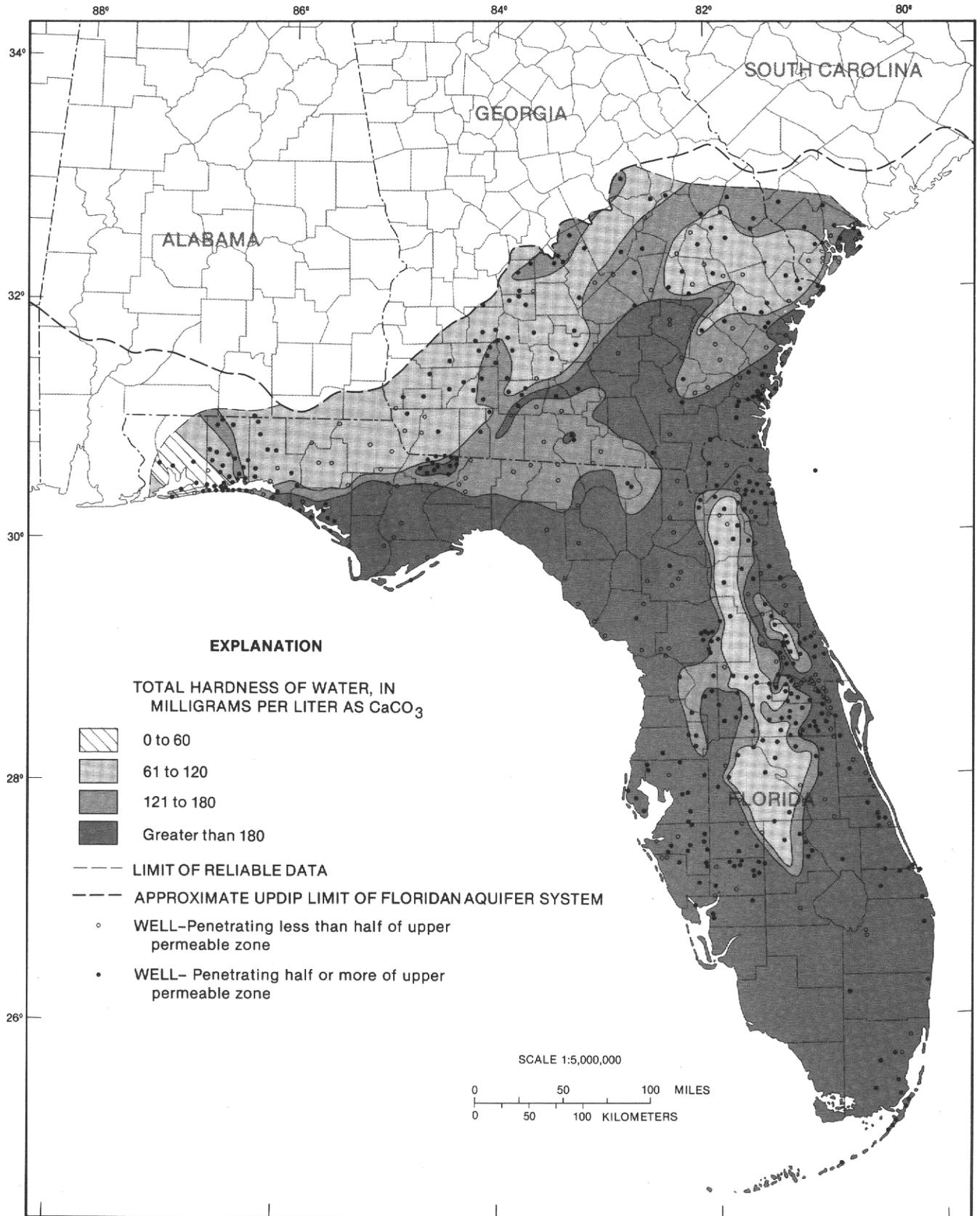


FIGURE 19.—Total hardness of water from the Upper Floridan aquifer.

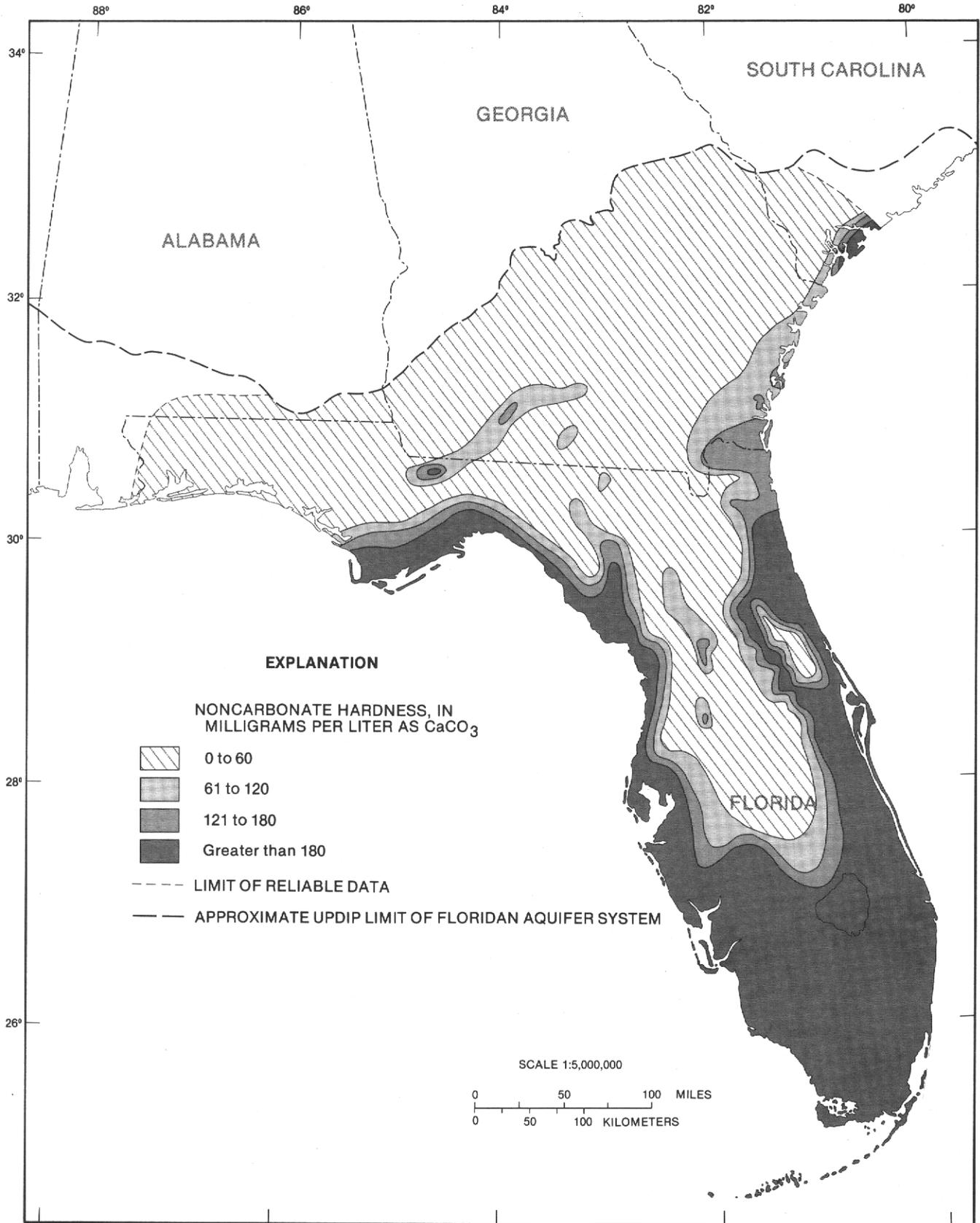
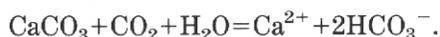


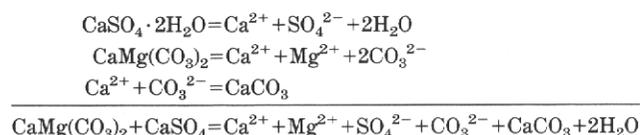
FIGURE 20.—Noncarbonate hardness of water from the Upper Floridan aquifer.

Trainer and Heath, 1976; Pitman, 1978) and the carbon isotope content of ground water (for example, Pearson and Hanshaw, 1970; Rightmire and Hanshaw, 1973; Deines and others, 1974; Fritz and others, 1978; Pearson and others, 1978; Rightmire, 1978). Drake and Wigley (1975) derived a general relation between soil P_{CO_2} and soil zone temperature which explained the P_{CO_2} in calcium-carbonate-saturated ground water that had evolved under essentially "closed system" conditions. Trainer and Heath (1976) developed a preliminary model of the bicarbonate concentrations in ground water from eastern North America using the timing of principal recharge (seasonal factor), soil and vegetation cover, soil zone P_{CO_2} , and soil zone temperature; their model generally accounted for observed latitudinal variations in dissolved carbonate species. Trainer and Heath cautioned, however, that data required for model computations were scanty and that, therefore, the parameter values assumed to make initial calculations needed to be field tested and refined both for better understanding of the processes involved and for making better quantitative evaluations. This prudent counsel is justified by nearly all the studies cited. Given the current understanding of the processes involved, quantitative evaluations of rock dissolution rates and carbon isotope contents in ground water may be made only after soil CO_2 pressures, soil temperatures, and soil water chemistry have been determined at a local scale.

The close relation between HCO_3^- concentrations and Ca^{2+} concentrations (pls. 1, 3) indicates that calcite solubility generally controls both Ca^{2+} and HCO_3^- concentrations in the Upper Floridan aquifer:



The dedolomitization reactions mentioned in the previous section have some effect on the total carbonate species in solution. As can be seen by combining the reactions involved,



total dissolved inorganic carbon should increase 1 mol for each mole of gypsum dissolved. Because the abundance of gypsum in the Upper Floridan aquifer is relatively low over most of the region, the general effect of these reactions on HCO_3^- concentrations is small. In north-eastern and west-central Florida, sulfate and magnesium concentrations are higher than expected from seawater dilution (based on Cl^- concentration), and the dedolomi-

tization reaction might be increasing the HCO_3^- concentration above 244 mg/L in these areas. Ground water in these two confined areas also contains measurable HS^- concentrations (fig. 26), indicating that oxidation of a reduced carbon species (peat?) is occurring. Although sulfate reduction produces CO_2 , the process probably increases local concentrations of HCO_3^- by only small amounts: Plummer and others (1983, p. 679) used ^{13}C and ^{34}S data to calculate that only about 6 percent of the total inorganic carbon added to ground water between Polk City and Wauchula, Fla., came from oxidation of peat.

Along the Gulf Coast of Florida, high HCO_3^- concentrations are mapped far inland from areas high in Ca^{2+} and Mg^{2+} ; high Ca^{2+} and Mg^{2+} concentrations occur nearer the coast, where seawater and freshwater mix in the aquifer. The anomalously high HCO_3^- concentrations might be related to increased dissolution of the aquifer in this unconfined recharge area (open-system dissolution) except that the chemical analyses from this area show excess anions, and the HCO_3^- concentrations are not balanced by the sum of the Ca^{2+} and Mg^{2+} concentrations (compare pls. 1, 2, 3). Much of this area is covered by hardwood and pine forests which generate organic litter high in soluble organic acids. These organic acids might be present in locally high concentrations in the water that recharges the Upper Floridan aquifer, and thus might have been titrated (along with inorganic carbon species) in the alkalinity determination. This hypothesis cannot be tested with the available data because dissolved organic carbon content was not determined in the original water samples. Some water samples from this area are colored, but quantitative estimates of the organic carbon content cannot be made because iron and manganese in solution also contribute to color. Whether or not the alkalinity titration measured only inorganic carbon species, the cation-anion imbalance is apparently due to unmeasured cations, possibly iron and ammonia. If these constituents are present in concentrations high enough to affect the charge balance, then significant biochemical activity is occurring in the aquifer. Biochemical activity could produce the excessive HCO_3^- "measured" by the alkalinity titration, but the exact nature and quantitative importance of the biochemical processes are unknown at this time. Seawater-freshwater mixing in the aquifer along the Gulf Coast is probably responsible for some dissolution of limestone and increase of HCO_3^- concentrations. Theoretical calculations (table 8) indicate that only about 0.3 mmol (<20 mg/L) of HCO_3^- would be added to ground water by calcite dissolution during mixing. A few wells in the Upper Floridan aquifer along the Gulf Coast yielded water samples with HCO_3^- concentrations greater than 350 mg/L, an almost 100-mg/L increase in HCO_3^- concentrations over samples from wells farther inland.

Apparently, freshwater-seawater mixing is responsible for only a fraction of the increase in HCO_3^- concentrations in water from wells in the Upper Floridan aquifer along the Gulf Coast of Florida. Most of the increased HCO_3^- in solution appears to be due to undefined biochemical processes occurring locally in the aquifer.

The area of high HCO_3^- concentrations in east-central Florida is partly related to the local recharge area in western Volusia County. Here, the confining unit overlying the Upper Floridan is thin and consists of calcareous sand, and recharge is sufficiently abundant to produce undersaturation with calcite and dolomite. On the eastern flank of the recharge area, calcite and dolomite apparently dissolve under a partly open system, producing moderately high HCO_3^- concentrations. The HCO_3^- concentrations are probably augmented by carbonate mineral dissolution occurring in the residual(?) seawater-freshwater mixing zone between the recharge area and the coast. Sulfate reduction also occurs locally, which adds some HCO_3^- to the ground water, but quantification is not currently possible because isotopic data are insufficient to calculate amounts of sulfide produced. Nearer the coast, Ca^{2+} and Mg^{2+} concentrations increase owing to greater amounts of seawater in the Upper Floridan aquifer, and both calcite and dolomite are supersaturated. The decline in HCO_3^- concentrations in the same area appears to be the result of calcite (and dolomite?) precipitation.

In western panhandle Florida, concentrations of HCO_3^- in water from the Upper Floridan aquifer are at the highest levels observed in this study. As discussed previously, Ca^{2+} concentrations in the area are very low, being controlled by cation exchange or calcite saturation. This is the only area where the Upper Floridan contains a sodium-bicarbonate hydrochemical facies (pl. 9). Upgradient concentrations of HCO_3^- are also anomalously high compared with other confined areas of the Upper Floridan. Measurable amounts of HS^- (fig. 26) indicate that the HCO_3^- concentration has been supplemented by microbial oxidation of organic material and sulfate reduction. However, upgradient sulfate concentrations are low—less than 20 mg/L (pl. 7)—indicating that sulfate reduction may not locally be an important source of CO_2 to the system. Nearer the coast, the seawater content of the ground water increases, based on evidence from chloride concentrations (pl. 6). In the western panhandle area, conservative mixing should produce sulfate concentrations of at least 140 mg/L where Cl^- concentrations are above 1,000 mg/L. Since observed sulfate concentrations are below 10 mg/L in the western panhandle, significant sulfate reduction must have occurred sometime in the past. As mentioned previously, ground-water flow within the Upper Floridan aquifer is sluggish in this area. It appears, therefore,

that the amount of CO_2 generated by sulfate reduction should currently be very small because sulfate concentrations are low and inflow of sulfate-rich water is not occurring under modern-day flow conditions. The high HCO_3^- concentrations measured in this area may be a chemical residue of previously higher levels of microbial activity in the Upper Floridan. Measurements of $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ in ground water from this area need to be made before the total effect of sulfate reduction on local HCO_3^- concentrations can be determined.

Although oxidation of organic materials is traditionally thought to be responsible for producing most of the bicarbonate in sodium-bicarbonate ground water (Renick, 1924b; Foster, 1950; Chapelle, 1983), this process appears to be of minor importance in western panhandle Florida, primarily because the Upper Floridan aquifer locally contains so little organic material. An exchange-driven carbonate-disequilibrium process previously described in sand aquifers (Foster, 1950; Back, 1966; Zack and Roberts, in press) may be the process generating the high HCO_3^- concentrations in the western panhandle area. As 2Na^+ for Ca^+ exchange occurs, carbonate minerals become locally undersaturated, allowing a small amount of calcite (and dolomite, if present) to dissolve and reestablish saturation. As ground water moves downgradient, the exchange-dissolution reactions progressively add bicarbonate and remove Ca^{2+} from solution. The carbon isotopic content of HCO_3^- in water from the Upper Floridan aquifer can be used to test this progressive disequilibrium hypothesis; unfortunately, the only $\delta^{13}\text{C}$ measurement in this area is from a well tapping the uppermost part of the Lower Floridan aquifer in northern Santa Rosa County, Fla. (regional monitor #3 of Hull and Martin, 1982; see pl. 3 for location). A sample from this well contained -4.5 ‰ $\delta^{13}\text{C}$; other major constituents measured in samples from this well (Hull and Martin, 1982, table 25) were similar to those in samples from the Upper Floridan aquifer in the area. Because the monitor well is located so near the updip limit of the Lower Floridan (fig. 9), it may be assumed that the hydrochemistry of the Lower Floridan aquifer is approximately that of the Upper Floridan aquifer in this area. If this assumption is valid, the $\delta^{13}\text{C}$ content of the Lower Floridan sample indicates that isotopically heavy carbonate species were added to solution, since $\delta^{13}\text{C}$ in the monitor well sample is heavier than in samples from recharge areas of the aquifer system (table 17). Alternatively, isotopically heavy carbonate may have been added to solution during methane production. Data from table 2 indicate that calcite (and dolomite) from the Upper Floridan have $\delta^{13}\text{C}$ near 0.0; if these minerals dissolve in a closed system, the $\delta^{13}\text{C}$ of the HCO_3^- in ground water would increase. In the panhandle area, there have been few measurements of

methane in water in the Upper Floridan; nonetheless, methane has been detected in three wells in Escambia and Santa Rosa Counties (table 4). Unfortunately, the regional effect of methane production on $\delta^{13}\text{C}$ of HCO_3^- in water in the Upper Floridan aquifer cannot be determined until the concentrations and $\delta^{13}\text{C}$ of methane have been more extensively measured. Lacking adequate data on either biogenic CO_2 or CH_4 contributions to the $\delta^{13}\text{C}$ content of water in the Upper Floridan in this area, the progressive dissolution of aquifer minerals seems a plausible explanation of the observed $\delta^{13}\text{C}$ at the monitor well. Further testing of the hypothesis must await more data from this area.

The lowest HCO_3^- concentrations in water from the Upper Floridan aquifer are in southern Alabama and southwestern Georgia. The aquifer is unconfined in these areas (fig. 11), and recharge reaches the aquifer after passing through thin, sandy residuum. Apparently, only small amounts of calcite react with the recharge water in the soil zone because HCO_3^- concentrations are low and ground water is undersaturated with calcite throughout these areas (fig. 16). Simulation of the predevelopment flow system in these areas (Bush and Johnston, 1988) indicates that discharge to the many streams draining the area is rapid and ground-water circulation rates are high. The intensity of local ground-water recharge and discharge is probably the most significant factor affecting the low HCO_3^- concentrations in the outcrop areas. An additional factor is the apparent lack of calcite reaction in the soils of this area. Other parts of the Upper Floridan where the upper confining unit is thin or absent have similarly high circulation rates, yet HCO_3^- concentrations are generally greater than 2 mmol (244 mg/L).

Another area of low HCO_3^- concentration is mapped in Decatur and Mitchell Counties, Ga. The low HCO_3^- concentrations occur in a narrow region immediately upgradient from a low- Ca^{2+} -concentration area adjacent to the Gulf Trough, which was discussed previously. These low HCO_3^- concentrations occur in an unconfined area, but there is no apparent reason for them to occur upgradient from the area of low Ca^{2+} concentration. As discussed previously, the underlying Eocene sand aquifers probably contain dilute water, dominated primarily by Na-HCO_3^- or $\text{Ca}^{2+}\text{-Na}^+\text{-HCO}_3^-$ ions. Conservative mixing of these types of water with the water dominated by $\text{Ca}^{2+}\text{-HCO}_3^-$ that is present in the Upper Floridan should dilute Ca^{2+} and HCO_3^- equally. If the dilution occurs with a $\text{Na}^+\text{-HCO}_3^-$ water, dissolved calcium should decrease even more than dissolved bicarbonate. At this time the best explanation seems to be that cumulative errors in determination of pH and alkalinity indicate an apparent decrease in HCO_3^- concentrations that is greater than the decrease in Ca^{2+} concentrations.

SODIUM AND POTASSIUM

The concentration of dissolved sodium (Na^+) and potassium (K^+) in water from the Upper Floridan aquifer ranges over several orders of magnitude. The lowest concentrations are near the concentrations in rainfall: about 1 mg/L of Na^+ and 0.2 mg/L of K^+ (table 1). In the coastal mixing zones and in inland areas where remnant seawater is present in the Upper Floridan, Na^+ concentrations exceed 500 mg/L, and K^+ concentrations exceed 20 mg/L. Over most of the region, Na^+ concentrations are less than 1 mmolar (<23 mg/L) (pl. 4) and K^+ concentrations are less than about 0.1 mmolar (<5 mg/L) (pl. 5).

Sodium and potassium are alkali metals which are highly soluble in water, and once dissolved, their ions tend to remain in solution. Both Na^+ and K^+ may exchange with other cations on clay minerals, but exchange reactions generally tend to increase the concentration of Na^+ and K^+ in dilute ground water. To determine areas where cation exchange might be occurring in the Upper Floridan, figure 21A was prepared showing molar excess Na^+ over Cl^- in ground water. Assuming either seawater or halite to be the source of Na^+ , the "normal" molar ratios of Na^+ to Cl^- in ground water should occur in the range 0.86 to 1.0. Precipitation over the region generally shows excess Na^+ because of leaching of soil particulates in the atmosphere (Junge and Werby, 1958, p. 419-420); the average Na^+/Cl^- molar ratio in precipitation over the region (table 1) is 1.23. A large excess of Na^+ over Cl^- in areas where the system is known to contain trace amounts of clay minerals is interpreted as evidence of exchange of 2Na^+ for Ca^{2+} . In unconfined areas of the system, excess Na^+ over Cl^- may be the result of sodium being leached from fertilizers applied to the soils. The very low Na^+/Cl^- ratios in central Georgia are calculated from water samples having very low concentrations of both sodium and chloride. Although the exchange of 2Na^+ for Ca^{2+} is a reversible process, these low ratios in central Georgia more likely are due to (1) analytical error in determining sodium and chloride in the water samples or (2) unidentified chloride sources in the recharge areas that are not sodium rich.

In most of the region, Na^+ concentrations are low owing to the trace amounts of Na^+ in precipitation and in the principal minerals of the aquifer system. Using trace metal data from Metrin (1979), calculations indicate that for each mole (about 100 g) of calcite dissolved, about 14 mg of Na^+ would be added to solution; similarly, about 155 mg of Na^+ would be added for each mole (about 185 g) of dolomite dissolved. Concentrations of Ca^{2+} and Mg^{2+} indicate that only about 1-2 mmol of calcite and about 0.5 to 1 mmol of dolomite are dissolved in the freshwater of the Upper Floridan. Dissolution of carbon-

ate minerals can add only a few tenths of a milligram per liter of Na^+ to freshwater in the aquifer; the remainder apparently is derived from evaporated precipitation recharging the system and other mineral sources, including ion exchange. Higher concentrations of Na^+ present in some inland areas are generally the result of remnant seawater in the Upper Floridan aquifer, as indicated by high Cl^- concentrations. For example, in Gadsden County, Fla., low-permeability zones in the Upper Floridan retain moderately saline water; water samples from the aquifer in this area contain high concentrations of all major ions in seawater (Pascale and Wagner, 1981). High concentrations of the major ions in seawater also occur in the Upper Floridan aquifer in the valley of the St. Johns River, where seawater may have entered the aquifer during the Pleistocene. In the western panhandle of Florida, high Cl^- concentrations (pl. 6) indicate that remnant seawater is present in the Upper Floridan in extreme southwestern Santa Rosa County and in southern Escambia County. Sodium concentrations increase in a downgradient direction, beginning about 30 mi northeast of this area, in southwestern Okaloosa County (pl. 4). Where increases in Na^+ begin, Na^+/Cl^- ratios are high (fig. 21A) and are accompanied by progressive downgradient decreases in Ca^{2+} concentrations (pl. 1). These concurrent changes in concentration in the downgradient direction are apparently due to ion exchange of 2Na^+ for Ca^{2+} . The large area of slightly higher Na^+ concentrations centered near Brunswick, Ga., is due to upward seepage of deeper saline water induced by many years of heavy pumpage. The hydraulic effects of the pumpage are discussed in detail by Krause and Randolph (in press); earlier studies of the chemical effects of pumpage in the Brunswick area emphasized local increases in chloride concentration (Wait, 1965; Gregg and Zimmerman, 1974). The pattern shown in plate 4 is not exactly duplicated in plate 6 because the maps were drawn with different ranges of concentration.

A map of K^+/Cl^- molar ratios in the Upper Floridan aquifer (fig. 21B) shows characteristically low ratios (<0.06) in coastal areas and in south Florida where seawater is present in the aquifer; the lowest ratios are near 0.02 (the ratio in seawater) where both Cl^- and K^+ concentrations are highest in the Upper Florida. Low K^+/Cl^- ratios also occur in Volusia County, Fla., and in outcrop areas of northwestern Florida, southern Alabama, and north-central Georgia. The ratios in these areas are less than 0.14, the average ratio in precipitation over the region (table 1). The loss of K^+ relative to Cl^- is probably due to uptake of K^+ by plants, as K^+ and Cl^- concentrations in ground water are not much more than average values for precipitation in these areas. Higher K^+/Cl^- ratios occur throughout most of central and panhandle Florida, and in southern Georgia; in these

areas, evaporation increases both K^+ and Cl^- concentrations in water recharging the system, but the K^+/Cl^- ratios are nearer values for precipitation. The highest K^+/Cl^- ratios occur in east-central Georgia and in western panhandle Florida. As previously discussed, ion exchange is probably responsible for the relative increase in K^+ concentrations in the panhandle area. In east-central Georgia, dilute water may be leaking into the Upper Floridan aquifer from underlying sand aquifers; this recharge could slightly increase K^+ concentrations and raise K^+/Cl^- ratios in the Upper Floridan. The high K^+/Cl^- ratios in southwestern Georgia occur in an area of extensive agriculture development and where the confining unit overlying the Upper Floridan is thin; surficial recharge enters the aquifer containing increased concentrations of K^+ due to leaching of fertilizers.

Potassium concentrations in most water from the Upper Floridan aquifer are low, because K^+ concentrations in precipitation are very low and K^+ -bearing minerals in the aquifer are present only in trace amounts. Aluminosilicate minerals containing potassium (glauconite, potassium feldspar, and micas?) that are present in trace quantities can dissolve and add very small amounts of K^+ to ground water. Unlike Na^+ , K^+ does not occur as a trace constituent in calcite or dolomite, owing to the much larger size of the K^+ ion. Except for western panhandle Florida, K^+ concentrations are therefore closely related to the amount of seawater (as indicated by chloride concentrations) in the Upper Floridan aquifer. In the western panhandle area, ion exchange (2K^+ for Ca^{2+} or Mg^{2+}) increases K^+ concentrations by about 5 mg/L. As discussed in a later section, silicate weathering is not considered a primary source of K^+ (or Na^+) in this part of the system, because dissolved-silica concentrations do not increase, and silica cements (or grain overgrowths) have not been reported in well cuttings or cores from the area.

CHLORIDE

The second important anion in water in the Floridan aquifer system is chloride (Cl^-). The principal source of Cl^- is seawater; natural salts of Cl^- (evaporite minerals) are not present in the system, and addition of Cl^- salts to remove road ice is not common practice in the region. The data in table 1 indicate that recharge water should be very low in Cl^- concentration, and Cl^- concentrations in the Upper Floridan aquifer are nearly zero in recharge areas. In nearly all coastal areas, wells that fully penetrate the Upper Floridan yield water having Cl^- concentrations that approach that of seawater, about 19,500 mg/L. Plate 6 depicts the general distribution of Cl^- concentration in water produced from the Upper Floridan aquifer. The map shows higher Cl^- concentrations in