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ABSTRACT

The concentrations of uranium, lanthanum, and 6 other elements in the suspended solids and the concentrations of uranium and 5 other elements in solution from river waters from 66 sites in the southeastern United States are compared with published ground-water and stream-sediment elemental concentrations from within the drainage basin above each sample site. The ground-water and stream sediment element concentrations represent the National Uranium Resource Evaluation data set of about 12,000 sampling locations in southeastern U. S. Elemental ratios show that most of the uranium and lanthanum transported in the suspended solids is in monazite. However, no relationship is found between the amount of monazite in suspension and the amount of monazite in the stream sediments. The amount of uranium in solution is positively related to the soluble aluminum concentration in the Piedmont rivers and to the soluble manganese and total suspended solids in the Coastal Plain rivers. Piedmont rivers have more monazite and total suspended solids in transport than Coastal Plain rivers. Coastal Plain rivers have higher concentrations of soluble uranium.

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INTRODUCTION

The purpose of this study is to compare elemental analyses of river waters from the southeastern U. S. with existing data on elemental concentrations within the river drainage basins to determine how uranium and lanthanide elements are transported. The National Uranium Resources Evaluation (NURE) program published analyses of stream sediments and ground waters used in this study to characterize each drainage basin (Fay et al, 1981; Cook et al, 1982; and Sargent et al, 1982). The river-water analyses are being published by the Savannah River Laboratory (SRL) (Fay, 1983).

The National Uranium Resources Evaluation Program

The NURE program was established to evaluate domestic uranium resources in the continental United States and to identify areas favorable for uranium exploration. The program included a hydrogeochemical and surface sediment reconnaissance of much of the U. S. and generated data bases of elemental analyses of stream sediments, stream waters, and ground waters.

The NURE stream-sediment and ground-water samples from the southeastern United States were collected and analyzed by the Savannah River Laboratory. Figures 1 and 2 illustrate the sampling of stream sediments and ground waters in North and South Carolina. Nominal ground water and stream sampling density varies from 13 to 25 square kilometers per site. The study area

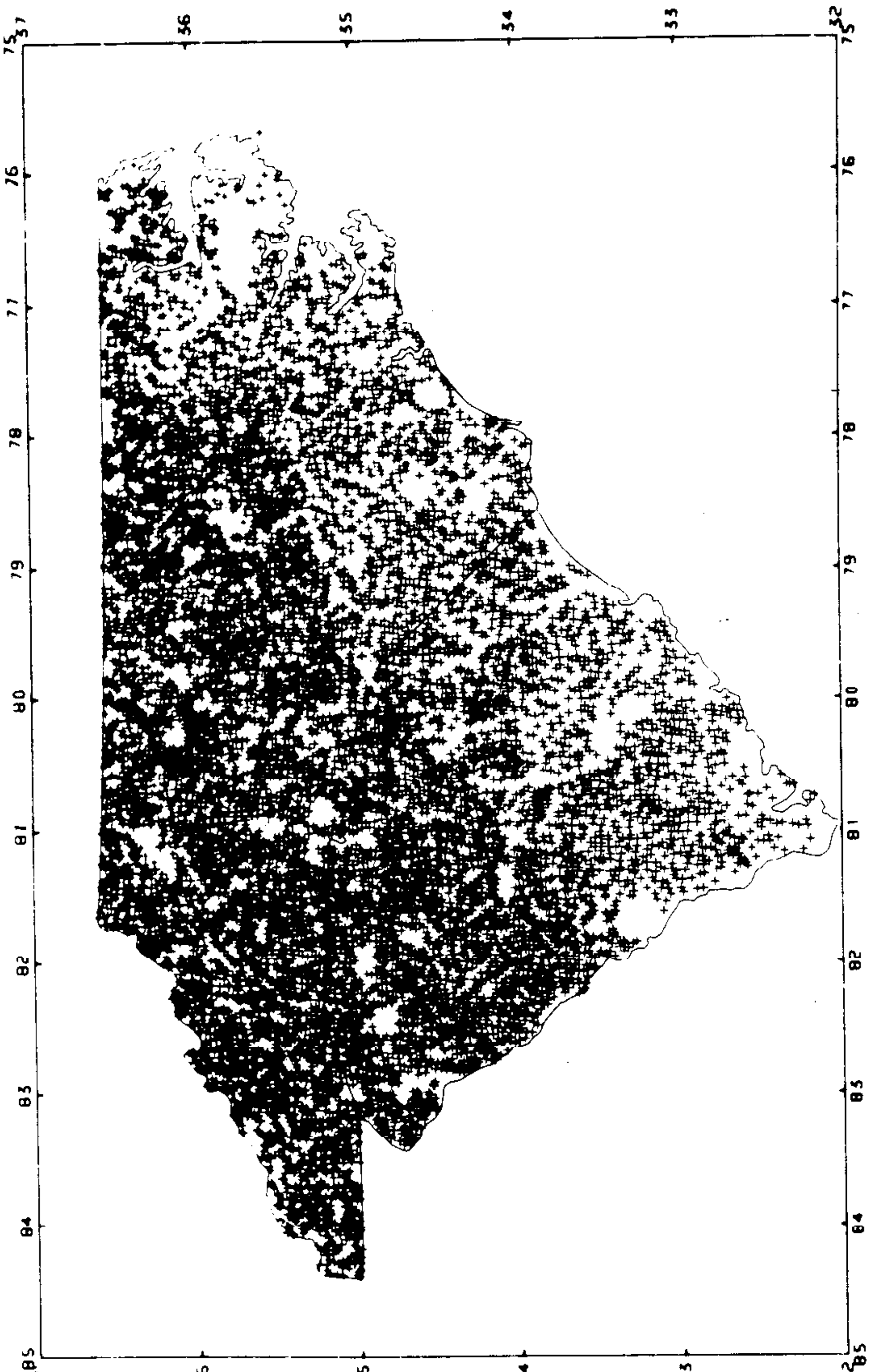

FIGURE 1. Sediment Sample Sites

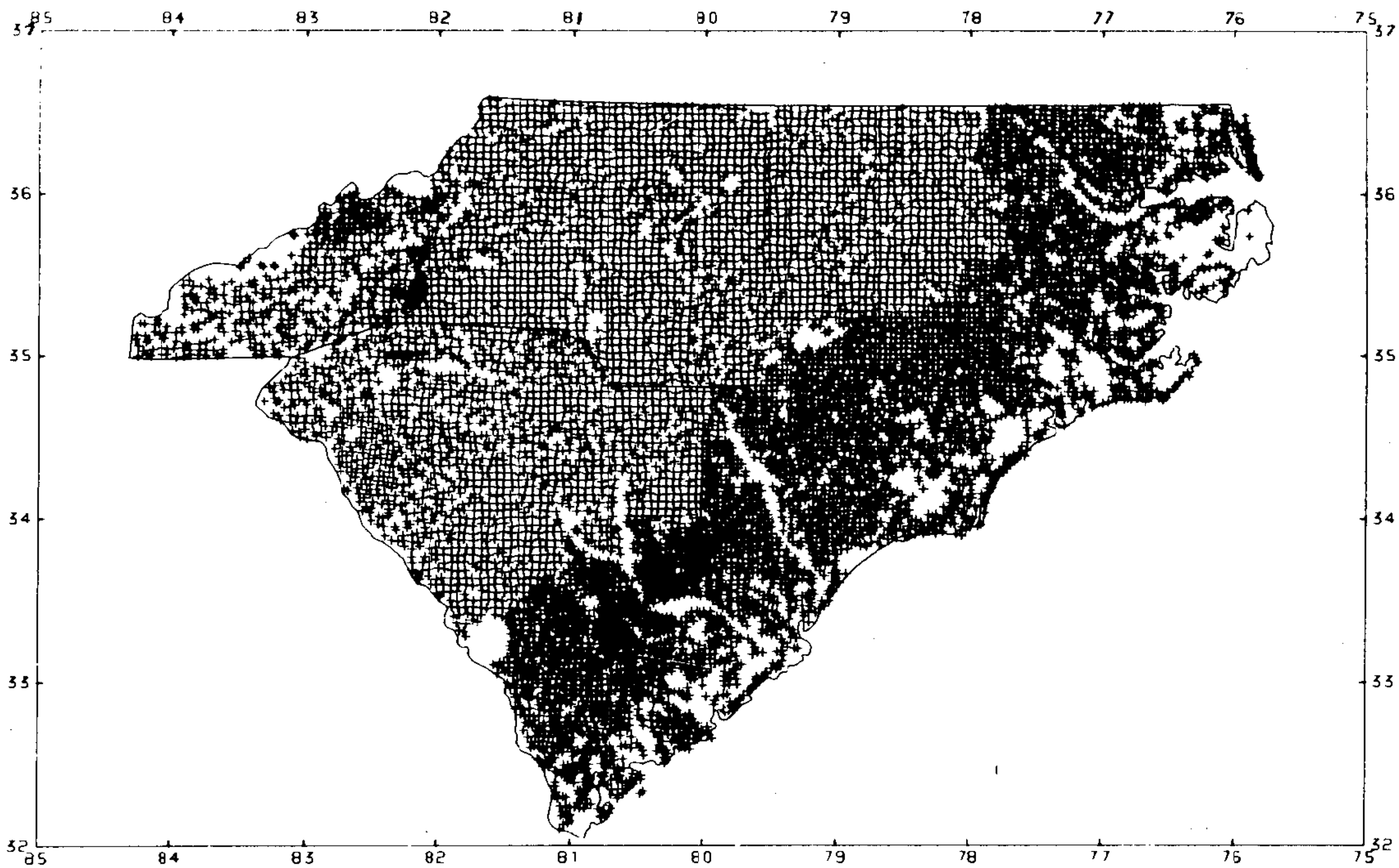

FIGURE 2. Ground Water Sample Sites

has 11,978 stream-sediment samples and 8,769 ground-water samples. In the Piedmont geologic province, stream sampling is generally denser than ground-water sampling while in the Coastal Plain the converse is true. The streams sampled drain from 2 to 15 square kilometers. The stream-sediment samples consist of 1.5 grams of material passing through a 150 micron sieve. In most areas 5 to 10 percent of the ground-water samples were collected from springs with the remaining samples collected from wells with mean depths of around 100 feet. The ground-water samples consist of one liter of water passed through a 0.8 micron filter and mixed with anion-cation exchange resin. The resin was dried and analyzed. Neutron activation was used to analyze all the samples.

River Sampling

River-water samples were collected from 66 sites in the southeastern U. S. (Figure 3). At each site one liter of water was passed through a 0.8 micron filter and mixed with anion-cation exchange resin. The filters and resins were analyzed using the SRL NURE methods. Water quality measurements were made at each site. The soluble fraction was not analyzed from 11 of the sites.

The drainage basin above each river-water collection site was characterized. By using digitized boundaries of the river drainage basins provided by the National Water Data Exchange, the NURE stream-sediment and ground-water samples above each river sample site were identifed. It is realized that ground waters

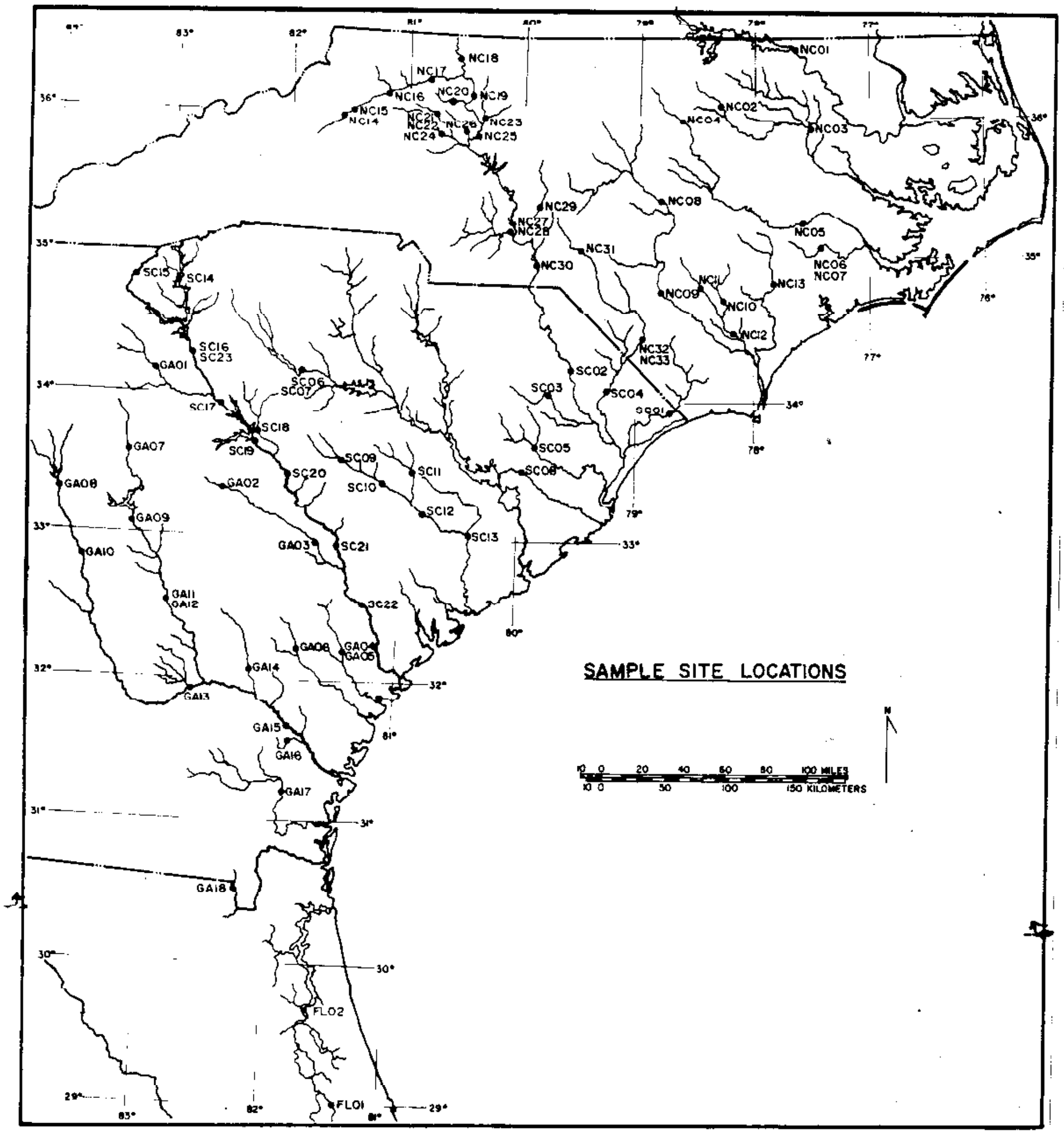

FIGURE 3. Sample Site Locations

within a drainage basin do not necessarily drain into the river which drains the streams of the drainage basin. A data set was generated of the mean elemental concentrations and water quality measurements from the stream sediments and ground-water samples in the drainage basin above each river site. The percentage of area covered by Coastal Plain sediments within the drainage basin above each river sample site was estimated. The rivers were divided into three classes; 23 Coastal Plain rivers which drain at least 80% Coastal Plain material, 36 Piedmont rivers which drain less than 20% Coastal Plain material, and 7 mixed rivers. The drainage basins draining the Blue Ridge province are included as Piedmont Rivers.

Geology and Topography

The study area consists of the unmetamorphosed Coastal Plain sediments and the crystalline Piedmont and Blue Ridge provinces. The Coastal Plain consists of Cretaceous to Quaternary sands, clayey sands, marls, and limestones deposited in subaerial, near-shore, and continental shelf environments. The land surface generally slopes to the southeast with low rolling hills bordering the Piedmont and flat low-lying areas elsewhere. The soils are generally highly weathered, particularly in the upland areas near the Piedmont. The Coastal Plain contains large aquifer systems which are recharged near the Piedmont and flow towards the coast.

The Piedmont and Blue Ridge provinces consist of low to high grade metamorphosed sedimentary, volcanic and igneous rocks, and unmetamorphosed intrusive rocks and Triassic sediments. The metamorphosed rocks consist of Grenville age gniesses and late Precambrian or lower Paleozoic island arc volcanics and sediments. These rocks were intruded by granitic to ultramafic rocks of upper Paleozoic age. There are several grabens filled with unmetamorphosed clastic sediments of Triassic age. The Piedmont consists of rolling hills with generally gentle slopes on the uplands and steeper slopes near the streams and rivers with total relief commonly about 30 meters. From 10 to 20 meters of saprolite overlies most areas. Ground water travels through the subsoil and fractured rock to seeps and springs in the valleys. The Blue Ridge province contains the lower Appalachian Mountains and has greater relief and rainfall than the Piedmont and Coastal Plain. The area is mostly forested with less soil development than the other provinces. The ground-water travel is similar to that of the Piedmont.

Mineralogy

The uranium and lanthanides may be transported within the original rock-forming minerals or released from these minerals and be transported in solution or sorbed on other particles. The most important distinction is between the amount of uranium held within the lattices of resistate heavy minerals versus the amount of uranium in other forms.

Several methods have been developed to estimate the mineralogy and the amount of uranium held in the heavy minerals in the stream sediments (Price and Ferguson, 1980). Koch _et al_. (1979) used literature values for typical ratios of uranium to other elements in detrital minerals to develop an empirical formula to estimate the amount of uranium held within each mineral. Rose et al. (1970) used multiple linear regressions to generate formulas to estimate the uranium concentrations of stream sediments based upon other elemental concentrations. Price and Ferguson (1977) used elemental ratios to correct for uranium resistate minerals in the Kings Mountain area, North Carolina. These methods are useful in estimating the mineralogy of the suspended solids of the river waters.

Data Base Generation

This study uses the analyses of the soluble Al, Cl, Mn, Na, U, and V in the river waters and ground waters. The analyses of Al, Hf, La, Mn, Na, Sc, U, and V are used for the suspended sediment in the river waters. The analyses of Al, Hf, La, Mn, Na, Sc, Th, Ti, U, and V are used from the stream sediments. (Tables 1 and 2).

Water quality measurements and river characterizations are included in the data base. Measurements of pH, conductivity, and alkalinity of the river water, ground water, and stream water are

TABLE 1. RIVER WATER DATA.

SITE	COASTAL PLAIN %	ALK	COND	PH	FLOW	MEAN FLOW	AREA
GA01	0	0.16	72	7.1	1200	1994	3700
GA02	20	0.24	129	6.8	.	.	22400
GA03	80	0.18	80	6.6	320	570	1670
GA04	100	0.18	91	6.8	734	2038	6860
GA06	100	0.08	65	6.7	17	432	1440
GA07	0	0.18	72	6.7	.	.	2820
GA08	0	0.20	89	6.8	1580	1865	3680
GA09	0	0.22	85	6.7	2590	2572	7640
GA10	0	0.20	103	6.5	2180	2733	5800
GA11	30	0.18	110	6.8	1170	3809	11400
GA13	50	0.26	125	6.8	3080	5378	13400
GA14	100	0.10	65	7.2	534	1031	2870
GA15	60	0.18	80	7.4	7350	13110	35200
GA16	100	0.01	69	4.0	94	158	540
GA17	100	0.03	51	4.8	1380	2544	7230
GA18	100	0.01	81	4.2	79	152	410
NC01	0	0.30	105	6.9	2670	10720	21780
NC02	0	0.28	99	5.7	92	568	1110
NC03	35	0.16	98	6.5	1100	3169	5540
NC04	0	0.28	118	5.4	128	954	1994
NC05	30	0.12	104	6.3	5150	3365	6970
NC06	100	0.28	160	6.3	209	209	435
NC08	5	0.20	95	6.0	1220	4685	8910
NC09	30	0.10	75	5.5	2460	6107	12460
NC10	100	0.09	65	4.6	1640	823	1760
NC11	95	0.05	70	4.6	1030	393	989
NC12	97	0.07	120	4.5	.	.	.
NC13	100	0.10	160	5.7	1090	795	1550
NC14	0	0.12	45	6.3	59	79	75
NC15	0	0.12	50	6.5	.	.	.
NC16	0	0.12	55	5.8	937	1318	1305
NC17	0	0.12	55	4.0	1560	2069	2251
NC18	0	0.16	79	5.4	356	510	598
NC19	0	0.12	82	4.3	2710	3730	4390
NC20	0	0.16	90	5.3	.	.	.
NC21	0	0.12	80	3.1	202	254	401
NC23	0	0.40	205	5.7	.	.	.
NC24	0	0.18	91	4.8	337	555	793
NC25	0	0.16	92	4.8	3520	4697	5900
NC26	0	0.36	131	5.1	1	1	3
NC27	0	0.42	220	8.1	410	2006	3533
NC29	0	0.22	119	7.4	35	177	275
NC30	0	0.16	115	5.5	10400	12950	17780
NC31	100	0.09	62	6.1	172	319	474
NC32	100	0.07	55	4.6	3560	1491	3160

SITE	SOLUBLE CONCENTRATIONS(PPB) AL	CL	MN	NA	U	V	SUSPENDED SOLIDS CONCENTRATIONS (PPB) AL	HF	LA	MN	NA	SC	U	V
GA01	569	1700	8	880	0.022	0.65	4530	.	2.90	98	51	0.71	.	3.8
GA02	92	6390	59	5710	0.013	0.66	890	0.04	0.85	20	24	0.13	0.04	0.7
GA03	88	3330	16	2080	0.010	0.31	280	0.04	0.31	22	17	0.04	.	0.2
GA04	124	3080	8	2140	0.016	0.40	550	0.05	0.51	22	16	0.08	.	0.5
GA06	148	2620	16	1370	0.019	0.32	120	0.02	0.14	1	11	0.01	.	0.1
GA07	216	2370	52	1420	0.013	0.44	2060	0.13	2.19	146	29	0.31	.	2.3
GA08	198	3010	50	2030	.	0.62	840	.	0.46	13	22	0.13	0.01	0.9
GA09	552	1970	255	1180	0.023	0.55	1770	0.09	1.17	16	22	0.32	0.04	1.9
GA10	317	3470	8	2460	0.015	0.74	3230	0.08	2.33	157	60	0.69	0.13	3.7
GA11	525	2350	13	2310	0.030	1.11	2170	0.07	1.86	56	31	0.44	0.08	2.7
GA13	377	3090	7	2350	0.026	0.83	3250	0.28	3.07	79	59	0.67	0.17	3.2
GA14	105	3380	10	1330	0.025	0.38	550	0.04	0.53	19	20	0.09	.	0.6
GA15	422	2840	8	2110	0.040	0.91	1650	0.11	1.30	35	48	0.26	0.05	1.9
GA16	285	2240	3	750	.	0.79	430	0.05	0.23	2	23	0.07	.	0.6
GA17	333	3190	10	1090	0.027	0.67	930	0.15	0.54	2	16	0.10	0.02	1.0
GA18	110	3040	2	1010	.	0.19	90	0.01	0.11	1	15	0.01	.	0.1
NC01	380	3700	37	2340	0.064	0.81	590	0.04	0.42	157	20	0.09	.	0.5
NC02	.	.	.	.	.	.	1620	0.05	1.38	21	47	0.29	0.07	2.1
NC03	.	.	.	.	.	.	1190	0.06	0.74	14	28	0.15	0.04	1.4
NC04	.	.	.	.	.	.	1490	0.14	0.95	16	54	0.28	0.04	2.0
NC05	.	.	.	.	.	.	580	0.03	0.35	8	24	0.13	.	0.7
NC06	.	.	.	.	.	.	870	0.08	0.79	7	18	0.15	0.06	1.0
NC08	151	3150	21	2580	0.010	1.38	1460	0.06	0.70	21	40	0.28	0.03	2.0
NC09	.	.	.	.	.	.	1430	0.07	0.84	7	26	0.28	0.03	2.1
NC10	255	4070	15	1790	0.020	0.58	400	0.02	0.38	2	12	0.05	.	0.5
NC11	332	3790	11	2050	0.011	0.53	120	0.01	0.10	1	17	0.02	.	0.2
NC12	261	3180	18	1340	0.018	0.63	270	0.03	0.26	1	12	0.03	.	0.4
NC13	256	8250	16	3940	0.032	0.75	520	0.04	0.33	5	15	0.07	.	0.7
NC14	48	1710	7	1080	.	0.13	350	0.02	0.35	2	25	0.05	.	0.4
NC15	58	1420	9	870	.	0.13	460	0.02	0.89	3	36	0.07	.	0.6
NC16	106	1580	5	910	.	0.30	2120	0.05	1.99	19	51	0.35	0.07	2.2
NC17	119	1480	12	840	.	0.31	2110	0.17	2.17	20	54	0.35	0.09	2.5
NC18	.	.	.	.	.	.	2230	0.12	1.74	15	463	0.24	0.06	1.8
NC19	.	.	.	.	.	.	2100	0.12	2.00	19	51	0.37	0.10	2.4
NC20	354	1970	27	840	.	0.39	1030	0.07	0.58	3	14	0.14	0.02	1.2
NC21	.	.	.	.	.	.	1140	0.05	0.93	6	19	0.18	0.04	1.2
NC23	.	.	.	.	.	.	1580	0.06	1.38	12	47	0.31	0.07	2.0
NC24	.	.	.	.	.	.	1650	0.04	1.19	18	27	0.28	0.03	2.8
NC25	144	2130	7	1390	.	0.36	1620	0.06	1.60	11	34	0.29	0.06	1.7
NC26	158	2450	36	1700	0.013	0.67	2400	.	1.76	22	45	0.55	0.08	4.1
NC27	96	8270	8	8950	0.018	0.97	1100	0.06	1.02	11	610	0.22	0.02	1.4
NC29	130	5150	5	3670	.	0.26	590	0.05	0.25	3	15	0.09	.	0.7
NC30	443	2550	14	1520	0.018	0.82	2750	.	3.40	45	59	0.37	0.23	3.6
NC31	127	2250	5	700	.	0.17	330	0.02	0.29	2	8	0.04	.	0.4
NC32	231	3570	13	1500	0.011	0.47	140	0.07	0.12	1	14	0.02	.	0.2

ALKALINITY AS MILLIEQUIVILENTS OF SULFURIC ACID PER LITER.
CONDUCTIVITY MEASURED IN MICROMHOS/CM.
FLOWS ARE IN CUBIC FEET PER SECOND.

TABLE 1. RIVER WATER DATA. (Cont)

								SOLUBLE CONCENTRATIONS(PPB)						SUSPENDED SOLIDS CONCENTRATIONS (PPB)							
SITE	COASTAL PLAIN %	ALK	COND	PH	FLOW	MEAN FLOW	AREA	AL	CL	MN	NA	U	V	AL	HF	LA	MN	NA	SC	U	V
.																					
SC01	100	0.03	110	4.9	7390	1452	2875	273	4120	14	1450	0.017	0.60	40	0.01	0.08	1	14	0.01	.	0.1
SC02	20	0.16	72	5.2	19500	13230	22870	199	2790	31	1590	0.025	0.73	1990	0.13	1.34	72	43	0.40	0.05	2.6
SC03	80	.	60	4.8	2240	1205	2670	162	3940	28	1790	0.029	0.44	670	0.09	.	8	61	0.10	.	0.7
SC04	100	0.05	59	4.7	13400	3241	7230	259	3260	18	1170	0.016	0.57	160	0.01	.	1	14	0.02	.	0.2
SC05	100	0.16	60	5.4	2490	1040	3243	236	4240	8	1740	0.030	0.56	200	0.02	0.05	2	13	0.03	.	0.2
SC06	0	0.43	60	6.3	853	2242	3522	78	3290	23	2530	.	0.26	480	0.02	0.34	22	19	0.08	.	0.6
SC08	15	0.18	85	6.3	479	2680	38100	132	4260	55	3010	.	0.35	690	0.03	0.47	23	16	0.11	.	1.0
SC09	90	0.05	42	6.2	.	.	.	201	2510	33	720	0.043	0.37	320	.	0.18	2	11	0.04	.	0.4
SC10	97	0.07	48	5.8	.	.	.	226	2630	32	770	0.037	0.62	470	0.04	0.41	7	11	0.06	.	0.5
SC11	100	0.09	45	5.9	3970	894	1770	266	2340	18	600	0.041	0.57	630	0.04	0.46	3	14	0.09	.	0.6
SC12	98	0.12	90	6.3	1370	2155	4450	76	5490	12	3720	0.013	0.56	450	0.03	0.43	19	12	0.05	.	0.5
SC13	99	0.12	85	6.8	1460	3358	7070	85	5030	7	3770	0.022	0.49	320	0.03	0.27	8	14	0.04	.	0.5
SC14	0	0.10	40	5.7	199	239	186	148	1790	4	700	.	0.31	2130	0.15	2.38	14	35	0.37	0.12	2.5
SC15	0	0.06	35	7.7	.	.	.	115	2310	1	690	.	0.18	610	0.04	0.38	4	20	0.09	.	0.5
SC16	0	0.10	38	6.5	6120	5850	5778	69	1770	94	790	.	0.11	540	0.04	0.43	25	20	0.09	0.02	0.5
SC17	0	0.08	69	7.3	7000	6809	7449	145	2050	6	1000	.	0.21	760	0.04	0.68	12	24	0.11	0.02	0.7
SC18	0	0.36	125	6.9	.	.	.	464	3780	18	3070	0.017	1.36	2580	0.13	1.31	96	84	0.59	0.07	4.5
SC19	0	0.12	55	6.4	.	.	.	100	1950	27	1050	.	0.16	740	.	0.34	76	22	0.11	.	0.7
SC20	0	0.16	71	7.0	8590	10770	19446	171	2270	13	2030	0.010	0.31	570	0.05	0.38	13	32	0.09	.	0.5
SC21	10	0.16	85	6.5	.	.	.	85	4130	7	3360	0.014	0.32	1420	0.06	1.11	37	37	0.23	0.05	1.4
SC22	25	0.18	91	6.8	7750	13000	25510	107	3870	5	2970	0.011	0.45	1190	0.08	0.89	20	36	0.22	0.04	1.0

ALKALINITY AS MILLIEQUIVILENTS OF SULFURIC ACID PER LITER.
CONDUCTIVITY MEASURED IN MICROMHOS/CM.
FLOWS ARE IN CUBIC FEET PER SECOND.

TABLE 2. NURE DATA ABOVE EACH RIVER SITE.

SITE	STREAM SEDIMENTS (PPM) SAMPLES	ALK	COND	PH	AL	HF	LA	MN	NA	SC	TH	TI	U	V	GROUND WATERS (PPB) SAMPLES	ALK	COND	PH	AL	CL	MN	NA	U	V
GA01	132	0.22	47	7.0	57090	49	195	1254	11288	14.1	61	12711	14.7	136	63	0.27	71	7.6	68	6230	29	3518	0.17	2.2
GA02	18	0.15	64	7.2	25194	68	281	544	3859	7.1	125	9444	16.4	84	8	0.22	153	7.3	9	1220	6	413	.	.
GA03	78	0.20	53	7.1	15412	104	268	422	1358	4.6	99	8805	16.9	44	56	0.99	148	7.6	94	9453	48	5892	0.15	.
GA04	103	0.14	46	6.2	9452	71	83	152	299	2.1	31	5087	7.5	19	138	1.60	209	7.7	127	6804	79	12623	0.06	1.8
GA06	64	0.13	49	6.1	12552	58	75	140	331	2.2	26	4528	7.0	21	95	1.76	192	7.7	124	7145	75	14016	0.09	1.5
GA07	198	-0.27	53	7.0	53154	54	206	1182	11831	9.7	77	12702	14.7	100	111	0.25	84	7.1	66	10845	47	5076	0.25	1.2
GA08	243	0.21	45	6.9	46266	117	373	955	3872	9.9	122	9399	22.9	51	181	0.29	83	7.0	84	13863	42	6076	0.24	1.8
GA09	486	0.38	62	7.6	51543	78	276	1539	8571	12.7	90	13201	15.8	108	286	0.35	98	8.1	60	11923	44	6059	0.79	3.6
GA10	381	0.29	53	7.1	48647	127	408	1270	4946	12.0	140	12202	25.4	83	254	0.37	96	7.0	83	14281	53	7622	0.59	3.1
GA11	675	0.36	61	8.2	44905	80	244	1333	7243	11.2	82	12453	14.9	94	469	0.53	119	8.1	85	11511	42	6394	0.56	3.3
GA13	737	0.30	53	7.3	38400	98	271	882	3840	9.1	96	9610	17.9	67	584	0.89	135	7.5	113	10968	61	8078	0.35	2.5
GA14	146	0.14	42	6.5	17934	56	108	167	356	3.0	39	4755	8.7	29	204	1.69	197	7.5	120	7229	65	8104	0.09	1.0
GA15	1829	0.29	54	7.8	36352	84	222	887	4362	8.6	77	9632	14.7	68	1661	1.11	154	7.8	112	9841	59	8414	0.32	2.7
GA16	0	.	.	.	.	.	.	.	.	.	.	.	.	.	14	1.62	179	7.3	105	5886	88	13759	0.05	.
GA17	0	.	.	.	.	.	.	.	.	.	.	.	.	.	76	0.67	144	6.8	210	10275	103	13265	0.07	1.0
GA18	0	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.
NC01	1367	0.47	79	7.9	43403	85	61	1184	10982	10.9	23	14569	6.3	109	836	1.08	141	7.3	41	8485	54	6884	0.28	2.9
NC02	72	0.43	80	7.4	52917	30	.	1405	20489	8.2	28	12786	4.0	107	39	1.26	155	7.4	23	9614	37	7443	0.24	2.6
NC03	334	0.34	70	7.3	38436	100	90	933	10986	7.8	45	13273	7.9	75	246	0.64	134	7.1	102	10834	69	10174	0.25	2.1
NC04	156	0.47	114	7.5	47778	13	60	1013	15492	9.4	47	7452	2.9	96	67	1.18	225	7.1	38	15838	64	12700	1.92	2.8
NC05	444	0.41	98	9.7	34884	31	50	661	9036	6.3	33	8666	3.7	68	300	0.53	155	6.8	196	13092	58	9832	0.84	2.9
NC06	13	0.15	53	6.1	13215	34	24	140	462	2.3	10	7085	2.8	28	20	2.05	272	7.8	249	9920	48	25646	0.06	1.0
NC08	551	0.40	102	7.5	50981	26	30	1115	12822	12.2	22	8041	3.8	112	336	1.12	221	7.3	55	21125	116	12503	0.44	3.2
NC09	717	0.35	90	7.4	42968	40	82	924	10218	10.5	49	8531	8.1	95	510	0.83	179	7.3	83	16899	88	10409	0.36	3.2
NC10	57	0.22	80	6.5	13121	111	123	156	307	3.5	54	8845	12.0	33	127	0.48	100	6.7	243	9959	64	13826	0.06	1.5
NC11	33	0.08	67	6.1	12348	68	151	191	285	3.7	62	7941	12.4	31	64	0.24	104	6.1	225	10171	42	10184	0.03	1.0
NC12	102	0.17	75	6.4	12450	113	134	184	300	3.7	65	9176	13.7	33	225	0.48	107	6.9	235	9849	59	13105	0.05	1.2
NC13	53	0.34	74	7.8	12088	89	46	223	286	3.1	20	10965	5.7	35	102	1.10	160	7.3	219	9987	76	10478	0.10	1.0
NC14	5	0.17	39	7.6	38740	57	30	193	5625	5.4	17	3480	6.9	80	3	0.33	41	7.0	24	4650	13	3915	0.09	.
NC15	14	0.21	30	7.4	42279	47	39	368	12740	6.9	18	4409	6.1	76	9	0.23	35	6.8	31	5238	10	2274	0.05	.
NC16	65	0.19	22	7.6	36284	35	52	458	6313	6.3	26	5974	6.6	79	37	0.27	39	6.6	28	4915	8	2878	0.12	1.7
NC17	157	0.17	18	7.5	35397	31	52	604	7037	5.3	29	8309	6.0	75	83	0.30	45	6.6	24	4814	22	2757	0.09	1.5
NC18	47	0.15	35	7.4	38535	36	.	1710	9772	5.3	9	21527	2.7	77	21	0.32	64	6.6	18	6690	30	3288	0.10	.
NC19	310	0.17	28	7.5	35938	45	45	988	7333	5.4	21	14225	4.8	71	162	0.29	51	6.7	48	5627	23	3109	0.09	1.4
NC20	3	0.33	55	7.3	35400	65	.	513	5133	5.2	66	8900	16.2	57	2	0.13	47	5.8	18	10900	11	4170	0.03	.
NC21	24	0.18	29	7.4	35783	30	.	388	7110	2.7	68	4659	10.3	24	12	0.37	61	7.1	34	5618	33	3671	0.15	1.0
NC23	30	0.46	82	7.8	46480	60	53	624	8257	5.9	19	9124	7.5	66	21	0.41	87	7.2	75	8876	118	8223	1.37	2.1
NC24	53	0.29	46	7.7	42575	69	.	594	7407	7.8	109	9850	18.5	66	26	0.32	50	6.8	51	5936	22	3557	0.05	3.0
NC25	419	0.24	40	7.5	38911	48	65	904	7446	5.8	27	13395	6.2	72	221	0.32	61	6.9	50	6227	39	4178	0.20	2.6
NC26	0	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.
NC27	195	0.53	118	7.5	43578	24	52	1265	7805	15.8	11	8446	2.8	122	131	1.26	262	7.3	84	28984	191	15277	0.69	4.8
NC29	17	0.19	49	6.8	34541	11	17	563	7500	12.3	14	5800	2.2	112	10	0.50	93	6.9	31	17140	9	9374	0.04	.
NC30	1139	0.37	71	7.6	43815	41	64	1030	7721	11.7	33	10426	6.1	100	662	0.78	140	7.1	65	13203	81	8407	0.71	4.9
NC31	33	0.13	23	5.7	10122	104	420	186	579	7.1	186	12761	34.0	50	13	0.20	54	6.5	63	6546	21	3138	1.02	.
NC32	137	0.08	41	5.7	9079	67	206	97	908	4.0	89	7837	17.5	32	180	0.35	100	6.5	250	8210	52	13060	0.14	2.8

ALKALINITY AS MILLIEQUIVILENTS OF SULFURIC ACID PER LITER.
CONDUCTIVITY MEASURED IN MICROMHOS/CM.

TABLE 2. NURE DATA ABOVE EACH RIVER SITE. (Contd)

	STREAM SEDIMENTS (PPM) ---------->														GROUND WATERS (PPB) ---------->									
SITE	SAMPLES	ALK	COND	PH	AL	HF	LA	MN	NA	SC	TH	TI	U	V	SAMPLES	ALK	COND	PH	AL	CL	MN	NA	U	V
SC01	95	0.13	57	6.1	10534	31	24	111	327	2.0	9	5304	2.6	23	138	2.99	414	8.0	259	37434	80	72797	0.03	1.5
SC02	1453	0.32	64	7.5	38664	50	125	854	6452	10.7	55	10099	8.9	89	891	0.64	124	7.1	83	12917	76	8649	0.64	4.8
SC03	192	0.17	54	6.6	20603	86	234	295	5192	7.8	110	6913	16.7	49	114	0.53	114	7.6	100	11187	58	7917	0.10	1.3
SC04	320	0.10	49	5.8	10337	55	133	110	493	3.3	55	7136	11.5	30	417	0.74	123	7.1	223	9792	61	18432	0.09	3.3
SC05	157	0.10	49	6.4	14157	63	142	131	3778	3.3	59	6529	12.8	31	269	0.80	111	7.9	75	7184	40	6830	0.06	.
SC06	298	0.30	56	7.2	46726	126	250	1024	8298	12.6	110	10926	19.1	69	119	0.31	72	7.1	52	8153	34	5048	0.08	3.1
SC08	2787	0.35	71	7.5	40922	77	156	876	7301	10.9	71	8844	12.7	86	1483	0.49	92	7.2	56	10692	39	6097	0.40	3.4
SC09	41	0.06	29	6.9	12290	96	379	191	1090	5.0	157	8022	24.4	30	17	0.17	82	6.2	68	11682	65	7403	0.15	.
SC10	118	0.07	26	6.6	11289	93	275	204	780	4.4	109	8391	17.8	30	94	0.27	62	6.7	69	7183	40	3822	0.14	.
SC11	121	0.07	28	6.6	12117	99	294	149	439	4.4	120	6933	18.4	29	89	0.25	48	6.8	76	7528	34	3422	0.46	.
SC12	275	0.07	29	6.6	10820	93	265	175	713	4.2	106	7248	16.9	28	248	0.59	82	7.2	62	7031	36	3522	0.24	.
SC13	407	0.11	39	6.7	9945	83	202	151	541	3.6	80	6826	13.4	25	469	1.34	137	7.6	53	7135	52	5112	0.27	1.0
SC14	2	0.14	20	6.6	23000	50	11	140	2700	2.7	5	1400	6.4	10	0	.	.	.	.	.	.	.	.	.
SC15	41	0.08	15	6.8	48779	66	333	660	9905	8.4	110	10082	15.6	96	14	0.16	37	7.1	82	5392	16	6463	2.07	1.0
SC16	445	0.16	32	7.0	50374	118	230	919	9412	11.9	82	12866	15.0	98	178	0.20	59	7.1	65	7310	29	4409	0.82	1.6
SC17	552	0.18	43	7.1	50862	117	252	937	9824	11.3	92	13181	16.9	97	227	0.24	67	7.3	64	7457	27	4740	0.92	1.8
SC18	127	0.65	118	7.6	41435	18	84	1447	7513	15.3	21	9443	3.0	114	45	1.14	235	7.1	112	30612	174	15357	0.17	3.3
SC19	1109	0.30	61	7.6	50395	84	210	1190	9737	12.3	79	12643	14.8	111	520	0.37	92	7.3	53	9467	35	5969	0.56	3.6
SC20	1360	0.33	67	8.1	47979	76	205	1198	9220	12.4	77	12153	13.7	109	622	0.42	100	7.3	54	11030	43	6570	0.50	3.5
SC21	1466	0.32	65	8.0	45513	78	213	1135	8613	11.8	80	12021	14.0	103	726	0.45	98	7.3	52	10234	42	6088	0.44	3.5
SC22	1594	0.31	65	8.0	43036	79	212	1075	8012	11.2	79	11681	14.0	98	867	0.62	113	7.5	55	9652	44	6227	0.40	3.5

ALKALINITY AS MILLIEQUIVILENTS OF SULFURIC ACID PER LITER.
CONDUCTIVITY MEASURED IN MICROMHOS/CM.

included. For those river samples collected at USGS gaging stations the flow of the river on the day of collection and the ratio of this flow to the average daily flow of the river during that water year are included.

A comparison of the aluminum concentration on the filters with the suspended solids measurement indicates that the suspended solids measurements have a sensitivity of about 5 milligrams of material. Since many of the river waters were measured at less than 5 milligrams of suspended solids per liter, the aluminum concentration can be used to estimate the amount of solids.

The aluminum concentration can be used to estimate the amount of clay collected on the filters. The aluminum concentration of kaolinite is about 19.6%, montmorillonite is about 10.6%, and illite is about 13.3% (Grim, 1968, p. 576-580). Neiheisel (1966) determined the percentages kaolinite, montmorillonite, and illite in sediments from rivers draining the Piedmont and Coastal Plain of South Carolina and Georgia. The aluminum concentration of the nine clay samples from the rivers has a mean of 16.86% $\pm$ 1.05%. Assuming that the type of clay suspended in the water can be represented by the clay in the river bed, we can calculate an amount of clay on the filter from the aluminum concentration on the filter by the formula:

$$\text{Clay (ug)} = \text{Al(ug)} / .1686$$

The clay concentration on the filters is not the same as the suspended solids concentration because suspended solids can contain material other than clays. Using the above formula, clay represents 48% $\pm$ 24% of the suspended solids for the 40 samples which have suspended solids measured at greater than 5 milligrams per liter. To avoid the conversion to clay content, the element concentration in the filters will be considered as a ratio to the aluminum concentration.

Single high concentration measurements bias statistical interpretation. Sample NC01 has a soluble uranium concentration of 0.064 micrograms per liter of water, which is more than twice as high as any other Piedmont River. This makes statistical evaluation of the data difficult because so much of the variability in soluble uranium is in a single sample. The reasons for this anomalous uranium concentration are unknown but for the purpose of understanding the general principles of the relationship between uranium and the other elements, site NC01 is not considered in studying interelemental relationships.

The data base was interpreted using the Statistical Analysis System (SAS) on an IBM computer. The procedures used include generating correlation mattrices, plotting of elemental concentrations and ratios, and performing stepwise linear regressions.

Suspended Solids In River Water

Based on aluminum concentrations, the suspended solids concentrations are higher in the Piedmont rivers than the Coastal

Plain rivers. There is no significant difference between the mean of the La:Al ratios of 0.00081 for Piedmont rivers and 0.00088 for Coastal Plain rivers showing a similarity in the suspended solids mineralogy. Since most of the suspended uranium concentrations are below detection in the Coastal Plain rivers it is not possible to determine if the ratio of uranium to aluminum in the suspended solids is different in the two provinces.

Suspended Solids in Southeastern Rivers

	All Rivers	Coastal Plain Rivers	Piedmont Rivers
Mean U (ppb)	0.062	0.039	0.062
# Above Detection	33 of 66	2 of 23	25 of 36
Mean Al (ppb)	1130	386	1500
# Above Detection	66 of 66	23 of 23	36 of 36
Mean La (ppb)	0.93	0.31	1.22
# Above Detection	64 of 66	21 of 23	36 of 36

The suspended solids have a higher lanthanum to uranium ratio than the stream sediments from the corresponding basins (Figure 4). Most of the suspended solids have lanthanum and uranium concentrations which are near the idealized ratio of monazite (Karfunkel et al, 1981). There is some lanthanum enrichment which may be due to preferential leaching of uranium from the surfaces of monazite grains or due to lanthanum transport sorbed on clays. The samples with the highest concentrations of lanthanum and uranium are enriched in uranium when compared to the monazite ratio possibly representing uranium transported in other forms. The stream

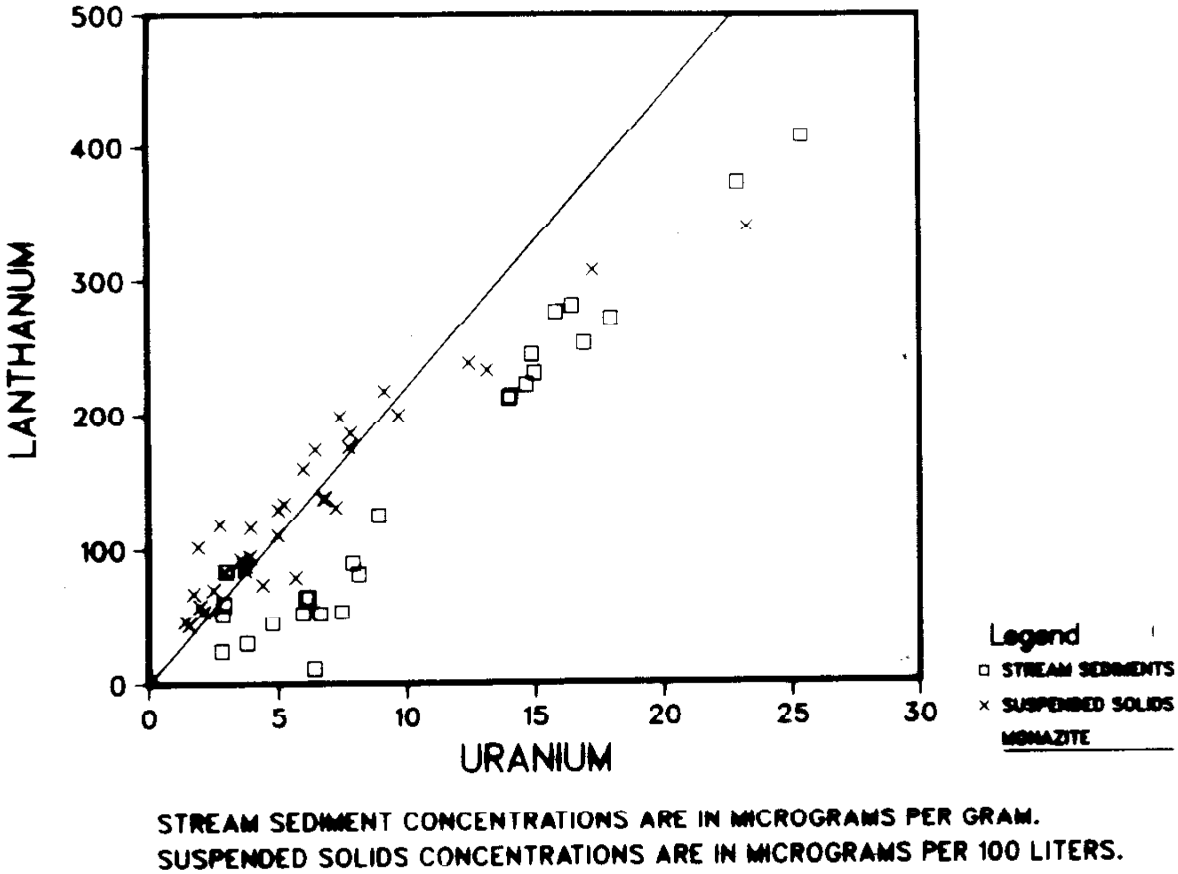

FIGURE 4. Uranium and Lanthanium Concentrations from Stream Sediments and Suspended Solids in River Waters.

sediments almost all are enriched in uranium compared to the monazite ratio indicating uranium held in forms other than monazite.

There are no distinct relationships between the concentrations of uranium and lanthanum in the suspended solids and the NURE analyses of stream sediments and ground waters from each basin in either the Coastal Plain or Piedmont rivers.

Soluble Components of River Water

The soils of the Coastal Plain are formed from highly weathered unconsolidated sediments, whereas the soils of the Piedmont are formed from the weathering of crystalline rocks. In general, the Piedmont soils should contribute more soluble ions to the waters passing through them. The Coastal Plain has large well-developed aquifer systems which drain into the ocean, which means that NURE ground water samples from these areas may represent water which will never enter the river.

The differences between the Piedmont and Coastal Plain are reflected in the chemistry of the waters. Sodium and chlorine tend to stay in solution in water so that if the different types of water in a drainage basin are interconnected then these concentrations should be similar. The tables below list the correlations between the conductivities and ion concentrations in the waters.

In the Piedmont there are strong correlations between the conductivities and ion concentrations in ground, stream and river waters. These strong correlations reflect the closed nature of the ground water and stream flows of the drainage basins.

Piedmont Waters Correlations

		Ground Water			River Water			Stream Water
		Cond.	Na	Cl	Cond.	Na	Cl	Cond.
Ground	Cond.	100	84	79	64	73	70	92
Water	Na		100	93	58	50	49	83
	Cl			100	55	54	51	77
River	Cond.				100	84	82	71
Water	Na					100	97	67
	Cl						100	64

In the Coastal Plain the relationships between ground, stream, and river waters are much weaker or not evident at all. The ground water has high internal relationships but is only weakly related to the river water and shows no relationships at all to the stream waters. The stream waters are only weakly related to the river waters. The lack of relationships may be partially due to the flooded condition of several of the rivers during collection of the samples. The lack of relationships between the ground water and stream water may reflect the ground water aquifers being isolated from the surface water.

Coastal Plain Waters Correlations

		Ground water			River Water			Stream Water
		Cond.	Na	Cl	Cond.	Na	Cl	Cond.
Ground	Cond.	100	86	71	53	*	*	*
Water	Na		100	92	36	*	*	*
	Cl			100	*	*	*	*
River	Cond.				100	63	72	51
Water	Na					100	87	*
	Cl						100	43

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* Indicates a less than 90% chance of a significant relationship.

Soluble uranium was detected in 19 of 23 Coastal Plain rivers with a mean of 0.023 ppb. This compares with 14 of 29 Piedmont rivers with a mean of 0.020 ppb. Coastal Plain rivers seem to have a higher soluble uranium concentration because a greater percentage of the samples were above detection.

Soluble uranium concentration in Piedmont Rivers has a 58% correlation with the soluble aluminum concentration, but no correlation with any of the stream-sediment or ground-water elemental concentrations. Soluble aluminum concentration has a 62% correlation with the suspended aluminum concentration in the river waters, suggesting that some of the soluble material is actually fine particulates passing through the 0.8 micron filter.

Soluble uranium in Coastal Plain rivers is weakly related, 56%, to the soluble manganese concentrations and to the filtered aluminum concentration. These relationships may be due to chemically-controlled processes releasing manganese and uranium into the water together.

A strong relationship, 75% correlation, exists between the ground-water concentration of uranium and the stream-sediment concentration of uranium in the Coastal Plain river basins. However there is no similar significant relationship in the Piedmont river basins. Elemental ratios indicate that most of the uranium in the stream sediments, Figure 5 occurs in monazite. The positive relationship in the Coastal Plain may be due to the leaching of monazite releasing uranium to the ground wasters. The lack of

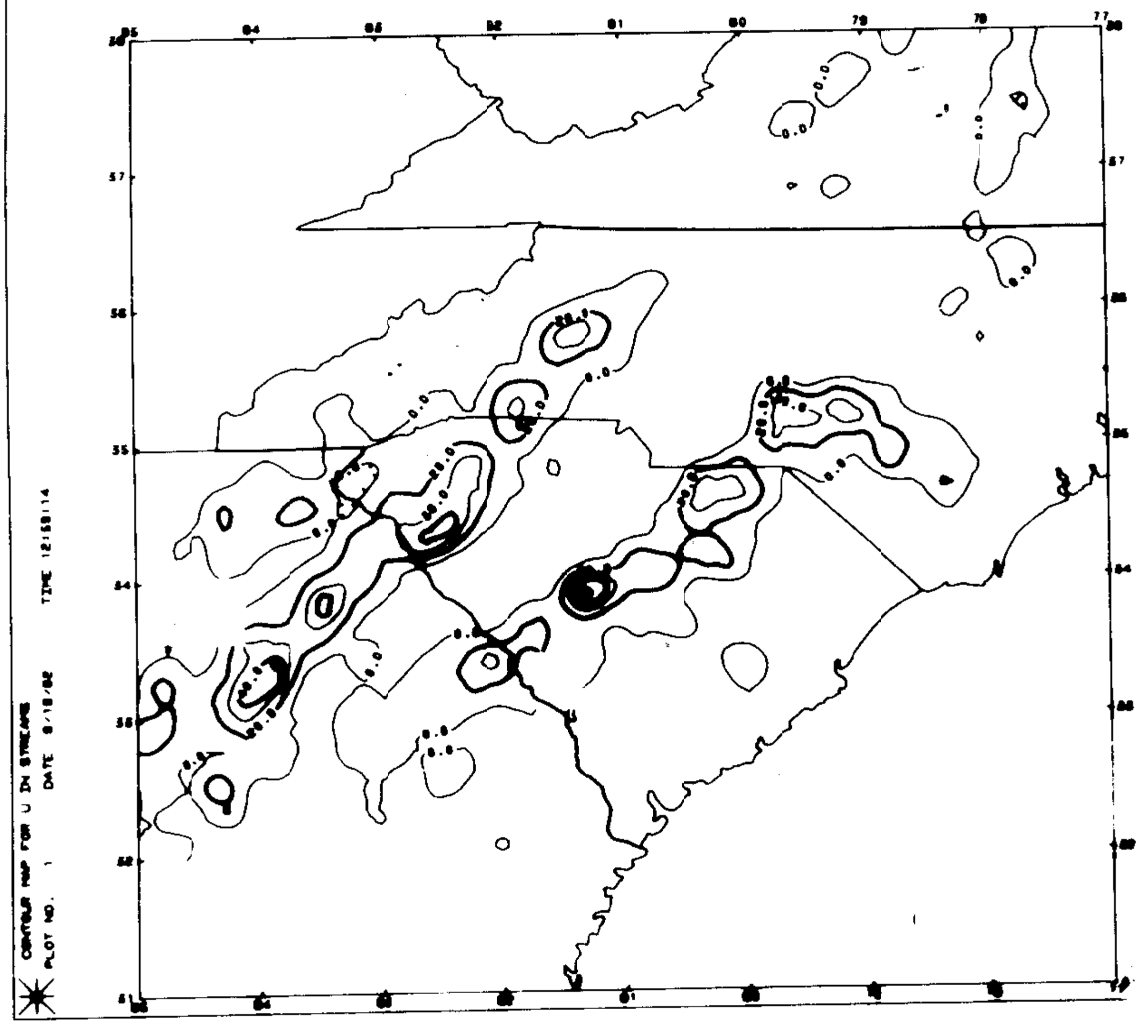

FIGURE 5. Contour Map of Uranium Concentration in Stream Sediments in ppm.

a similar relationship in the Piedmont may be due to uranium in forms other than monazite being leached from the rocks into the ground water but not occurring in the stream sediments.

CONCLUSION

Elemental ratios show that most of the uranium and lanthanum transported in the suspended solids is in monazite. No relationship is found between the amount of monazite in suspension and the amount of monazite in the stream sediments. The amount of uranium in solution is positively related to the soluble aluminum concentration in the Piedmont rivers and to the soluble manganese and total suspended solids in the Coastal Plain rivers. Piedmont rivers have more monazite and total suspended solids in transport than Coastal Plain rivers. Coastal Plain rivers have higher concentrations of soluble uranium.

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