U.S. Department of the Interior

U.S. Geological Survey

Preliminary Geochemical Data from Santa Fe Group Sediments in the 98th St. Drill Core, Middle Rio Grande Basin near Albuquerque, New Mexico

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USGS Open-File Report 98-230

Prepared in cooperation with the
CITY OF ALBUQUERQUE

ABSTRACT

Major and trace elements in Santa Fe Group sediments from the 98th St. drill core on the western side of the City of Albuquerque exhibit similar patterns and ranges of abundance with depth. Seventy-five composite samples representing 20 of 22 core lithologic units, and 60 discrete samples at 1-ft intervals from the 655-760 ft interval where most elements reach their highest abundances, were analyzed using ICP-AES (inductively coupled plasma-atomic emission spectrometry) and ICP-MS (inductively coupled plasma-mass spectrometry) methods. The abundances of most individual elements vary over broad ranges throughout the sediment section but patterns of element abundances are generally similar within a given lithologic unit. The discrete samples show elemental abundances and patterns similar to the composite samples but on a more detailed scale.

These preliminary analyses provide geochemical data for a nearly 1600-ft section of Santa Fe Group sediments that host major groundwater-supply aquifers in the Albuquerque area. An additional objective of this work was to examine element abundances and associations in Santa Fe Group sediments with respect to arsenic (As), an element that has become of increasing concern because of its aqueous concentration (up to nearly 50 μg/L) in some portions of the groundwater system.

The highest composite As values (≤14 parts per million [ppm]) were dominantly within silty, fine-to-medium sands whose centers are located at approximately 470, 580, 720, and 1270 ft below the land surface; the layer centered at 720 ft is dominantly a green silty clay with silty fine-to-medium sand (Stone and others, 1997).

The sediment interval centered at approximately 720 ft was analyzed in greater detail using discrete samples at 1-ft intervals. In 47 of these 60 discrete samples, arsenic ranges from 4 to 25 ppm, or 2-14 times its crustal abundance value (CAV; Fortescue, 1992) of 1.8 ppm. The maximum values of many elements, including As, Fe, V, Co, Cu, and Zn, are found within the interval centered at 720 ft. Regression/correlation analysis of samples from the 655-760 ft interval show that the strongest associations of arsenic ($r = 0.83$-0.85) are with Fe, Co, V, and Zn. Below approximately 800 ft, As abundances drop to values that are only equal to or less than those As values above 760 ft, except for an increase to almost 6 ppm in the 1270 ft interval.

Mineralogy of bulk samples and some clay separates has been determined using X-ray diffraction (XRD) methods. The minerals identified include major quartz; varying abundances of other aluminosilicates such as albite, orthoclase, sanidine, and muscovite; carbonates including major calcite and trace dolomite; to date, no sulfides (e.g., pyrite) have been detected. Dominant clay minerals include illite, smectite, mixed-layer illite/smectite, and kaolinite. The clay richterite and the zeolite heulandite were identified in many samples, while chlorite and the zeolite chabazite were detected in only a few samples.

INTRODUCTION

Purpose and Scope

In the Fall of 1996, a cooperative core drilling project sponsored by the City of Albuquerque, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR), and U.S. Geological Survey Mapping

(USGS-NMD), Geologic (USGS-GD), and Water Resources (USGS-WRD) Divisions, was undertaken to obtain samples of Santa Fe Group basin-fill sediments on the western side of the City of Albuquerque. One initial goal of this multifaceted coring project was to determine bulk geochemical and mineralogical characteristics of Santa Fe Group sediments that host major aquifers in the Albuquerque area. In addition, the drill hole would provide relatively pristine groundwater from an area having locally-high (up to 50 parts per billion [ppb]) total dissolved arsenic concentrations.

Although the aqueous geochemistry of As is not within the scope of this preliminary report, investigations of the sediment-aquifer system are continuing to better define rock-water interactions and resulting elemental (especially As) abundances in Santa Fe Group sediments and groundwaters. This initial report focuses on element abundances (particularly As and elements associated with As) and X-ray diffraction analyses of Santa Fe Group sediments in the 98th St. drill core. A subsequent report (in preparation) will examine the geochemical interaction of Santa Fe Group sediments with the local groundwater system.

SAMPLING AND ANALYTICAL METHODS

Core Sampling

A total of 1560 feet was drilled through Santa Fe Group sediments using a wireline drill rig with 10-ft intervals recovered between each addition of drill stem sections (for details of the drilling procedure, see Stone and others, 1997). Recovery was approximately 50% over the entire depth of the borehole. The greatest recovery (≥50-100%) was obtained from intervals dominated by medium- and fine-grained sands, silts, and clays, while the poorest recovery (≤50%) occurred in intervals dominated by coarse-grained sands and gravels.

At the site, cores were gently washed with deionized water and scraped to remove excess drilling mud and other potential outer-layer contaminants, drained, wrapped in cellulose film, and enclosed in airtight PVC tubes in 2-ft or 4-ft lengths for temporary storage. Composite, discrete, and grab samples were taken and are described in the sections below. The discrete samples are composites over 1-foot intervals, and are referred to as "discrete" to distinguish them from the longer-interval composites. Composite and grab samples were taken 3 months after the core was placed in storage; the 1-ft discrete samples were taken 6 months after storage began.

The sample depths and intervals reported here are measured relative to the land surface which is taken as zero feet; depths are reported as increasingly positive downward. Upper and lower depths for composite samples are noted in the data tables, but for ease of reference, the center (or average) depth of each sampled interval is used to describe geochemical and mineralogical results of composited samples. For example, sample ALB018C was composited over the interval 439-465 ft. Its center (average) depth is thus 452 ft; this value is used to refer to this sampled interval.

Composite Samples

As a result of the large length of core but intermittent recovery, composite samples were considered best-suited for initial reconnaissance because geochemical data is generally lacking for Santa Fe group sediments. Therefore, a set of composite samples to represent the 22 lithologies initially identified by Stone and others (1997) was first collected and analyzed to establish elemental distributions and abundances in the drilled section. Although incomplete recovery resulted in some portions of a lithologic unit not being available for collection, all lithologies identified by Stone and others (1997) except unit 22 (consisting of the uppermost surficial eolian and arroyo deposits) and unit 20 (from 60-80 ft), are represented by the composite samples. Subsequently, the discrete samples were taken to study the elemental abundances in detail from the interval having the highest As values in the composite samples.

Subsamples were taken perpendicular to the drilling direction over the length of the available cored lithologic units. A 2-in long by 1/2-in diameter subsample was removed from the core using a plastic syringe whose tapered end had been cut off; each subsample of the composite represents a sediment layer 1/2-in thick. In order to obtain comparable amounts of sediment and adequate coverage from each unit, several (up to 12) of the 1/2-in subsamples were taken to be composited and analyzed. Subsamples were taken at 2-ft intervals when the total lithology thickness was <25 ft, at 4-ft intervals when the thickness was ≥25-≤100 ft, and at 8-ft intervals when the thickness was >100 ft. Within each unit, samples were further noted for differences in color, grain size, degree of consolidation or type of cementation (Fe-oxide or carbonate), presence or absence of carbonate nodules, alteration (e.g., pseudomorphs, staining), and other characteristics.

The composite samples (approximately 0.5 kg) were air-dried if necessary, crushed, mixed, and split into two equal portions. One portion was archived while the other portion was pulverized in a Spex Mill Shatterbox© to <100 mesh for use in ICP-AES, ICP-MS, and bulk mineralogical analyses. Because ICP-AES was used primarily as a screening tool, those data are not presented in this report. The analyses presented are the element abundances determined by ICP-MS in the final composite or discrete sample.

Discrete Samples

The two highest As values from the composite samples (13 and 14 ppm; samples ALB029 and ALB030, respectively) represent the interval from approximately 655-760 ft and encompass lithologies 11, 10, and 9 (see Stone et al., 1997). Based on these composite sample results, a detailed sampling and analysis (by ICP-MS) of this interval at every foot from 656-760 ft (referred to as the 655-760 ft interval) feet was undertaken to further define the range of As and other element abundances in this section. Samples from the 664-667, 674-675, 677, 681-692, 697, 699-701, 724-731, 733-741, 746, 749-752, and 761 ft intervals were not recovered during coring; thus, no analyses were obtainable for these intervals. As a result of incomplete recovery and because the As abundance decreases to less than 6 ppm from 761 to 795 ft. in composite samples, additional 1-ft samples were not available or not taken below 760 ft.

Grab Samples

Several grab samples were collected to use for XRD and SEM examination, and clay separations. These samples were selected on criteria such as grain size, color, cementation, heavy or opaque minerals, and degree of Fe-staining. Grab samples represent the smallest intervals (on the scale of a few [1-5] inches to 2-3 feet) examined in this work.

ICP-AES Analyses

Composite samples were first analyzed for 40 major and trace elements using inductively coupled plasma-atomic emission spectrometry (ICP-AES; Briggs, 1990). As noted above, ICP-AES was used to establish ranges of elemental abundances because geochemical data on the depth scale of the drill core is generally not available for Santa Fe Group sediments. A 0.2 g aliquot of the analytical split was sequentially decomposed by adding, in the following order, small volumes of concentrated 1)HCl (3 mL), 2)HNO_3 (2 mL), 3)$HClO_4$ (1 mL), and 4)HF (2 mL); this solution was evaporated to dryness at 110 °C. Next, 1 mL conc. $HClO_4$ was added and the solution was evaporated to dryness again at 150 °C. This residue was redissolved in 1 mL of aqua regia (3 conc. HCl:1 conc. HNO_3 by volume) and brought to a final weight of 10.0 g with 1% HNO_3; the solution is nebulized into the ICP-AES plasma discharge for the analysis (Briggs, 1990). Duplicate samples, quality assurance, and quality control (QA/QC) standards were included with each batch of samples submitted for analysis.

ICP-MS Analyses

For inductively coupled plasma-mass spectrometry (ICP-MS), the powdered composite samples were treated in the same manner as for the ICP-AES analysis, except that the residue from the 150 °C drying step was redissolved only in conc. HNO_3 to alleviate interference from chloride ion. Similar to the ICP-AES procedure, duplicate samples, quality assurance, and quality control (QA/QC) standards were submitted with each batch of samples. The 1-ft discrete samples were prepared similarly to the composite samples but analyzed only by ICP-MS; no ICP-AES analysis was run on these samples.

X-Ray Diffraction Analyses

For X-ray diffraction work, aliquots of the <100 mesh composite or grab samples were prepared as packed powder mounts and scanned using a Philips® XRG 3000 diffractometer with Ni-filtered Cu K_α radiation. The analytical parameters for all samples analyzed were generator settings of 40 Kv and 25 mA, a step size of 0.025, and a one-second count time from 4°-65° 2θ. The detection limit of a mineral phase with this method is ≤5 volume percent.

Mineralogical results are reported as major (>25% by volume), minor (≥5 to ≤25% by volume), or trace (<5% by volume). Major, minor, and trace mineralogical designations are for qualitative purposes and are used only as a guide to convey the relative abundances of crystalline phases detected in a sample. These abundances do not imply a quantitative determination of any mineral in either the composite (bulk) sediments or individual (grab) samples.

Clay Separates

Clay separates were processed from grab samples that had not been sieved, crushed, or split; these were first X-rayed for bulk mineralogy. For the clay separation, the sediment was soaked overnight in deionized water, disaggregated, and wet-sieved through a -230 mesh screen to remove the sand (>62μm) fraction. Silt and clay were separated by the centrifugation-resuspension method detailed in

Starkey and others (1984). Separates from the 124 ft, 148 ft, and the As-bearing 715 ft (655-760 ft) layers were examined for the types of clay minerals present.

RESULTS

General Observations on Element Abundances

Analytical results and descriptive statistics [mean, standard deviation, standard error, and range (minimum and maximum)] for the core sediment samples are summarized in Table 1 (ICP-MS data; composite samples) and Table 2 (ICP-MS data; discrete samples). Regardless of the sample type (composite vs discrete), major element abundances (e.g., Ca, K, Na, Fe) in Santa Fe Group sediments do not vary greatly among one another with depth. That is, most major elements show similar highs and lows of abundance at the same depths or within the same interval. This is not unexpected because the core sediments are composed of sandstones and siltstones that are dominated by minerals such as quartz, feldspar, other aluminosilicates such as muscovite, and clay minerals.

Rare earth elements (REE) and alkaline earth elements generally do not vary greatly in abundance with depth, and exhibit similar patterns of abundance in the core. Minor element (trace metals) chemistry shows slightly greater variation in individual samples than major or REE elements. No statistical data or plots are presented for the following 6 elements whose values in the composite samples were all below the limit of detection by ICP-MS: Au, In, Re, S, Se, and Te.

Although a "dilution" effect was seen between the larger-interval composite samples and the 1-ft interval discrete samples, it does not result in extreme (order of magnitude) differences in the ranges of element abundance. Arsenic in the 705-723 composite was 14 ppm, while in the discrete 723 ft sample, As was 23 ppm. When all 1-ft discrete samples over the 705-760 ft interval are averaged, the As value is 9.4 ppm; the average As value from the 2 composites that cover this interval (705-723 ft, 742-760.5 ft) is 13.5 ppm.

Table 1. Analytical data from ICP-MS analyses of composite samples, 98th St. drill core. [The "/x" notation (where x = 2 or 3) in the Field No. column signifies an average of 2, or 3, analyses. U.D. = Upper depth (ft) of sample composite; L.D. = Lower depth (ft) of sample composite; C.D. = Center (average) depth of composite interval].

Field No	U.D.,ft	L.D.,ft	C.D,ft	Li PPM	Be PPM	Na %	Mg %	Al %	P %	K %	Ca %	Sc PPM
ALB 01C/3	25	47	36	13	1.3	1.2	0.4	4.2	0.02	1.7	2	4
ALB 01CS/2	25	47	36	12	1.1	1.2	0.39	4.2	0.02	1.7	2	4
ALB 02C	48	58	53	12	1.3	1.1	0.41	4	0.02	1.7	2.4	4
ALB 03C	81	98.6	90	14	0.9	1.1	0.34	4.2	0.01	1.7	1.9	4
ALB 04C	102	118	110	17	1.3	1	0.39	4.2	0.01	1.7	1.5	4
ALB 05C	120	138.8	129	22	1.3	1	0.49	4.5	0.01	1.7	1.7	5.1
ALB 06C	140	160.5	150	17	1.2	1.1	0.39	4.3	0.01	1.8	2.2	4
ALB 07C	161	180	171	23	1.5	1	0.5	4.4	0.02	1.7	2.3	5
ALB 08C	181.5	202.5	192	29	1.2	0.92	0.6	4.7	0.01	1.8	1.5	5.5
ALB 09C	203	223.5	213	28	1.1	0.84	0.58	4.5	0.01	1.6	3.4	5.8
ALB 010C	236.5	255	246	38	1.6	0.76	0.73	5	0.02	1.8	1.8	7
ALB 011C/2	260	280	270	22	1.2	0.89	0.42	4.1	0.01	1.7	1.2	4
ALB 012C	280.5	305	293	15	1.2	0.91	0.27	3.9	< 0.01	1.7	1.2	3
ALB 013C	306	325	316	23	1.1	0.71	0.48	4.2	0.01	1.6	1.7	5.2
ALB 014C	325.5	354	340	17	1	0.86	0.31	3.9	0.01	1.7	1.3	4
ALB 015C	358	380	369	15	1.1	0.88	0.27	3.7	< 0.01	1.6	1.3	4
ALB 016C	395	412	404	16	1	0.95	0.27	3.9	< 0.01	1.7	1.3	4
ALB 017C	417	437	427	14	1	0.94	0.24	3.6	< 0.01	1.6	1.2	3
ALB 018C	439	465	452	37	1.3	0.64	0.69	4.7	0.02	1.6	2	7.2
ALB 019C	466	487	477	20	1	0.74	0.42	4.2	0.01	1.6	1.2	5.4
ALB 020C	489	505	497	19	1.2	0.9	0.35	4.2	0.01	1.7	1.4	4
ALB 021C/2	506	526	516	17	1.2	0.81	0.32	3.9	0.01	1.6	2	4
ALB 022C	529	551	540	23	1.4	0.72	0.51	4.7	0.01	1.6	1.3	6.4
ALB 023C	552	573	563	39	1.5	0.51	0.89	6.1	0.02	1.5	1.5	11
ALB 024C	576	612	594	32	1.5	0.62	0.69	5.5	0.01	1.5	1.8	8.7
ALB 025C	612.5	628	620	38	1.4	0.61	0.8	5.3	0.02	1.5	2.4	8.5
ALB 026C	635	651.9	643	22	1.1	0.81	0.42	4	0.01	1.6	1.9	4
ALB 027C	656	680	668	23	1.2	0.72	0.47	4.3	0.01	1.6	1	5.1
ALB 028C	681	704	693	23	1.2	0.64	0.44	4.1	0.01	1.6	0.91	5
ALB 029C	705	723	714	40	1.4	0.44	0.86	6.1	0.02	1.6	1.4	11
ALB 030C	742	760.5	751	33	1.6	0.53	0.65	5.4	0.02	1.6	1.3	8.8
ALB 031C/3	761	795	778	29	1.2	0.75	0.54	4.2	0.01	1.6	1.8	4.8
ALB 031CS/2	761	795	778	28	1.2	0.72	0.52	4.1	< 0.01	1.5	1.8	4.5
ALB 032C	795.5	820.5	808	16	0.8	1	0.25	3.9	0.01	1.8	1.4	3
ALB 033C	821	880.5	851	24	1.4	1.3	0.47	4.9	0.02	1.8	2.1	5.2
ALB 034C	889.5	932	911	15	0.7	0.98	0.24	3.7	0.01	1.7	3	3
ALB 035C	933	1004.5	969	21	1.1	0.92	0.39	4	0.01	1.6	3.7	4
ALB 036C	1017	1056	1037	31	1.1	0.93	0.51	4.3	0.02	1.7	2.1	5.3
ALB 037C	1057	1102.5	1080	20	0.9	0.99	0.31	4	0.01	1.8	2.3	4
ALB 038C	1112	1166	1139	19	1	0.94	0.3	3.8	0.01	1.7	1.4	4
ALB 039C	1167	1197	1182	28	1.1	0.9	0.4	4	0.01	1.7	0.67	4
ALB 040C	1203	1227	1215	16	0.6	0.83	0.2	3.3	< 0.01	1.6	1.2	2
ALB 041C/2	1234	1263	1249	23	0.7	0.8	0.31	3.3	< 0.01	1.5	1.7	3.5
ALB 042C	1264	1284	1274	30	0.7	0.87	0.39	3.8	0.01	1.7	2	4
ALB 043C	1284.5	1319.5	1302	31	1.1	1.1	0.37	4.2	0.02	1.7	3.1	4
ALB 044C	1320	1346	1333	40	1.3	1.2	0.49	4.6	0.02	1.7	4	5.6
ALB 045C	1355	1385	1370	38	1.1	1.2	0.42	4.5	0.02	1.7	2.8	5.3
ALB 046C	1385.5	1410	1398	46	1.1	1.1	0.47	4.3	0.02	1.7	1.6	5
ALB 047C	1411	1436	1424	26	0.7	0.94	0.24	3.4	0.01	1.5	3.7	3
ALB 048C	1436.5	1451	1444	57	1.6	1.5	0.48	5.2	0.02	1.9	2.3	5.6
ALB 049C	1452	1478	1465	55	1.3	1.1	0.49	4.3	0.01	1.7	5.4	5.1
ALB 050C	1482	1496	1489	82	1	1.1	0.6	4.6	0.02	1.8	2.3	5.5

Table 1, continued.

Field No	U.D.,ft	L.D.,ft	C.D,ft	V PPM	Fe %	Mn PPM	Co PPM	Ni PPM	Cu PPM	Zn PPM	Ga PPM	Ge PPM	As PPM
ALB 01C/3	25	47	36	51	1.8	510	5.1	6.6	5	30	9.9	0.9	8.8
ALB 01CS/2	25	47	36	47	1.8	490	4.9	6.4	4	30	9.6	0.8	8.1
ALB 02C	48	58	53	52	1.9	520	5.4	6.7	7	30	10	0.8	5.8
ALB 03C	81	98.6	90	38	1.3	340	4.1	4.7	4	30	10	0.9	4
ALB 04C	102	118	110	41	1.4	320	4.5	5.6	4	30	11	0.8	4
ALB 05C	120	138.8	129	45	1.5	320	4.8	6.5	5	33	12	0.9	4
ALB 06C	140	160.5	150	36	1.3	340	4	5.5	5	52	10	1	4
ALB 07C	161	180	171	43	1.5	360	4.7	6.7	4	30	11	1	4
ALB 08C	181.5	202.5	192	47	1.6	310	5	7.5	8	36	12	0.9	4
ALB 09C	203	223.5	213	46	1.6	340	5.4	8.4	6	36	11	0.9	5.1
ALB 010C	236.5	255	246	54	1.9	330	6	10	10	44	13	1	5.3
ALB 011C/2	260	280	270	38	1.3	260	4.1	6	4	30	10	0.9	4
ALB 012C	280.5	305	293	30	1	220	3.2	4.4	< 3	20	9.4	0.9	4
ALB 013C	306	325	316	43	1.4	290	5	7.6	6	33	10	0.9	5
ALB 014C	325.5	354	340	32	1.1	230	3.4	5.2	6	20	9.2	1	4
ALB 015C	358	380	369	31	1.1	220	3.3	4.6	3	20	8.9	0.8	3
ALB 016C	395	412	404	30	1.1	220	3.5	4.8	< 3	20	9.3	1	4
ALB 017C	417	437	427	25	0.96	180	2.9	3.9	4	20	8.4	0.8	3
ALB 018C	439	465	452	58	1.8	500	7.4	11	10	42	12	1	5.9
ALB 019C	466	487	477	48	1.5	230	4.8	7.6	8	34	11	1	5.9
ALB 020C	489	505	497	36	1.2	240	3.9	5.9	5	30	10	1	4
ALB 021C/2	506	526	516	36	1.2	330	4	5.7	6	25	9	0.9	4
ALB 022C	529	551	540	52	1.8	270	6	9.2	9	39	12	0.9	5.9
ALB 023C	552	573	563	81	2.8	360	9.3	15	20	66	16	1.2	9.5
ALB 024C	576	612	594	66	2.2	290	7.5	12	20	50	14	1	7.5
ALB 025C	612.5	628	620	61	2.3	320	8	13	10	51	14	1	6.2
ALB 026C	635	651.9	643	35	1.3	240	4.1	5.8	20	30	9.5	0.8	4
ALB 027C	656	680	668	44	1.5	200	4.9	7.8	6	35	10	1	7.4
ALB 028C	681	704	693	41	1.3	160	4	7	7	30	9.8	1	5.5
ALB 029C	705	723	714	94	2.6	200	8.4	16	10	66	16	1	14
ALB 030C	742	760.5	751	76	2.1	240	7	11	10	52	14	1.1	13
ALB 031C/3	761	795	778	46	1.4	240	4.5	7.9	9	33	10	0.9	5.2
ALB 031CS/2	761	795	778	44	1.3	230	4.2	7.6	6	31	10	0.9	5
ALB 032C	795.5	820.5	808	23	0.87	180	2.7	3.6	< 3	20	9	1	3
ALB 033C	821	880.5	851	44	1.6	300	5.3	7.3	7	35	12	1	3
ALB 034C	889.5	932	911	30	0.95	230	3.2	4.2	5	20	8.4	0.9	3
ALB 035C	933	1004.5	969	30	1.1	230	3.6	5.7	6	20	9.2	0.8	3
ALB 036C	1017	1056	1037	42	1.5	460	5.3	7.9	7	32	10	1	4
ALB 037C	1057	1102.5	1080	33	1.2	230	3.9	5.6	6	20	9.5	0.9	4
ALB 038C	1112	1166	1139	38	1.3	250	4.1	5.6	3	20	9.1	0.9	4
ALB 039C	1167	1197	1182	35	1.2	210	4.4	6.1	4	30	9.4	1	3
ALB 040C	1203	1227	1215	22	0.86	150	2.4	4.1	6	20	7.4	0.9	4
ALB 041C/2	1234	1263	1249	27	0.99	210	3.1	4.9	< 3	20	7.9	0.8	5.3
ALB 042C	1264	1284	1274	35	1.2	440	4	6.2	6	20	8.8	0.9	5.6
ALB 043C	1284.5	1319.5	1302	32	1.2	640	4.3	6.3	4	20	10	0.9	4
ALB 044C	1320	1346	1333	47	1.8	480	5.8	8	5	34	12	1	4
ALB 045C	1355	1385	1370	45	1.6	320	5.3	7.4	7	32	11	1	3
ALB 046C	1385.5	1410	1398	38	1.5	250	5.2	8.4	10	31	10	1.1	4
ALB 047C	1411	1436	1424	30	1.1	260	3.4	5	< 3	20	8	0.8	3
ALB 048C	1436.5	1451	1444	50	1.8	320	6	7.9	6	36	13	1	3
ALB 049C	1452	1478	1465	47	1.7	560	5.5	8.6	8	32	11	0.9	4
ALB 050C	1482	1496	1489	49	1.5	330	5.6	8.2	8	32	11	1.1	4

Table 1, continued.

Field No	U.D.,ft	L.D.,ft	C.D,ft	Rb PPM	Sr PPM	Y PPM	Zr PPM	Nb PPM	Mo PPM	Ag PPM	Cd PPM	Sn PPM
ALB 01C/3	25	47	36	72	440	12	60	4.2	1.2	0.2	< 0.1	0.6
ALB 01CS/2	25	47	36	71	440	12	64	6.1	1.2	< 0.1	< 0.1	0.6
ALB 02C	48	58	53	72	440	12	68	4.9	0.7	0.1	0.1	0.6
ALB 03C	81	98.6	90	77	460	11	76	5.4	0.5	< 0.1	< 0.1	0.7
ALB 04C	102	118	110	79	440	12	67	5.8	0.5	< 0.1	< 0.1	0.8
ALB 05C	120	138.8	129	86	450	13	78	6.8	0.5	< 0.1	< 0.1	0.9
ALB 06C	140	160.5	150	81	460	12	78	4	0.5	< 0.1	< 0.1	0.7
ALB 07C	161	180	171	82	440	13	78	6.2	0.5	< 0.1	< 0.1	0.9
ALB 08C	181.5	202.5	192	89	430	12	83	7.2	0.5	< 0.1	< 0.1	1
ALB 09C	203	223.5	213	85	430	13	73	5.8	0.6	< 0.1	0.1	1
ALB 010C	236.5	255	246	98	360	14	92	8.1	0.6	< 0.1	< 0.1	1
ALB 011C/2	260	280	270	81	340	11	75	6.1	0.6	< 0.1	< 0.1	0.8
ALB 012C	280.5	305	293	80	310	10	60	4.4	0.4	< 0.1	< 0.1	0.6
ALB 013C	306	325	316	85	280	13	83	6.5	0.5	< 0.1	0.1	1
ALB 014C	325.5	354	340	80	310	9.9	60	5.2	0.4	< 0.1	< 0.1	0.8
ALB 015C	358	380	369	77	320	10	66	5.7	0.4	< 0.1	< 0.1	0.7
ALB 016C	395	412	404	82	330	9.8	64	5.3	0.4	< 0.1	< 0.1	0.7
ALB 017C	417	437	427	76	350	9.1	59	5.3	0.4	< 0.1	< 0.1	0.6
ALB 018C	439	465	452	88	310	15	95	8.5	0.7	< 0.1	0.1	1
ALB 019C	466	487	477	83	280	12	80	6.8	0.6	< 0.1	< 0.1	1
ALB 020C	489	505	497	84	320	11	70	5.8	0.4	< 0.1	< 0.1	0.9
ALB 021C/2	506	526	516	76	290	10	68	5.2	0.5	< 0.1	0.1	0.7
ALB 022C	529	551	540	85	300	15	97	7.5	0.6	< 0.1	< 0.1	1
ALB 023C	552	573	563	98	350	19	120	12	0.9	0.1	0.1	2
ALB 024C	576	612	594	91	340	17	100	9	0.8	0.1	0.1	2
ALB 025C	612.5	628	620	90	370	17	100	9.3	0.6	< 0.1	0.1	2
ALB 026C	635	651.9	643	78	320	11	73	5.9	0.4	< 0.1	0.2	0.8
ALB 027C	656	680	668	83	280	12	76	6.4	0.6	< 0.1	< 0.1	1
ALB 028C	681	704	693	81	250	11	64	5.6	0.5	< 0.1	< 0.1	0.9
ALB 029C	705	723	714	100	290	18	120	12	1.5	0.1	< 0.1	2
ALB 030C	742	760.5	751	93	280	15	98	8.6	0.9	< 0.1	0.1	2
ALB 031C/3	761	795	778	82	310	9.7	64	4.2	0.5	0.2	0.1	0.9
ALB 031CS/2	761	795	778	80	310	9.9	70	4.7	0.4	< 0.1	< 0.1	0.8
ALB 032C	795.5	820.5	808	77	340	8.3	55	3.2	0.4	0.1	< 0.1	0.5
ALB 033C	821	880.5	851	76	510	11	85	4.3	0.4	< 0.1	< 0.1	0.8
ALB 034C	889.5	932	911	72	170	10	50	2.4	0.4	< 0.1	< 0.1	0.5
ALB 035C	933	1004.5	969	75	460	12	58	2.8	0.3	< 0.1	< 0.1	0.6
ALB 036C	1017	1056	1037	78	470	11	84	4.4	0.4	< 0.1	< 0.1	0.8
ALB 037C	1057	1102.5	1080	75	370	11	69	3.3	0.4	< 0.1	< 0.1	0.6
ALB 038C	1112	1166	1139	73	380	9.8	59	3.5	0.4	< 0.1	< 0.1	0.6
ALB 039C	1167	1197	1182	77	330	8.8	61	4.1	0.4	< 0.1	< 0.1	0.7
ALB 040C	1203	1227	1215	73	260	7.4	40	2.5	0.5	< 0.1	< 0.1	< 0.5
ALB 041C/2	1234	1263	1249	69	280	9.7	52	2.8	0.4	< 0.1	< 0.1	0.5
ALB 042C	1264	1284	1274	78	320	9.7	56	3.4	0.3	< 0.1	< 0.1	0.6
ALB 043C	1284.5	1319.5	1302	74	430	11	72	3.3	0.3	< 0.1	0.1	0.6
ALB 044C	1320	1346	1333	74	500	13	94	5.1	0.5	< 0.1	< 0.1	0.8
ALB 045C	1355	1385	1370	74	480	12	84	4.6	0.4	< 0.1	< 0.1	0.6
ALB 046C	1385.5	1410	1398	78	440	11	79	4	0.4	< 0.1	< 0.1	0.7
ALB 047C	1411	1436	1424	67	370	8.8	48	2.5	0.3	< 0.1	< 0.1	< 0.5
ALB 048C	1436.5	1451	1444	74	650	12	93	4	0.4	< 0.1	< 0.1	0.8
ALB 049C	1452	1478	1465	73	530	11	67	3.7	0.4	< 0.1	0.1	0.7
ALB 050C	1482	1496	1489	81	580	12	84	5.1	0.4	< 0.1	< 0.1	0.8

Table 1, continued.

Field No	U.D.,ft	L.D.,ft	C.D,ft	Sb PPM	Cs PPM	Ba PPM	La PPM	Ce PPM	Pr PPM	Nd PPM	Sm PPM	Eu PPM
ALB 01C/3	25	47	36	0.5	2.3	990	23	46	5.4	20	3.6	0.97
ALB 01CS/2	25	47	36	0.5	2.3	1000	24	44	5.1	18	3.3	0.98
ALB 02C	48	58	53	0.5	2.2	1000	24	44	5.4	19	3.5	1
ALB 03C	81	98.6	90	0.4	2.4	1100	21	39	4.8	18	3.2	0.95
ALB 04C	102	118	110	0.5	2.8	820	25	48	5.9	21	4	1
ALB 05C	120	138.8	129	0.6	3.4	800	23	44	5.6	20	3.8	1
ALB 06C	140	160.5	150	0.5	3	870	22	43	5.2	19	3.5	1
ALB 07C	161	180	171	0.5	3.6	880	24	47	5.9	21	3.9	1.1
ALB 08C	181.5	202.5	192	0.6	4.2	740	24	46	5.6	20	3.8	1
ALB 09C	203	223.5	213	0.6	5.4	700	24	46	5.6	20	3.9	1
ALB 010C	236.5	255	246	0.8	7	820	26	52	6.3	22	4.2	1
ALB 011C/2	260	280	270	0.6	4.3	710	23	45	5.5	19	3.8	0.95
ALB 012C	280.5	305	293	0.6	3	720	19	37	4.6	16	3.1	0.84
ALB 013C	306	325	316	0.8	4.9	620	24	46	5.6	20	3.7	0.94
ALB 014C	325.5	354	340	0.6	3.4	720	20	36	4.5	16	3	0.84
ALB 015C	358	380	369	0.5	3.1	710	20	37	4.6	16	3	0.86
ALB 016C	395	412	404	0.5	3.8	770	21	39	4.7	17	3.2	0.85
ALB 017C	417	437	427	0.5	3	750	18	34	4.2	15	2.8	0.82
ALB 018C	439	465	452	0.7	8.3	680	28	56	6.6	24	4.5	1
ALB 019C	466	487	477	0.7	4.7	670	24	47	5.6	20	3.8	0.94
ALB 020C	489	505	497	0.6	3.9	800	22	42	5.1	18	3.4	0.98
ALB 021C/2	506	526	516	0.5	3.5	760	21	40	4.7	17	3.1	0.88
ALB 022C	529	551	540	0.7	5.1	670	28	55	6.4	23	4.3	1.1
ALB 023C	552	573	563	1	8.6	580	36	71	8.6	30	5.8	1.3
ALB 024C	576	612	594	0.8	6.4	600	32	63	7.4	27	5.1	1.2
ALB 025C	612.5	628	620	0.8	6.8	570	33	66	7.8	28	5.3	1.2
ALB 026C	635	651.9	643	0.6	3.4	800	22	42	5.2	19	3.5	0.95
ALB 027C	656	680	668	0.8	4.1	680	23	46	5.6	20	3.9	0.94
ALB 028C	681	704	693	0.7	3.8	600	22	42	5	18	3.3	0.82
ALB 029C	705	723	714	1.2	8.6	470	35	71	8.3	30	5.6	1.2
ALB 030C	742	760.5	751	1	6.6	700	30	60	7	24	4.5	1.1
ALB 031C/3	761	795	778	0.6	3.5	660	20	39	4.6	16	2.9	0.82
ALB 031CS/2	761	795	778	0.5	3.5	670	20	38	4.5	16	2.9	0.81
ALB 032C	795.5	820.5	808	0.5	1.8	740	18	31	4	14	2.6	0.82
ALB 033C	821	880.5	851	0.3	2.2	870	23	43	5.2	19	3.4	0.99
ALB 034C	889.5	932	911	0.4	1.8	730	20	33	4.4	15	2.8	0.82
ALB 035C	933	1004.5	969	0.4	2.2	740	20	34	4.6	17	3.1	0.95
ALB 036C	1017	1056	1037	0.4	2.7	770	23	44	5.4	19	3.5	0.96
ALB 037C	1057	1102.5	1080	0.4	1.9	730	20	36	4.7	16	3.2	0.86
ALB 038C	1112	1166	1139	0.5	1.8	750	19	34	4.2	16	2.9	0.83
ALB 039C	1167	1197	1182	0.5	2.2	700	18	34	4.2	15	2.7	0.8
ALB 040C	1203	1227	1215	0.5	1.7	650	15	26	3.4	12	2.2	0.71
ALB 041C/2	1234	1263	1249	0.5	1.9	640	19	34	4.3	15	2.8	0.79
ALB 042C	1264	1284	1274	0.5	2.4	710	19	35	4.4	16	2.9	0.84
ALB 043C	1284.5	1319.5	1302	0.4	2	800	22	38	5	18	3.3	0.98
ALB 044C	1320	1346	1333	0.4	2.4	760	25	46	5.8	21	3.8	1
ALB 045C	1355	1385	1370	0.4	2.1	780	22	40	5.2	18	3.4	0.98
ALB 046C	1385.5	1410	1398	0.5	2.4	840	21	40	4.9	18	3.2	0.97
ALB 047C	1411	1436	1424	0.4	1.6	660	18	30	4	14	2.6	0.81
ALB 048C	1436.5	1451	1444	0.3	1.9	880	27	50	6.2	22	3.9	1.2
ALB 049C	1452	1478	1465	0.4	2.3	760	21	38	4.9	18	3.2	0.95
ALB 050C	1482	1496	1489	0.5	2.8	810	23	43	5.4	19	3.7	1

Table 1, continued.

Field No	U.D.,ft	L.D.,ft	C.D,ft	Tb PPM	Gd PPM	Dy PPM	Ho PPM	Er PPM	Tm PPM	Yb PPM	Hf PPM	Ta PPM
ALB 01C/3	25	47	36	0.42	2.8	2.4	0.44	1.3	0.18	1.2	1	0.3
ALB 01CS/2	25	47	36	0.39	2.5	2.3	0.42	1.3	0.17	1.1	1	0.4
ALB 02C	48	58	53	0.41	2.6	2.3	0.43	1.2	0.18	1.2	2	0.2
ALB 03C	81	98.6	90	0.37	2.4	2.1	0.38	1.2	0.17	1.1	2	0.4
ALB 04C	102	118	110	0.43	3	2.4	0.44	1.3	0.18	1.1	2	0.3
ALB 05C	120	138.8	129	0.43	2.9	2.4	0.46	1.3	0.19	1.3	2	0.3
ALB 06C	140	160.5	150	0.4	2.7	2.3	0.45	1.3	0.17	1.2	2	0.2
ALB 07C	161	180	171	0.45	3	2.6	0.47	1.4	0.2	1.3	2	0.4
ALB 08C	181.5	202.5	192	0.42	2.9	2.5	0.45	1.3	0.19	1.2	2	0.5
ALB 09C	203	223.5	213	0.47	3	2.6	0.48	1.4	0.2	1.3	2	0.3
ALB 010C	236.5	255	246	0.49	3.3	2.8	0.52	1.6	0.21	1.4	2	0.6
ALB 011C/2	260	280	270	0.4	2.7	2.3	0.41	1.2	0.18	1.1	2	0.4
ALB 012C	280.5	305	293	0.35	2.4	2	0.37	1.1	0.16	0.99	2	0.2
ALB 013C	306	325	316	0.43	2.8	2.5	0.47	1.4	0.19	1.3	2	0.4
ALB 014C	325.5	354	340	0.33	2.3	1.9	0.37	1	0.15	1	1	0.3
ALB 015C	358	380	369	0.34	2.3	1.9	0.37	1.1	0.15	1	2	0.4
ALB 016C	395	412	404	0.34	2.4	2	0.36	1.1	0.15	1	2	0.4
ALB 017C	417	437	427	0.3	2	1.8	0.33	0.99	0.15	0.91	1	0.3
ALB 018C	439	465	452	0.55	3.5	3	0.55	1.6	0.22	1.4	2	0.6
ALB 019C	466	487	477	0.42	2.8	2.4	0.44	1.4	0.19	1.2	2	0.5
ALB 020C	489	505	497	0.39	2.5	2.2	0.39	1.2	0.17	1.1	2	0.4
ALB 021C/2	506	526	516	0.36	2.4	2.1	0.39	1.1	0.16	1.1	2	0.4
ALB 022C	529	551	540	0.5	3.3	2.8	0.54	1.6	0.22	1.4	2	0.5
ALB 023C	552	573	563	0.68	4.7	3.9	0.71	2.1	0.29	1.8	3	0.9
ALB 024C	576	612	594	0.6	4.1	3.4	0.62	1.8	0.27	1.6	3	0.6
ALB 025C	612.5	628	620	0.62	4.1	3.5	0.64	1.9	0.27	1.6	3	0.7
ALB 026C	635	651.9	643	0.4	2.6	2.3	0.42	1.2	0.18	1.2	2	0.4
ALB 027C	656	680	668	0.43	2.9	2.4	0.43	1.3	0.17	1.1	2	0.5
ALB 028C	681	704	693	0.38	2.5	2.1	0.4	1.2	0.17	1	2	0.4
ALB 029C	705	723	714	0.64	4.3	3.7	0.69	2	0.29	1.9	3	0.9
ALB 030C	742	760.5	751	0.52	3.6	3	0.57	1.6	0.24	1.5	2	0.6
ALB 031C/3	761	795	778	0.33	2.2	1.9	0.36	1	0.15	0.97	1	0.3
ALB 031CS/2	761	795	778	0.34	2.2	1.9	0.36	1.1	0.15	1	2	0.4
ALB 032C	795.5	820.5	808	0.29	2	1.6	0.3	0.83	0.12	0.8	1	0.2
ALB 033C	821	880.5	851	0.38	2.6	2.2	0.41	1.1	0.17	1.1	2	0.3
ALB 034C	889.5	932	911	0.32	2.1	1.8	0.35	1	0.15	1.1	1	0.2
ALB 035C	933	1004.5	969	0.37	2.4	2.2	0.41	1.2	0.18	1.2	1	0.2
ALB 036C	1017	1056	1037	0.38	2.6	2.2	0.42	1.2	0.17	1.2	2	0.4
ALB 037C	1057	1102.5	1080	0.37	2.4	2	0.38	1.1	0.16	1	2	0.2
ALB 038C	1112	1166	1139	0.32	2.1	1.9	0.36	1	0.15	0.96	1	0.2
ALB 039C	1167	1197	1182	0.32	2.2	1.8	0.34	0.91	0.13	0.85	1	0.3
ALB 040C	1203	1227	1215	0.25	1.7	1.4	0.26	0.78	0.11	0.69	0.8	0.2
ALB 041C/2	1234	1263	1249	0.32	2.1	1.8	0.35	1	0.14	0.98	1	0.2
ALB 042C	1264	1284	1274	0.31	2.1	1.8	0.33	0.99	0.14	0.95	1	0.2
ALB 043C	1284.5	1319.5	1302	0.37	2.5	2.2	0.4	1.2	0.17	1.1	2	0.2
ALB 044C	1320	1346	1333	0.44	2.8	2.5	0.46	1.4	0.2	1.3	2	0.3
ALB 045C	1355	1385	1370	0.39	2.6	2.2	0.43	1.2	0.19	1.2	2	0.3
ALB 046C	1385.5	1410	1398	0.36	2.4	2.1	0.39	1.1	0.16	1	2	0.3
ALB 047C	1411	1436	1424	0.3	2	1.7	0.31	0.89	0.13	0.88	1	0.1
ALB 048C	1436.5	1451	1444	0.44	2.9	2.5	0.44	1.2	0.17	1.2	2	0.3
ALB 049C	1452	1478	1465	0.38	2.4	2.1	0.4	1.1	0.17	1.1	2	0.2
ALB 050C	1482	1496	1489	0.42	2.7	2.4	0.42	1.3	0.18	1.1	2	0.3

Table 1, continued.

Field No	U.D.,ft	L.D.,ft	C.D,ft	W PPM	Tl PPM	Pb PPM	Bi PPM	Th PPM	U PPM
ALB 01C/3	25	47	36	1.1	0.4	15	0.08	5.2	2.3
ALB 01CS/2	25	47	36	1.3	0.4	14	0.09	5.4	2.3
ALB 02C	48	58	53	0.7	0.4	15	0.09	4.6	3.7
ALB 03C	81	98.6	90	0.6	0.4	13	0.09	4.8	2
ALB 04C	102	118	110	0.5	0.4	13	0.1	8.1	2
ALB 05C	120	138.8	129	0.7	0.5	14	0.1	5.8	2.1
ALB 06C	140	160.5	150	0.6	0.4	14	0.1	5.5	1.9
ALB 07C	161	180	171	0.6	0.4	14	0.1	5.9	2.2
ALB 08C	181.5	202.5	192	0.8	0.5	14	0.1	6.6	2.4
ALB 09C	203	223.5	213	0.9	0.4	14	0.1	6.3	2.4
ALB 010C	236.5	255	246	1.1	0.5	16	0.2	7.7	2.8
ALB 011C/2	260	280	270	0.8	0.4	12	0.1	6.1	2
ALB 012C	280.5	305	293	0.6	0.4	12	0.08	4.9	1.8
ALB 013C	306	325	316	0.8	0.5	14	0.1	6.4	2.2
ALB 014C	325.5	354	340	0.8	0.4	13	0.1	5	1.7
ALB 015C	358	380	369	0.6	0.4	12	0.1	4.9	1.7
ALB 016C	395	412	404	0.6	0.4	12	0.1	5.3	1.7
ALB 017C	417	437	427	0.9	0.4	12	0.08	4.7	1.6
ALB 018C	439	465	452	1.4	0.5	17	0.2	8.1	2.7
ALB 019C	466	487	477	0.9	0.4	15	0.1	6.6	2.2
ALB 020C	489	505	497	0.7	0.4	13	0.1	5.5	1.8
ALB 021C/2	506	526	516	0.8	0.4	12	0.09	5.3	1.8
ALB 022C	529	551	540	0.9	0.4	15	0.2	7.6	2.6
ALB 023C	552	573	563	1.4	0.6	18	0.54	11	3.7
ALB 024C	576	612	594	1.2	0.5	16	0.2	9.1	3.1
ALB 025C	612.5	628	620	1.1	0.5	16	0.2	9.4	2.9
ALB 026C	635	651.9	643	1	0.4	14	0.1	5.6	2
ALB 027C	656	680	668	0.8	0.4	13	0.1	6.6	2.1
ALB 028C	681	704	693	1.2	0.4	12	0.1	5.9	1.9
ALB 029C	705	723	714	1.4	0.6	18	0.2	12	3.8
ALB 030C	742	760.5	751	1.2	0.5	16	0.2	9.3	3.1
ALB 031C/3	761	795	778	0.6	0.5	14	0.1	5.5	2
ALB 031CS/2	761	795	778	0.7	0.4	12	0.1	5.5	1.9
ALB 032C	795.5	820.5	808	0.5	0.4	11	0.07	4.2	1.3
ALB 033C	821	880.5	851	0.6	0.4	13	0.09	5.6	1.8
ALB 034C	889.5	932	911	0.5	0.4	10	0.06	3.9	1.6
ALB 035C	933	1004.5	969	0.6	0.4	10	0.07	4.6	1.8
ALB 036C	1017	1056	1037	0.7	0.4	12	0.09	5.6	2.6
ALB 037C	1057	1102.5	1080	0.6	0.4	11	0.07	5	2.9
ALB 038C	1112	1166	1139	0.6	0.4	11	0.06	4	2.4
ALB 039C	1167	1197	1182	0.6	0.4	12	0.08	4.5	3.2
ALB 040C	1203	1227	1215	0.6	0.4	10	< 0.05	3.8	2.1
ALB 041C/2	1234	1263	1249	0.5	0.3	10	0.07	4.2	2.2
ALB 042C	1264	1284	1274	0.6	0.4	11	0.07	4.7	2.1
ALB 043C	1284.5	1319.5	1302	0.5	0.4	12	0.08	4.6	2.6
ALB 044C	1320	1346	1333	0.6	0.4	13	0.09	5.8	2.8
ALB 045C	1355	1385	1370	0.6	0.4	13	0.08	5.1	3
ALB 046C	1385.5	1410	1398	0.5	0.4	14	0.08	5	3.2
ALB 047C	1411	1436	1424	0.4	0.3	9.8	0.05	3.6	1.9
ALB 048C	1436.5	1451	1444	0.4	0.4	14	0.08	5.7	2.7
ALB 049C	1452	1478	1465	0.5	0.4	13	0.09	4.8	2.6
ALB 050C	1482	1496	1489	0.6	0.4	13	0.09	5.5	2.6

Table 1, continued: Descriptive statistics for ICP-MS analyses of composite samples, 98th St. drill core.

	Mean	Std. Dev.	Std. Error	Minimum	Maximum
Li PPM	27	13.1	1.82	12	82
Be PPM	1.2	0.2	0.03	0.6	1.6
Na %	0.91	0.2	0.03	0.44	1.5
Mg %	0.45	0.2	0.02	0.2	0.89
Al %	4.3	0.6	0.08	3.3	6.1
P %	0.01	<0.01	<0.01	0.01	0.02
K %	1.7	0.1	0.01	1.5	1.9
Ca %	1.97	0.9	0.12	0.67	5.4
Sc PPM	5.0	1.9	0.26	2	11
V PPM	43	14.0	1.94	22	94
Fe %	1.48	0.4	0.06	0.86	2.8
Mn PPM	310	110.6	15.34	150	640
Co PPM	4.8	1.5	0.20	2.4	9.3
Ni PPM	7.2	2.6	0.37	3.6	16
Cu PPM	7	3.9	0.57	3	20
Zn PPM	32	11.2	1.56	20	66
Ga PPM	10.6	1.9	0.26	7.4	16
Ge PPM	0.9	0.1	0.01	0.8	1.2
As PPM	5.0	2.3	0.32	3	14
Rb PPM	80	7.3	1.02	67	100
Sr PPM	370	92.5	12.82	170	650
Y PPM	11.7	2.4	0.33	7.4	19
Zr PPM	74	16.9	2.35	40	120
Nb PPM	5.5	2.2	0.30	2.4	12
Mo PPM	0.5	0.2	0.03	0.3	1.5
Sn PPM	0.9	0.4	0.06	0.5	2
Sb PPM	0.6	0.2	0.03	0.3	1.2
Cs PPM	3.6	1.8	0.26	1.6	8.6
Ba PPM	750	115.9	16.08	470	1100
La PPM	23	4.3	0.60	15	36
Ce PPM	43	9.7	1.35	26	71
Pr PPM	5.3	1.1	0.15	3.4	8.6
Nd PPM	19	3.8	0.53	12	30
Sm PPM	3.5	0.7	0.10	2.2	5.8
Eu PPM	0.95	0.1	0.02	0.71	1.3
Tb PPM	0.41	0.1	0.01	0.25	0.68
Gd PPM	2.7	0.6	0.09	1.7	4.7
Dy PPM	2.3	0.5	0.07	1.4	3.9
Ho PPM	0.43	0.1	0.01	0.26	0.71
Er PPM	1.25	0.3	0.04	0.78	2.1
Tm PPM	0.18	0.0	0.01	0.11	0.29
Yb PPM	1.16	0.2	0.03	0.69	1.9
Hf PPM	1.8	0.6	0.08	0.8	3
Ta PPM	0.4	0.2	0.02	0.1	0.9
W PPM	0.8	0.3	0.04	0.4	1.4
Tl PPM	0.4	0.1	0.01	0.3	0.6
Pb PPM	13	2.0	0.28	10	18
Bi PPM	0.11	0.1	0.01	0.05	0.54
Th PPM	5.9	1.8	0.24	3.6	12
U PPM	2.3	0.6	0.08	1.3	3.8

Table 2. Analytical data from ICP-MS analyses of discrete (1-ft interval) samples from the 655-760 ft interval, 98th St. drill core.

[The "/2" notation in the Field No. column signifies an average of 2 analyses].

Field No	Depth, ft	Li PPM	Be PPM	Na %	Mg %	Al %	P %	S %	K %	Ca %	Sc PPM
ALB656C/2	656	34	1.5	1	1.1	6.1	< 0.01	< 0.1	2	2	7.4
ALB657C	657	51	2.3	0.69	1.3	7.5	< 0.01	0.1	1.8	3.3	12
ALB658C	658	49	1.2	0.75	1.2	7.4	< 0.01	< 0.1	1.9	2.7	11
ALB659C	659	45	2	0.76	1.2	7.7	< 0.01	< 0.1	1.8	2.3	11
ALB660C	660	16	0.9	1.2	0.41	4.4	< 0.01	< 0.1	2.1	1.4	3
ALB661C	661	16	1	1.2	0.4	4.3	< 0.01	< 0.1	2	0.88	3
ALB662C/2	662	38	1.6	0.84	0.99	6.5	< 0.01	0.1	1.9	2	8.5
ALB663C	663	33	1.7	0.86	1.1	6	< 0.01	< 0.1	1.9	1.5	7.3
ALB668C	668	18	1.2	1.1	0.5	4.7	< 0.01	< 0.1	2.1	0.82	4
ALB669C	669	26	1.6	0.98	0.75	5.3	< 0.01	0.1	2	1.2	5.4
ALB670C/2	670	20	1	1	0.55	4.6	< 0.01	< 0.1	2	1	4
ALB671C	671	23	1.1	0.85	0.63	4.7	< 0.01	0.1	2	1.4	5.5
ALB672C	672	24	1	0.89	0.67	4.9	< 0.01	0.1	2	1.2	5.6
ALB673C	673	48	2.2	0.6	1.2	8.8	< 0.01	< 0.1	2	2.1	14
ALB676C	676	38	1.5	0.79	0.9	6.6	< 0.01	< 0.1	2	2.2	9.7
ALB678C	678	26	1.6	0.96	0.77	5.3	< 0.01	< 0.1	2	1.4	6.4
ALB679C	679	20	1.2	1.1	0.53	4.6	< 0.01	< 0.1	2.1	0.91	4
ALB680C	680	17	0.5	0.79	0.5	3.8	< 0.01	< 0.1	1.6	8.3	4
ALB693C	693	46	1.9	0.6	1	7.6	< 0.01	< 0.1	1.9	1.7	11
ALB694C	694	26	0.9	0.94	0.72	5.2	< 0.01	0.1	2.1	0.87	5.1
ALB695C	695	21	1.2	0.97	0.59	4.7	< 0.01	0.1	2	0.82	4
ALB696C	696	23	1.3	0.88	0.65	4.8	< 0.01	0.1	1.9	0.97	5
ALB698C	698	21	1.3	0.84	0.61	4.6	< 0.01	0.1	1.8	3.7	4
ALB703C	703	22	1.5	0.88	0.56	4.4	< 0.01	< 0.1	2	1.2	5
ALB704C	704	33	1.5	0.8	0.9	5.8	< 0.01	0.1	2	1.5	7.4
ALB705C	705	31	1.5	0.78	0.97	6.1	< 0.01	< 0.1	2	1.2	7.9
ALB706C	706	27	1.5	0.83	0.66	5.2	0.04	< 0.1	1.9	1.4	6.4
ALB707C	707	22	1.1	0.67	0.53	4.5	0.03	< 0.1	1.6	5.4	5.2
ALB708C	708	47	1.8	0.59	1.3	7.1	0.06	< 0.1	2	3.7	11
ALB709C	709	46	1.5	0.53	1.4	7.6	0.06	< 0.1	1.9	2.6	12
ALB710C	710	27	1.6	0.8	0.96	4.8	0.04	< 0.1	1.9	2.2	6
ALB711C	711	27	1.2	0.78	0.69	5.1	0.04	< 0.1	1.8	1.7	6.5
ALB712C	712	22	1.1	0.85	0.51	4.3	0.03	< 0.1	1.9	1.4	4
ALB713C	713	40	1.5	0.47	0.99	6.6	0.05	< 0.1	1.7	6.6	10
ALB714C/2	714	44	1.5	0.57	1.2	7.6	0.06	< 0.1	1.8	4.3	11
ALB715C	715	54	2.2	0.43	1.5	9.3	0.06	< 0.1	1.9	2.3	15
ALB716C	716	55	2.5	0.4	1.4	9.9	0.06	< 0.1	1.9	2.1	15
ALB717C	717	52	2.5	0.47	1.4	9.1	0.06	< 0.1	2	2.6	14
ALB718C	718	52	2.5	0.5	1.5	8.7	0.06	< 0.1	1.9	2.8	13
ALB719C	719	55	2.2	0.5	1.5	9.3	0.06	< 0.1	2	2.4	15
ALB720C	720	56	2.3	0.51	1.5	9.9	0.06	< 0.1	2	2.4	15
ALB721C	721	49	2.2	0.51	1.4	8.7	0.06	< 0.1	1.9	3.3	14
ALB722C	722	51	2.5	0.48	1.4	9.4	0.06	< 0.1	2	2.3	14
ALB723C	723	48	2.4	0.54	1.3	8.6	0.06	< 0.1	2	2.2	13
ALB723.6C	724	16	1	0.65	0.4	3.7	0.02	< 0.1	1.5	8.4	4
ALB732.8C	733	10	0.7	0.67	0.26	2.8	0.02	< 0.1	1.3	13	2
ALB742C	742	18	0.9	0.85	0.38	3.9	0.03	< 0.1	1.8	2.2	4
ALB743C	743	21	1.2	0.92	0.45	4.5	0.04	< 0.1	2	0.93	4
ALB744C	744	17	0.8	0.82	0.38	3.7	0.03	< 0.1	1.7	5.4	3
ALB745C	745	18	0.9	0.83	0.36	3.6	0.03	< 0.1	1.7	4.6	3
ALB747C	747	31	1.4	0.82	0.64	5.4	0.05	< 0.1	2	1.1	6.9
ALB748C	748	47	1.9	0.68	1.2	8	0.06	< 0.1	2	1.5	12
ALB753C	753	49	2.3	0.57	1.2	9.2	0.05	< 0.1	2	1.4	14
ALB754C	754	51	2.4	0.5	1.3	9.8	0.05	< 0.1	1.9	1.3	15
ALB755C	755	42	2	0.61	1.1	8.4	0.03	< 0.1	2	0.9	12
ALB756C	756	34	1.6	0.77	0.72	6.7	0.04	< 0.1	2	1	8.6
ALB757C	757	41	1.9	0.67	1.1	8.2	0.05	< 0.1	2	1	12
ALB758C	758	41	2.1	0.7	1.1	8.2	0.04	< 0.1	2	0.97	11
ALB759C	759	43	2.1	0.67	1.2	8.3	0.04	< 0.1	1.9	0.83	12
ALB760C	760	22	1	0.93	0.53	4.9	0.02	< 0.1	2	1.5	4

Table 2, continued.

Field No	Depth, ft	V PPM	Fe %	Mn PPM	Co PPM	Ni PPM	Cu PPM	Zn PPM	Ga PPM	Ge PPM	As PPM
ALB656C/2	656	55	2.1	300	7.4	11	20	50	14	1.1	7.7
ALB657C	657	75	3.2	410	11	18	20	79	18	1.2	14
ALB658C	658	75	3	300	10	16	20	72	17	1.2	11
ALB659C	659	81	3.3	290	11	16	20	76	18	1.2	12
ALB660C	660	24	0.96	170	2.9	3.7	5	20	8.7	0.9	2
ALB661C	661	27	0.98	170	3	3.8	7	20	8.3	0.9	2
ALB662C/2	662	59	2.4	310	8.2	13	20	60	15	1.1	6.7
ALB663C	663	53	2.2	260	6.8	11	10	55	14	1.1	5
ALB668C	668	32	1.2	190	3.8	5.4	5	30	9.2	1	2
ALB669C	669	44	1.3	200	5.2	8.6	10	37	11	1.1	4
ALB670C/2	670	40	1.4	200	4.2	6.3	8	30	9.4	1	3
ALB671C	671	52	1.6	210	5	8.5	9	37	9.9	1	4
ALB672C	672	55	1.3	200	5.3	9.2	10	39	10	1.1	4
ALB673C	673	120	3.5	320	12	22	20	90	21	1.3	24
ALB676C	676	88	2.7	320	9.1	17	20	77	15	1.2	8.6
ALB678C	678	53	1.5	260	6.2	11	10	46	11	1.2	9.1
ALB679C	679	49	1.3	170	4.1	6.7	9	30	9.6	1	3
ALB680C	680	30	1.2	620	3.4	5.6	7	30	8	0.9	2
ALB693C	693	99	2.8	250	8.7	18	20	70	18	1.2	13
ALB694C	694	41	1.4	160	4.5	8	7	33	11	1	4
ALB695C	695	36	1.4	150	4	6.4	9	30	9.8	0.9	3
ALB696C	696	41	1.5	170	4.3	7.1	8	32	9.8	1	3
ALB698C	698	38	1.4	250	4	7.1	6	31	9.4	0.9	3
ALB703C	703	41	1.4	190	4.4	7.4	8	34	9.4	1.1	4
ALB704C	704	76	2.1	210	7	13	10	57	13	1.2	9.6
ALB705C	705	62	2.1	200	6.7	12	10	51	13	1.1	8.4
ALB706C	706	54	1.9	240	6.3	11	8	49	11	1	9.8
ALB707C	707	45	1.5	540	4.8	8.2	6	34	9.7	0.8	5
ALB708C	708	94	2.9	340	9.2	19	20	74	16	1.1	11
ALB709C	709	100	2.9	230	9.2	19	30	77	18	1.1	14
ALB710C	710	51	1.7	140	5.4	11	7	45	10	1	5.4
ALB711C	711	53	1.8	130	5.5	10	8	45	11	1	5
ALB712C	712	38	1.3	130	4.3	7.7	7	35	8.7	1	4
ALB713C	713	85	2.7	620	8.2	16	20	65	15	1	11
ALB714C/2	714	95	2.9	520	9.1	18	10	71	17	1.1	9
ALB715C	715	120	3.6	250	11	22	20	90	21	1.3	12
ALB716C	716	120	3.5	230	11	22	30	94	22	1.2	11
ALB717C	717	120	3.3	270	10	21	20	85	20	1.2	9.7
ALB718C	718	110	3.3	240	10	22	30	86	19	1.1	11
ALB719C	719	120	3.6	240	11	23	20	92	21	1.3	12
ALB720C	720	120	3.7	240	12	23	20	94	22	1.3	13
ALB721C	721	110	3.3	470	10	20	20	82	19	1.2	12
ALB722C	722	120	3.6	250	11	22	20	91	21	1.2	15
ALB723C	723	120	3.3	230	10	21	20	85	19	1.2	23
ALB723.6C	724	33	1.1	620	3.7	5.9	6	20	7.4	0.7	3
ALB732.8C	733	18	0.73	1000	2	3.5	< 3	10	5.2	0.6	3
ALB742C	742	32	1.3	310	3.8	5.8	4	30	7.8	0.9	4
ALB743C	743	34	1.3	150	4.1	6.8	8	31	9	1	4
ALB744C	744	26	1	400	3.4	5.4	< 3	20	7.3	0.8	3
ALB745C	745	29	1.1	400	3.7	5.4	6	20	7.4	0.8	3
ALB747C	747	63	2	150	6.4	12	20	54	12	1.1	6
ALB748C	748	100	3.2	250	10	18	20	81	18	1.3	13
ALB753C	753	120	3.5	280	10	19	20	87	20	1.3	13
ALB754C	754	120	3.6	280	11	20	20	88	21	1.2	13
ALB755C	755	100	3	250	9	16	20	72	18	1.2	13
ALB756C	756	69	2.3	370	8.4	12	20	55	14	1.2	9.4
ALB757C	757	96	2.9	280	8.3	16	20	72	18	1.2	13
ALB758C	758	96	2.9	310	8.9	16	20	70	18	1.2	17
ALB759C	759	100	3.1	340	10	16	20	73	18	1.2	25
ALB760C	760	44	1.3	140	5	6.4	7	30	9.9	0.9	5.5

Table 2, continued.

Field No	Depth, ft	Se PPM	Rb PPM	Sr PPM	Y PPM	Zr PPM	Nb PPM	Mo PPM	Ag PPM	Cd PPM	In PPM
ALB656C/2	656	< 1	83	270	23	140	13	0.5	0.2	< 0.1	< 0.1
ALB657C	657	2	92	310	32	190	17	0.7	0.2	< 0.1	< 0.1
ALB658C	658	< 1	88	320	28	170	15	0.6	0.2	< 0.1	< 0.1
ALB659C	659	< 1	87	300	29	190	16	0.7	0.2	< 0.1	< 0.1
ALB660C	660	1	72	230	14	72	6.3	0.3	< 0.1	0.2	< 0.1
ALB661C	661	< 1	70	220	14	62	6.7	0.3	< 0.1	< 0.1	< 0.1
ALB662C/2	662	< 1	83	270	24	150	13	0.5	0.1	< 0.1	< 0.1
ALB663C	663	< 1	81	260	21	120	11	0.5	0.1	< 0.1	< 0.1
ALB668C	668	1	74	210	15	89	7.3	0.4	< 0.1	< 0.1	< 0.1
ALB669C	669	< 1	78	220	16	88	8.3	0.4	< 0.1	0.4	< 0.1
ALB670C/2	670	1	71	200	15	89	8.1	0.5	0.1	< 0.1	< 0.1
ALB671C	671	< 1	77	180	17	92	8.5	0.5	< 0.1	< 0.1	< 0.1
ALB672C	672	1	80	170	18	95	9	0.6	0.1	< 0.1	< 0.1
ALB673C	673	1	100	280	31	210	18	1.2	0.2	< 0.1	< 0.1
ALB676C	676	1	90	230	28	160	15	1	0.1	< 0.1	< 0.1
ALB678C	678	1	80	180	22	130	11	0.8	0.1	< 0.1	< 0.1
ALB679C	679	1	76	200	15	100	8.1	0.4	0.1	< 0.1	< 0.1
ALB680C	680	2	58	180	19	70	6.4	0.4	< 0.1	0.4	< 0.1
ALB693C	693	1	95	250	25	170	15	0.9	0.1	< 0.1	< 0.1
ALB694C	694	< 1	77	190	16	84	8	0.5	< 0.1	< 0.1	< 0.1
ALB695C	695	1	73	190	16	73	7.7	0.4	0.1	< 0.1	< 0.1
ALB696C	696	1	72	190	16	94	8.6	0.4	0.1	< 0.1	< 0.1
ALB698C	698	1	70	190	20	73	6.9	0.4	< 0.1	0.2	< 0.1
ALB703C	703	1	73	170	16	88	8	0.5	0.1	< 0.1	< 0.1
ALB704C	704	1	85	190	24	150	12	0.9	0.1	< 0.1	< 0.1
ALB705C	705	1	85	180	22	140	12	0.8	0.1	< 0.1	< 0.1
ALB706C	706	< 1	86	170	21	120	12	1	0.2	< 0.1	< 0.1
ALB707C	707	< 1	72	170	21	84	9	0.7	0.1	0.6	< 0.1
ALB708C	708	1	100	240	33	170	16	1.4	0.1	0.4	< 0.1
ALB709C	709	1	110	240	28	170	16	1.7	0.1	< 0.1	< 0.1
ALB710C	710	1	84	170	20	110	10	1	< 0.1	< 0.1	< 0.1
ALB711C	711	< 1	82	170	20	130	11	0.8	< 0.1	< 0.1	< 0.1
ALB712C	712	1	80	150	16	93	7.8	0.7	< 0.1	< 0.1	< 0.1
ALB713C	713	1	93	230	27	150	14	1.2	0.1	0.6	< 0.1
ALB714C/2	714	< 1	99	250	29	160	14	1.1	0.1	0.6	< 0.1
ALB715C	715	1	120	280	31	200	19	1.6	0.1	0.1	< 0.1
ALB716C	716	1	120	290	31	200	20	1.5	0.1	0.1	< 0.1
ALB717C	717	5	120	270	31	180	18	1.4	0.1	0.4	< 0.1
ALB718C	718	2	110	270	30	180	18	1.7	0.1	0.2	< 0.1
ALB719C	719	< 1	140	280	32	200	19	1.6	0.1	0.1	< 0.1
ALB720C	720	1	120	280	33	210	20	1.5	0.2	0.1	< 0.1
ALB721C	721	1	110	260	34	190	18	1.3	0.1	0.9	< 0.1
ALB722C	722	1	120	280	32	200	20	1.6	0.1	< 0.1	< 0.1
ALB723C	723	< 1	110	260	30	180	18	1.5	0.1	0.1	< 0.1
ALB723.6C	724	< 1	60	160	15	54	5.6	0.4	< 0.1	0.8	< 0.1
ALB732.8C	733	< 1	50	160	21	42	4	0.3	< 0.1	0.3	< 0.1
ALB742C	742	1	71	150	15	76	6.7	0.5	< 0.1	< 0.1	< 0.1
ALB743C	743	< 1	78	160	15	93	7.7	0.5	< 0.1	< 0.1	< 0.1
ALB744C	744	< 1	67	150	14	59	6	0.6	< 0.1	0.2	< 0.1
ALB745C	745	< 1	69	150	14	74	6.3	0.4	< 0.1	0.2	< 0.1
ALB747C	747	1	92	190	23	140	12	0.7	< 0.1	0.1	< 0.1
ALB748C	748	1	110	250	30	190	17	1.1	0.1	0.1	< 0.1
ALB753C	753	< 1	110	280	32	200	18	1.3	0.1	0.1	< 0.1
ALB754C	754	< 1	110	280	30	190	18	1.3	0.1	0.1	< 0.1
ALB755C	755	< 1	100	250	23	160	15	1	0.1	< 0.1	< 0.1
ALB756C	756	1	91	210	22	140	12	0.7	< 0.1	0.1	< 0.1
ALB757C	757	< 1	100	250	26	160	15	0.8	0.1	0.1	< 0.1
ALB758C	758	< 1	100	260	26	160	15	0.8	0.1	0.1	< 0.1
ALB759C	759	< 1	100	270	25	160	14	1	< 0.1	0.1	< 0.1
ALB760C	760	1	81	200	17	86	8	0.4	< 0.1	< 0.1	< 0.1

Table 2, continued.

Field No	Depth, ft	Sn PPM	Sb PPM	Te PPM	Cs PPM	Ba PPM	La PPM	Ce PPM	Pr PPM	Nd PPM	Sm PPM
ALB656C/2	656	1	0.5	< 0.5	5.7	630	33	66	7.7	28	5.4
ALB657C	657	3	0.7	< 0.5	8.9	470	44	90	10	37	7.4
ALB658C	658	2	0.6	< 0.5	7.9	510	38	78	9	33	6.4
ALB659C	659	2	0.7	< 0.5	8	500	41	83	9.6	35	6.8
ALB660C	660	< 0.5	0.3	< 0.5	2.2	1300	22	38	4.7	17	3.2
ALB661C	661	< 0.5	0.2	< 0.5	2.1	740	21	38	4.7	17	3.3
ALB662C/2	662	2	0.5	< 0.5	6.2	620	36	71	8.3	30	5.8
ALB663C	663	1	0.5	< 0.5	5.3	580	32	61	7.1	26	4.9
ALB668C	668	0.5	0.4	< 0.5	2.7	1100	23	43	5.2	19	3.7
ALB669C	669	0.8	0.5	< 0.5	4.4	650	27	52	6	22	4.1
ALB670C/2	670	0.7	0.4	< 0.5	3.2	700	24	46	5.6	20	4
ALB671C	671	0.8	0.5	< 0.5	4.2	610	29	56	6.4	24	4.5
ALB672C	672	1	0.5	< 0.5	4.5	600	27	54	6.3	23	4.5
ALB673C	673	3	1.1	< 0.5	11	450	45	92	10	38	7.4
ALB676C	676	2	0.9	< 0.5	7.4	500	38	78	9	33	6.3
ALB678C	678	1	0.6	< 0.5	4.6	590	30	62	7	26	5.1
ALB679C	679	0.6	0.5	< 0.5	3.2	680	24	46	5.3	19	3.8
ALB680C	680	< 0.5	0.3	< 0.5	2.5	550	29	48	6	21	4
ALB693C	693	2	0.7	< 0.5	8.6	480	37	75	8.5	30	5.9
ALB694C	694	0.8	0.4	< 0.5	3.9	650	25	47	5.6	20	3.9
ALB695C	695	0.7	0.4	< 0.5	3.2	680	24	45	5.5	20	3.9
ALB696C	696	0.7	0.4	< 0.5	3.5	630	23	44	5.4	20	3.8
ALB698C	698	0.6	0.4	< 0.5	3.3	600	27	46	5.7	20	3.8
ALB703C	703	0.6	0.4	< 0.5	3.4	640	27	52	6	22	4.2
ALB704C	704	2	0.7	< 0.5	6.1	560	36	73	8.2	30	6
ALB705C	705	2	0.6	< 0.5	5.6	560	31	64	7.3	26	5
ALB706C	706	2	0.8	< 0.5	4.4	530	29	59	6.8	25	4.7
ALB707C	707	1	0.6	< 0.5	3.6	620	27	53	5.8	21	4
ALB708C	708	2	1	< 0.5	8.7	420	42	85	9.6	35	6.8
ALB709C	709	3	1	< 0.5	8.6	410	39	79	8.8	32	6.1
ALB710C	710	1	0.8	< 0.5	4.4	510	28	57	6.5	24	4.6
ALB711C	711	1	0.7	< 0.5	4.5	490	29	58	6.6	24	4.6
ALB712C	712	0.9	0.6	< 0.5	3.4	560	24	48	5.5	20	3.9
ALB713C	713	2	1	< 0.5	7.5	390	36	72	8	29	5.6
ALB714C/2	714	2	0.9	< 0.5	8.7	420	39	85	8.9	33	6.4
ALB715C	715	4	1.1	< 0.5	11	380	44	91	9.9	36	7
ALB716C	716	4	1.1	< 0.5	11	380	44	90	10	36	7
ALB717C	717	3	1	< 0.5	10	400	44	90	9.9	36	7.1
ALB718C	718	3	1	< 0.5	9.7	420	42	87	9.6	35	6.7
ALB719C	719	3	1.1	< 0.5	11	410	46	79	10	38	7.3
ALB720C	720	4	1.3	< 0.5	11	420	46	80	10	38	7.6
ALB721C	721	3	1.1	< 0.5	9.9	400	44	93	10	37	7.2
ALB722C	722	3	1.2	< 0.5	10	400	45	91	10	37	7.3
ALB723C	723	3	1.1	< 0.5	9.7	420	43	87	9.7	36	6.8
ALB723.6C	724	0.8	0.4	< 0.5	2.6	450	22	38	4.3	15	3
ALB732.8C	733	0.6	0.3	< 0.5	1.4	690	16	30	3.3	12	2.4
ALB742C	742	0.6	0.5	< 0.5	2.4	560	22	45	4.9	18	3.4
ALB743C	743	0.8	0.6	< 0.5	2.8	590	22	44	5	19	3.5
ALB744C	744	0.5	0.4	< 0.5	2.1	940	19	36	4.1	15	2.9
ALB745C	745	0.6	0.5	< 0.5	2.1	760	20	38	4.4	16	3.2
ALB747C	747	1	0.9	< 0.5	5.4	580	33	68	7.7	28	5.4
ALB748C	748	3	1.2	< 0.5	8.8	520	42	87	9.6	35	6.8
ALB753C	753	3	1.2	< 0.5	9.9	480	44	90	9.9	36	7.2
ALB754C	754	3	1.2	< 0.5	10	450	45	93	10	38	7.1
ALB755C	755	2	1	< 0.5	8.6	510	37	76	8.3	30	5.6
ALB756C	756	2	0.8	< 0.5	5.8	550	31	66	7.2	27	5.2
ALB757C	757	2	1	< 0.5	7.8	490	38	71	8.3	30	5.8
ALB758C	758	2	1	< 0.5	7.9	510	36	73	8.3	30	5.7
ALB759C	759	2	1	< 0.5	8.4	520	38	79	8.7	32	6
ALB760C	760	0.8	0.5	< 0.5	3.3	640	22	43	5	19	3.6

Table 2, continued.

Field No	Depth, ft	Eu PPM	Tb PPM	Gd PPM	Dy PPM	Ho PPM	Er PPM	Tm PPM	Yb PPM	Hf PPM	Ta PPM
ALB656C/2	656	1.3	0.74	4.8	4.1	0.88	2.5	0.39	2.4	4	0.8
ALB657C	657	1.6	0.98	6.5	5.6	1.2	3.4	0.53	3.1	5.2	1.3
ALB658C	658	1.4	0.88	5.8	5	1	3	0.48	2.8	5	1.2
ALB659C	659	1.4	0.9	6.1	5.1	1.1	3	0.49	3	5.2	1.2
ALB660C	660	0.85	0.41	2.8	2.3	0.5	1.4	0.22	1.3	2	0.5
ALB661C	661	0.84	0.43	2.8	2.4	0.5	1.4	0.22	1.4	1	0.5
ALB662C/2	662	1.3	0.77	5	4.2	0.93	2.6	0.4	2.4	4	1.1
ALB663C	663	1.2	0.66	4.4	3.8	0.82	2.3	0.36	2.1	4	1
ALB668C	668	0.92	0.49	3.2	2.8	0.6	1.7	0.26	1.6	2	0.5
ALB669C	669	1	0.52	3.7	3	0.64	1.8	0.3	1.7	2	0.6
ALB670C/2	670	0.89	0.52	3.4	2.8	0.59	1.6	0.25	1.5	2	0.6
ALB671C	671	1	0.58	3.9	3.2	0.7	1.9	0.29	1.9	2	0.6
ALB672C	672	1	0.6	3.9	3.3	0.7	2	0.32	1.8	2	0.6
ALB673C	673	1.6	0.98	6.5	5.7	1.2	3.4	0.54	3.2	5.9	1.5
ALB676C	676	1.4	0.87	5.7	4.8	1.1	3	0.48	3	4	1.1
ALB678C	678	1.2	0.72	4.4	3.9	0.86	2.4	0.38	2.3	3	0.8
ALB679C	679	0.9	0.49	3.3	2.8	0.61	1.7	0.27	1.7	3	0.6
ALB680C	680	0.98	0.54	3.5	3.1	0.7	2	0.3	1.8	2	0.4
ALB693C	693	1.3	0.82	5.3	4.5	0.99	2.9	0.44	2.6	5	1.1
ALB694C	694	0.94	0.5	3.4	2.9	0.62	1.8	0.26	1.7	2	0.6
ALB695C	695	0.93	0.52	3.5	2.9	0.65	1.7	0.27	1.6	2	0.5
ALB696C	696	0.94	0.52	3.4	3	0.65	1.8	0.3	1.8	2	0.6
ALB698C	698	1	0.57	3.6	3.2	0.7	2	0.31	1.9	2	0.4
ALB703C	703	0.97	0.56	3.7	3	0.64	1.8	0.28	1.6	2	0.5
ALB704C	704	1.3	0.8	5.2	4.4	0.96	2.6	0.4	2.6	4	0.7
ALB705C	705	1.2	0.7	4.5	3.9	0.87	2.3	0.38	2.3	4	0.9
ALB706C	706	1.1	0.67	4.3	3.8	0.82	2.2	0.36	2.2	4	0.9
ALB707C	707	1	0.59	3.8	3.4	0.75	2.1	0.31	2	2	0.6
ALB708C	708	1.5	0.97	6.4	5.6	1.2	3.4	0.5	3.1	5.2	1.3
ALB709C	709	1.3	0.86	5.6	4.9	1.1	3	0.46	2.8	5	1.2
ALB710C	710	1	0.64	4.4	3.8	0.82	2.3	0.34	2.2	4	0.8
ALB711C	711	1	0.62	4.1	3.6	0.78	2.2	0.34	2	4	0.9
ALB712C	712	0.87	0.5	3.4	3	0.62	1.8	0.27	1.6	3	0.6
ALB713C	713	1.2	0.8	5.2	4.8	1	2.8	0.44	2.7	5	1.2
ALB714C/2	714	1.4	0.92	5.8	5.2	1.1	3.2	0.49	2.9	5.1	1.2
ALB715C	715	1.5	0.98	6.2	5.7	1.2	3.5	0.54	3.3	6.3	1.7
ALB716C	716	1.5	0.97	6.2	5.6	1.2	3.4	0.54	3.2	6.5	1.7
ALB717C	717	1.5	1	6.3	5.7	1.2	3.4	0.54	3.3	5.7	1.7
ALB718C	718	1.4	0.93	6.2	5.6	1.2	3.3	0.49	3.2	5.8	1.5
ALB719C	719	1.6	1	6.6	5.9	1.2	3.6	0.54	3.3	6.1	1.6
ALB720C	720	1.6	1	6.9	6	1.3	3.7	0.56	3.5	6.6	1.9
ALB721C	721	1.5	1	6.6	5.9	1.3	3.7	0.54	3.4	5.8	1.6
ALB722C	722	1.5	1	6.6	5.9	1.3	3.6	0.54	3.5	6.4	1.7
ALB723C	723	1.4	0.95	6.2	5.4	1.2	3.3	0.51	3.2	5.5	1.4
ALB723.6C	724	0.78	0.42	2.7	2.4	0.54	1.5	0.23	1.5	2	0.4
ALB732.8C	733	0.69	0.41	2.5	2.8	0.65	2	0.29	1.8	1	0.3
ALB742C	742	0.84	0.46	3.2	2.7	0.59	1.6	0.25	1.5	2	0.4
ALB743C	743	0.87	0.47	3.1	2.7	0.58	1.6	0.24	1.6	3	0.6
ALB744C	744	0.71	0.4	2.6	2.2	0.49	1.4	0.22	1.3	2	0.4
ALB745C	745	0.79	0.43	2.8	2.5	0.51	1.5	0.23	1.5	2	0.4
ALB747C	747	1.2	0.77	4.9	4.4	0.95	2.6	0.39	2.5	4	1
ALB748C	748	1.5	0.94	6.2	5.4	1.2	3.3	0.49	3	5.9	1.3
ALB753C	753	1.5	0.98	6.2	5.7	1.2	3.4	0.53	3.2	6.2	1.6
ALB754C	754	1.6	1	6.5	5.8	1.2	3.4	0.52	3.3	6.1	1.6
ALB755C	755	1.2	0.77	5	4.4	0.95	2.7	0.41	2.7	5.2	1.3
ALB756C	756	1.2	0.72	4.6	4.2	0.87	2.5	0.38	2.3	4	1
ALB757C	757	1.4	0.82	5.2	4.8	0.98	2.8	0.42	2.7	5.2	1.3
ALB758C	758	1.3	0.82	5.2	4.7	1	2.8	0.43	2.7	5	1.2
ALB759C	759	1.4	0.84	5.5	4.6	1	2.8	0.42	2.8	5	1.2
ALB760C	760	0.88	0.52	3.3	3	0.66	1.8	0.28	1.7	3	0.6

Table 2, continued.

Field No	Depth, ft	W PPM	Re PPM	Au PPM	Tl PPM	Pb PPM	Bi PPM	Ti %	Th PPM	U PPM
ALB656C/2	656	1	< 0.05	< 0.05	0.5	19	0.2	0.3	8.9	2.6
ALB657C	657	1.7	< 0.05	< 0.05	0.6	21	0.3	0.4	13	3.3
ALB658C	658	1.5	< 0.05	< 0.05	0.5	20	0.2	0.4	12	3.2
ALB659C	659	1.7	< 0.05	< 0.05	0.6	20	0.3	0.4	12	3.4
ALB660C	660	0.5	< 0.05	< 0.05	0.4	11	0.06	0.1	5	1.4
ALB661C	661	0.5	< 0.05	< 0.05	0.4	12	0.05	0.2	4.6	1.4
ALB662C/2	662	1.6	< 0.05	< 0.05	0.5	16	0.2	0.3	9.6	2.7
ALB663C	663	2.5	< 0.05	< 0.05	0.5	17	0.2	0.2	8.8	2.5
ALB668C	668	0.8	< 0.05	< 0.05	0.4	13	0.06	0.2	5.4	1.8
ALB669C	669	0.6	< 0.05	< 0.05	0.5	15	0.1	0.2	7.1	2.2
ALB670C/2	670	0.8	< 0.05	< 0.05	0.4	14	0.09	0.2	7.2	2
ALB671C	671	1.1	< 0.05	< 0.05	0.4	14	0.1	0.2	7.1	2.3
ALB672C	672	1.2	< 0.05	< 0.05	0.4	14	0.1	0.2	7.6	2.4
ALB673C	673	2.1	< 0.05	< 0.05	0.6	22	0.3	0.4	14	4.4
ALB676C	676	1.3	< 0.05	< 0.05	0.6	20	0.2	0.4	12	3.5
ALB678C	678	1	< 0.05	< 0.05	0.5	16	0.1	0.3	8.5	2.6
ALB679C	679	0.8	< 0.05	< 0.05	0.4	13	0.09	0.2	6.2	2
ALB680C	680	0.5	< 0.05	< 0.05	0.3	10	0.05	0.2	5	1.5
ALB693C	693	1.7	< 0.05	< 0.05	0.6	18	0.2	0.3	12	3.6
ALB694C	694	1.5	< 0.05	< 0.05	0.5	13	0.1	0.2	6.8	1.9
ALB695C	695	1.5	< 0.05	< 0.05	0.4	14	0.07	0.2	6.1	1.7
ALB696C	696	1.4	< 0.05	< 0.05	0.4	13	0.09	0.2	6	1.9
ALB698C	698	0.8	< 0.05	< 0.05	0.4	13	0.07	0.2	5.5	1.7
ALB703C	703	0.6	< 0.05	< 0.05	0.4	14	0.1	0.2	7.7	2.2
ALB704C	704	1.1	< 0.05	< 0.05	0.5	18	0.2	0.3	11	3.2
ALB705C	705	1.1	< 0.05	< 0.05	0.5	15	0.1	0.3	9.8	2.9
ALB706C	706	1.1	< 0.05	< 0.05	0.5	17	0.2	0.3	9.2	2.6
ALB707C	707	0.9	< 0.05	< 0.05	0.4	14	0.1	0.2	6.5	2
ALB708C	708	1.4	< 0.05	< 0.05	0.6	19	0.3	0.4	13	3.8
ALB709C	709	1.5	< 0.05	< 0.05	0.6	19	0.3	0.4	13	3.9
ALB710C	710	0.8	< 0.05	< 0.05	0.5	16	0.2	0.3	8.8	2.8
ALB711C	711	0.9	< 0.05	< 0.05	0.4	15	0.1	0.3	9.1	3
ALB712C	712	0.7	< 0.05	< 0.05	0.4	15	0.1	0.2	7.3	2.4
ALB713C	713	1.5	< 0.05	< 0.05	0.5	19	0.2	0.4	11	3.5
ALB714C/2	714	1.6	< 0.05	< 0.05	0.5	19	0.3	0.4	12	4
ALB715C	715	2.1	< 0.05	< 0.05	0.6	23	0.3	0.4	15	4.8
ALB716C	716	2.2	< 0.05	< 0.05	0.7	22	0.3	0.4	15	4.9
ALB717C	717	1.9	< 0.05	< 0.05	0.6	21	0.3	0.4	14	4.5
ALB718C	718	1.9	< 0.05	< 0.05	0.7	22	0.3	0.5	15	4.7
ALB719C	719	2.1	< 0.05	< 0.05	0.7	21	0.3	0.4	16	4.9
ALB720C	720	2.2	< 0.05	< 0.05	0.7	24	0.3	0.5	16	5
ALB721C	721	1.9	< 0.05	< 0.05	0.6	21	0.3	0.4	14	4.3
ALB722C	722	2.1	< 0.05	< 0.05	0.7	23	0.3	0.4	15	4.7
ALB723C	723	1.8	< 0.05	< 0.05	0.6	21	0.3	0.5	14	4.2
ALB723.6C	724	0.6	< 0.05	< 0.05	0.3	12	0.08	0.2	5	2.2
ALB732.8C	733	0.4	< 0.05	< 0.05	0.2	9.5	< 0.05	0.1	3	0.98
ALB742C	742	0.7	< 0.05	< 0.05	0.3	12	0.08	0.2	5.9	1.8
ALB743C	743	0.7	< 0.05	< 0.05	0.4	13	0.08	0.2	6.2	2
ALB744C	744	0.6	< 0.05	< 0.05	0.3	11	0.06	0.2	4.9	1.6
ALB745C	745	0.6	< 0.05	< 0.05	0.4	12	0.07	0.2	5.1	1.7
ALB747C	747	1.3	< 0.05	< 0.05	0.5	18	0.2	0.3	11	3.4
ALB748C	748	2	< 0.05	< 0.05	0.6	22	0.3	0.5	14	4.1
ALB753C	753	2.1	< 0.05	< 0.05	0.6	22	0.3	0.4	14	4.4
ALB754C	754	2	< 0.05	< 0.05	0.6	22	0.3	0.4	15	4.7
ALB755C	755	1.7	< 0.05	< 0.05	0.6	19	0.3	0.4	13	3.9
ALB756C	756	1.5	< 0.05	< 0.05	0.5	17	0.2	0.4	9.8	3
ALB757C	757	1.9	< 0.05	< 0.05	0.5	18	0.2	0.4	12	3.9
ALB758C	758	1.9	< 0.05	< 0.05	0.6	18	0.2	0.4	12	3.9
ALB759C	759	2.3	< 0.05	< 0.05	0.6	21	0.2	0.4	13	4
ALB760C	760	1.1	< 0.05	< 0.05	0.4	14	0.1	0.2	6.1	2

Table 2, continued: Descriptive statistics for ICP-MS analyses of discrete (1-ft interval) samples, 655-760 ft interval, 98th St. drill core.

	Mean	Std. Dev.	Std. Error	Minimum	Maximum
Li PPM	34	13.4	1.73	10	56
Be PPM	1.6	0.5	0.07	0.5	2.5
Na %	0.75	0.2	0.03	0.4	1.2
Mg %	0.90	0.4	0.05	0.26	1.5
Al %	6.4	2.0	0.26	2.8	9.9
P%	0.05	<0.01	<0.01	0.02	0.06
K%	1.9	0.1	0.02	1.3	2.1
Ca %	2.44	2.2	0.28	0.82	13
Sc PPM	8.4	4.1	0.53	2	15
V PPM	70	33.2	4.28	18	120
Fe %	2.24	0.9	0.12	0.73	3.7
Mn PPM	290	151.8	19.60	130	1000
Co PPM	7.1	2.9	0.37	2	12
Ni PPM	12.9	6.1	0.79	3.5	23
Cu PPM	14	7.1	0.94	4	30
Zn PPM	55	24.7	3.19	10	94
Ga PPM	13.9	4.8	0.62	5.2	22
Ge PPM	1.1	0.2	0.02	0.6	1.3
As PPM	8.5	5.5	0.71	2	25
Se PPM	1	0.7	0.13	1	5
Rb PPM	89	18.3	2.37	50	140
Sr PPM	220	48.2	6.22	150	320
Y PPM	23	6.4	0.83	14	34
Zr PPM	133	48.6	6.28	42	210
Nb PPM	12.3	4.6	0.59	4	20
Mo PPM	0.8	0.4	0.05	0.3	1.7
Ag PPM	0.1	0.0	0.01	0.1	0.2
Sn PPM	1.8	1.0	0.14	0.5	4
Sb PPM	0.7	0.3	0.04	0.2	1.3
Cs PPM	6.1	3.0	0.39	1.4	11
Ba PPM	560	163.5	21.11	380	1300
La PPM	33	8.7	1.12	16	46
Ce PPM	65	18.8	2.43	30	93
Pr PPM	7.4	2.0	0.26	3.3	10
Nd PPM	27	7.5	0.97	12	38
Sm PPM	5.2	1.5	0.19	2.4	7.6
Eu PPM	1.18	0.3	0.04	0.69	1.6
Tb PPM	0.72	0.2	0.03	0.4	1
Gd PPM	4.7	1.3	0.17	2.5	6.9
Dy PPM	4.1	1.2	0.15	2.2	6
Ho PPM	0.89	0.3	0.03	0.49	1.3
Er PPM	2.5	0.7	0.09	1.4	3.7
Tm PPM	0.39	0.1	0.01	0.22	0.56
Yb PPM	2.4	0.7	0.09	1.3	3.5
Hf PPM	3.9	1.7	0.21	1	6.6
Ta PPM	1.0	0.4	0.06	0.3	1.9
W PPM	1.3	0.6	0.07	0.4	2.5
Tl PPM	0.5	0.1	0.02	0.2	0.7
Pb PPM	17	3.9	0.50	10	24
Bi PPM	0.18	0.1	0.01	0.05	0.3
Ti %	0.3	0.1	0.01	0.1	0.5
Th PPM	9.9	3.6	0.47	3	16
U PPM	3.0	1.1	0.14	0.98	5

Element Abundances in Composite Samples

The box plots in Figures 1A through 1L provide a means for comparing element abundances in the composite samples from Santa Fe Group sediments. The samples are placed in groups with like ranges of values, whether in percent or ppm. Besides the six elements noted in the previous section that were below the limit of detection (in all samples), Ag and Cd did not have sufficient numbers of samples with values above the lower limit of detection (Table 1), and thus are not shown on the box plots.

The notches represent the 95% confidence bands about the median (50th percentile, the line through the center of the box). The top and bottom of the box represent the 75th and 25th percentiles, respectively. The vertical line extending above the box encompasses the 75th to 90th percentiles; the vertical line extending below the box encompasses the 25th to 10th percentiles. Values beyond 10th and 90th percentiles (outliers) are displayed as circles. The range encompasses the lowest to highest values, i.e., from the uppermost to lowermost outliers. Distributions that are symmetric will show the median in the exact center of the box. Major elements tend to have symmetric distributions, for example, Al, Ca, and Na, while most trace metal distributions are asymmetric, suggesting larger variation in these elements within the core sediments. Additionally, boxes whose "thickness" are large also indicate greater heterogeneity of element values in the samples, for example, Co vs Ca (Fig. 1F).

The absence of Se is of interest because Se behaves chemically similar to As and often substitutes for As in many solid phases (Ward, 1970). (However, ICP-MS Se analysis is subject to greater uncertainty due to interferences from matrix effects and other element lines, so the Se results are not completely reliable. Se was not detected in any sample by ICP-AES, either). The lack of detectable Se suggests that 1)As alone was present in the source rocks, 2)Se was not a component of the original source rocks, or 3)Se is not present or available in the sediment-groundwater system.

The lack of detectable sulfur in any sample is even more striking because S is a major component of sulfide minerals such as arsenopyrite ($FeAsS_2$), which might be a potential source of dissolved As. Additionally, As is known to substitute for S in other mineral phases (Ward, 1970). Thus, it appears that weathering of As-bearing sulfide minerals would not be a readily-available source of the elevated levels of As observed in groundwater samples in the immediate area of the drill hole (D. Grimes, unpub. data, 1997). However, mineralogical analyses are not yet complete, and the apparent lack of sulfide minerals may be the result of insufficient numbers of samples having been examined to this point.

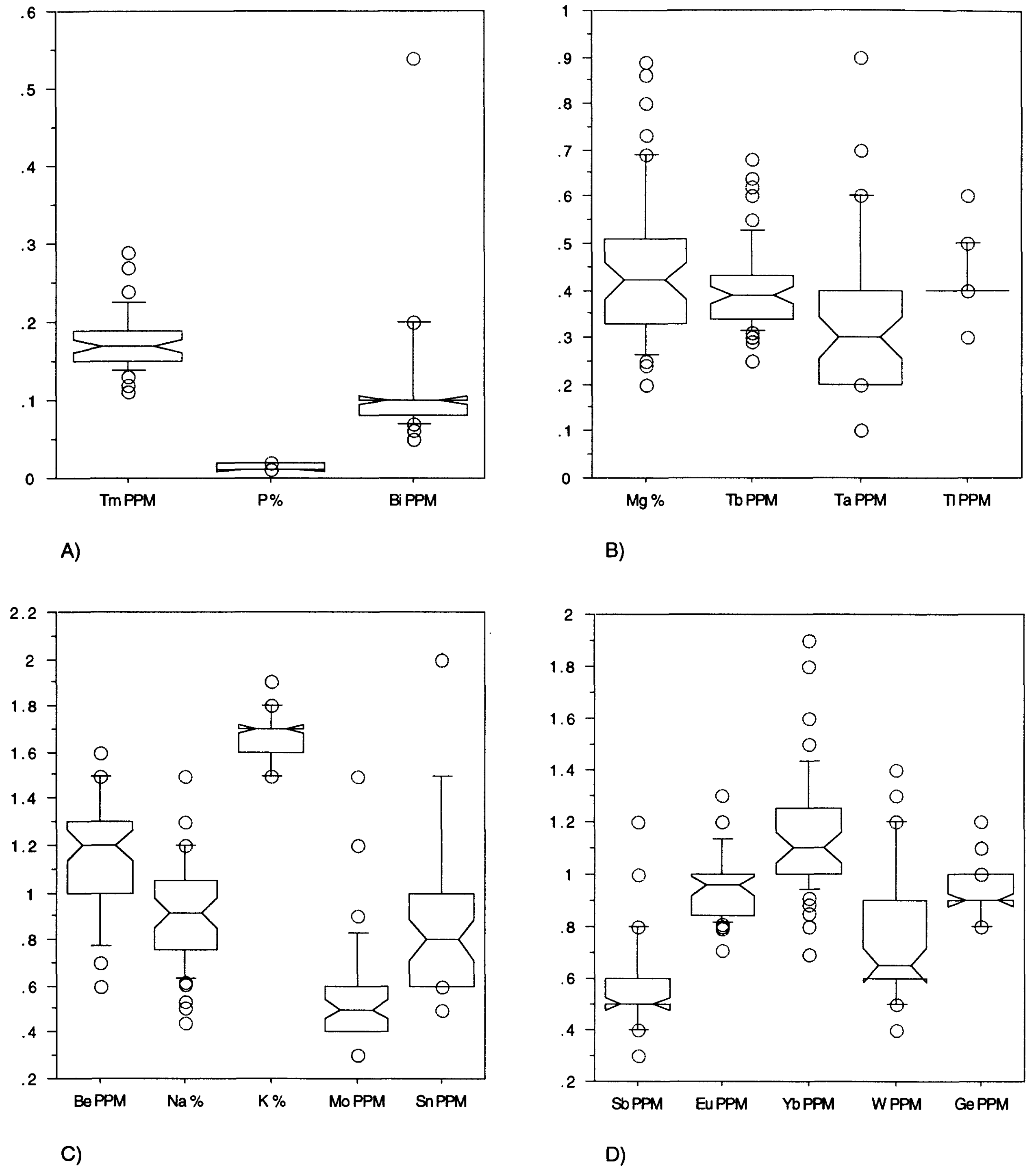
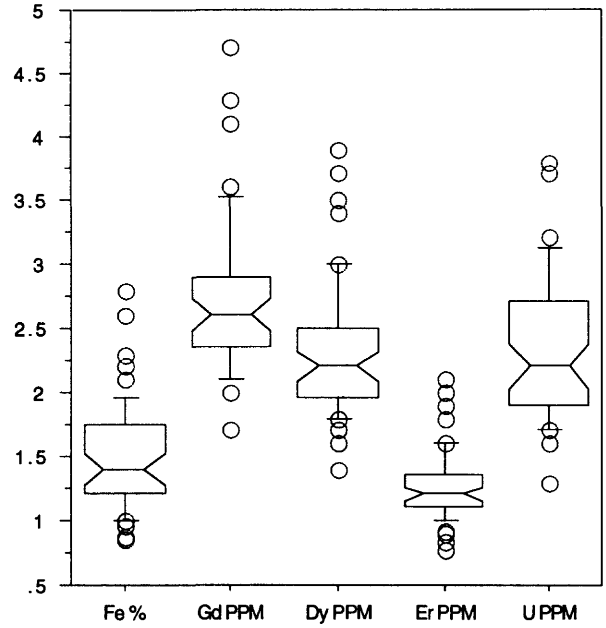
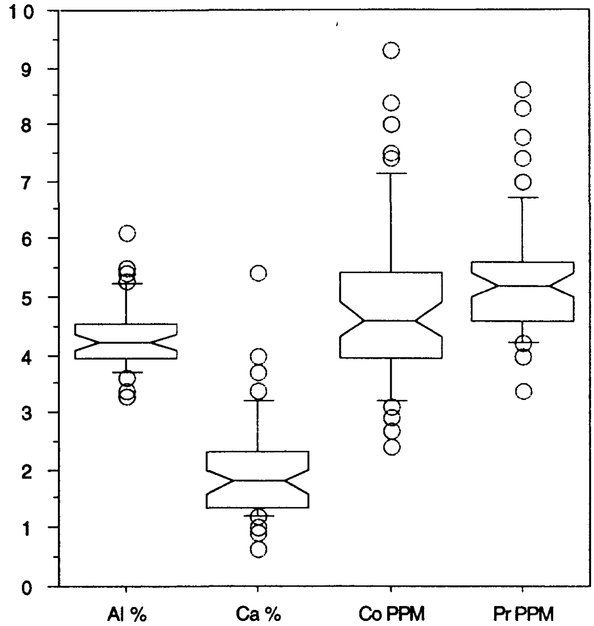


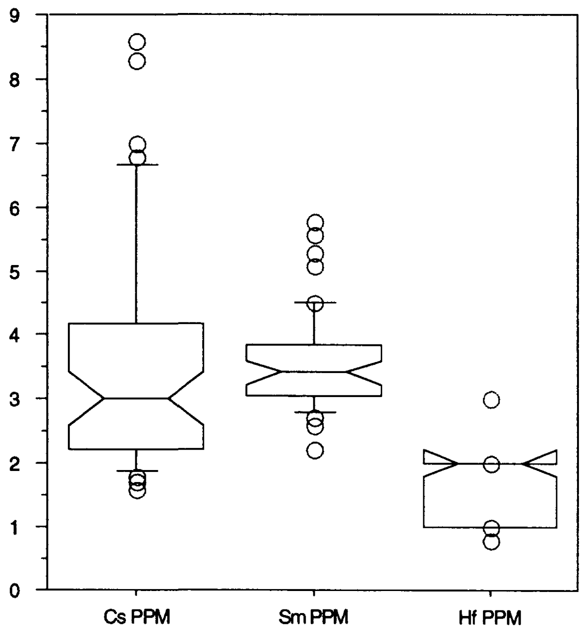
Figure 1A-1D. Box plots (notched) for element abundances in composite samples from the 98th St. drill core. A)Tm, P, and Bi. B)Mg, Tb, Ta, and Tl. C)Be, Na, K, Mo, and Sn. D)Sb, Eu, Yb, W, and Ge.



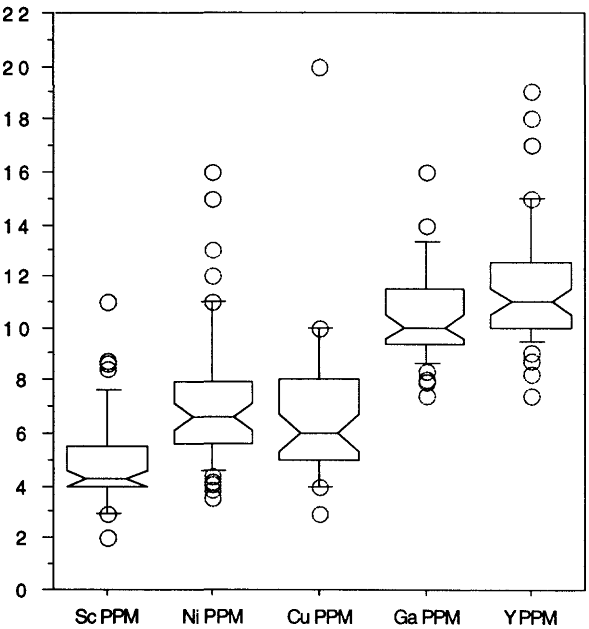
E)



F)



G)



H)

Figure 1E-1H. Box plots (notched) for element abundances in composite samples from the 98th St. drill core. E)Fe, Gd, Dy, Er, and U. F)Al, Ca, Co, and Pr. G)Cs, Sm, and Hf. H)Sc, Ni, Cu, Ga, and Y.

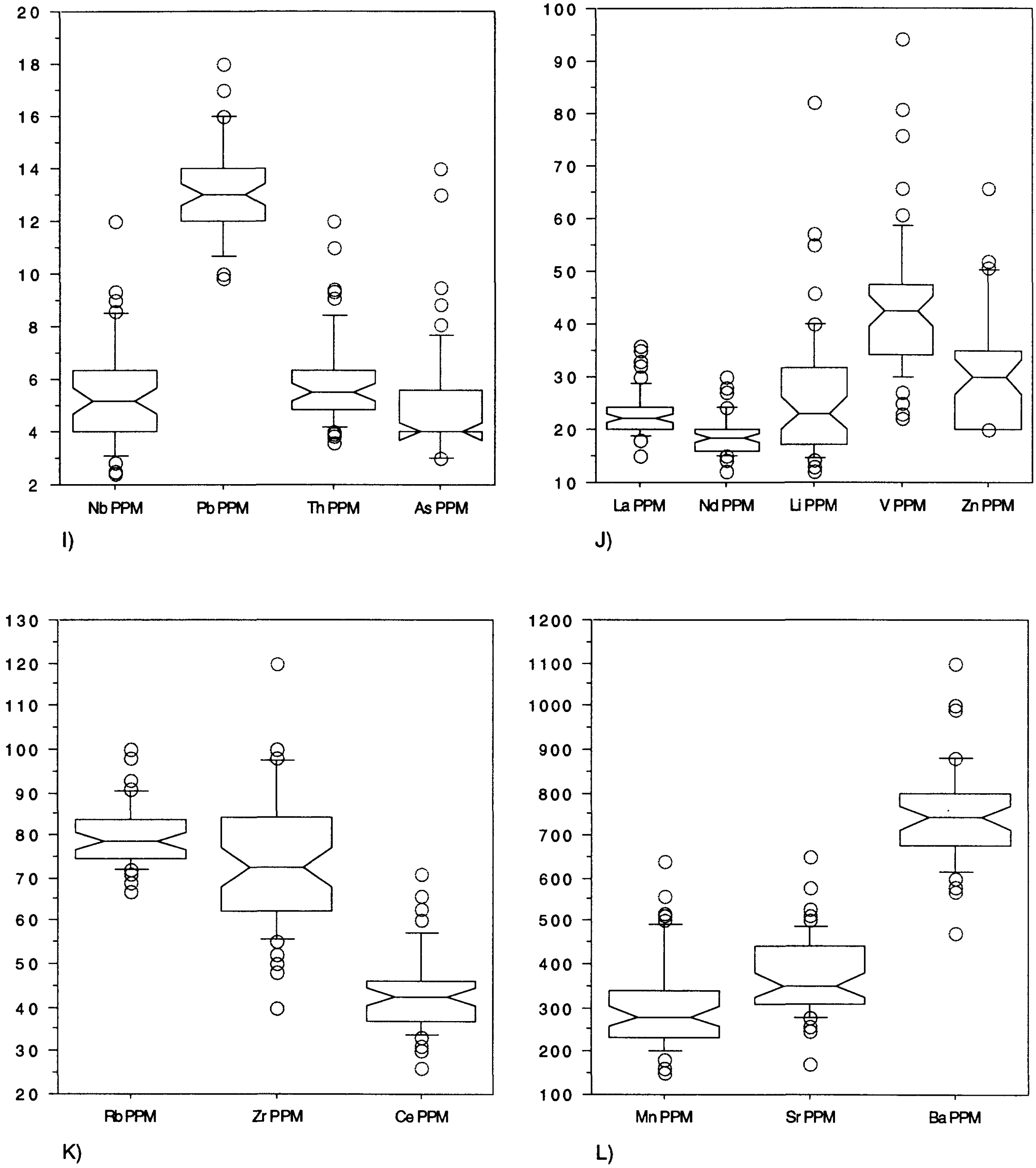


Figure 1I-1L. Box plots (notched) for element abundances in composite samples from the 98th St. drill core. I)Nb, Pb, Th, and As. J)La, Nd, Li, V, and Zn. K)Rb, Zr, and Ce. L)Mn, Sr, and Ba.

Element Abundances with Depth in Composite Samples

Element abundances with depth in the composite samples are illustrated in Figures 2A through 2J. On each plot, the 22 lithologic units encompassed by the samples are included on the left-hand side of the figure to illustrate the abundance of an element within each lithology. This descriptive lithologic column was compiled by Stone and others (1997) from their work on grain size and other characteristics (e.g., magnetic susceptibility) of these samples.

Most major and trace elements, including As, reach their greatest abundances in the composite samples within the zone centered near 720 ft (unit 10). In fact, nearly all elements attain their highest concentrations relative to other core sections in this interval (see Figs. 2A-2J). The zone at 580 ft has the second-highest abundances of similar suites of elements as 720 ft; two other zones having higher elemental abundances are centered at 470 ft and 1270 ft. Specific reasons for the increased abundances are unknown but suggest that similar geochemical, geological, or sedimentological processes may have produced enrichment or localization of elements in the 4 zones relative to other sediment layers. The higher As zones may be the result of an original high As content within the sediments (or source rocks for the sediments), or a secondary enrichment process.

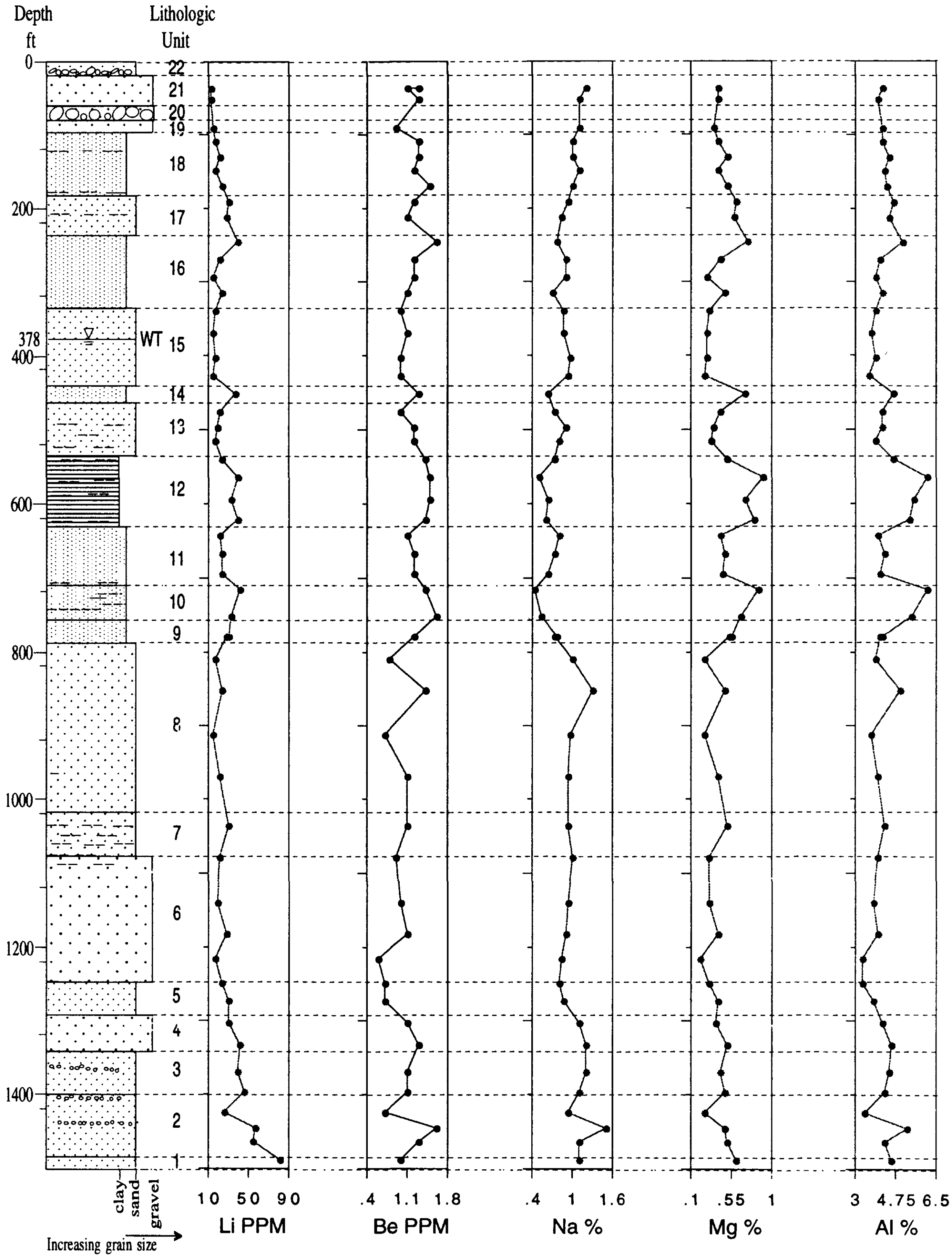


Figure 2A. Downhole plots of Be and Li (ppm), and Na, Mg, and Al (%) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

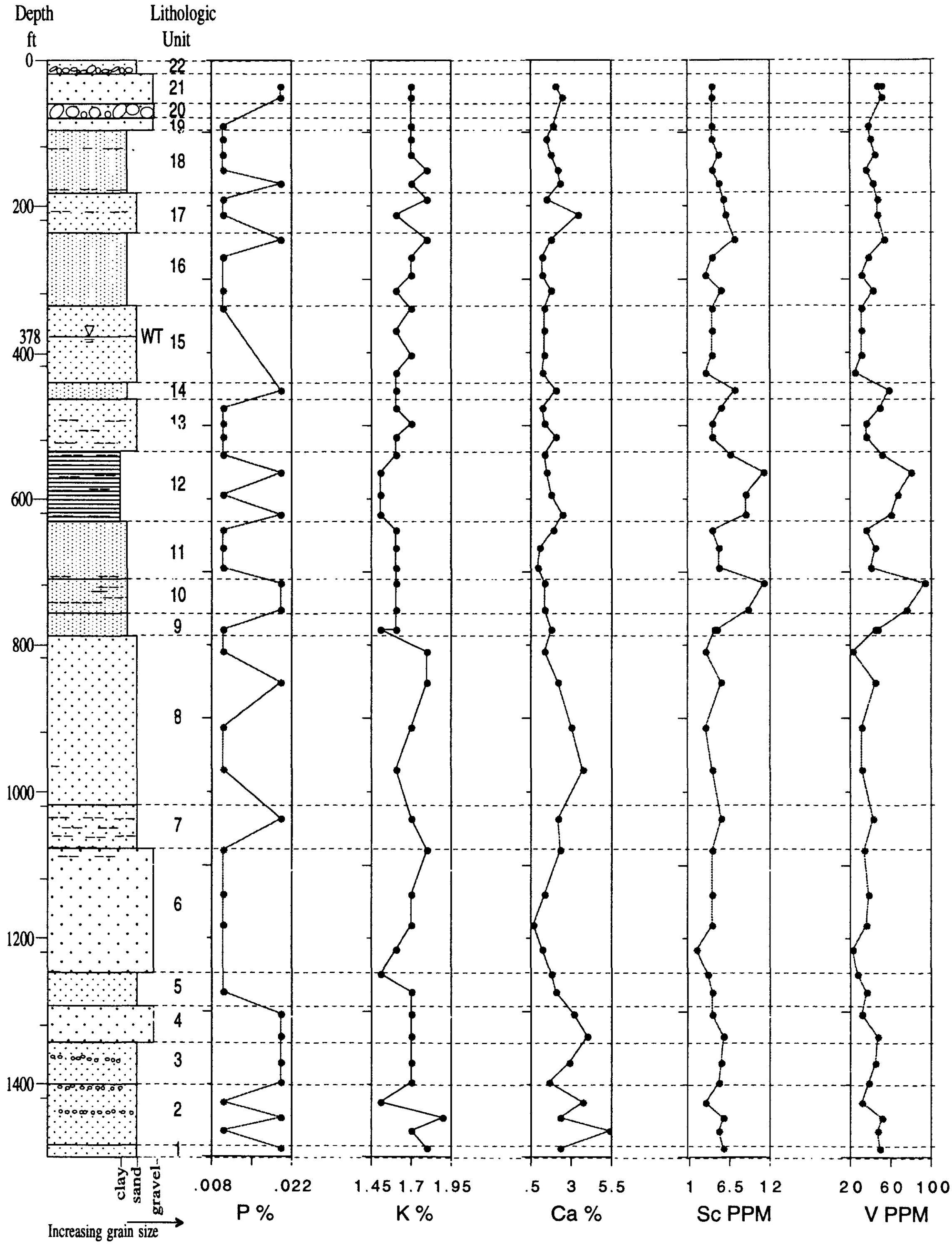


Figure 2B. Downhole plots of P, K, and Ca (%), and Sc and V (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

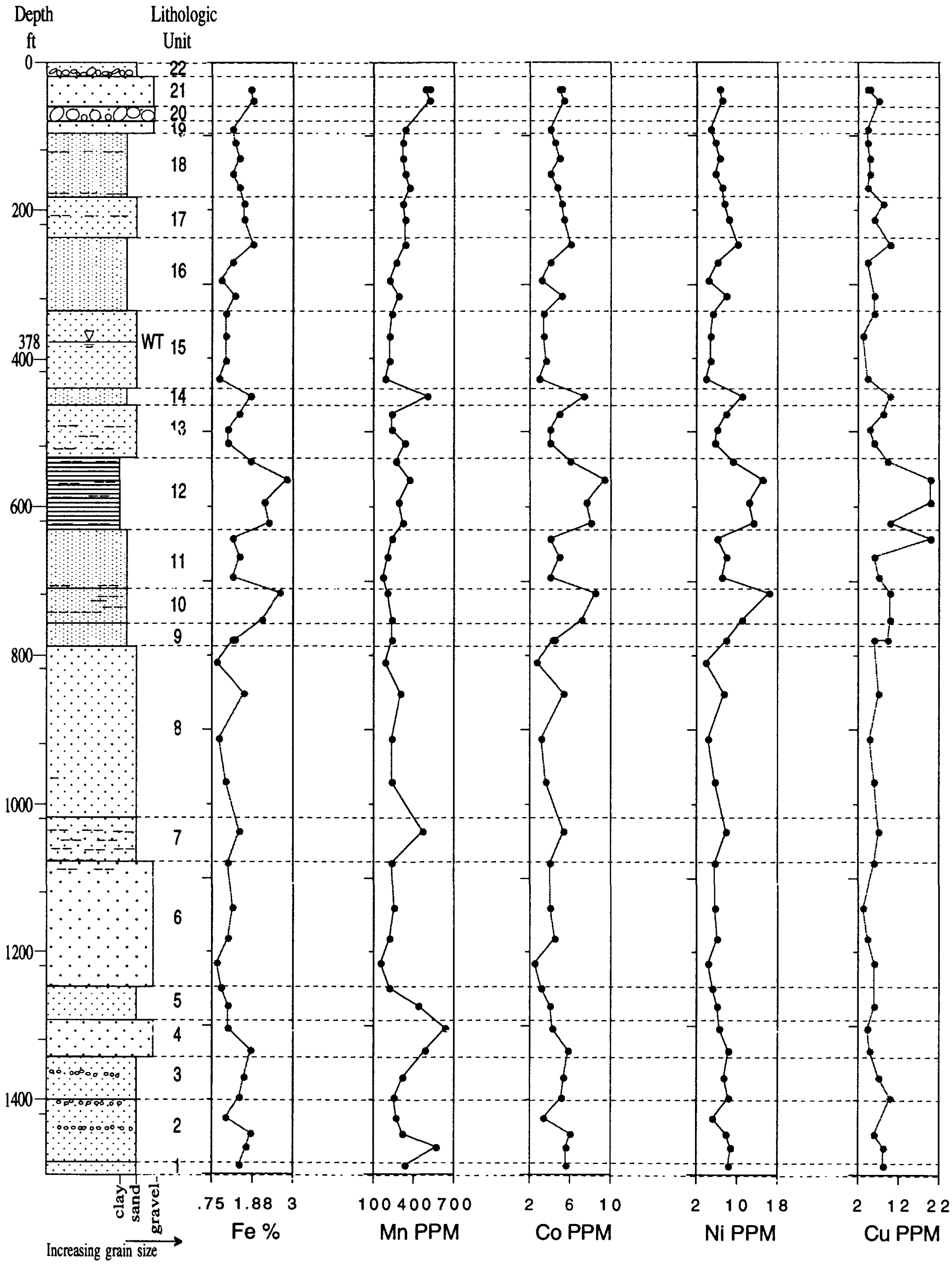


Figure 2C. Downhole plots of Fe (%), and Mn, Co, Ni, and Cu (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

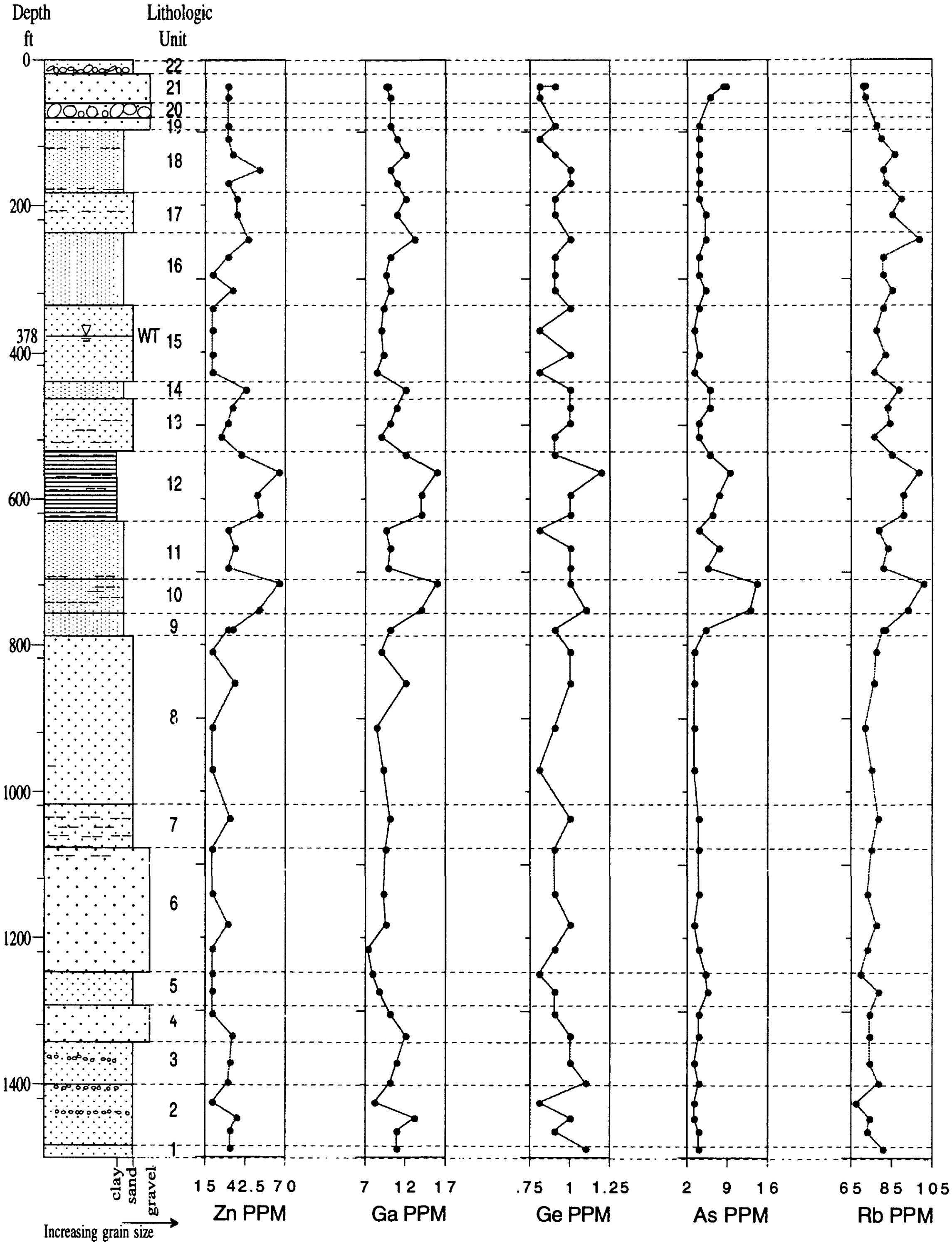


Figure 2D. Downhole plots of Zn, Ga, Ge, As, and Rb (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

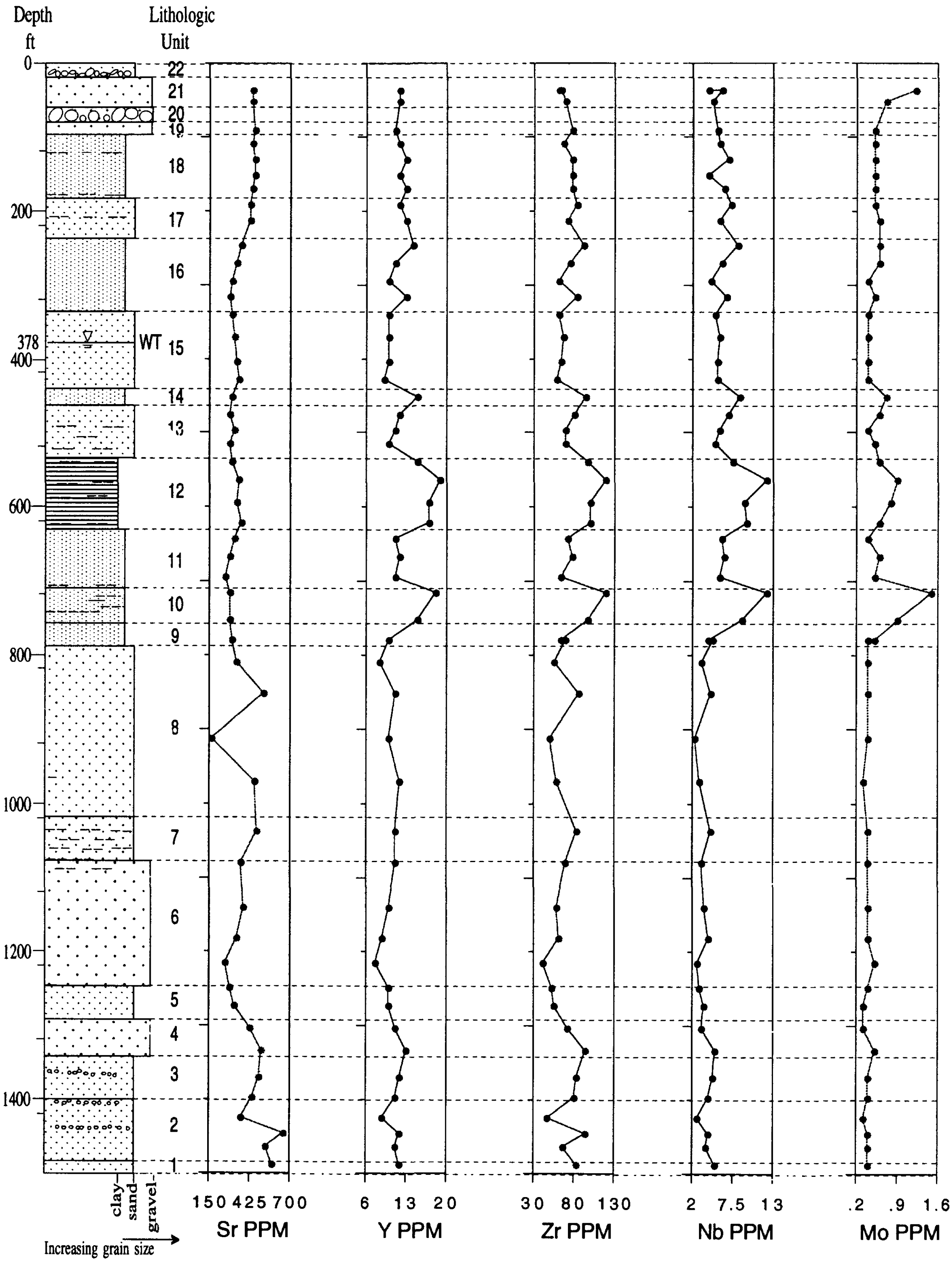


Figure 2E. Downhole plots of Sr, Y, Zr, Nb, and Mo (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

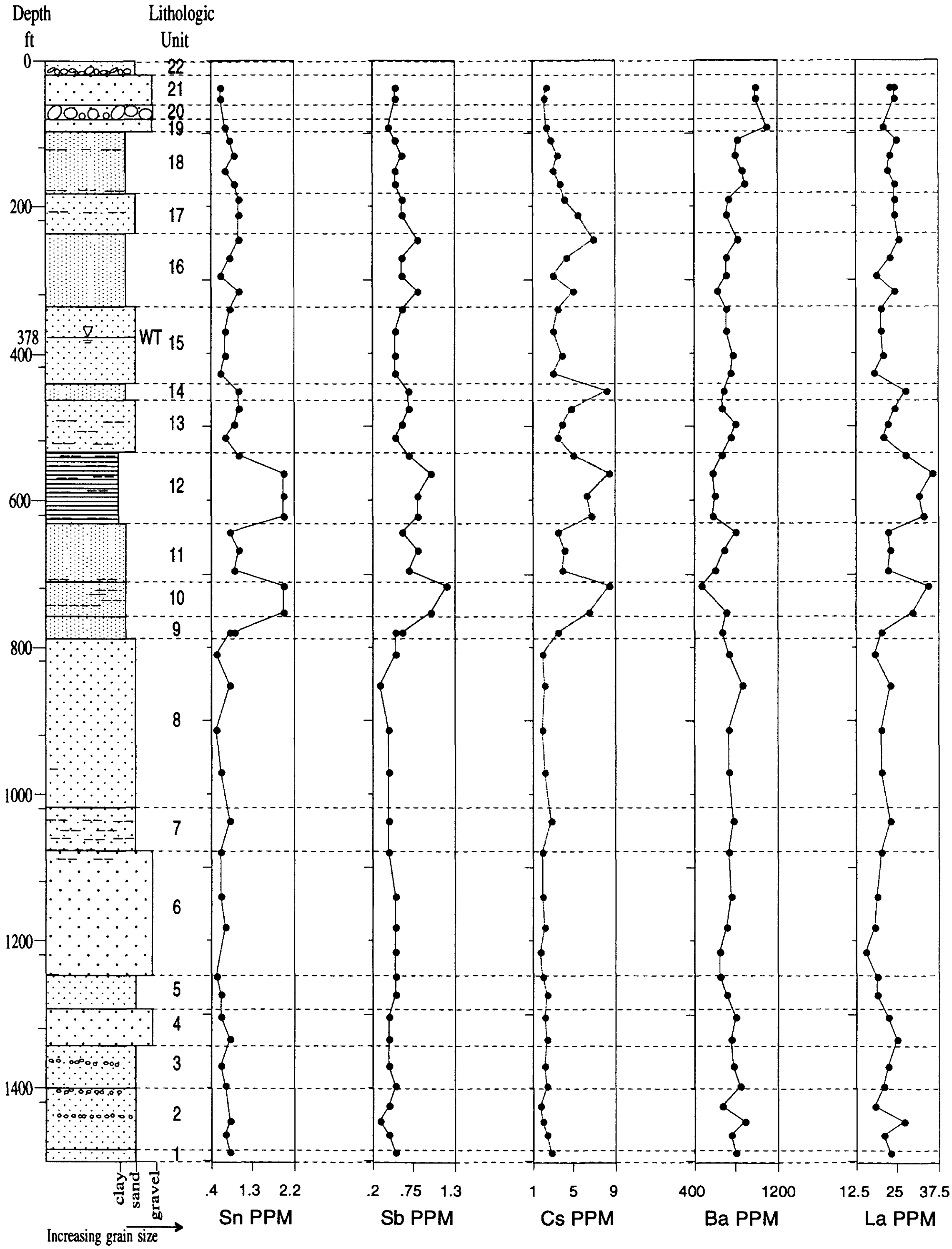


Figure 2F. Downhole plots of Sn, Sb, Cs, Ba, and La (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

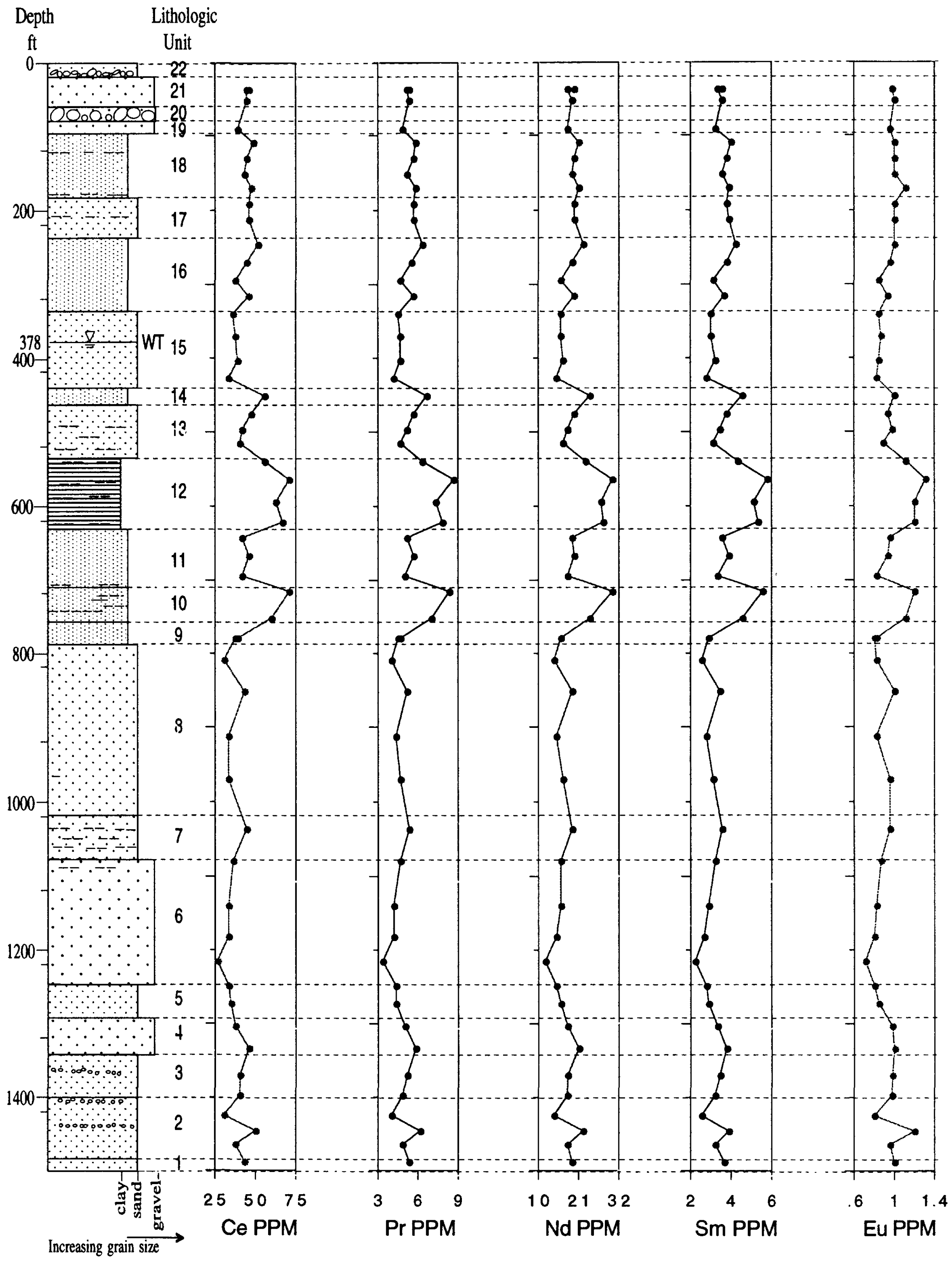


Figure 2G. Downhole plots of Ce, Pr, Nd, Sm, and Eu (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

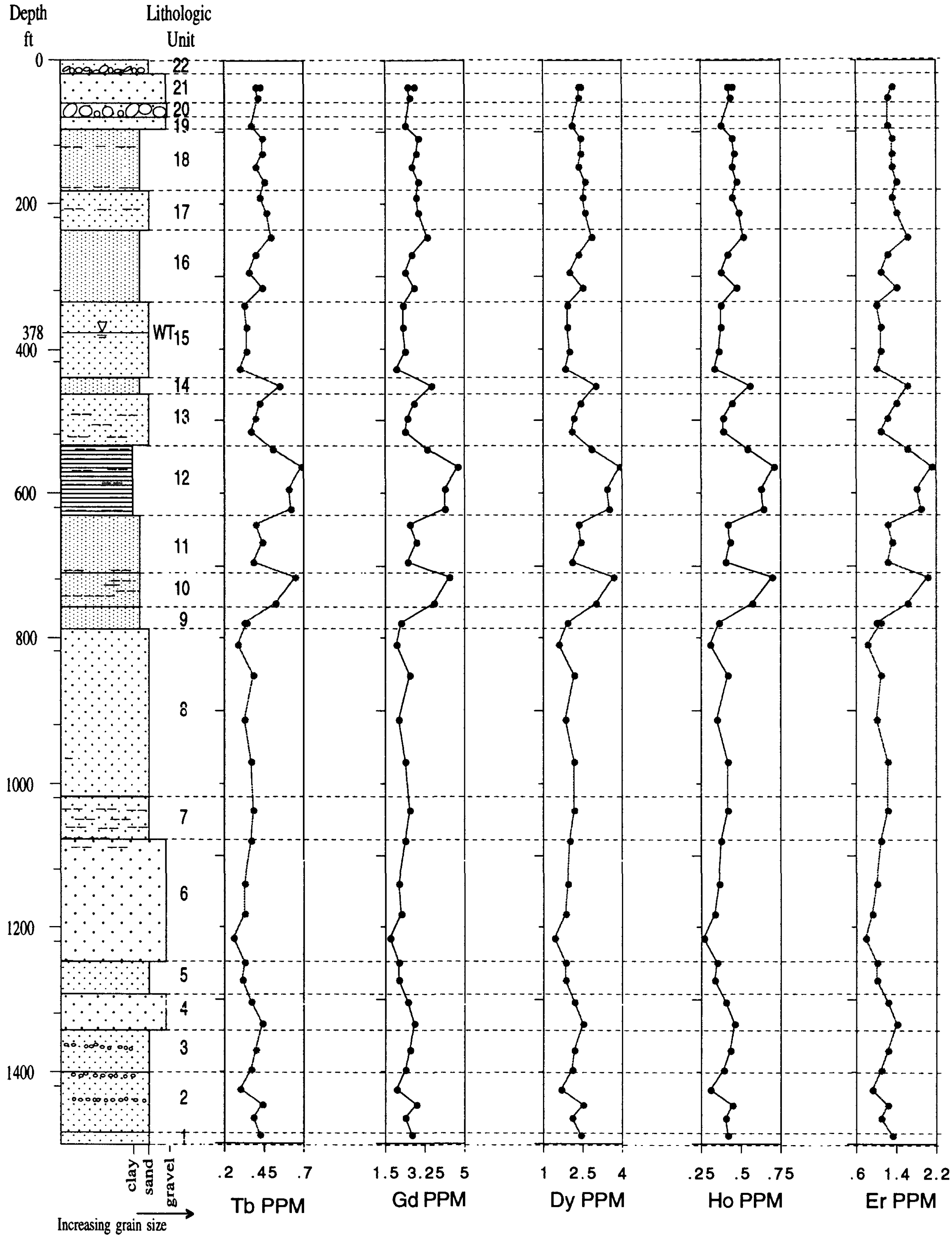


Figure 2H. Downhole plots of Tb, Gd, Dy, Ho, and Er (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

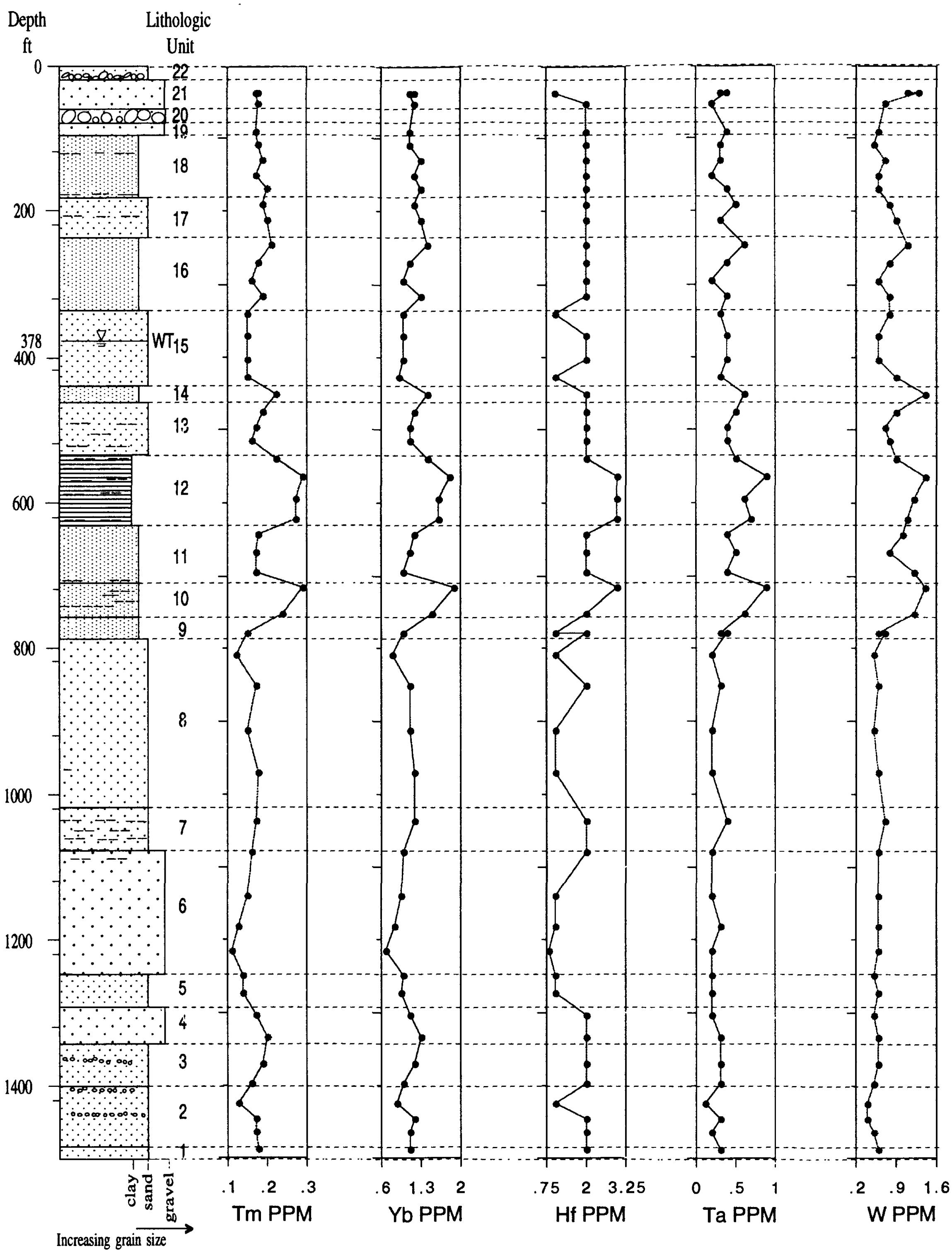


Figure 2I. Downhole plots of Tm, Yb, Hf, Ta, and W (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

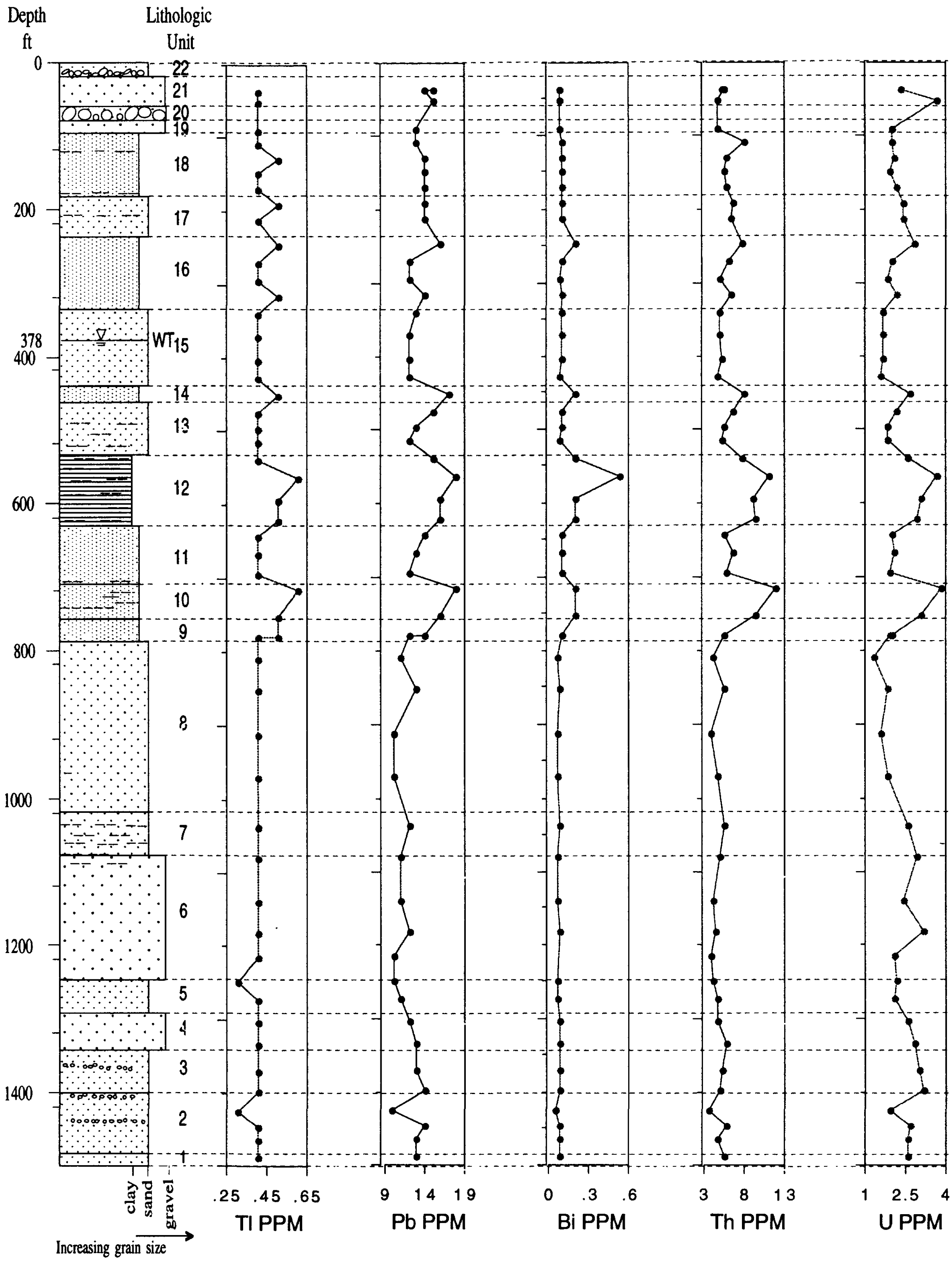


Figure 2J. Downhole plots of Tl, Pb, Bi, Th, and U (ppm) abundances in composite samples from the 98th St. drill core. Sample points represent the center depth (in feet), the average depth between the upper and lower depth intervals from which the sample was collected. Lithologic column from Stone and others (1997).

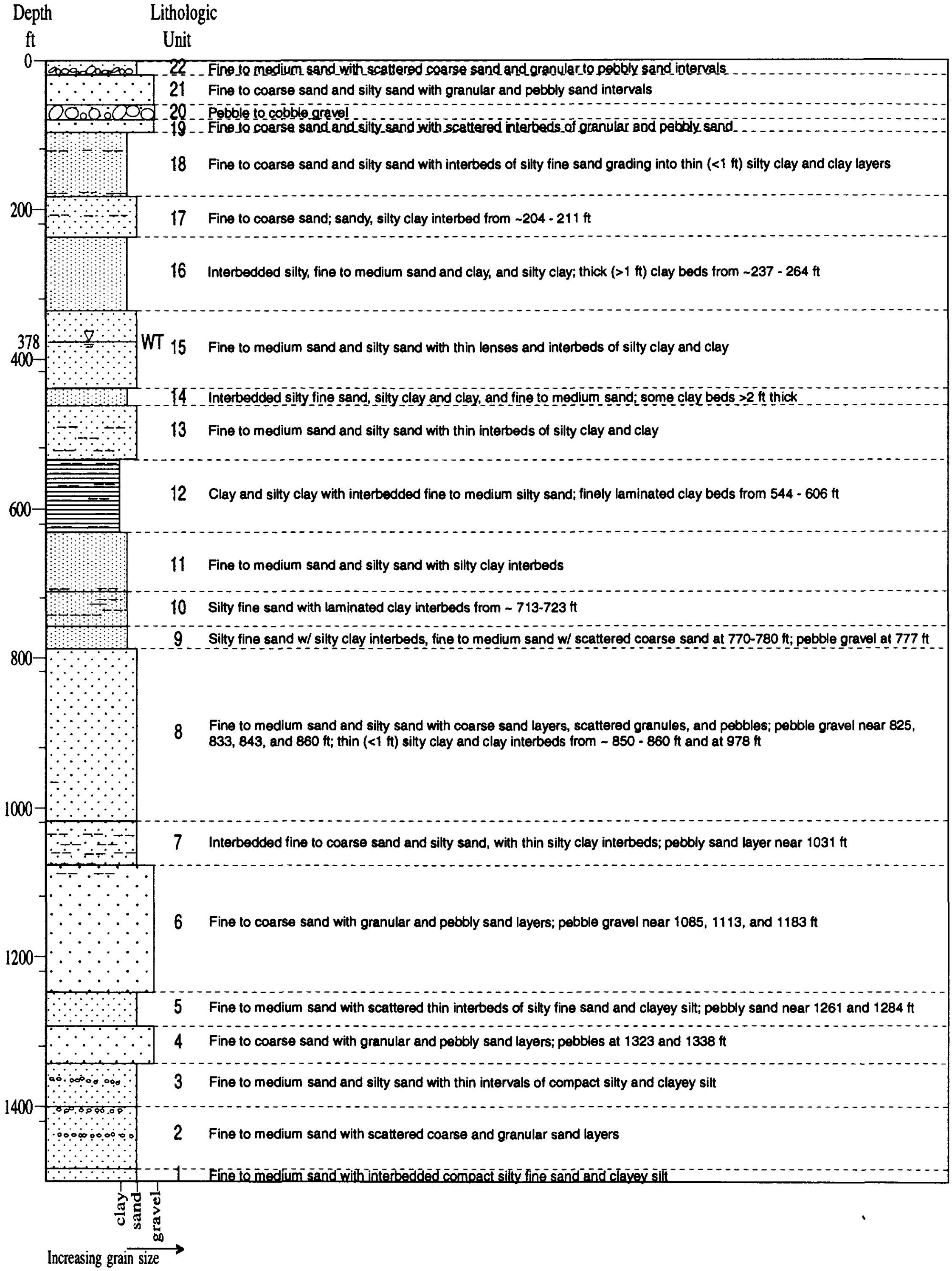


Figure 2K. Key to lithologic descriptions for composite samples from the 98th St. drill core. Lithologic column and descriptions from Stone and others (1997).

Element Abundances in Discrete Samples

Box plots for element abundances in the discrete samples are illustrated in Figures 3A through 3L. Some qualitative observations about the abundances of As, and the trace metals Fe, Co, V, and Zn are presented here. Only discrete samples are examined because these are a "less-dilute" sample than longer-interval composites. Mean trace metal abundances in the discrete samples compared to the metal's crustal abundance value (CAV; see Fortescue, 1992) indicate varying degrees of enrichment; most other trace metals are at or above their CAV. The mean As abundance over the entire earth's crust is 1.8 ppm. In the samples, the mean As abundance is 8.5, or about 5X its average crustal abundance.

Arsenic and the 4 trace metals show some enrichment compared to an "average" sandstone, the dominant lithology in the core. In an average sandstone As has a CAV of 1 ppm; again, As is 8.5 ppm in the discrete core samples. The average Fe value in sandstone is 0.98 wt%; in the samples, its mean value is 2.24 wt%. Co in an average sandstone is 0.3 ppm, while in the 98th St. samples it is 2.9 ppm. The average V abundance in sandstone is 20 ppm and 70 in the discrete samples, an enrichment factor of nearly 3.5. Zn has an abundance of 16 ppm in an average sandstone and 55 ppm in the discrete samples; thus, Zn is approximately 3.5 times more abundant in the core samples than in the "average" sandstone.

Because the sources of the sediments likely had a volcanic component, it is not surprising to see slightly higher As abundances in the core samples. With the average As abundance in a basaltic (volcanic) rock at 2 ppm, it appears As has become slightly-enriched in the sediments. These comparisons are noted only to qualitatively illustrate that Santa Fe group sediments contain slightly-higher abundances of As, Fe, V, Co, and Zn, and it is these 5 elements that form the strongest associations in the discrete samples (described on p. 55).

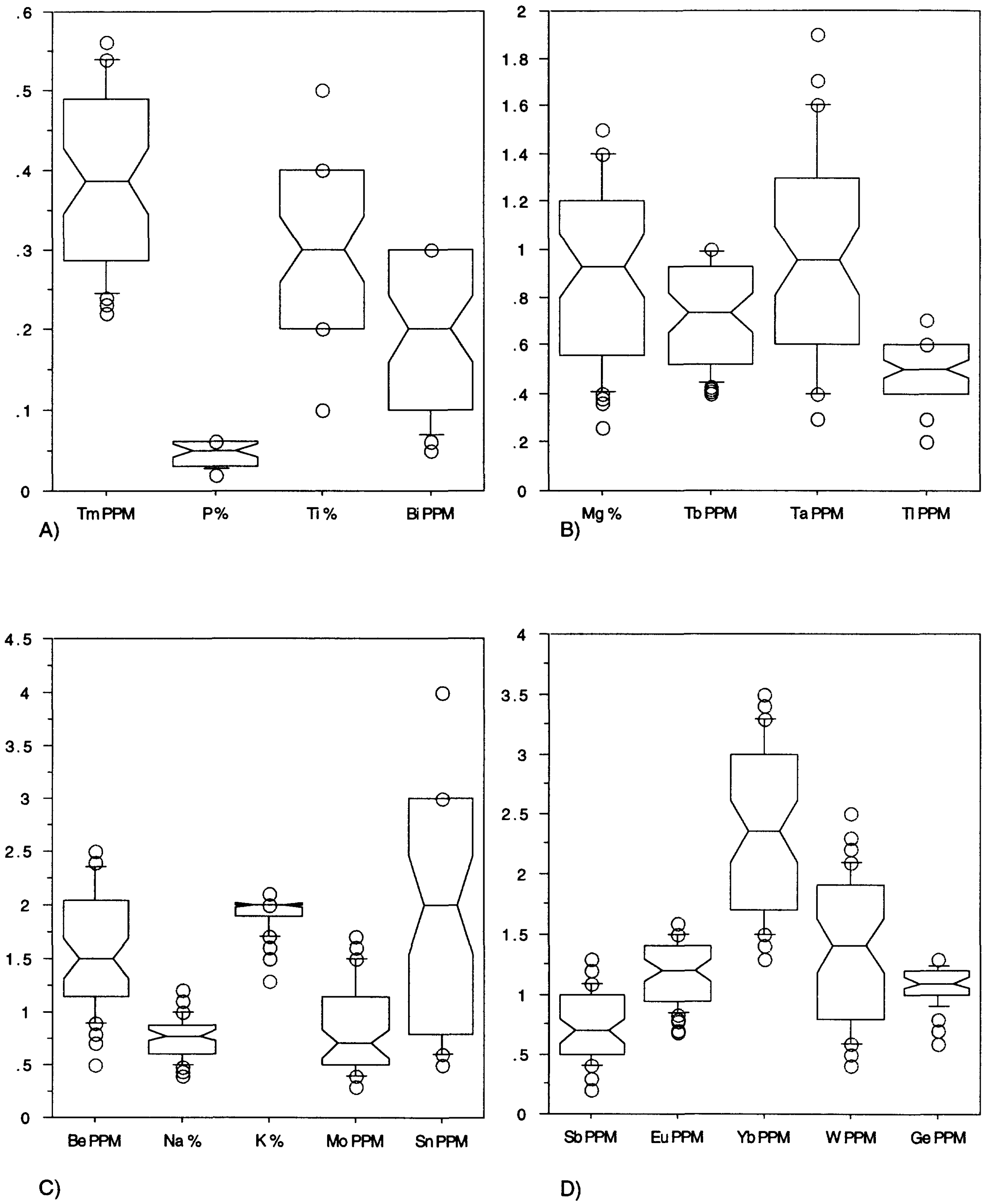


Figure 3A-3D. Box plots (notched) for element abundances in discrete samples from the 98th St. drill core . A)Tm, P, Ti, and Bi. B)Mg, Tb, Ta, and Tl. C)Be, Na, K, Mo, and Sn. D)Sb, Eu, Yb, W, and Ge.

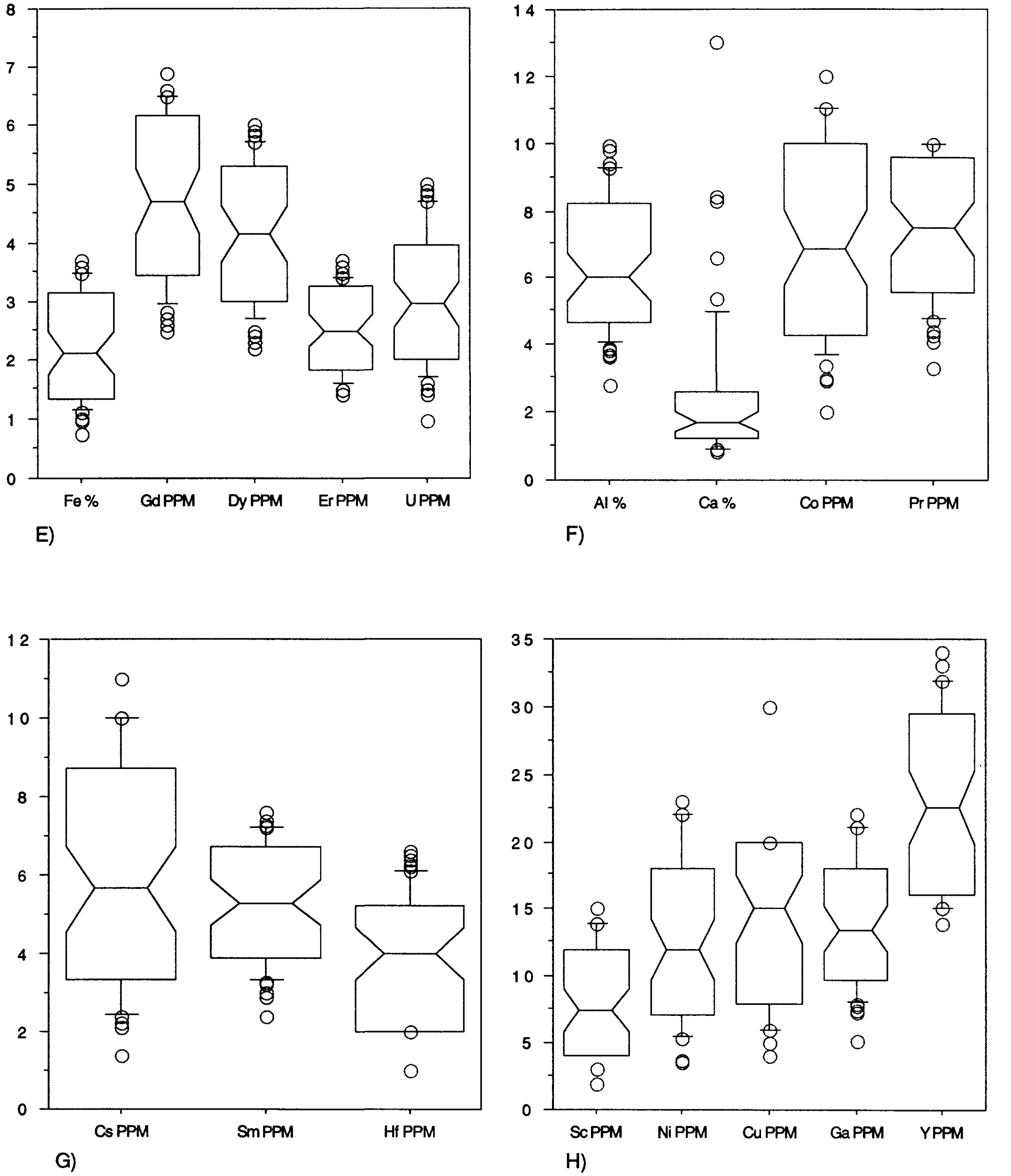


Figure 3E-3H. Box plots (notched) for element abundances in discrete samples from the 98th St. drill core. E)Fe, Gd, Dy, Er, and U. F)Al, Ca, Co, and Pr. G)Cs, Sm, and Hf. H)Sc, Ni, Cu, Ga, and Y.

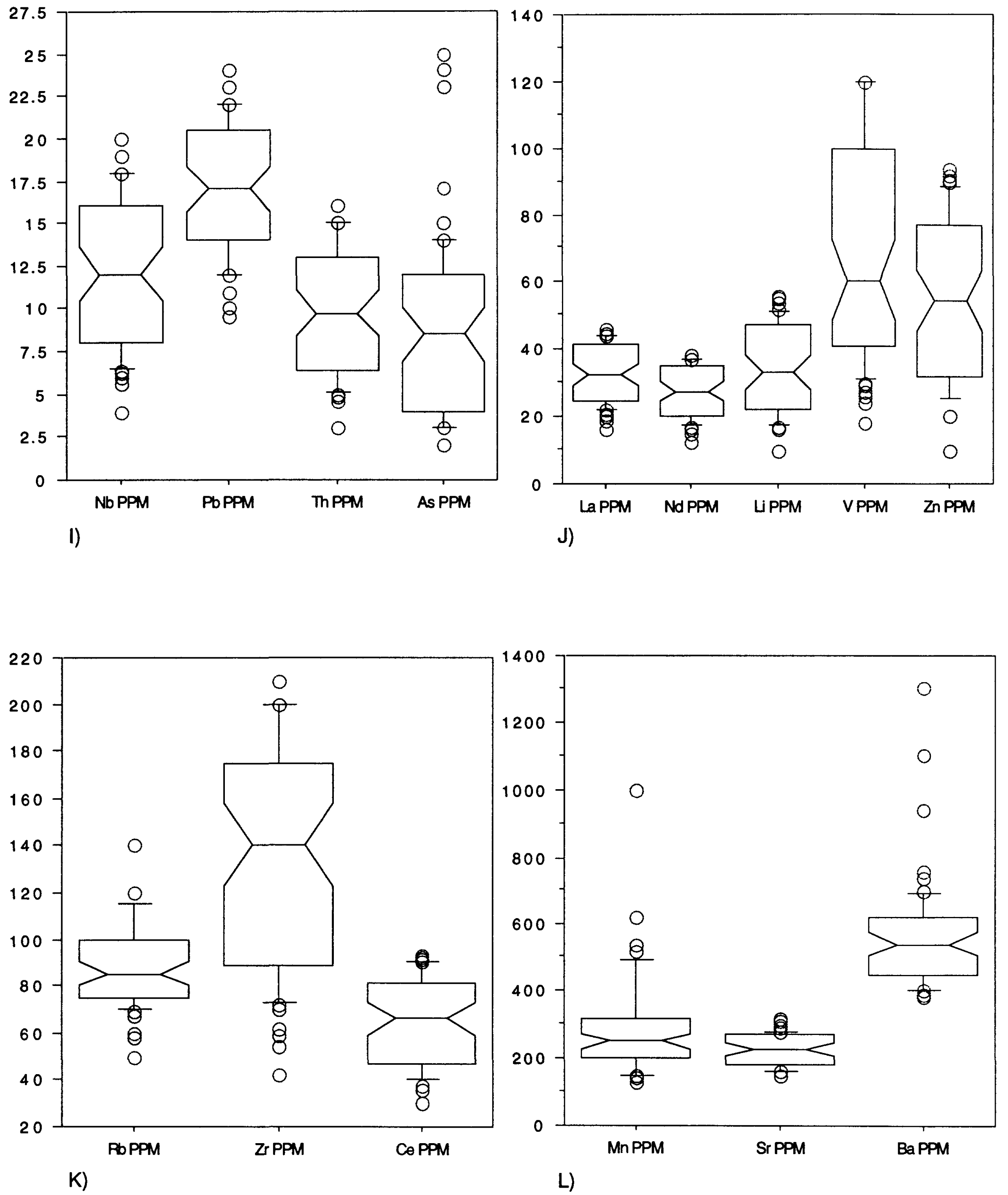


Figure 3I-3L. Box plots (notched) for element abundances in discrete samples from the 98th St. drill core. I)Nb, Pb, Th, and As. J)La, Nd, Li, V, and Zn. K)Rb, Zr, and Ce. L)Mn, Sr, and Ba.

Element Abundances with Depth in Discrete Samples

Element abundances with depth in the discrete samples are illustrated in the downhole plots in Figures 4A through 4K. Again, the numbered lithologic units are shown on the left-hand side to illustrate the element abundances in each lithologic type (units 11, 10 and 9; see Figure 2K for descriptions of these units). The downhole plot covers the interval 655-765 ft, but not all these 1-ft intervals were available to sample (see Methods section).

Detectable levels of Se (above 1 ppm) were present in only 4 discrete samples, with the maximum value (5 ppm) at 717 ft. The second-highest concentration of As (23 ppm) is close to the depth (723 ft) where the highest concentration of Se was found. But in general, relatively higher levels of both As and Se do not coincide within the sediment layers. And again, Au, In, Re, S, and Te were not detected in the discrete samples.

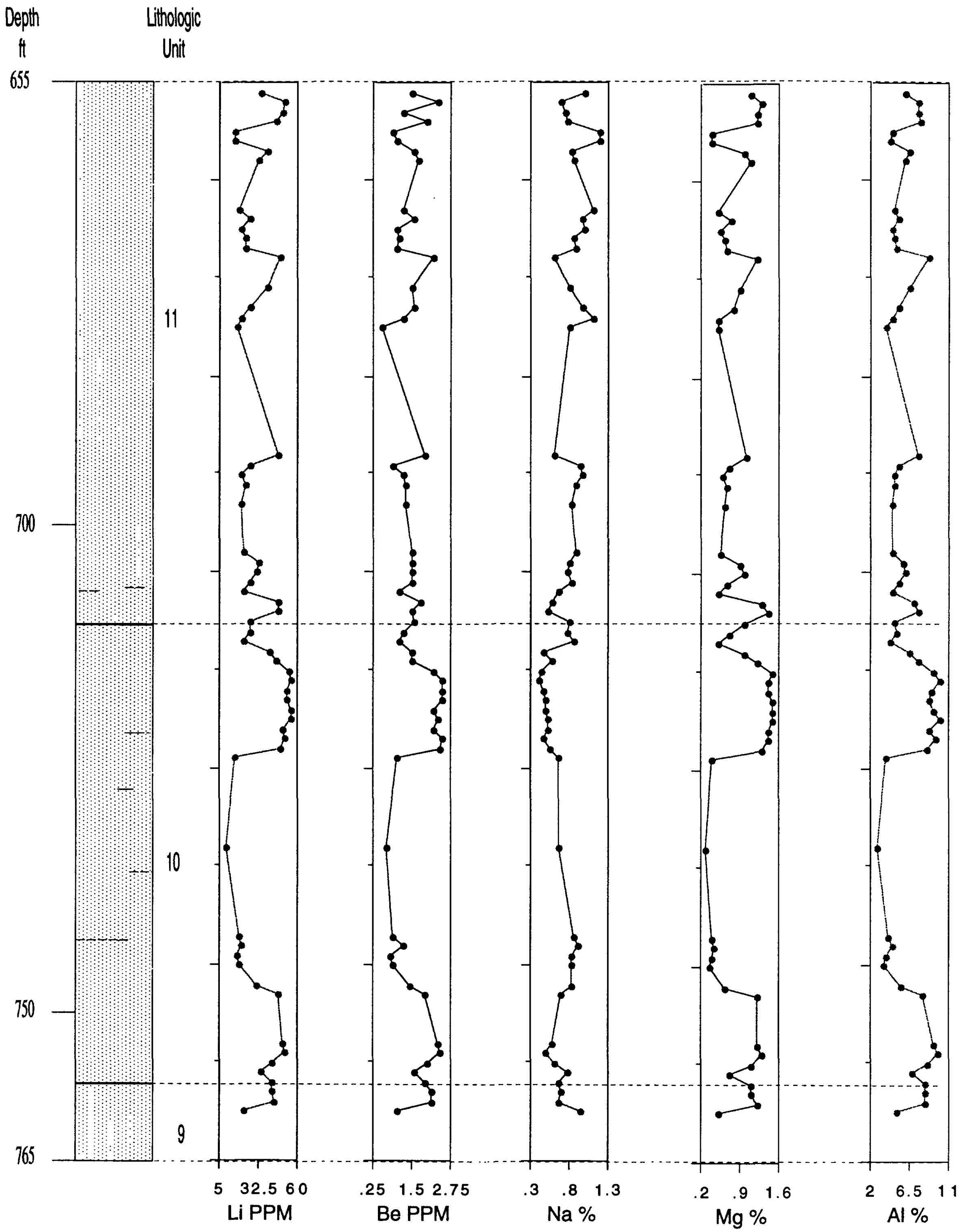


Figure 4A. Downhole plots of Li, Be (ppm), and Na, Mg, and Al (%) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note that there are differing scales (ppm or %) and ranges of values for each element. Lithologic column adapted from Stone and others (1997).

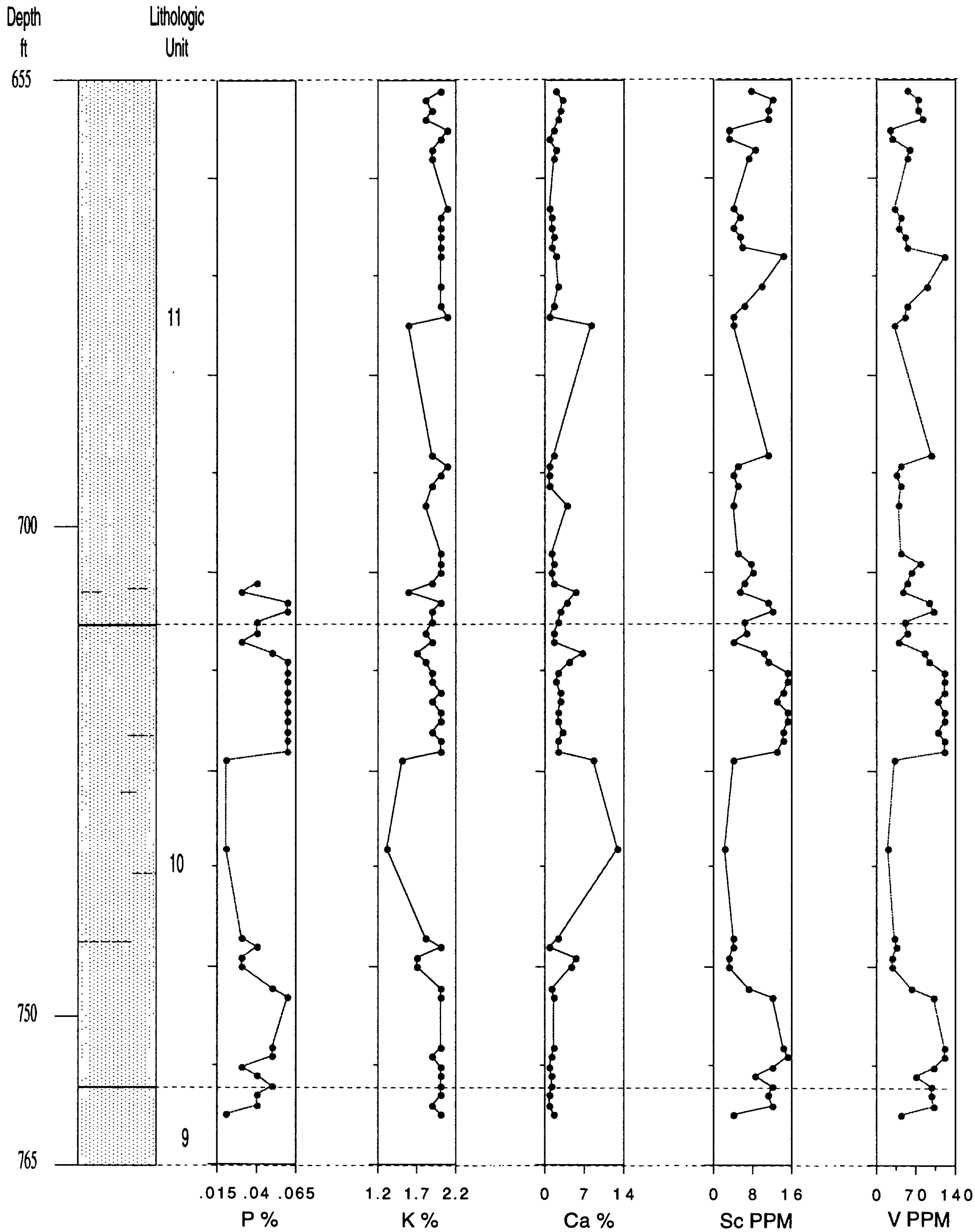


Figure 4B. Downhole plots of P, K, and Ca (%), and Sc and V (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note that there are differing scales (ppm or %) and ranges of values for each element. Lithologic column adapted from Stone and others (1997).

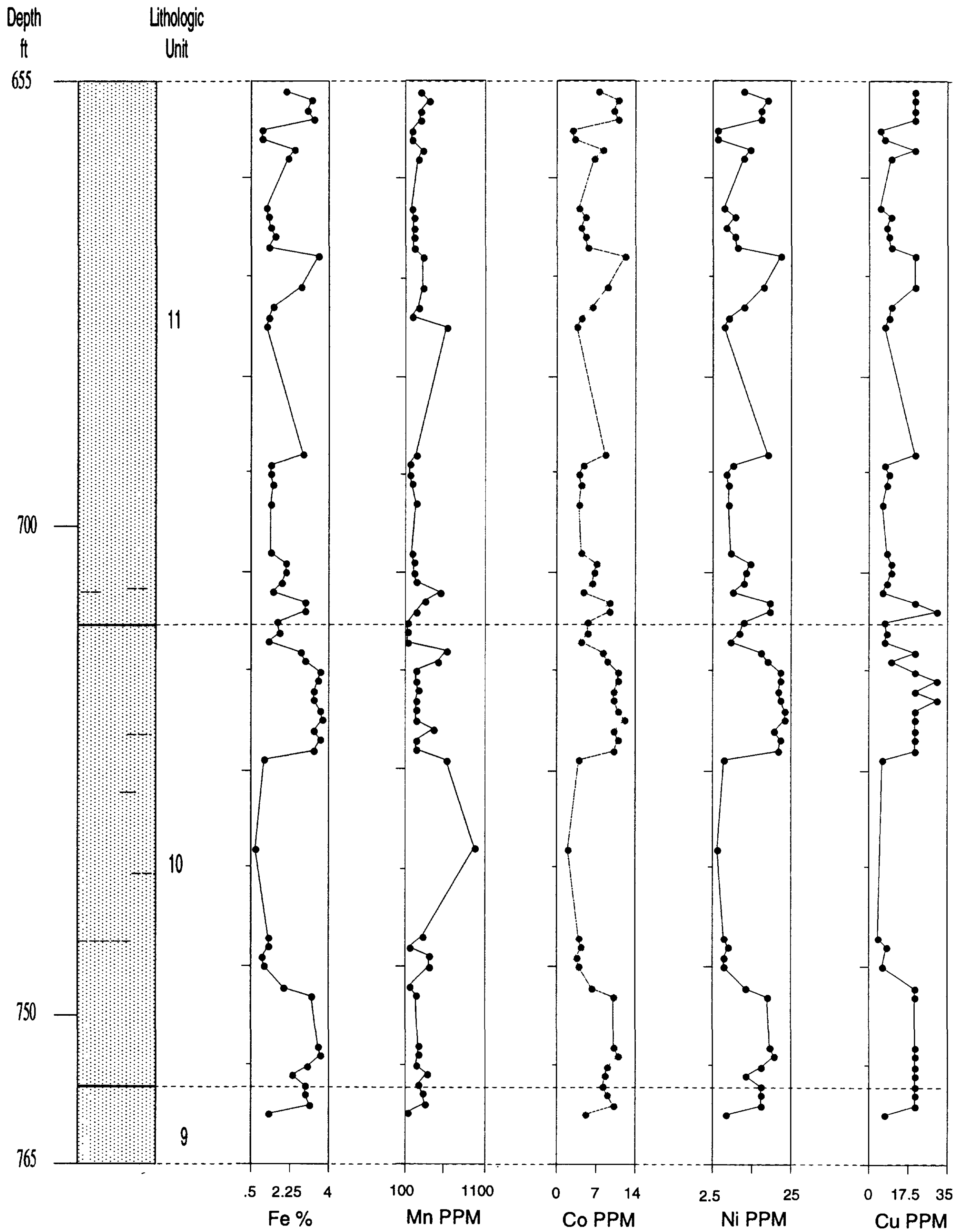


Figure 4C. Downhole plots of Fe (%), and Mn, Co, Ni, and Cu (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note that there are differing scales (ppm or %) and ranges of values for each element. Lithologic column adapted from Stone and others (1997).

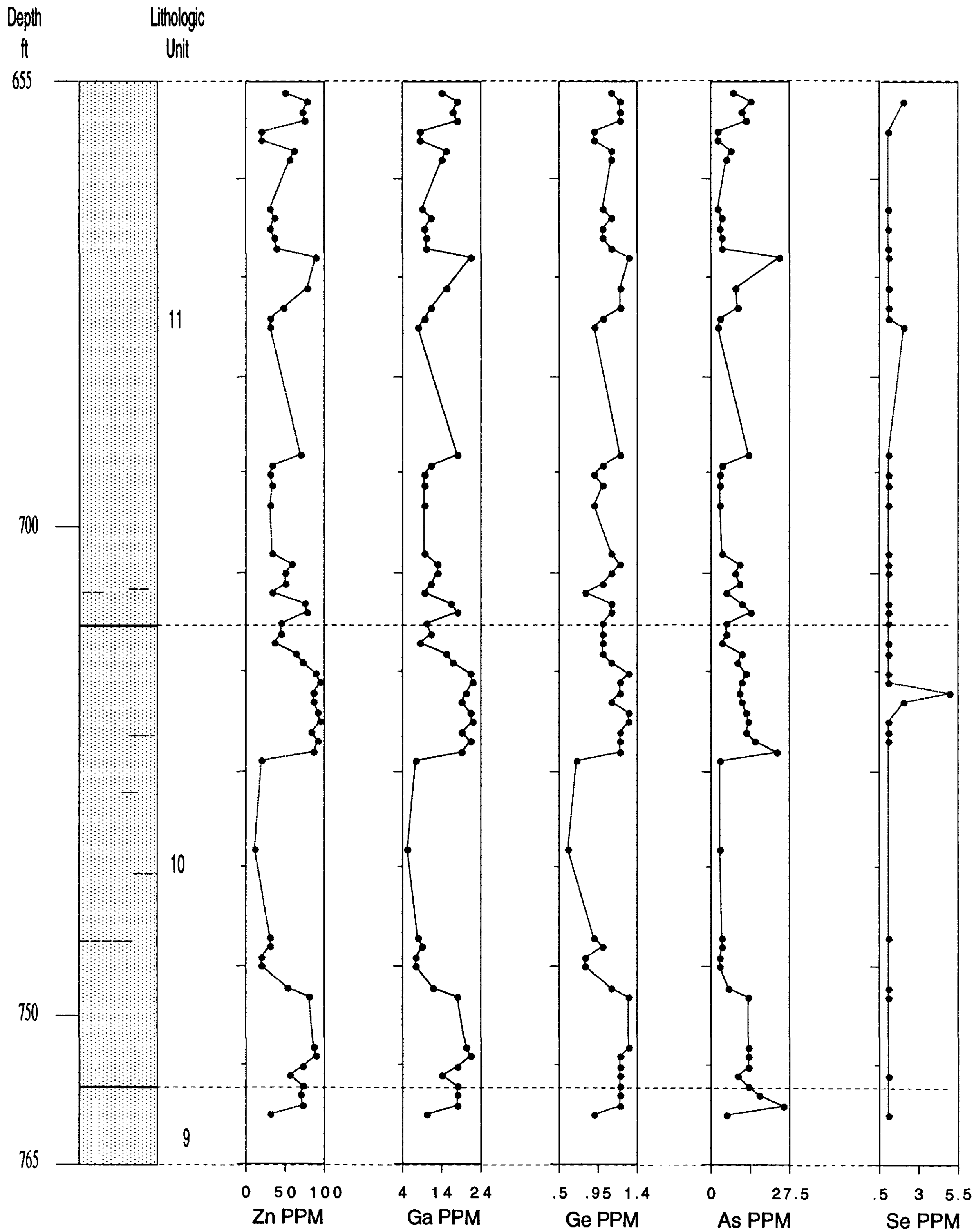


Figure 4D. Downhole plots of Zn, Ga, Ge, As, and Se (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

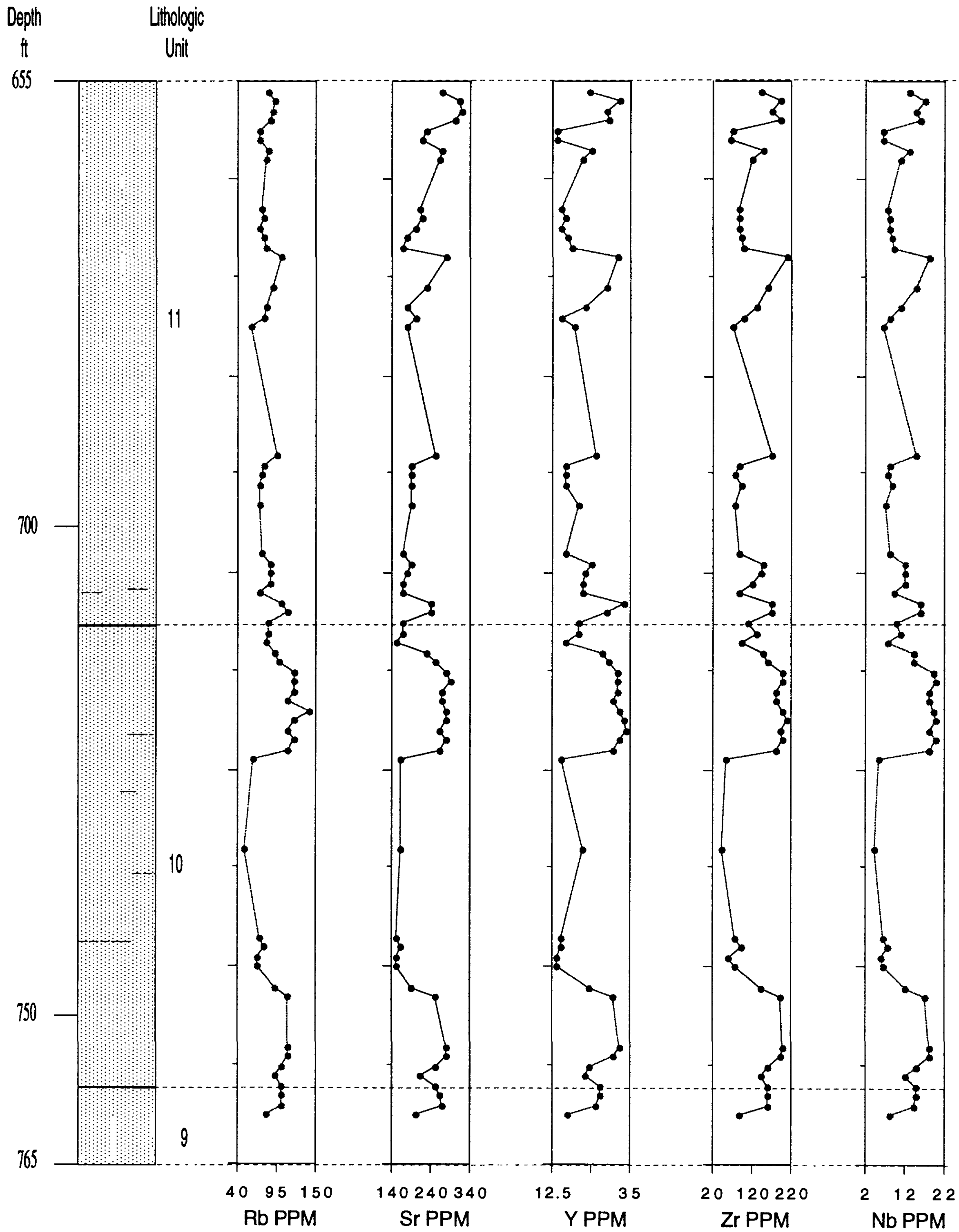


Figure 4E. Downhole plots of Rb, Sr, Y, Zr, and Nb (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

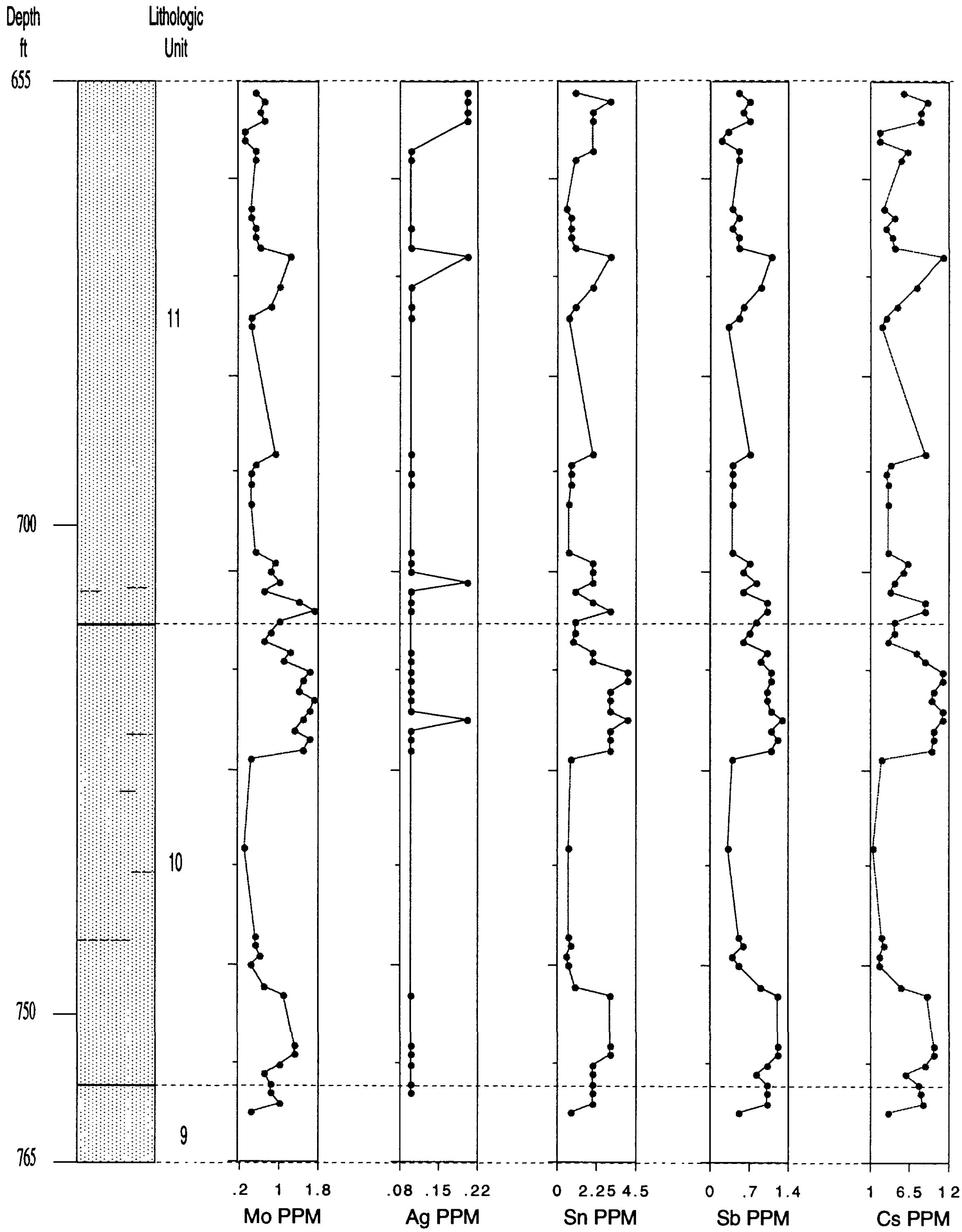


Figure 4F. Downhole plots of Mo, Ag, Sn, Sb, and Cs (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

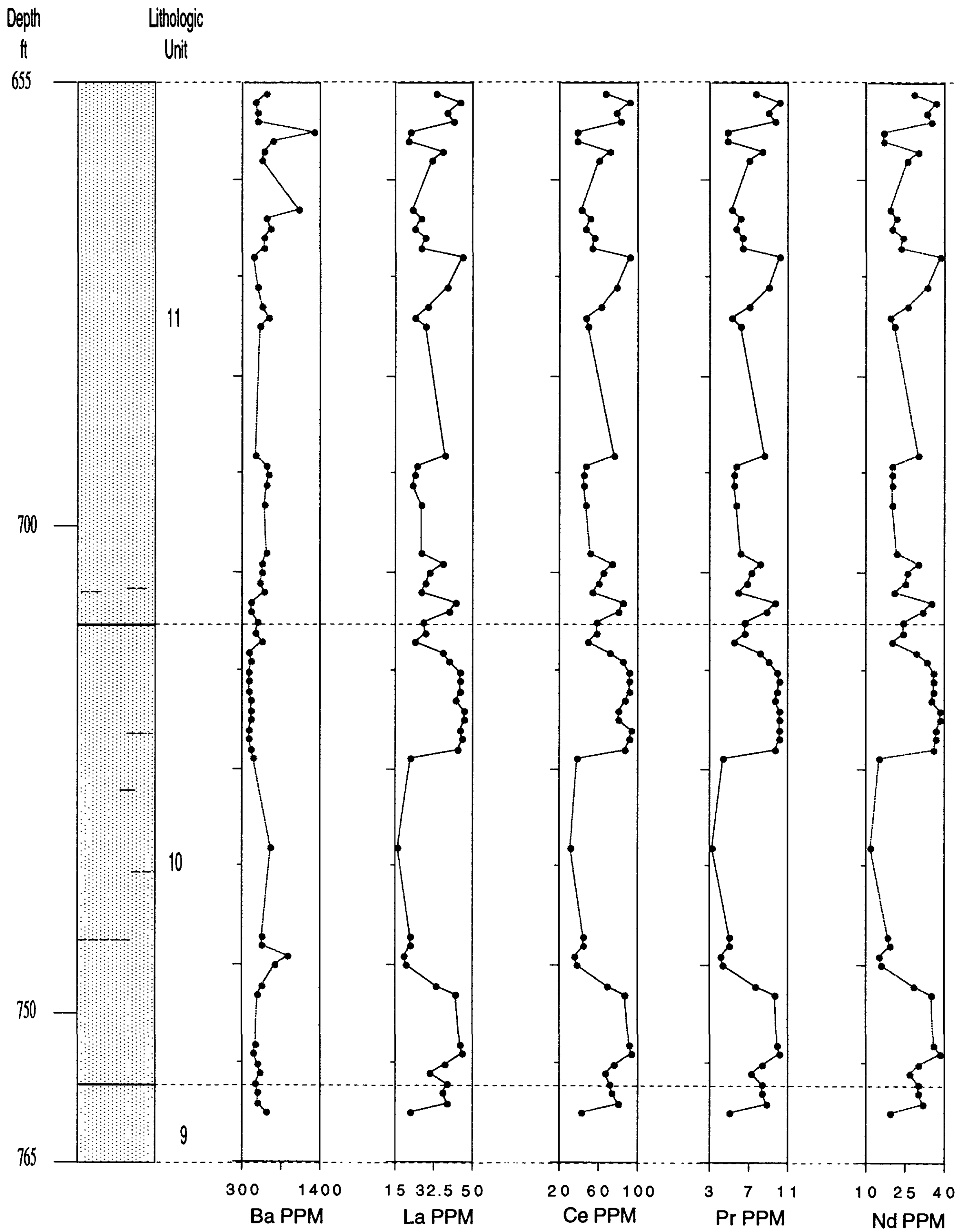


Figure 4G. Downhole plots of Ba, La, Ce, Pr, and Nd (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

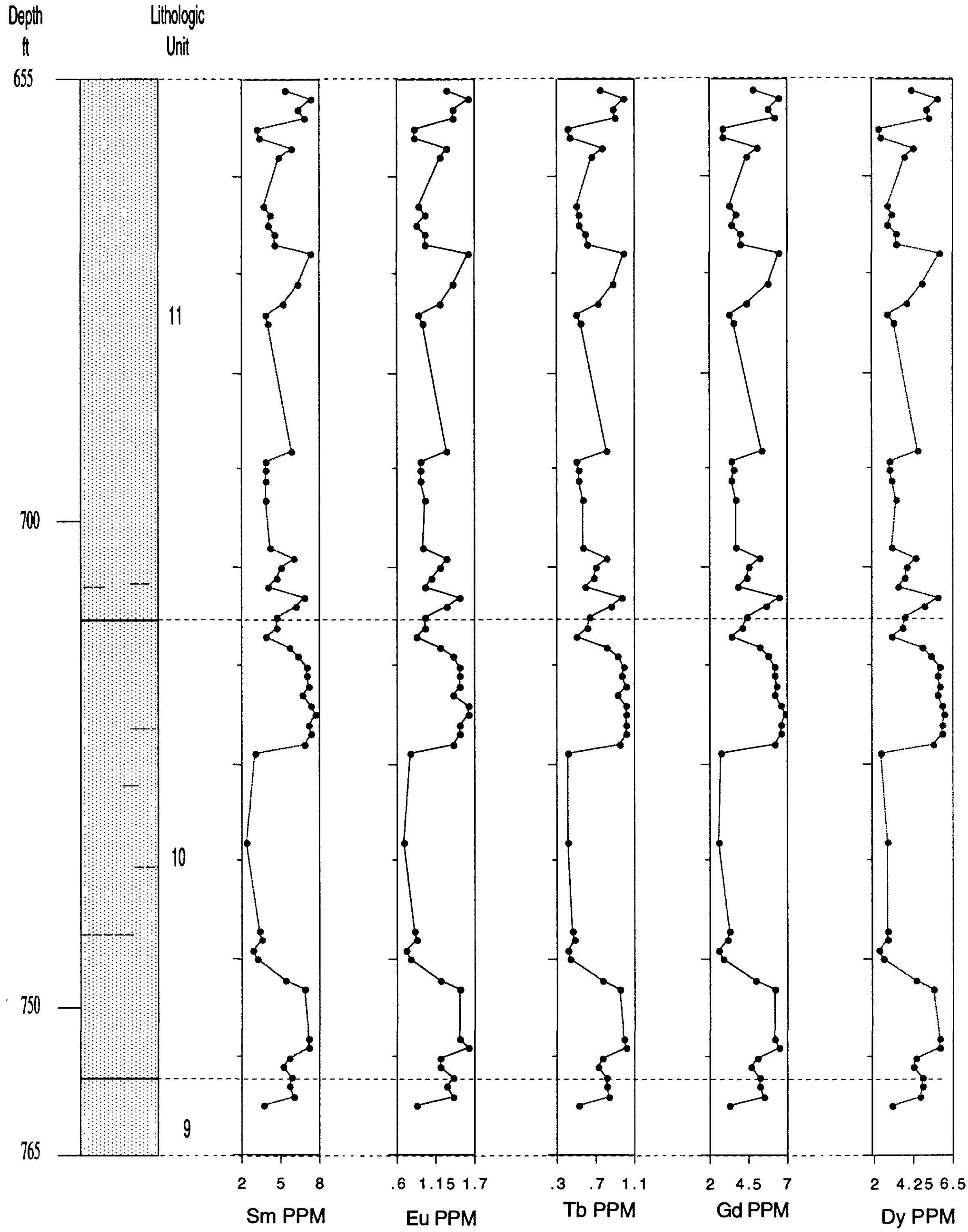


Figure 4H. Downhole plots of Sm, Eu, Tb, Gd, and Dy (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

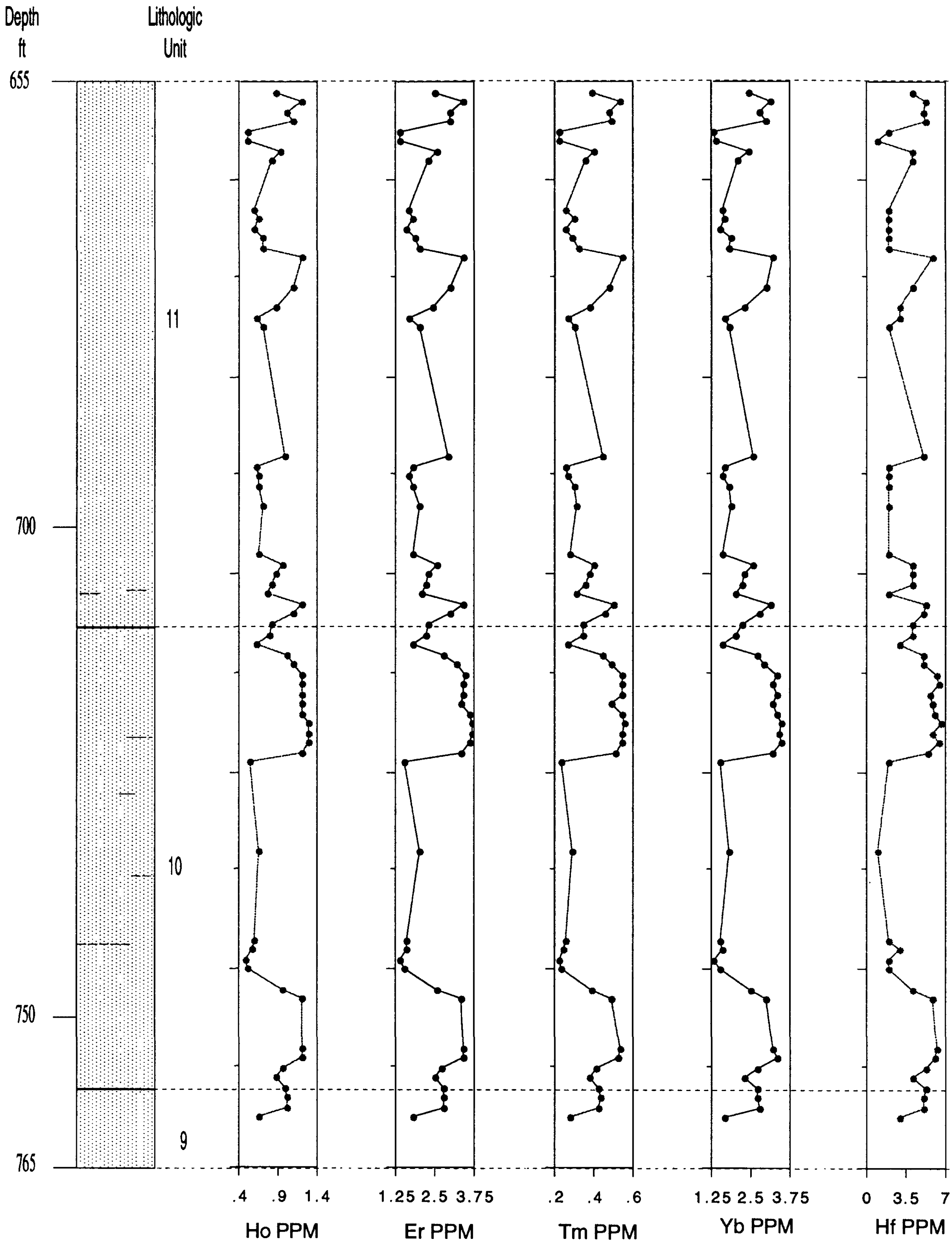


Figure 4I. Downhole plots of Ho, Er, Tm, Yb, and Hf (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

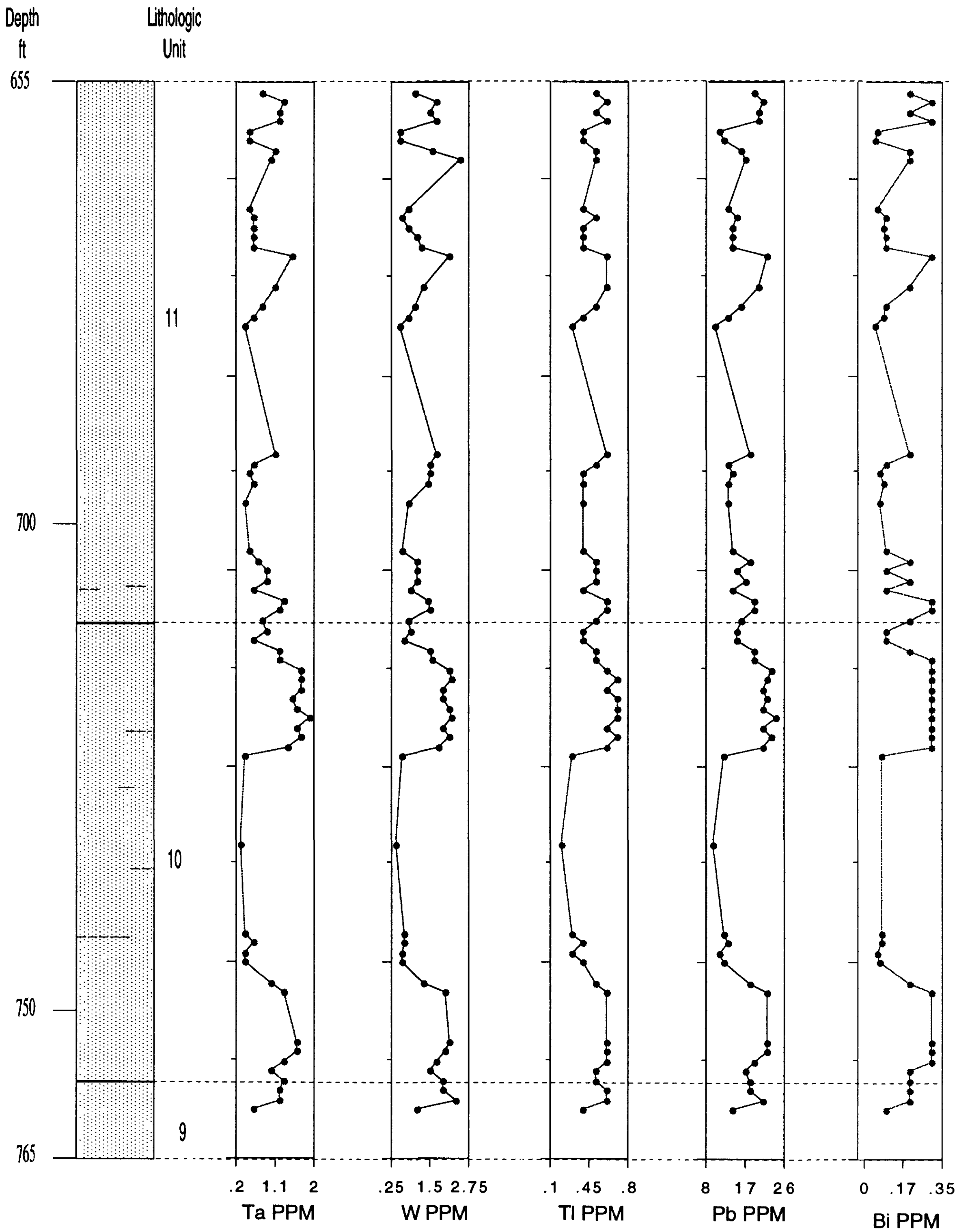


Figure 4J. Downhole plots of Ta, W, Tl, Pb, and Bi (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

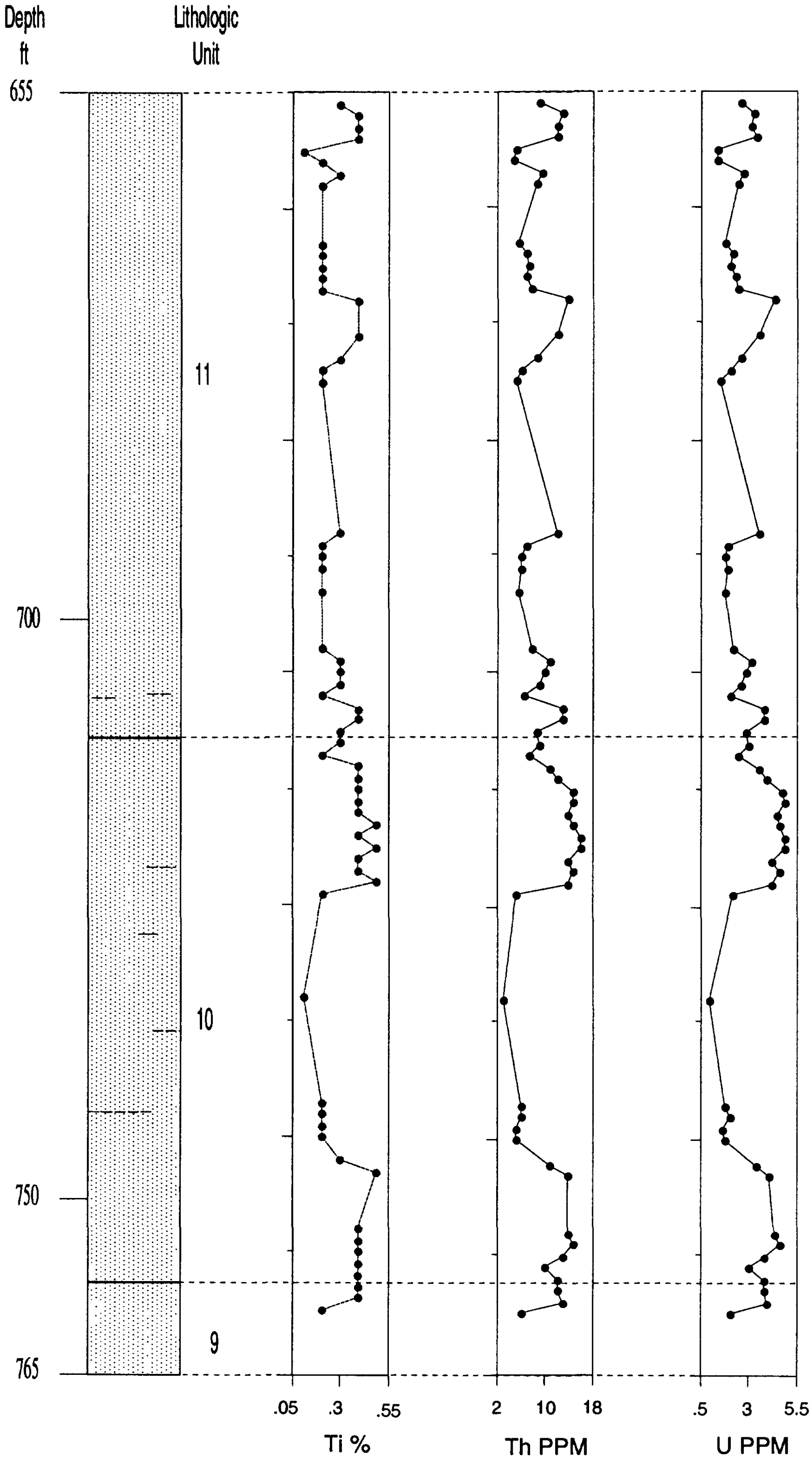


Figure 4K. Downhole plots of Ti (%), and Th and U (ppm) abundances in discrete samples from the 98th St. drill core. Each sample point represents a 1-ft interval. Note the different ranges of values (x-axes) for each element. Lithologic column adapted from Stone and others (1997).

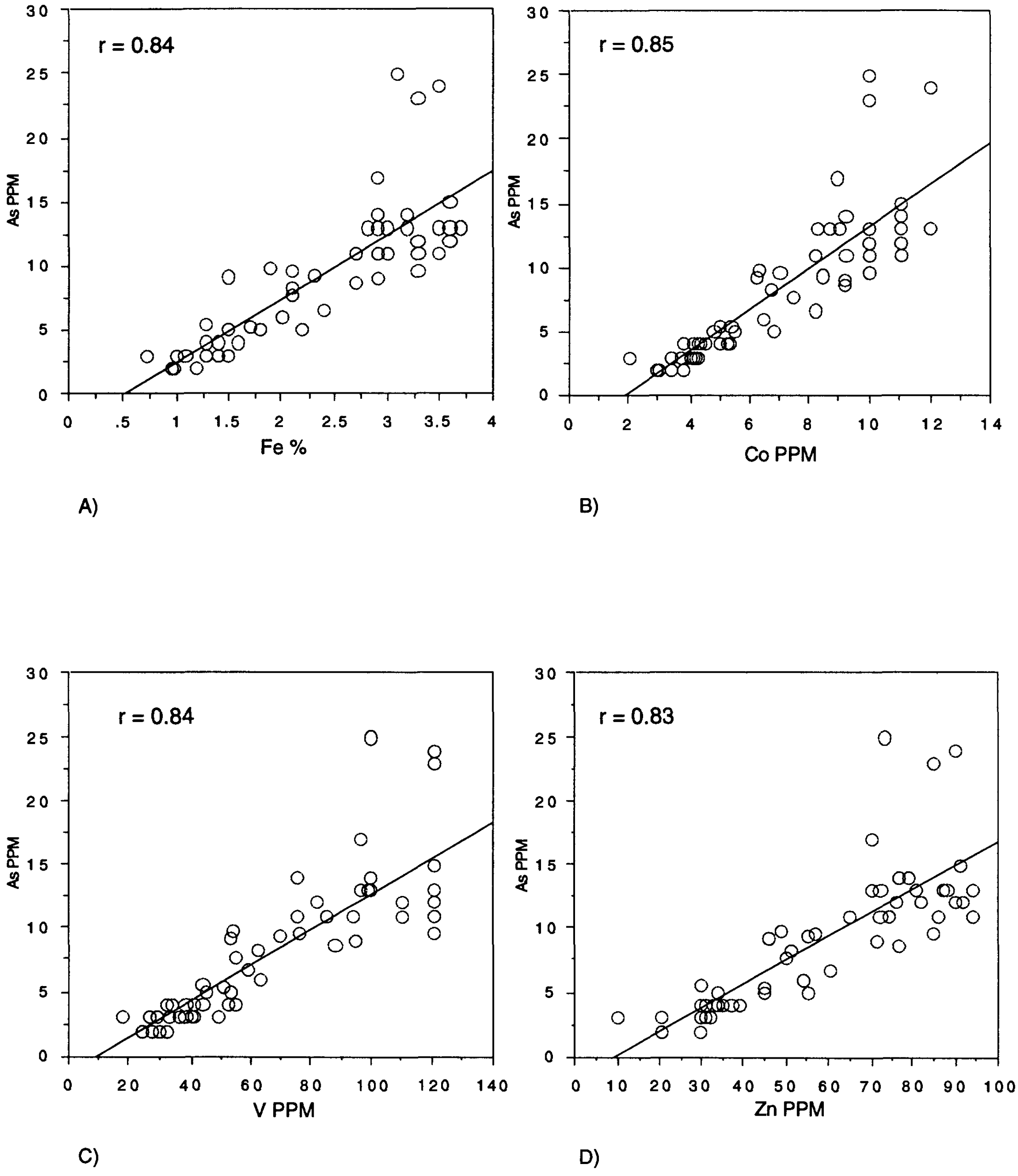
Associations of Arsenic with Other Elements

A preliminary examination of the geochemical data of the discrete samples using simple linear regression/correlation analysis indicated a relatively strong association of As with V. In addition, arsenic is associated with chalcophile elements such as Fe, Co, Ni, and Zn; these elements are often present in iron sulfide minerals. Figures 5A-5D show the relationship of As with the trace metals Fe, Co, V, and Zn. Figures 5E-5F show the relationship of As with the "major" elements Mn, Ca, Sr, and Ba. Although the associations with trace metals are relatively weak at the 95 percent confidence level (r, the correlation coefficient, is 0.83 to 0.85; r = +1 would be the strongest correlation possible), they are stronger than any relationship of As with major elements such as the four listed above (where r = 0.69 for Sr and is negative for Mn, Ca, and Ba), as well as Na, K, and Mg. These associations initially suggest that As might be found in sulfide minerals such as pyrite (FeS_2) and arsenopyrite ($FeAsS_2$). However, it was noted earlier that sulfide minerals have not been detected in either bulk or size-separate mineralogical analyses, and that sulfur was not detected by ICP-AES or ICP-MS analyses of the sediment samples.

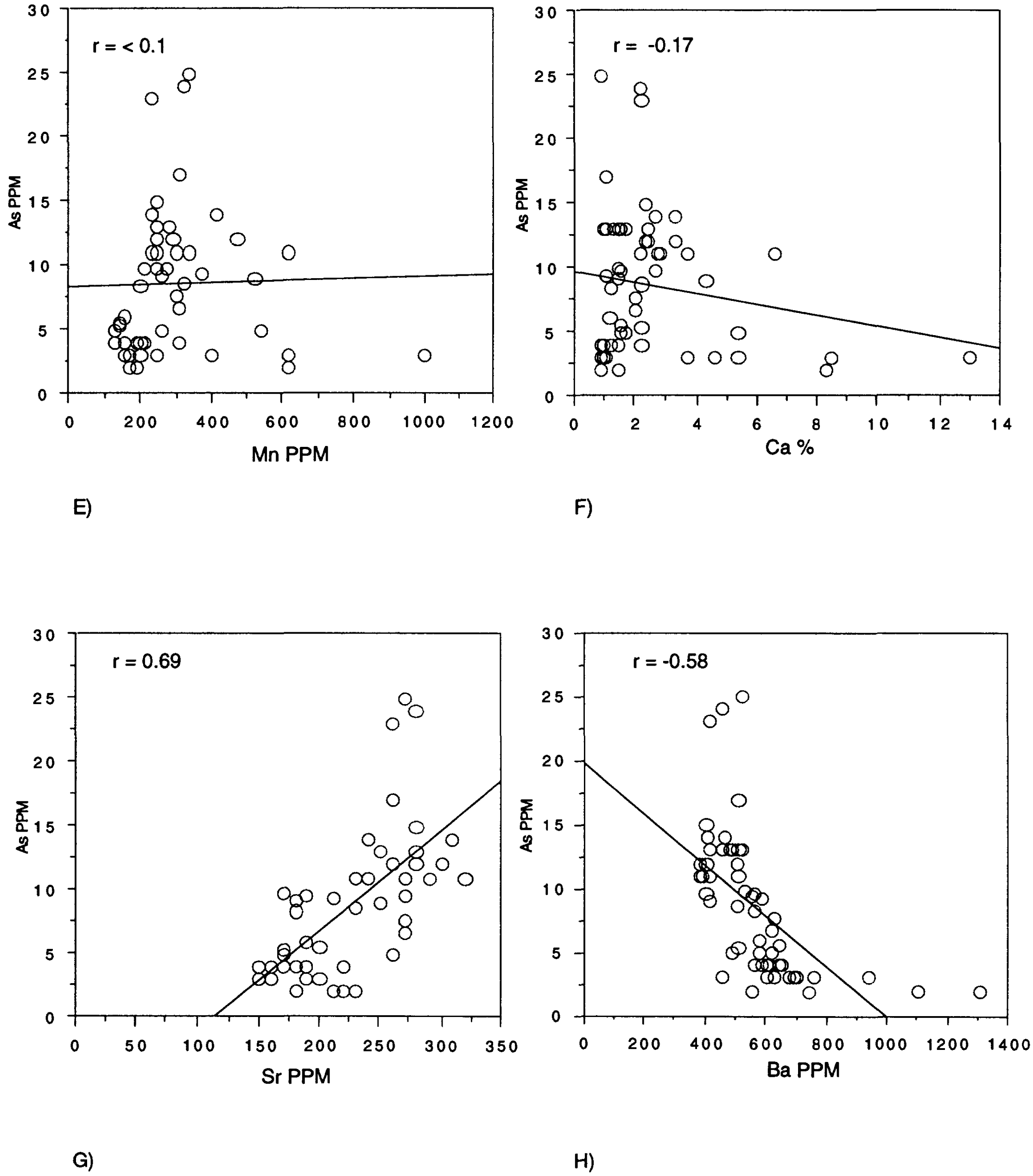
Pseudomorphs of an (unidentified) Fe-oxide were noted in the 723 ft grab sample. The cubic form of these pseudomorphs suggests they had formed from pyrite or some other Fe-bearing (sulfide?) mineral that was once present in this interval. Whether this sulfide(?) was As-bearing is unknown, but the presence of these pseudomorphs indicates further detailed examination for sulfide minerals throughout the entire core is needed.

An alternative explanation for the stronger relations (relative to major elements) of As with Fe and chalcophile elements is that these elements are residing in Fe-oxides. Fe-oxides are strong adsorbents for many trace elements, including chalcophiles, As, and V (Manceau, 1995; Postma, 1993). Red and orange-to-yellow staining indicative of Fe-oxide minerals was observed on both the surfaces and in the interior of most core sediments. Taken together, the associations of As with Fe, V, Co, Ni, and Zn suggest that As may be present in Fe-oxide phases.

Partial sequential extraction studies are underway to determine which solid phase(s) contain the highest concentrations and/or readily-mobilized forms of As.



Figures 5A-5D. Regression plots of As versus trace elements Fe, Co, V, and Zn in discrete samples from the 98th St. drill core.



Figures 5E-5H. Regression plots of As versus major elements Mn, Ca, Sr, and Ba in discrete samples from the 98th St. drill core.

X-ray Diffraction Analyses

Mineralogy of both bulk and sieved fractions of the composite and grab samples shows that the major mineral phases (≥25 vol. %) are aluminosilicates, including quartz, orthoclase, albite, and sanidine; muscovite was nearly always a trace constituent.

In most samples, calcite was present as a major or minor phase; dolomite was rarely present and only as a trace mineral. In samples where carbonate was visible, it was generally present as thin (≤2.5 cm) lenses, layers, or nodules located within thicker layers of aluminosilicate sediment.

Not all diffraction analyses are included or discussed here because many samples produced nearly identical patterns. Some variation in mineralogical abundances was observed (e.g., major vs minor calcite), but the results in Table 3 are generally characteristic of most composite and grab samples.

Mineralogical Abundances

Table 3 contains the results from several XRD analyses of grab samples from the 98th St. core. As noted, the reported mineralogical abundances are qualitative indicators of relative abundances.

Table 3. Mineralogical composition and qualitative mineral abundances in selected samples from the 98th St. drill core. [Abundances are defined as follows: Major, >25 volume percent; Minor, ≥5 to ≤25 volume percent; Trace, <5 volume percent].

Sample Depth Interval 10.0 ft (surface deposits)

Mineral Phase ID	Formula	Abundance
Albite, ordered	$NaAlSi_3O_8$	Minor
Calcite, syn	$CaCO_3$	Minor
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2\ 4H_2O$	Trace
Muscovite-1M, syn	$KAl_2Si_3AlO_{10}(OH)_2$	Trace
Orthoclase, barian	$(K,Ba,Na)(SiAl)_4O_8$	Minor
Quartz, syn	SiO_2	Major
Richterite, potassian	$KNaCaMg_5Si_8O_{22}(OH)_2$	Trace
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Minor

Sample Depth Interval 37.6-39.8 ft

Mineral Phase ID	Formula	Abundance
Albite, ordered	$NaAlSi_3O_8$	Major
Calcite, syn	$CaCO_3$	Minor
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2\ 4H_2O$	Trace
Muscovite-1M, syn	$KAl_2Si_3AlO_{10}(OH)_2$	Trace
Orthoclase, barian	$(K,Ba,Na)(SiAl)_4O_8$	Major
Quartz, syn	SiO_2	Major
Richterite, potassian	$KNaCaMg_5Si_8O_{22}(OH)_2$	Trace
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Major

Sample Depth Interval 49.4-51.4 ft

Mineral Phase ID	Formula	Abundance
Albite, ordered	$NaAlSi_3O_8$	Minor
Calcite, syn	$CaCO_3$	Minor
Magnesiohornblende	$(Ca,Na)_{2.26}(Mg,Fe,Al)_{5.15}(Si,Al)_8O_{22}(OH)_2$	Trace
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2\ 4H_2O$	Trace
Muscovite-2M#1	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	Trace

Table 3, continued.

Orthoclase, barian	$(K,Ba,Na)(SiAl)_4O_8$	Minor
Quartz, syn	SiO_2	Major
Richterite, syn	$Na_2CaMg_5Si_8O_{22}(OH)_2$	Trace

Sample Depth Interval 91.5-93.0 ft

Mineral Phase ID	Formula	Abundance
Albite, disordered	$Na(Si_3Al)O_8$	Major
Calcite, syn	$CaCO_3$	Trace
Heulandite	$Ca(Si_7Al_2)O_{18}\cdot 6H_2O$	Trace
Muscovite-2M#1	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	Trace
Quartz, syn	SiO_2	Major
Richterite, syn	$Na_2CaMg_5Si_8O_{22}(OH)_2$	Trace
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Major

Sample Depth Interval 101.1-103.5 ft

Mineral Phase ID	Formula	Abundance
Albite, disordered	$Na(Si_3Al)O_8$	Major
Calcite, syn	$CaCO_3$	Trace
Heulandite	$Ca(Si_7Al_2)O_{18}\cdot 6H_2O$	Trace
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2\ 4H_2O$	Minor
Muscovite-2M#1	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	Trace
Quartz, syn	SiO_2	Major
Richterite, calcian,syn	$Na_{0.75}(Ca_{1.25}Na_{0.75})Mg_5Si_8O_{22}(OH)_2$	Trace
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Major

Sample Depth Interval 107.6-109.3 ft

Mineral Phase ID	Formula	Abundance
Albite, disordered	$Na(Si_3Al)O_8$	Major
Calcite, syn	$CaCO_3$	Trace
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2\cdot 4H_2O$	Minor
Muscovite-3T	$(K,Na)(Al,Mg,Fe)_2(Si_{3.1}Al_{0.9})O_{10}(OH)_2$	Trace
Quartz, syn	SiO_2	Major
Richterite, syn	$Na_2CaMg_5Si_8O_{22}(OH)_2$	Trace
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Major

Sample Depth Interval 124.4-125.4 ft

Mineral Phase ID	Formula	Abundance
Albite, disordered	$Na(Si_3Al)O_8$	Trace
Calcite, syn	$CaCO_3$	Major
Heulandite	$Ca(Si_7Al_2)O_{18}\cdot 6H_2O$	Trace
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2\ 4H_2O$	Minor
Muscovite-3T	$(K,Na)(Al,Mg,Fe)_2(Si_{3.1}Al_{0.9})O_{10}(OH)_2$	Trace
Quartz, syn	SiO_2	Major
Richterite, syn	$Na_2CaMg_5Si_8O_{22}(OH)_2$	Trace
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Trace

Sample Depth Interval 148.9-149.9 ft

Mineral Phase ID	Formula	Abundance
Albite, disordered	$Na(Si_3Al)O_8$	Minor
Calcite, syn	$CaCO_3$	Minor
Heulandite	$Ca(Si_7Al_2)O_{18}\cdot 6H_2O$	Trace

Table 3, continued.

Mineral Phase ID	Formula	Abundance
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot 4H_2O$	Minor
Muscovite-3T	$(K,Na)(Al,Mg,Fe)_2(Si_{3.1}Al_{0.9})O_{10}(OH)_2$	Trace
Quartz, syn	SiO_2	Major
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Minor

Sample Depth Interval 166.6-168.6 ft

Mineral Phase ID	Formula	Abundance
Albite, disordered	$Na(Si_3Al)O_8$	Minor
Calcite, syn	$CaCO_3$	Minor
Heulandite	$Ca(Si_7Al_2)O_{18} \cdot 6H_2O$	Trace
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2$ $4H_2O$	Minor
Muscovite-3T	$(K,Na)(Al,Mg,Fe)_2(Si_{3.1}Al_{0.9})O_{10}(OH)_2$	Trace
Quartz, syn	SiO_2	Major
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Minor

Sample Depth Interval 651.0-651.9 ft

Mineral Phase ID	Formula	Abundance
Albite, disordered	$Na(Si_3Al)O_8$	Trace to Minor
Calcite, syn	$CaCO_3$	Minor
Montmorillonite-15A	$Ca_{0.2}(Al,Mg)_2Si_4O_{10}(OH)_2$ $4H_2O$	Trace to Minor
Quartz, syn	SiO_2	Major
Sanidine, potassian, disordered, syn	$(Na,K)(Si_3Al)O_8$	Minor

Sample Depth Interval 715.8 ft

Mineral Phase ID	Formula	Abundance
Kaolinite - 1A- $Al_2Si_2O_5(OH)_4$		Minor
Montmorillonite - 14A - $Na_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot xH_2O$		Minor
Quartz, syn - SiO_2		Major
Calcite, syn - $CaCO_3$		Minor
Orthoclase - $KAlSi_3O_8$		Trace
Dolomite - $CaMg(CO_3)_2$		Trace

Clay Separates

The major clay minerals in the 124 ft (124.4-125.4 ft) zone are are illite, smectite, mixed-layer illite/smectite (up to 60/40 I/S), and kaolinite, with quartz also present. Interestingly, one peak indicative of an unidentified zeolite (chabazite?) was present in the diffraction pattern for the 124 ft interval. However, the abundance of this zeolite would be low (<5 vol. %) because it was not detected in the bulk diffractogram.

In the 148 ft (148.9-149.9 ft) clay separate, smectite, illite, mixed-layer illite/smectite, and clinoptilolite were present; traces of quartz, plagioclase, and calcite ($CaCO_3$) were also identified. Again, evidence for an unknown zeolite was seen in the clay-fraction diffractogram but not in the bulk XRD pattern.

In the 715.8 ft sample, major clays were smectite, illite, mixed-layer illite/smectite, and kaolinite; traces of quartz and calcite were also identified in the clay separate. There was no evidence of a zeolite as in the 124 ft and 148 ft layers.

The presence of these different clay minerals does not suggest any unusual characteristics of the sediments. Current studies of the ultrafine fraction (<0.1 µm) show that the material is Fe-rich and Si-saturated (B. Jones, USGS, oral commun., 1998), and suggests that this fraction may not be a potential adsorbent of aqueous species of As. In brief, the ultrafine material cannot adsorb or accomodate additional ions because of the high degree of Si-saturation. Yet, it is worth noting again that the highest levels of As are usually found within the finer-grained sand, silt, and clay sediments. Additional work on the silt, clay, and ultrafine fractions is underway to determine if As can or does reside as an adsorbed(?) species in these fractions.

SUMMARY

Element abundances in Santa Fe Group sediments generally do not show large variations with depth or lithology (i.e., grain size). The highest abundances of arsenic, however, are generally associated with finer-grained sediments, such as those present in lithologic units 9 through 12. The dominance of rock-forming silicate minerals such as quartz and feldspar in most samples was confirmed by X-ray diffraction. Pyrite pseudomorphs appear to be present in some samples but distinct sulfide phases have not yet been observed.

Minor element chemistry, particularly trace metals such as V, Co, and Zn, show somewhat greater variation in the samples. Arsenic does not correlate positively with most major elements and shows a relatively-strong relationship (r >0.8) with only 3 elements, Fe, V, and Co. Arsenic may be most abundant in Fe-oxides based on stronger associations with Fe, V, Co, and chalcophile elements such as Zn.

The weaker associations of As with major elements such as Ca, Mn, Sr, and Ba suggest As does not reside in minerals formed by these elements in oxidizing environments (primarily carbonates and sulfates). In addition, these four major elements do not strongly correlate with Fe, V, Co, or chalcophile elements.

In summary, the results suggest As does not reside in minerals where Ca, Mn, Sr, and Ba would be the major cations; As is probably located in a solid such as an Fe- bearing oxide. A systematic evaluation is underway to determine if As abundances in the sediments are capable of supporting the relatively higher (10's of ppb) levels of dissolved As detected in some groundwater samples from Santa Fe Group aquifers. Additional investigations are continuing to examine specific mineral residences of As and to determine As mobility between aqueous and solid phases in Santa Fe Group sediments.

Acknowledgment: We thank Al Meier and Paul Briggs of the USGS Minerals Team in Denver for the ICP-MS and ICP-AES analyses, respectively. Bruce Allen (NMBMMR) and Byron Stone (USGS) provided access to drill core samples and lithologic logs. Blair Jones (USGS) provided valuable information about the structure and composition of the ultrafine solid fraction in selected core samples. Violette Valerio-Hirschfeld and other City of Albuquerque personnel granted access to city wells that are being sampled as part of this study. NM USGS-WRD personnel Laura Bexfield, Jim Bartolino, and Conde Thorn helped coordinate sampling efforts at the 98th St. site and provide access to additional wells.

REFERENCES CITED

Briggs, P. H., 1990, Elemental analysis of geologic materials by inductively coupled plasma-atomic emission spectrometry, in Arbogast, B. F., ed., Quality assurance manual for the Branch of Geochemistry, U.S. Geological Survey. U.S. Geological Survey Open-File Report 90-668, p. 83-91.

Fortescue, J.A.C., 1992, Landscape geochemistry - retrospect and prospect - 1990. Applied Geochemistry, v.7, p.1-54.

Manceau, A., 1995, The mechanism of anion adsorption on iron oxides: Evidence for the bonding of arsenate tetrahedra on free $Fe(O,OH)_6$ edges: Geochimica et Cosmochimica Acta, v. 59, p. 3647-3654.

Postma, D., 1993, The reactivity of iron oxides in sediments: A kinetic approach: Geochimica et Cosmochimica Acta, v. 57, p. 5027-5034.

Starkey, Harry C., Blackmon, Paul D., and Hauff, Phoebe L., 1984, The routine mineralogical analysis of clay-bearing samples. U.S. Geological Survey Bulletin 1563, 32 p.

Stone, B. D., Allen, B. D., Miklas, M., Hawley, J. W., Johnson, P., and Thorn, C. R., 1997, Preliminary lithostratigraphy, interpreted geophysical logs, and hydrogeologic characteristics of the 98th St. core hole, Albuquerque, New Mexico. U.S. Geological Survey Open-File Report 97-XXX (in press), 69 p.

Ward, J.C., 1970, The properties of some iron sulphides: Pure and Applied Chemistry, v. 20, p. 175-206.