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WATER-QUALITY RECONNAISSANCE OF CRETACEOUS AQUIFERS IN THE SOUTHEASTERN COASTAL PLAIN

By Gerald L. Feder and Roger W. Lee

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CONTENTS

ILLUSTRATIONS

TABLES

WATER-QUALITY RECONNAISSANCE OF CRETACEOUS AQUIFERS IN THE SOUTHEASTERN COASTAL PLAIN

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ABSTRACT

A reconnaissance sampling program was initiated to obtain data on ground-water quality in Cretaceous aquifers in the Southeastern Coastal Plain of North Carolina, South Carolina, Georgia, and Alabama. The preliminary data from eight wells indicate some of the waters have dissolved-solids concentrations less than 100 milligrams per liter, and all ground waters have magnesium concentrations less than 4 milligrams per liter. Concentrations of trace constituents generally were less than 50 micrograms per liter, except for iron and manganese which were variable from sample to sample. Iron concentrations ranged from 4 to 1,800 micrograms per liter, and manganese concentrations ranged from less than 1 to 100 micrograms per liter. Dissolved organic-carbon concentrations in the ground waters generally were large, ranging from 0.4 to 6.0 milligrams per liter with a geometric mean of 2.2 milligrams per liter.

Waters in the Tuscaloosa Formation and equivalent formations in the northern part of the study area generally are saturated or supersaturated with respect to quartz (chalcedony) and lateritic minerals indicative of a weathered (leached) environment. In the southern part of the area, geologic time equivalent aquifer materials (Upper Cretaceous) contain more clays, marls, and sulfide minerals, which is reflected in the greater dissolved-solids concentrations of the waters.

INTRODUCTION

Although ground waters of the Southeastern Coastal Plain have been widely developed and studied for many years, chemical data on these waters are incomplete by current standards. A reconnaissance sampling program of the area was completed during the spring of 1980, to aid in planning a detailed geochemical study for the Regional Aquifer Systems Analysis (RASA) of the Southeastern Coastal Plain. Eight water-supply wells yielding water from Cretaceous aquifers (mostly from the Tuscaloosa Formation in Alabama, or formations that are geologic time equivalents to the Tuscaloosa Formation elsewhere in the study area) were sampled for major and minor chemical constituents, radiochemicals, dissolved gases, and dissolved organic carbon. Results of this reconnaissance sampling program are presented in this preliminary report, in addition to preliminary geochemical interpretation of the data.

HYDROGEOLOGY

The Southeastern Coastal Plain (not including Florida) is underlain by unconsolidated clay, sand, gravel, and consolidated limestone. The deposits, ranging in age from Cretaceous to Holocene form an arc extending from southern Virginia through the Carolinas, Georgia, Alabama, and into eastern Mississippi (fig. 1) (Cederstrom and others, 1979). The sands are thin at the Fall Line and thicken seaward; this also is the direction of a dip, which is slight. Cretaceous sedimentary rocks are exposed near the Fall Line, providing a long narrow area of recharge to the aquifers.

Rainfall and, occasionally, snowmelt recharge the Cretaceous aquifers in the outcrop areas near the Fall Line and percolate downgradient in the general direction of the coastal areas (Brown and others, 1979). The samples collected for this study are usually near the recharge area.

WATER CHEMISTRY

A previous study (Cederstrom and others, 1979) has indicated that waters in the Cretaceous aquifers near the recharge areas contain less than 100 mg/L (milligrams per liter) of dissolved solids and has very low hardness, generally less than 50 mg/L of hardness as $CaCO_3$ (calcium carbonate). Previous analyses of these ground waters generally have been limited to major cations and anions, without consideration of numerous trace constituents, radiochemicals, dissolved gases, and dissolved-organic carbon.

Wells in two counties of each Southeastern Coastal Plain State--North Carolina, South Carolina, Georgia, and Alabama--were chosen for sampling (fig. 1). All the wells sampled were either used for municipal water supplies or military-base water supplies, and were screened in one or more producing zones. Well logs were obtained for each well sampled. All samples were collected at the well, before treatment, after pumping for at least 15 minutes. Alkalinity, specific conductance, pH, and water-temperature values were determined at the sampling site using methods described by Wood (1976). Water samples for laboratory analysis were collected and shipped to U.S. Geological Survey laboratories in Doraville, Georgia, or Denver, Colorado. Gas samples were collected at six of the eight wells and shipped in special collection vessels (Hobba and others, 1977) and analyzed in Reston, Virginia, by D. L. Fisher of the U.S. Geological Survey.

A statistical summary of the data collected for this reconnaissance study is shown in table 1. The complete data set is given in table 2. Some of the wells sampled yield water having among the lowest dissolved-solids concentrations of any ground waters in the United States. These waters may be characterized as acidic, soft, and containing small concentrations of dissolved solids and trace elements (except for iron and manganese) but these waters have relatively high dissolved-organic-carbon concentrations. These waters

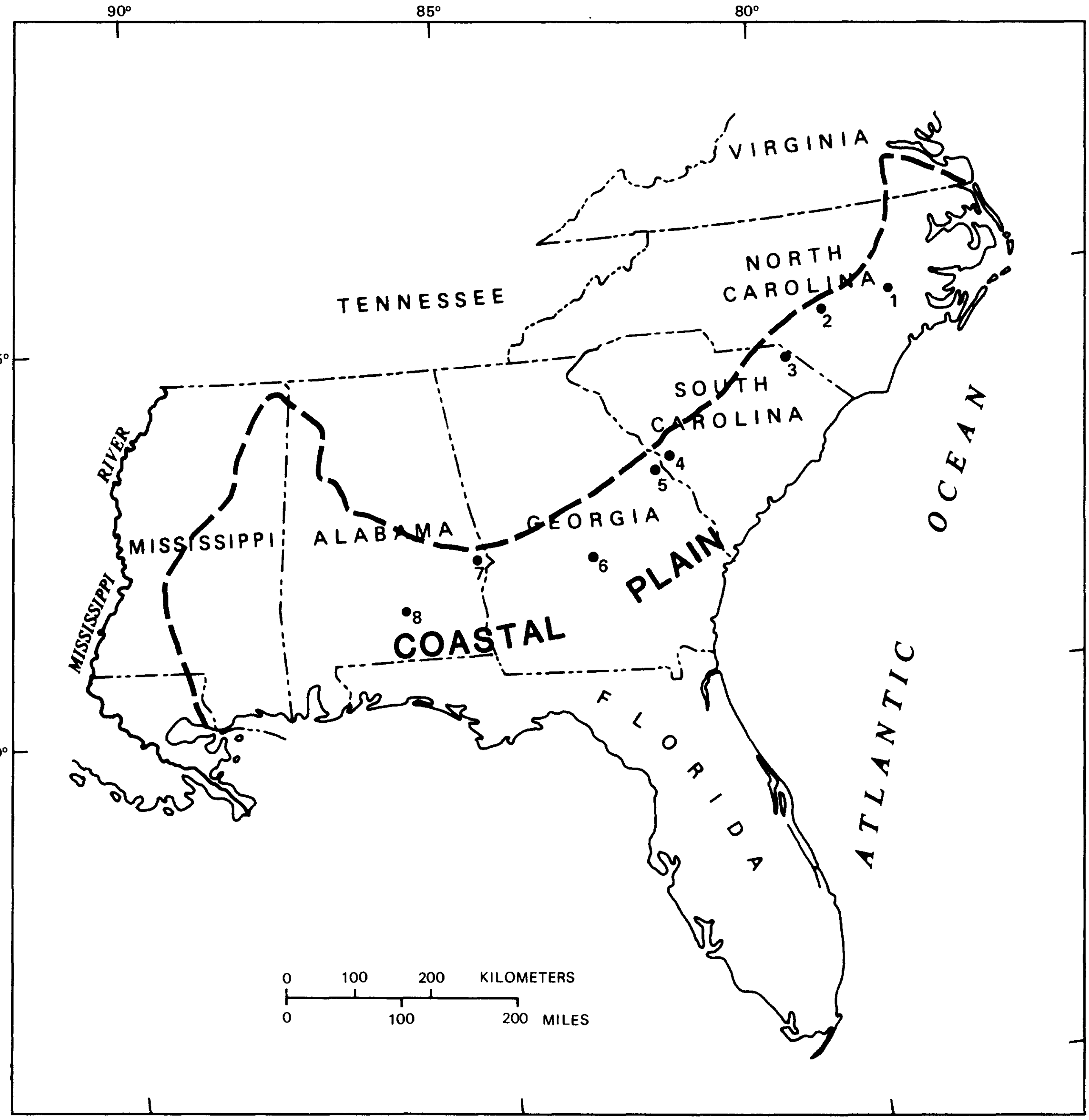

Figure 1.-- Location of sample sites in the Southeastern Coastal Plain region.

Table 1.--*Summary statistics for water quality in the Southeastern Coastal Plain aquifers from North Carolina to Alabama*

[GM = geometric mean; GD = geometric deviation; m = meters; mg/L = milligrams per liter; μg/L = micrograms per liter; pCi/L = picocuries per liter; °C = degrees Celsius.]

	Parameter			Parameter	
	GM	GD		GM	GD
Depth (m)	89	0.4	Aluminum (μg/L)	24	0.3
Specific conductance[1/]			Arsenic (μg/L)	1	0.0
(Laboratory)	127	0.6	Barium (μg/L)	49	0.5
pH[2/]	6.3	1.4	Beryllium (μg/L)	<0.7	---
Temperature (0°C)	19.6	0.04	Boron (μg/L)	27	0.3
			Cadmium (μg/L)	5.5	0.2
Alkalinity (mg/L)	10	1.8	Chromium (μg/L)	<10	---
Hardness (mg/L)	28	0.6	Lead (μg/L)	2.5	0.5
			Iron (μg/L)	47	1.1
Calcium (mg/L)	7.1	0.7	Manganese (μg/L)	10	1.0
Magnesium (mg/L)	1.3	0.3	Molybdenum (μg/L)	<10	---
Potassium (mg/L)	1.1	0.2	Selenium (μg/L)	<1	---
Sodium (mg/L)	8.5	0.6	Strontium (μg/L)	55	0.9
			Thallium (μg/L)	<1	---
Bicarbonate (mg/L)	12	1.8	Zinc (μg/L)	9.0	1.1
Chloride (mg/L)	6.3	0.4			
Fluoride (mg/L)	0.1	0.4	Radium-226 (pCi/L)	0.37	0.5
Nitrate (mg/L)	0.2	1.4			
Phosphate (mg/L)	0.03	0.7	Dissolved organic		
Silica (mg/L)	17	0.2	carbon (mg/L)	2.2	0.3
Sulfate (mg/L)	8.0	0.7			

1/ Specific conductance (micromhos per centimeter at 25°C).

2/ pH in standard units, arithmetic statistics.

Table 2.--*Chemical analysis of ground water from the Southeastern Coastal Plain region*

[Units: A - Black Creek Formation; B - Tuscaloosa equivalents; C - Upper Cretaceous Series; D - Tuscaloosa Group; m = meter; mg/L = milligrams per liter; µg/L = micrograms per liter; °C = degrees Celsius; µmho/cm = micromhos per centimeter at 25° Celsius; pCi/L = picocuries per liter; L/s = liters per second]

Variable / Sample number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Location	Wayne County, North Carolina	Cumberland County, North Carolina	Marlboro County, South Carolina	Barnwell County, South Carolina	Richmond County, Georgia	Dodge County, Georgia	Russell County, Alabama	Crenshaw County, Alabama
Depth of well below land surface (m)	27	26	43	244	111	162	198	152
Discharge (L/s)	9	9	19	11	9	63	13	32
Formation	A	B	B	B	C	C	D	C
Alkalinity (mg/L as $CaCO_3$)	74	44	0	7	72	130	143	260
Aluminum (µg/L)	20	20	100	40	20	<1	20	20
Arsenic (µg/L)	1	1	1	1	1	1	1	1
Barium (µg/L)	80	110	220	40	9	120	40	10
Beryllium (µg/L)	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate (mg/L)	90	54	0	8	2	160	174	312
Boron (µg/L)	20	20	20	20	20	20	150	40
Bromide (µg/L)	-	200	100	700	140	-	<100	<100
Cadmium (µg/L)	8	5	6	7	8	8	10	5
Calcium (mg/L)	21	6.5	1.8	3.1	0.5	50	65	5.3
Chloride (mg/L)	10	2.5	20	5.1	1.6	2.6	13	20
Chromium (µg/L)	<10	<10	<10	<10	<10	10	10	<10
Cobalt (µg/L)	4	7	9	5	4	<3	<3	<3
Copper (µg/L)	<10	<10	23	22	<10	<10	<10	<10
Dissolved organic carbon (mg/L)	1.3	4.1	6.0	1.2	4.9	0.4	1.9	2.3
Dissolved solids at 180°C (mg/L)	136	87	75	28 (calculated)	-	168	299	357

Table 2.--*Chemical analysis of ground water from the Southeastern Coastal Plain region*--Continued

Variable								
Sample number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride (mg/L)	0.1	0.2	<0.1	0.1	<0.1	0.1	0.1	0.1
Hardness - Total (mg/L)	66	25	13	11	3	130	170	23
Iodide (µg/L)	-	10	60	10	30	-	-	10
Iron (µg/L)	1100	1800	32	4	6	4	360	11
Lead (µg/L)	2	5	5	27	1	1	1	1
Lithium (µg/L)	14	<4	<4	<4	<4	4	<4	8
Magnesium (mg/L)	3.3	2.0	1.9	0.84	0.35	1.6	0.58	2.2
Manganese (µg/L)	95	55	100	17	2	3	24	<1
Mercury (mg/L)	<0.1	<0.1	0.3	0.2	<0.1	<0.1	<0.1	<0.1
Molybdenum (µg/L)	<10	<10	<10	<10	<10	<10	<10	<10
Nitrate total as NO_3 (mg/L)	0.53	0.04	19	7.1	0.31	0.75	<0.01	<0.01
pH, standard units (onsite)	6.3	6.5	4.4	5.3	4.8	7.4	7.4	8.3
Phosphate total as PO_4 (mg/L)	0.28	0.03	<0.01	0.03	0.03	0.03	<0.01	0.09
Potassium (mg/L)	3.7	3.8	1.4	0.5	0.2	1.2	3.8	2.2
Selenium (µg/L)	<1	<1	<1	<1	<1	<1	<1	<1
Silica (mg/L)	23	30	9.6	8.0	19	29	19	12
Sodium (mg/L)	13	10	14	3.7	1.0	2.0	28	74
Specific conductance (laboratory) (mho/cm at 25°C)	202	106	116	43	9	256	466	586
Strontium (µg/L)	110	55	40	10	2	130	1100	490
Sulfate (mg/L)	18	13	0.6	2.4	0.7	3.0	78	32
Temperature (°C)	18.0	17.9	18.4	19.0	19.7	20.5	21.4	22.8
Thallium (µg/L)	<1	<1	<1	<1	<1	<1	<1	<1
Vanadium (µg/L)	<6	10	<6	<6	<6	7	7	<6
Zinc (µg/L)	140	74	59	12	29	4	<4	<4
Potassium-40 (pCi/L)	2.8	2.8	1.0	0.4	0.2	0.9	2.8	1.6
Radium-226 (pCi/L)	0.2	0.2	0.8	1.4	0.8	0.2	0.9	<0.1
Gross Alpha--uranium-natural (pCi/L)	<1.0	<0.5	3.9	2.9	0.2	<0.5	<1.8	<2.0
Gross Alpha--uranium-natural (µg/L)	<0.5	<0.7	5.8	4.3	1.2	<0.7	<2.7	<3.0

Table 2.--*Chemical analysis of ground water from the Southeastern Coastal Plain region*--Continued

Variable								
Sample number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gross Beta--cesium-137 (pCi/L)	3.2	3.8	4.3	1.4	1.1	0.7	4.9	<1.9
Gross Beta--strontium-90 (pCi/L)	3.0	3.5	4.1	1.3	1.0	0.7	4.4	<1.8
Dissolved O_2 (mg/L)	<.01	-	3.3	9.2	7.9	3.2	<.01	-
Dissolved CO_2 (mg/L)	65	-	56	31	31	8.6	9.2	-
Dissolved CH_4 (mg/L)	0.50	-	-	-	-	-	0.004	-
Dissolved Ar (mg/L)	0.80	-	0.44	0.77	0.70	0.95	1.01	-
Dissolved N_2 (mg/L)	21	-	11	21	18	24	26	-

generally are obtained from the Tuscaloosa Formation and equivalent rocks. A few of the samples had higher dissolved-solids concentrations, but these were associated with aquifers containing marls or clays. It is interesting to note that even the harder waters in this region have very low magnesium concentrations; the maximum magnesium concentration was 3.3 mg/L and the minimum concentration was 0.35 mg/L.

Two of the water samples contained more than 1,000 µg/L (micrograms per liter) of iron, and three of the samples contained more than 50 µg/L of manganese. Many rural and municipal water users in the study area report problems with high concentrations of iron or manganese in their ground-water supplies, but the problem appears to be nonuniform, and as the data in table 2 indicate, some ground waters have less than 20 µg/L of iron and manganese. None of the waters were found to exceed any National Interim Primary Drinking Water Regulations established by the U.S. Environmental Protection Agency (1976).

Concentrations of solutes in any ground water are largely controlled by aquifer mineralogy and solution chemistry. Although the general lithology of these aquifers is known, the proportions of minerals and their chemical stoichiometry is not known. Keller (1981) points out that the Southeastern Coastal Plain soils and shallow aquifers can be described as comprising a "leached" environment characterized by the predominance of ". . . quartz and other resistant sand-sized minerals, and lateritic clay compounds . . ." To determine which minerals were precipitating or no longer dissolving, and which minerals were still dissolving, saturation indices (SI) for the ground-water samples with respect to a large number of minerals were calculated using the computer program WATEQF (Plummer and others, 1976). The WATEQF analysis showed that most of the ground waters sampled in this study were undersaturated (negative SI) with respect to most silicate, sulfide, carbonate, and evaporite minerals, and were saturated (zero SI) or supersaturated (positive SI) with respect to quartz (chalcedony) and lateritic minerals. This relationship is more pronounced in the northern part of the Cretaceous aquifers. A facies change in the Tuscaloosa Formation and its stratigraphic equivalents in southwestern Georgia and Alabama results in more clays and carbonate minerals occurring in this part of the aquifer. Water from wells 6, 7, and 8 probably had contact with a less thoroughly leached environment, and therefore were saturated with respect to more complex silicate minerals and carbonates. These relationships are shown for a few selected minerals in figure 2. It should be noted that waters from the northern part of the Tuscaloosa Formation (samples 1-5) are probably in contact with the minerals shown, while the other ground waters (samples 6-8) are in contact with complex alumino-silicate minerals, iron sulfides, and carbonates. The minerals shown in figure 2 may occur as precipitates in the aquifer matrix after the above-mentioned minerals undergo complex dissolution processes.

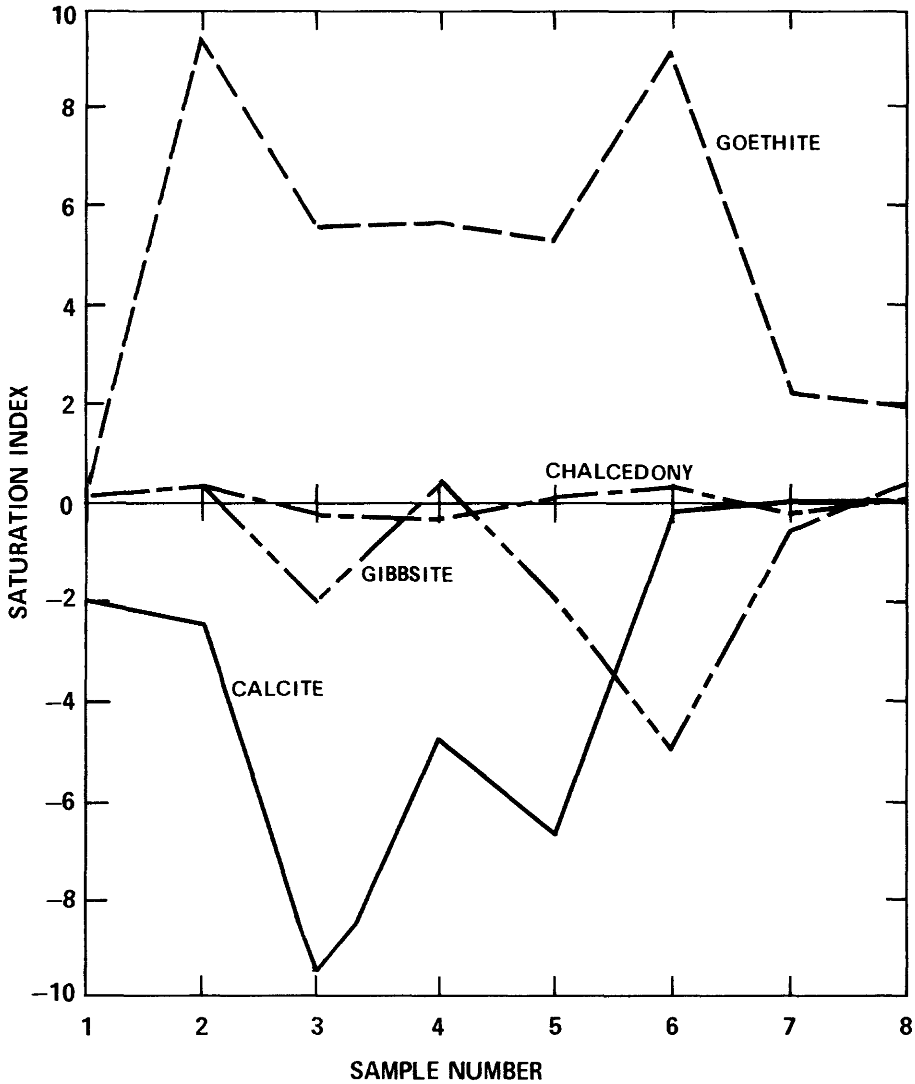

Figure 2.-- Saturation indices of ground-water samples with respect to selected minerals.

SUMMARY

Results of a reconnaissance-sampling program to obtain preliminary data on ground-water quality in the Southeastern Coastal Plain of North Carolina, South Carolina, Georgia, and Alabama, indicate some of the waters have dissolved-solids concentrations less than 100 milligrams per liter, and all ground waters have magnesium concentrations less than 4 milligrams per liter. None of the waters were found to exceed any National Interim Primary Drinking Water Regulations established by the U.S. Environmental Protection Agency (1976), but some of the ground waters do contain objectionable concentrations of iron and manganese.

Most of the ground waters in this area are saturated or super-saturated with respect to quartz and lateritic minerals indicative of a highly weathered (leached) environment.

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