DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 86-41
SHEET 2 OF

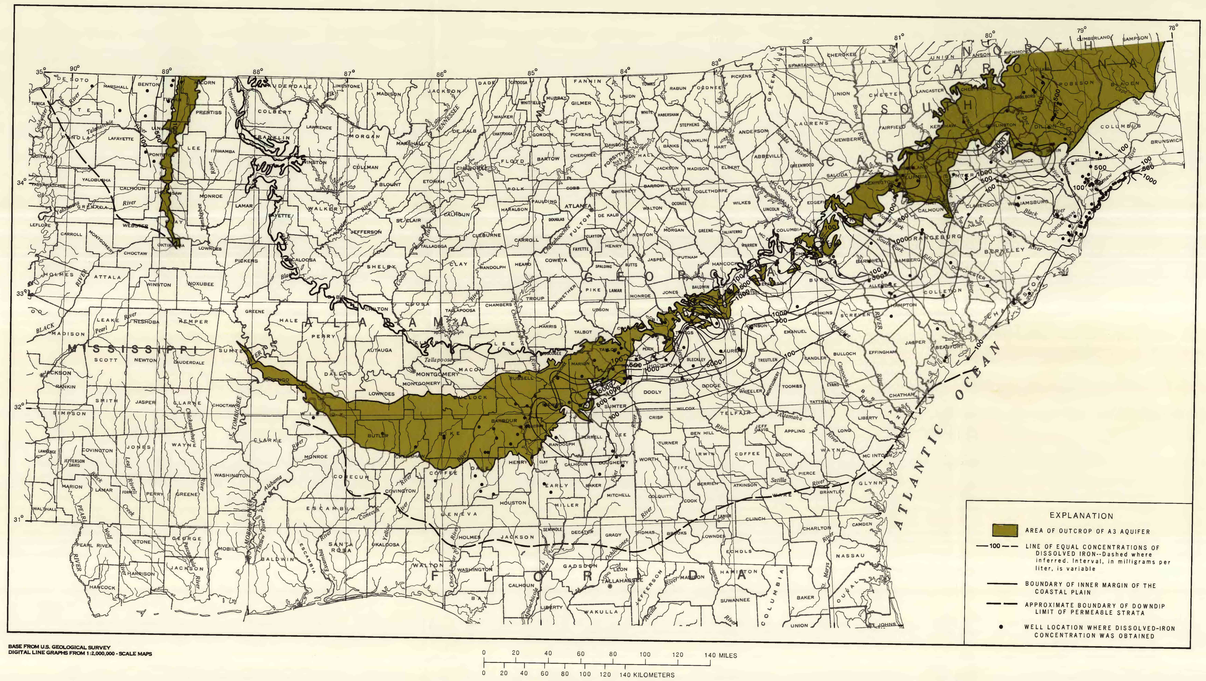

Figure 4.--Dissolved iron in the A3 aquifer.

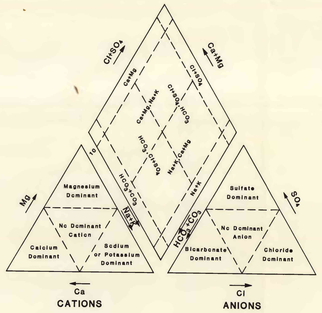

Figure 5.--Modified Piper diagram depicting the classification scheme for hydrochemical facies.

Dissolved Iron

Concentrations of dissolved iron exceed 5,000 µg/L in ground waters in many parts of the A3 aquifer. Such elevated concentrations of dissolved iron are found in narrow bands near the outcrop areas of the aquifer in Georgia and South Carolina (fig. 4). Lee (1985) demonstrated that dissolved iron is removed from ground water by precipitation of an iron-bearing solid phase (siderite) in the aquifer downgradient from the areas of elevated concentration. Concentration of dissolved iron increases farther downgradient as iron solubility increases owing to increasing chloride content of the ground water. Dissolved-iron data are poorly distributed throughout the study area and are generally not accurate within normal quantitative limits of ± 5 percent, especially for waters containing elevated concentrations of iron. Because a coarse contour interval was used (100-500-1,000-5,000 µg/L), estimation of local concentrations of dissolved iron throughout the study area should be made with caution.

Concentrations of dissolved iron in the A3 aquifer in northeastern Mississippi approach 1,000 µg/L then appear to diminish farther downgradient. Available dissolved-iron data in Alabama were few and generally did not exceed 100 µg/L. Bands of elevated concentrations of dissolved iron (up to 5,000 µg/L) occur near outcrop areas in Georgia and South Carolina. Concentrations of dissolved iron diminish to less than 100 µg/L downgradient from these bands. Concentrations of dissolved iron in recharge areas in Lexington and Richland Counties, South Carolina, approach 500 µg/L and may be due to high-acidity ground water from pyrite (FeS_2) oxidation. Substantial concentrations of dissolved sulfate present in water samples from these areas support this hypothesis.

Hydrochemical Facies

Hydrochemical facies refers to a classification of natural waters based on the dominance of major cations and anions (Back, 1961). The diagram from Piper (1953) shows graphically the major ion chemistry of water samples (fig. 5). The dominance criterion is determined from the percentage of milliequivalents of each major cation (calcium, magnesium, and sodium plus potassium trilinear) and each major anion (chloride, sulfate, and bicarbonate plus carbonate trilinear) in solution. Thus in a calcium-bicarbonate dominated water, the calcium ion is greater than 50 percent of the total milliequivalents of cations, and the bicarbonate (plus carbonate) ion is greater than 50 percent of the milliequivalents of total anions. This differs slightly from the nomenclature of Back (1961). Each equivalence percent would plot in the appropriate dominance field of the trilinear parts of the diagram in figure 5, taking its designations from the specific dominance field. A multiple ion designation in decreasing order of dominance is used for water containing no cations or anions that individually amount to 50 percent or more of the total cations or anions. For example, a magnesium-calcium-chloride-sulfate water is a water containing magnesium ion in greater concentration than calcium ion, and chloride ion in greater concentration than sulfate ion; however, none of the ions are greater than 50 percent of the total milliequivalents of cation or anions. Each equivalence percent of this water would plot in the no dominant cation and no dominant anion fields of the trilinear parts of the diagram in figure 5, with the order of designation coming from the quadrilinear part of the diagram. The locations of the various cation-anion dominances of the water samples have been mapped to show areal distribution of the hydrochemical facies.

Three hydrochemical facies (fig. 6) occur most frequently in the A3 aquifer; calcium bicarbonate, sodium bicarbonate, and sodium chloride. Near the recharge areas, facies are variable or there is no dominate facies owing to low dissolved-solids concentrations. In very dilute ground-water solutions, analytical errors or minor changes in the chemistry of recharge (rainfall) may cause apparent 'shifts' in the hydrochemical facies that are unrelated to flow and general water chemistry in the A3 aquifer. Thus, concentrations of low dissolved solids may permit a fourth classification in the recharge areas, variable or no dominant facies. Downgradient, the concentrations of dissolved solids increase, and sodium bicarbonate and calcium bicarbonate are the prevalent facies as a result of water-rock chemical interactions (Lee, 1985). Farther downgradient, concentrations of dissolved solids exceed 500 mg/L, and sodium and chloride are commonly the dominate solutes from mixing of freshwater with saline waters known to exist in the downgradient parts of the aquifer. In northeastern Mississippi, ground water in recharge areas is dominated by calcium bicarbonate facies, but evolves downgradient to sodium bicarbonate facies. Eventually, the freshwater mixes with saline water present in the deeper downgradient part of the aquifer, establishing the sodium chloride facies. Large areas of calcium bicarbonate facies in eastern Alabama and western Georgia may be due to water from carbonate aquifers or calcareous sand in overlying aquifers. An area dominated by sodium bicarbonate facies extends along the Alabama-Georgia State line from Barbour County, Alabama, to Early County, Georgia, and probably results from upward movement of sodium bicarbonate dominated ground water in deeper aquifers. In coastal South Carolina, ground water is sodium bicarbonate dominated, owing to the chemical evolution of high bicarbonate concentrations (Foster, 1950). Variable or no dominant facies, and calcium bicarbonate facies typically are observed near outcrop areas.

Sodium chloride facies occur in the downgradient parts of the study area, and extend updip approximately to the 1,000 mg/L lines of concentrations of dissolved solids published for Georgia by Brown and others (1979) and for Mississippi by Gandl (1982).

CONCLUSIONS

Water-quality maps of ground water in the A3 aquifer in the Southeastern Coastal Plain show the spatial distributions of concentrations of dissolved solids, dissolved chloride, and dissolved iron, and hydrochemical facies. Concentrations of dissolved solids and dissolved chloride progressively increase from outcrop areas toward downgradient areas, owing to water-rock chemical interactions and mixing with saline waters in the deeper parts of the A3 aquifer. Elevated concentrations of dissolved iron (more than 5,000 µg/L) occur in narrow bands which are roughly parallel and near the recharge areas. Farther downgradient, however, concentrations of dissolved iron decrease, but may increase again as ground water becomes more saline.

Three major hydrochemical facies characterize ground water in the A3 aquifer – calcium bicarbonate facies in the supragelant recharge areas, sodium bicarbonate facies in waters that contain concentrations of dissolved solids less than 500 mg/L downgradient from the recharge areas, and sodium chloride facies in the deep downgradient parts of the aquifer. In the recharge areas, ground-water solutions are so dilute (concentrations of dissolved solids < 50 mg/L) that a variable facies or no dominant facies condition may occur.

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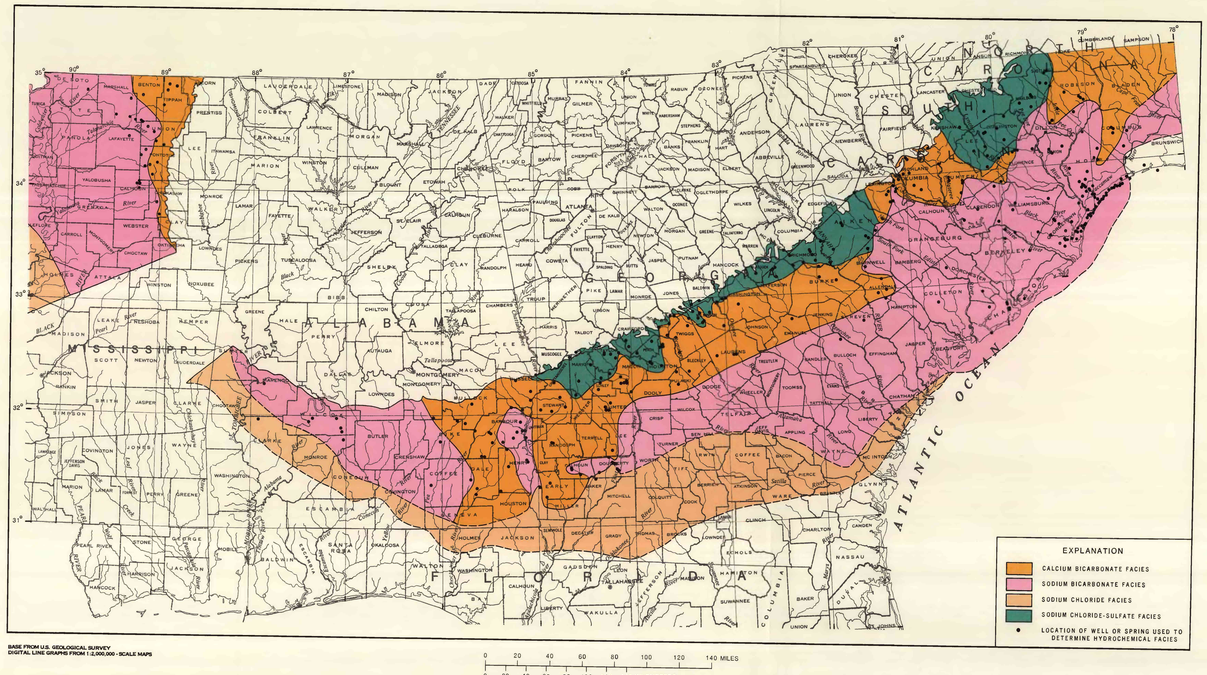

Figure 6.--Hydrochemical facies in the A3 aquifer.

WATER-QUALITY MAPS FOR THE UPPER CRETACEOUS AND LOWER TERTIARY AQUIFER IN THE SOUTHEASTERN COASTAL PLAIN OF MISSISSIPPI, ALABAMA, GEORGIA, SOUTH CAROLINA, AND SOUTHEASTERN NORTH CAROLINA

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