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Research on the Characterization and Conditioning of Uranium Mill Tailings

I. Characterization and Leaching Behavior of Uranium Mill Tailings

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EXECUTIVE SUMMARY

The goal of these studies on tailings characterization was to determine the mineralogical and elemental composition of various tailings materials, as well as to evaluate their contaminant leachability and radon emanation properties. Extreme variability within and between tailings piles was noted for major, minor, and trace elements and radionuclides. The most commonly enriched contaminants found in 12 tailings site composites were As, Se, U, and V. The ^{226}Ra content of these composites was consistently lower than the most commonly cited estimates. The most common highly leachable components of these tailings include potentially toxic trace contaminants such as U, As, Mo, and Se and major constituents such as Ca, SO_4^{-2}, Na, Mn, and V. Appreciable leachable metal ions (e.g., Zn, Cu, Ni, Co, and Cd) were found for a few tailings materials. These studies have shown the necessity of complete characterization of each individual type of tailings because of differences in total and leachable constituents between tailings.

A pilot study on data derived from neutron activation analysis of core samples from two tailings sites indicates that, by statistical treatments such as cluster analysis, samples can be separated into distinct classes such as tailings, contaminated soil, or background soil. This information could be very significant in determining the degree of contaminant migration beneath a tailings pile. If such chemical and statistical analyses were made on a complete set of core samples, it is likely that a clearer discrimination of sample type could be developed.

Results on sulfuric and leaching tests indicated that appreciable quantities of U, V, Mo, and Co could be extracted from some types of tailings. An economic analysis of reprocessing has shown that for piles requiring relocation as part of remedial action, sufficient mineral values can be extracted from some tailings to provide a net economic benefit. These preliminary results indicate that reprocessing should receive a thorough, fair, and reasonable assessment at several sites, with the aim of performing reprocessing as an integral and beneficial part of the overall remedial action.

RESEARCH ON THE CHARACTERIZATION AND CONDITIONING OF URANIUM MILL TAILINGS

I. Characterization and Leaching Behavior of Uranium Mill Tailings

by

D. R. Dreesen, M. E. Bunker, E. J. Cokal, M. M. Denton,
J. W. Starner, E. F. Thode, L. E. Wangen, and J. M. Williams

ABSTRACT

The initial step in developing and evaluating means of conditioning uranium mill tailings is to characterize the composition and mineralogy of the starting materials and determine the magnitude of contaminant releases from untreated tailings. The emanation of ^{222}Rn gas and the leaching of hazardous elements are the release mechanisms of primary importance. A variety of tailings samples have been characterized; these materials cover wide ranges of major, minor, and trace element compositions and primary mineral components. Vast differences in leaching behavior have been found. The within- and between-pile variability in composition and leachable constituents has also been assessed. The removal of radionuclides and valuable metals by sulfuric acid leaching has also been evaluated.

I. INTRODUCTION

The stabilization, and containment, of uranium mill tailings is often perceived to be strictly an engineering problem requiring the development of suitable liner and cap materials and the selection of a suitable site having geologic stability. The interaction of the tailings and these containment materials caused by physical, chemical, and biological activity has been recognized as an obstacle to the ability of these conventional stabilization methods to meet long-term (1000 year) requirements. Response to this recognition has generally caused most researchers to alter their stabilization studies simply by including more complex barrier systems. We have investigated a different philosophic approach to tailings management for the US Department of Energy's Uranium Mill Tailings Remedial Action Project. Instead of concentrating on more complex means of containing the tailings in a repository, we have examined means of making the tailings less noxious, which will require less complex means of containing them. The barrier philosophy of waste management generally concentrates on the boundary between the waste and the environment. The conditioning philosophy has, as its prime component, a manipulation of the events that allow the release of contaminants into a transport medium (air or water).

The conditioning of uranium mill tailings can be broadly defined as any modification of the composition or structure of tailings to limit the release of contaminants. In essence, such modifications are aimed at controlling contaminant mobility on the micro or particle scale versus more typical disposal scenarios using barriers to isolate the entire tailings mass from the environment. The types of conditioning we have evaluated are (a) the immobilization of contaminants by altering the structure (i.e., mineralogy) of tailings by thermal treatment at high temperatures (~1200°C)—"thermal stablization"—and (b) the removal of hazardous radionuclide and toxic metal contaminants using concentrated or strong aqueous sulfuric acid phases.

The development of conditioning processes requires an understanding of the chemical composition and mineralogical structure of uranium mill tailings in order to comprehend the physicochemical alterations caused

by conditioning and thus to decide how the conditioning might be improved. A variety of analytical techniques have been employed to characterize tailings, including neutron activation analysis (NAA), atomic absorption spectrophotometry (AA), inductively coupled argon plasma emission spectroscopy (ICP), ion chromatography (IC), powder x-ray diffractometry (XRD), electron microprobe studies, gamma spectrometry, laser fluorimetry (LF), and alpha scintillation counting. Many of these techniques were also applied to the determination of the magnitude of contaminant releases from untreated tailings, specifically the emanation of ^{222}Rn gas and the aqueous leaching of hazardous inorganic constituents. These results provide a base line from which to compare contaminant release from conditioned tailings.

Three sets of tailings samples have been characterized to different degrees and include

(a) near-surface materials collected from inactive tailings piles at Salt Lake City, Utah; Shiprock, New Mexico; Durango, Colorado; and Ambrosia Lake, New Mexico.

(b) materials collected at the Salt Lake City pile to prepare bulk composite tailings for a pilot-scale demonstration of thermal stabilization.

(c) tailings collected by Mountain States Research and Development for their program to assay U, V, and Mo values in tailings from 12 different inactive sites.

In the following sections, we will discuss the results of our analyses on these different sets of tailings samples. Detailed sample preparation and analytical procedures, as well as complete data tables, are included in the appendixes. We will also discuss the extractability of tailings contaminants by strong sulfuric acid as a means of conditioning tailings. The possibility of reprocessing some higher grade tailings is examined in relation to the results of this extraction experiment.

II. CHARACTERIZATION OF NEAR-SURFACE TAILINGS MATERIALS

A. Sampling and Preparation of Tailings

Tailings samples were collected at four inactive uranium mill sites — Salt Lake City, Utah (SLC); Shiprock, New Mexico (SHIP); Durango, Colorado (DGO); and Ambrosia Lake, New Mexico (AML). These samples were generally obtained from the top 1 m of tailings (2 m at SLC) and therefore represent near-surface tailings from, at most, 12 locations at each tailings site (see Figs. A-1 through A-3). Details regarding sampling methods are presented in Appendix A.1.

The samples, upon receipt at the laboratory, were prepared for preliminary characterization steps. Splits of samples were dried and pulverized to provide subsamples for solids analysis and conditioning experiments. The other portion of each split sample was not altered to preserve it as an as-received archival sample. Sample preparation methods are described in Appendix A.1.

B. Characterization of Near-Surface Tailings

As outlined above, the as-received tailings were analyzed to determine loss-on-drying, neutralization capacity, pH, Eh, and leachable constituents. Details of these procedures are presented in Appendix A.2. The dried and pulverized solids were analyzed by automated NAA techniques to determine contents of 39 elements.

1. Eh-pH Relationships and Neutralization Capacity

A diagram of pH vs Eh for all the tailings samples is presented in Fig. 1. The regions described in these figures are as reported by Sato (1960). As seen in Fig. 1, most of the tailings samples are located in Sato's "weathering environment," the boundaries of which correspond to soils or ore bodies exposed to surface moisture and the atmosphere. Because the Eh measurements do not truly represent field conditions, it is possible that some of the values reported on the diagram are shifted upward from actual *in situ* redox potentials. However, the fact that these samples were collected from shallow depths corresponds very well with their location in the "weathering environment" above the "normal water table" on the figure. In addition, the samples shown below the $Fe^{+2}/Fe(OH)_3$ line were found to contain considerable leachable Fe. The correlation between sample behavior and the prediction of the pH-Eh diagram is satisfactory. It appears probable that the oxygen-hydrogen peroxide couple controls the Eh of samples within the "weathering environment." The low pH points, which lie outside the "weathering zone" plotted limits, probably have Eh values controlled by the $Fe^{+2}/Fe(OH)_3$ couple.

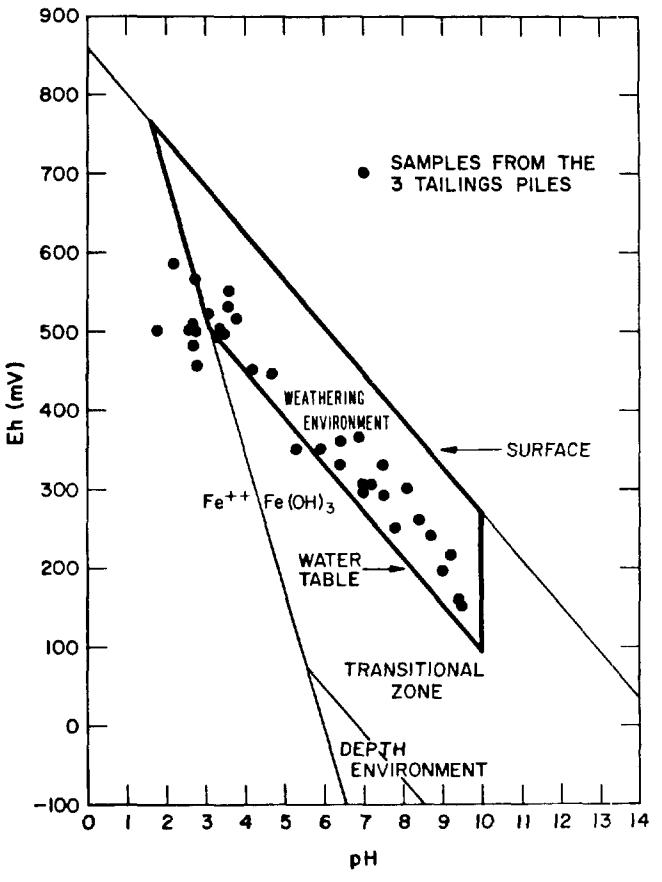


Fig. 1. Diagram of pH vs Eh for all tailings samples.

The Salt Lake City samples cover a broad pH range, 1.8 to 7.2, and Eh range, +295 to +585 mV. The data (see Fig. A-4) show that the samples from the south pile (vanadium tailings) tend to be somewhat more reduced than samples from the southwest pile. Several data points lie below the H_2O_2-O_2 couple equilibrium (water table) line. The four samples to the left of the $Fe^{+2}/Fe(OH)_3$ line in Fig. A-4 did have appreciable leachable Fe, as predicted. The maximum neutralization capacity for any Salt Lake City sample was 309 meq/kg, with many samples requiring less than 6 meq/kg for neutralization.

The Shiprock samples are grouped between pH 2.7 and 4.2 and Eh +450 to +565 mV, with one exception — pH 7.5, Eh +330 (as shown in Fig. A-5). Again, several samples had leachable Fe, as would be indicated by the pH-Eh diagram. Maximum neutralization capacity was 560 meq/kg for a Shiprock slime, with most samples requiring less than 30 meq/kg.

The Durango samples were all neutral to alkaline. Samples from the large pile had pH values from 7.8 to 9.4 and Eh values of +150 to +250 mV, whereas samples from the small pile tended to be less alkaline (pH 6.4 - 9.0) and have higher redox potentials, +195 to +360 mV (as seen in Fig. A-6). Sample number 11 represents tailings from early processing by the US Army and is unlike the other tailings from the large pile. Neutralization of Durango tailings consumed little acid, with the maximum capacity being 59 meq/kg.

2. Elemental Analyses

Analysis of the tailings solids by NAA produced data for 39 elements. The purpose of this phase of the work was to establish similarities/dissimilarities among the samples.

The complete set of analytical results from NAA on the solids is presented in Table A-I. The results are summarized in Table I for ranges of concentration for tailings from the three sites, as well as typical soil concentrations reported by Bowen (1966).

As seen in Table I, Salt Lake City tailings contain many elements much in excess of soil concentrations — Fe, Cl, V, Cr, Zn, U, As, Se, Co, Sb, Th, and W. The ferrophos vanadium tailings deposited on the south pile seem to be present in samples 5A, 5B, and 6A, as indicated by Fe content greater than 5%. Vanadium is found at high levels (>0.1%) in samples 3A, 5A and B, and 6A and B. The vanadium tailings are also enriched compared with other SLC tailings for the following elements: Ca, Co, Cr, Cl, and Mn. Samples 4A and 4B stand out because of high concentrations of Al, As, Cs, La, Sb, and W.

From visual observations and Al content, it is evident that Shiprock samples 5, 6, 7, and, to a lesser degree, sample 9 are all or part slimes. These slimes are appreciably enriched compared with Shiprock sands in the following elements: Al, As, Ca, Co, Cs, K, Sb, Sc, Se, Th, Ti, and V, as well as a number of rare earth (lanthanide series) elements. This pattern of slime enrichment is somewhat evident for Ba, Mg, Rb, and Sr, but not for Cl, Mn, Na, and Zn. Uranium levels are fairly low for all samples, 25-56 μg/g, with a slight, but significant, enrichment in slimes. Iron also fits the pattern of enrichment in slimes, except for sand sample 1B, which shows elevated Fe and Mn. This is the only Shiprock sample with a pH greater than 7. Shiprock tailings (Table I) generally have only a few elements with concentrations in excess of soil concentrations — V, Zn, U, As, and Se.

Durango samples 1-5 are from the large (upper) pile, samples 6-10 from the small pile, and sample 11 from the

TABLE I

RANGE OF ELEMENTAL CONCENTRATIONS IN TAILINGS SOLIDS FROM SALT LAKE CITY (SLC), SHIPROCK (SHIP), AND DURANGO (DGO)

(Compared with mean concentration in typical soils)

Element	Conc Range[a] SLC	SHIP	DGO	Mean Concentration in Typical Soils[b]
Fe (%)	0.8 – 11.0	0.2 – 1.1	1.0 – 4.1	3.8
Ca (%)	2.5 – 8.2	0.9 – 8.7	0.7 – 5.7	1.4
Al (%)	2.0 – 6.7	1.1 – 4.3	1.4 – 7.2	7.1
K (%)	<0.5 – 2.5	0.6 – 1.9	<0.1 – 0.8	1.4
Mg (%)	<0.2 – 1.4	<0.1 – 0.7	<0.2 – 1.0	0.5
Na (%)	0.4 – 1.0	0.1 – 0.2	0.7 – 4.7	0.6
Cl	<55 – 6820	<27 – 122	521 – 2700	100
V	158 – 3040	709 – 4440	1540 – 4110	100
Cr	22 – 7250	18 – 54	12 – 3950	100
Ti	1420 – 3720	471 – 3130	<553 – 3160	5000
Zn	<24 – 231	<17 – 175	155 – 2270	50
Ba	<194 – 2380	726 – 1240	869 – 40 800	500
Mn	79 – 2080	21 – 114	91 – 1280	850
Sr	<198 – 948	<71 – 418	<127 – 575	300
U	58 – 217	25 – 56	170 – 477	1
As	73 – 419	21 – 200	44 – 632	6
Ce	44 – 159	18 – 76	77 – 279	50
Se	5.9 – 69	23 – 233	<0.7 – 28.6	0.2
Co	5.5 – 42	0.8 – 4.9	9.2 – 138	8
Rb	46 – 131	18 – 79	<39	100
Ga	<19 – 76	<19	<27 – 123	30
Sb	8.6 – 54	1.2 – 67	<0.5 – 10.1	2 – 10
I	<8 – 49	<16	<34	5
La	10.9 – 35.7	4.6 – 27.6	8.1 – 43.8	30
Sm	3.6 – 16.7	2.0 – 8.3	9.7 – 34.0	3
^{232}Th	4.5 – 33.1	1.2 – 7.0	1.9 – 9.6	5
W	4.6 – 18.8	<0.05 – 7.6	<0.05 – 8.7	1
Cs	4.5 – 15.1	0.9 – 4.1	1.3 – 4.4	6
Dy	<1.2 – 5.7	0.6 – 5.9	1.2 – 13.1	7
Sc	3.0 – 9.5	1.1 – 6.9	1.8 – 8.4	7
Hf	2.9 – 7.0	3.5 – 8.0	4.1 – 8.7	6
Yb	<1.1 – 6.3	<0.5 – 4.2	<0.8 – 5.8	2
Br	<1.4 – 6.3	<1.7	<5.0	5
Tb	<0.2 – 1.3	<0.1 – 5.4	<0.2 – 2.3	0.6
Ta	<0.6 – 1.9	<1.0	<0.5 – 2.6	0.8
Eu	0.35 – 1.33	0.33 – 1.27	0.36 – 2.13	0.5
Lu	<0.11 – 0.46	0.07 – 0.33	0.21 – 0.67	0.1
Hg	<0.01 – 0.13	<0.03	<0.01 – 0.30	0.03
Au	<0.012 – 0.102	<0.016	<0.043	0.004

[a]Conc in μg/g unless otherwise noted.
[b]Source: Bowen (1966).

US Army process tailings. One pattern of elemental enrichment includes samples 1 through 5 and the presumed slime samples from the small pile (samples 7 and 10) having similar concentrations. These enriched elements include Al, Ca, Co, Fe, Na, Th, V, and Zn. A similar pattern exists in this set of samples, except that samples 7 and 10 have higher concentrations than the large pile samples for As, Sb, U, and some rare earths. The barium concentration in sample 7 (4.1%) is very abnormal and is 20 times higher than the concentration in any other Durango tailings sample. In general, samples from the large pile (1-5) have elevated levels of Cr, Cl, Mn, and Ti, and lesser levels of Se, compared with samples from the lower pile (6-10). Of the larger pile samples (1-5), sample 3 has low concentrations of Al, As, Ca, Cr, Cl, Fe, Mn, Na, Th, Ti, V, and Zn. However, sample 3 does not seem depleted for many of the rare earth elements and Ba, K, and U. In general, Durango tailings have elevated concentrations of Cl, V, Cr, Zn, U, As, Se, Co, and Ga, compared with soil.

3. Leachable Constituents

Patterns in the data (see Appendix Table A-III) of leachable constituents in the various tailings are not prevalent; however, a few trends do seem apparent. The lack of mobility of Ba is as expected because of the extremely low solubility of $BaSO_4$ and the high levels of SO_4^{-2} in the tailings and leachates. For trace elements, solubility limitations do not seem to control concentrations to the observed levels. The most probable mechanisms to explain the control of trace species are adsorption and coprecipitation, which are sensitive functions of pH. The pH control of acid-mobile species is evident for Zn, Cd, Pb, Fe, Mn, Cu, Co, and Ni for tailings from all three sites. The most acidic leachate samples (pH 2.5-3.0) contain the greatest soluble amount of these metals, whereas alkaline leachates (pH 7.0-9.6) contain negligible, or undetectable, concentrations of these elements.

a. Salt Lake City Tailings Leachates. These leachates covered a wide range of pH values from 2.5 to 7.6. The major measured constituents (exceeding 10 μg/g for at least one sample) in these solutions, in approximate order of decreasing concentration, are Ca, Na, Si (reported as SiO_2), Mg, V, Cu, Zn, K, Fe, U, Mo, and Mn. As already mentioned, pH seems to be a primary controller of the mobility of base metals in these tailings. Samples 1A through 2B contain the highest amounts of soluble U in these samples. Salt Lake City samples had much more leachable molybdenum than was found in Shiprock or Durango tailings. Large differences in leachable vanadium are apparent among the samples from the Salt Lake City site. Because vanadium tailings were deposited in the south tailings pile, it is reasonable that samples 3A through 6B would have elevated leachable vanadium. In addition, potassium concentrations in the leachates seem to be related to sample location and are higher in the vanadium tailings leachates.

b. Shiprock Tailings Leachates. These leachates spanned a pH range of 2.9 to 4.8, except for one solution with a pH of 7.5. The major measured constituents found in the Shiprock leachates are Ca, Si (reported as SiO_2), Na, Mg, K, V, and Mn. The coarser samples (3, 10, and 11) have less soluble Na and Mg, whereas soluble Ca is fairly uniform among the samples, probably as a result of the solubility of $CaSO_4 \cdot 2H_2O$. A small amount of vanadium is water soluble in these tailings. Appreciable leachable uranium was found in the slime samples (6 and 7). As was seen with the Salt Lake City Tailings, the more acidic leachates (pH 2.9-3.3) contained moderate quantities of the transition metals.

c. Durango Tailings Leachates. The Durango leachates were neutral to alkaline (pH 6.4-9.6) and were mainly composed of Ca, Si (reported as SiO_2), Na, V, Mg, and K. The samples from the large pile (1 through 5) had much less soluble Ca than the other Durango samples. Sodium was the predominant species measured in leachates 1 and 4. Vanadium was quite water soluble from the alkaline Durango tailings, probably as an anionic species of V(IV) (as judged from the measured Eh values). Only small amounts of the remaining uranium are water leachable, and negligible quantities of the acid-mobile transition metals are labile in these alkaline solutions. Samples from the large pile (1-5) show little soluble selenium and less leachable SiO_2 than the samples from the small pile.

C. Preparation and Analysis of Composites of Near-Surface Tailings Samples

To perform conditioning experiments on a modest number of samples, we composited individual samples in an effort to represent the range in composition. The composites were prepared from the individual samples (locations shown in Figs. A-1, A-2, and A-3) and include

Shiprock

SHIP Sands — composite of high SiO_2 content samples (other elements low).
SHIP Fines — composite of low SiO_2 and high major/minor, trace elements.

Salt Lake City

SLC 1AB — high SiO_2; low Fe, Mn, As, Se, V.
SLC 4AB — high Al, As, Se; low SiO_2.
SLC 5AB — high Ca, Fe, Cl, Cr, Mn, V; low SiO_2.

Durango

DGO LP — all large pile samples, fairly homogeneous.
DGO SP Sands — high SiO_2; low Al, Ca, Fe, Na.
DGO SP Fines — high Al, As, Ca, Fe, Na, V; low SiO_2.

These composites were analyzed by neutron activation analysis and by atomic absorption spectrophotometry; these data are presented in Appendix Tables A-IV through A-VIII, along with the composition of shales and soils from the Colorado Plateau. Table II shows those elements having significant enrichment over the maximum soil values. The following elements are generally enriched in tailings: V, Se, U, Mo, As, Sb, and Pb. All of these elements except lead are uranium analog elements in that they are often enriched in sandstone uranium deposits as a result of common geochemical behavior (Brookins 1977). The high concentrations of Fe, Mn, and Cr in SLC 5AB indicate the presence of ferrophos vanadium tailings. The coarse composites SHIP Sands and SLC 1AB are depleted in a number of major and minor elements, including Fe, Mg, and Mn.

TABLE II

ELEMENTS ENRICHED OR DEPLETED IN TAILINGS COMPOSITES COMPARED WITH GRANTS, NEW MEXICO SOILS

Site	Composite	>50X	>10X	>3X	<1/3X
SHIP	Sands	Se	V, Mo, Pb	As, U	Al, Fe, Mg, Na, Mn, Ti, Co, Rb, Th
	Fines	V, Se	As, U, Mo, Pb	Ca, Cl, Zn, Sb	Mn
SLC	1AB		Sb, U, Mo	Ba, As	Fe, Mg, Mn, Ni
	4AB	Se, Sb, Mo	Cl, As, U, Cu, Pb	V, Zn	
	5AB	Cl, Cr	V, As, Sb, U Cu, Mo, Ni, Se	Ca, Fe, Mn Co, Pb	Mg
DGO	LP	U	Cl, Cr, V, Zn As, Cu, Pb	Na, Ba, Co Sb, Mo, Ni	K
	SP Fines	V, U, Se	Ba, Cl, Zn, As Co, Cu, Pb	Na, Cr, Sb Mo, Ni	
	SP Sands	U	Cl, V, As, Pb	Ba, Cr, Zn Sb, Cu, Mo	Rb, Th
AML	Fines	Se	V, U	Na, As, Mo, Pb	Ni

Note: Se soil value = 0.4 μg/g.
Cu soil value = 20.
Mo soil value = 2.
Ni soil value = 40.
Pb soil value = 10.
Source: Bowen (1966 and 1979).

1. Radionuclides

The radionuclide contents of these composites were determined using gamma spectroscopy and are presented in Appendix Table A-IX. A measure of the U extraction efficiency has been obtained by comparing the residual U content with ^{226}Ra, which should indicate the content of U in the original ore at secular equilibrium. Thorium-234 is a short-lived daughter of ^{238}U and its activity reflects the U content quite well. Note that the extraction efficiencies are high (>93%) except for the Durango mill, which had efficiencies of about 90%. Because these analyses were made on near-surface samples, which may have been subjected to leaching by meteoric water, these extraction efficiencies represent upper bounds and, in all probability, lower efficiencies were actually achieved during milling.

The ^{238}U progeny (^{230}Th, ^{226}Ra, and ^{210}Pb) have sufficiently long half-lives that the chemical reactions during the milling or, subsequently, in the tailings pond, could perturb the radioactive equilibrium that was present in the original input ores. One means of evaluating this perturbation (assuming the ores were in secular equilibrium) is to investigate the activity ratios of these radionuclides.

The $^{230}Th/^{226}Ra$ ratios show a definite trend related to the leaching process; sulfuric-acid-leached tailings (SHIP and SLC) have ratios (0.19 to 0.56) less than 1, whereas carbonate-leached tailings have ratios (1.06 to 1.29) greater than 1. The results reported by Ryon et al. (1977) show similar trends for sulfuric-acid-leached tailings (0.13 to 0.68) and carbonate-leached tailings (0.91 to 1.37). Thus, the sulfuric acid leach apparently removes a significant fraction (40-80%) of ^{230}Th from the ore. This is consistent with the Itzkovitch and Ritcey (1979) report that 50% of the thorium is dissolved during acid leaching. It is not expected, however, that more than 5% of the ^{230}Th would be found in the yellowcake product (Itzkovitch and Ritcey 1979). Thus, the residence of the leached ^{230}Th is unknown. One possibility is that the acidic tailings solution contains the thorium and that it precipitates when the acidic tailings solutions contact neutral or alkaline soils. Thus, ^{230}Th enrichment may occur at the tailings/soil interface. Since the composite tailings we are investigating represent surface samples, we may be missing samples enriched in thorium. The apparent leachability of ^{230}Th in sulfuric acid mill processes adds credence to the use of sulfuric acid to remove ^{230}Th, the precursor to ^{226}Ra. The $^{230}Th/^{226}Ra$ ratios that are greater than 1 for carbonate tailings would most probably result from a greater solubility of ^{226}Ra than ^{230}Th in alkaline mill circuits; this likelihood is described by Itzkovitch and Ritcey (1979).

The $^{226}Ra/^{210}Pb$ ratios show the same trend as previously discussed; ratios are less than 1 for sulfuric acid tailings (except SLC 5AB) and AML Fines; $^{226}Ra/^{210}Pb$ ratios are greater than 1 for Durango tailings. The analytical uncertainty associated with the ^{226}Ra and ^{210}Pb analysis may result in these ratios being not significantly different from 1. This trend would indicate that ^{226}Ra may be slightly more soluble than ^{210}Pb in acid tailings.

The ^{238}U progeny, ^{226}Ra, should have 22 times the activity of the ^{235}U progeny (^{231}Pa and ^{227}Ac) if the original ores had normal isotopic abundances and were in secular equilibrium. This activity ratio is closely approximated for all the tailings composites (if the activities have $\pm 20\%$ uncertainty, the ratio could range from 15 to 33). The activity of the ^{232}Th progeny illustrates the relatively insignificant radioactive contribution from these radionuclides.

2. Particle Size Analyses and Mineralogy

Particle size analyses of the tailings composites were performed using wet-sieving and sedimentation techniques (see Appendix A.3. and Table A-X for details and results). The results substantiate our classification of sands and fines on the basis of SiO_2 and other major element contents.

The quantified mineral composition of the tailings is reported in Table III, along with identified, but unquantified, minerals or mineral types (see Appendix A.3. for x-ray diffraction procedure). Crystalline quartz was predominant in tailings sands (SHIP Sands, SLC 1AB, and DGO SP Sands), making up more than ~70% of the total material. Tailings fines (SHIP Fines, SLC 4AB, DGO SP Fines, and AML Fines) contained substantial crystalline quartz (17 to 46%) with appreciable "non-crystalline" quartz (5 to 12%), which may result from the presence of submicron quartz particles produced during the grinding of uranium ore. Gypsum was present in large amounts in some of the sulfuric acid-leached tailings (SHIP and SLC); this mineral was most probably formed subsequent to milling. Substantial amounts of clays other than kaolinite and illite were found in fine tailings from SHIP, SLC, and AML. Calcite and albite (sodium aluminosilicate) were also present in the AML Fines. Unquantified minerals, which are apparently present in appreciable quantities, include

TABLE III

MINERAL COMPOSITION OF URANIUM MILL TAILINGS DETERMINED BY X-RAY DIFFRACTION

		% Composition									
		Quartz									
Site	Composite	Crystal.	Non Crystal.	Gypsum	"Clay"	Illite	Kaolinite	Calcite	Feldspars[a]	Unknown	Other Identified Minerals Not Quantified
SHIP	Sands	90		7					2	1	
SHIP	Fines	23	9	34	12	3	1			18	Plagioclase (low albite?)
SLC	1AB	68		14	5	4	1		7	1	
SLC	4AB	34	12	7	11	11	2			23	
SLC	5AB	34	1	1					3	59	Clino–chloroapatite; α–hematite
DGO	LP	43	2							55	Mostly plagioclase-type aluminosilicates; some nonaluminum silicates
DGO	SP Fines	17	5	2						76	Mostly plagioclase-type aluminosilicates; some nonaluminum silicates; barite; pyrrhotite?
DOG	SP Sands	88							11	1	
AML	Fines	46	10		23		6	5	18	8	

[a]Albite or high albite.

plagioclase-type minerals in SHIP Fines, DGO LP, and DGO SP Fines. The DGO tailings also contained nonaluminosilicate minerals. In addition, barite was found in DGO SP Fines, which is reasonable considering the high Ba content (~2%) of this composite.

The iron-rich SLC 5AB tailings, which we consider to represent the "ferrophos" vanadium tailings, contain a moderate amount of quartz and substantial unquantified minerals. Identified, but unquantified, mineral constituents include α-hematite, which may represent the principal iron mineral, and clino-chloroapatite, which may be the predominant phosphate mineral.

One method of substantiating these mineralogical assays of tailings is to relate our data to the mineralogy of the source ore. For the AML Fines, a fairly complete mineralogical evaluation of the source sandstone ore from the Westwater Canyon member in the vicinity of Ambrosia Lake, New Mexico has been reported by Squyres (1970). Squyres describes the typical sandstone as containing 50 to 75% quartz (our value 56%); 25% potassium feldspars and sodic plagioclase (our value 18% for albites); a predominance of montmorillonite clay over illite (our clay value 23%, no illite); and authigenic materials such as calcite and kaolinite (our values 5 and 6%, respectively). The correspondence between Squyres' analysis and our values substantiates the validity of our technique with regard to identification of major mineral forms.

Another piece of substantiating evidence is the result of electron microprobe elemental analysis of individual particles in size-fractioned SHIP Fines. These data are presented in summary form in Appendix Table A-XI, along with our inferences about the mineral form that might account for these elemental distributions. We have inferred the presence of quartz, gypsum, feldspars and clays, iron oxides, and an organic particle, which might be a coalified, highly altered, humic substance.

D. Mobility of Contaminants in Composite Tailings

The causes of the major health and environmental hazards posed by uranium mill tailings are (1) the emanation of ^{222}Rn gas from tailings particles and its subsequent release from tailings piles and (2) the leaching of radionuclides and toxic stable elements by surface and/or ground water. The following section will discuss the ^{222}Rn emanation characteristics of the composite tailings materials and the mobility of contaminants when leached by water.

1. Radon Emanation

Emanating and total ^{226}Ra in the composite tailings are reported in Table IV, along with their emanation coefficients. Particle size analyses and silica content of these tailings are also presented in Table IV. Emanating

TABLE IV

EMANATING ^{226}Ra, TOTAL ^{226}Ra, EMANATION COEFFICIENTS, AND PARTICLE SIZE DISTRIBUTION OF TAILINGS COMPOSITES

Site	Composite	Emanating ^{226}Ra (pCi/g)	Total ^{226}Ra (pCi/g	Emanation Coefficient (%)	Particle Size Distribution Sand (%)	Silt (%)	Clay (%)	Predicted SiO_2 (%)
SHIP	Sands	39	396	10	77	17	6	90
SHIP	Fines	214	2020	11	10	78	12	53
SLC	1AB	136	1180	12	47	47	6	75
SLC	4AB	125	1070	12	14	76	10	61
SLC	5AB	63	316	20	64	33	3	43
DGO	LP	212	973	22	47	52	1	67
DGO	SP Fines	473	1810	26	11	86	3	57
DGO	SP Sands	140	719	19	81	19	1	87
AML	Fines	546	1330	41	–	–	–	–

^{226}Ra levels range from 39 to 546 pCi/g; total ^{226}Ra levels range from 316 to 2020 pCi/g. Emanation coefficients for Shiprock and Salt Lake City tailings (except SLC 5AB) are appreciably lower (10 to 12%) than those for Durango tailings (19 to 26%). In general, the coarse tailings sands (SHIP Sands and DGO SP Sands) have lower emanating ^{226}Ra levels than the corresponding tailings fines. However, there is not a great difference in emanation coefficients between sands and fines from the same pile. The emanation character of the iron-rich (ferrophos) Salt Lake City tailings (5AB) is not similar to those of the "uranium" tailings (SLC 1AB and 4AB).

Ryon et al. (1977) report the range of emanation coefficients for four sulfuric-acid-leached tailings as 9 to 17% (average 12%) with carbonate-leached tailings having higher emanation coefficients (14 and 45%). These results correspond well with the emanation coefficients in Table IV for sulfuric-acid-leached tailings (10 to 20%) and carbonate-leached tailings (19 to 41%). Macbeth et al. (1978) report emanation coefficients for Salt Lake City tailings (17 to 27%), which are generally higher than our results; these inconsistencies may result from the use of different measurement techniques [gamma counting of de-emanated solids (Macbeth et al. 1978) vs alpha counting of ^{222}Rn (this study)] or moisture contents.

The control of radon flux resulting from the physicochemical conditioning of tailings can be evaluated on a laboratory scale by examination of the reduction in emanating radium or emanation coefficients. Thus, these baseline emanation measurements form the basis for evaluating radon flux control. Radon flux is dependent on many factors other than emanating ^{226}Ra (e.g., porosity, diffusion coefficients, moisture content); however, evaluation of conditioned tailings can be performed in the most direct manner by comparing emanation characteristics.

2. Leachate Composition

The eight composite tailings materials from the three high-priority sites have been subjected to leaching tests to assess their potential for releasing soluble components to surface or ground water (see Appendix A.3. for details). The results of these analyses are reported in Table V, along with water quality standards or criteria (US EPA 1973, 1976, 1980) and health Minimum Acute Toxicity of Effluents (MATE) concentrations (Cleland and Kingsbury 1977).

Concentrations of all listed elements except Ag, Ba, K, Mg, Na, and Sb exceed these criteria values by amounts sufficient to warrant additional scrutiny. The following elements are high only in the leachates from acid tailings: Al, Be, Cd, Co, Fe, Ni, Pb, and Zn; only V is particularly high in alkaline tailings leachates. Uranium is highly water leachable from SLC uranium tailings and somewhat leachable from Durango tailings. Molybdenum is present in high concentrations in leachates of two Salt Lake City tailings and Cr is high in one (SLC 4AB). These concentrations reflect the qualitative pH behavior expected for these elements. Concentrations of most transition and heavy metals are controlled at low levels by insoluble hydroxides and/or carbonates. In contrast, the chemistry of elements such as Mo, Se, U, and V suggests their presence as negatively charged ions or complexes that could remain in solution under alkaline conditions. Thus, the uranium extraction process, acid or carbonate, may be of paramount importance in determining mobile elements in tailings. Mineralogy of the uranium ores is undoubtedly an additional important factor controlling mobility.

For most elements (particularly acid-mobile species), SLC 4AB gave the highest leachate concentrations of the tailings under study. This tailings composite generates the most acidic leachate (pH = 2.7) and has a fine-grained texture (86% silt and clay). The variability in elemental mobility at each site illustrates the complexity in predicting how "average" tailings might interact with surface or ground water. What commonality there is appears to be primarily a result of the inherent pH of the material and its particle size. The influence of particle size on mobility reflects surface area and the tendency for the fine-grained material to have higher contaminant concentrations.

The contamination potential for each element will depend to a considerable extent on natural dilution, permeability, and attenuation properties of the surrounding geologic material. These mechanisms would generally tend to mitigate against high concentrations of many of the contaminants in this study (particularly acid-mobile species).

These data will serve as the basis for comparison of conditioned tailings regarding aqueous mobility of contaminants. The advantage gained from conditioning can be quantified on the basis of laboratory experiments. The conditioning process may alter (1) the general chemical environment (pH, TDS, redox potential); (2) the level of

TABLE V

CONCENTRATIONS OF ELEMENTS IN AQUEOUS LEACHATES FROM COMPOSITE TAILINGS (mg/ℓ)

	SHIP Sands	SHIP Fines	SLC 1AB	SLC 4AB	SLC 5AB	DGO LP	DGO SP Fines	DGO SP Sands	Water Quality Standards	MATE
Major Constituents										
pH	3.5	3.2	3.2	2.7	7.2	9.4	7.9	8.1	na	na
Al	6	36	28	180	<0.1	<0.1	<0.1	0.1	5.0	80
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	1.0[a]	5.0
Ca	710	520	650	440	680	11	520	330	na[b]	240
Fe	0.1	0.8	13	46	<0.1	<0.1	<0.1	<0.1	0.3	1.5
K	4	13	5	12	6	5	7	3	na	na
Mg	17	92	11	98	32	6	18	6	na	na
Na	13	75	3	344	129	21	29	5	na	800
Minor Constituents										
Ag	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05[a]	0.25
Be	<0.01	0.01	0.40	0.11	<0.01	<0.01	<0.01	<0.01	na	0.03
Cd	0.03	0.09	0.08	0.16	<0.01	<0.01	<0.01	<0.01	0.01[a]	0.05
Co	0.1	0.2	1.1	1.4	<0.1	<0.1	<0.1	<0.1	0.05	0.75
Cr	0.02	0.02	0.01	0.49	<0.01	0.08	0.06	0.01	0.05[a]	0.25
Cu	0.5	0.6	1.3	22	<0.1	<0.1	<0.1	<0.1	1.0	5.0
Mn	0.5	3	2.8	7.3	0.1	<0.1	0.1	0.1	0.05	0.25
Mo	0.1	0.1	0.1	5.4	3.4	<0.1	0.7	0.1	0.05[a]	75
Ni	0.07	0.81	0.61	1.6	0.13	0.01	<0.01	<0.01	0.2	0.23
Pb	0.28	0.29	0.19	1.2	<0.05	<0.05	<0.05	<0.05	0.05[a]	0.25
Sb	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	na	7.5
Se	0.1	0.2	<0.1	<0.1	0.1	<0.1	0.1	0.1	0.01[a]	0.05
U	0.1	0.7	8.6	8.0	<0.05	1.8	1.1	0.25	0.03[a]	60
V	0.3	0.9	0.1	3.2	24	5.8	10	10.8	na	2.5
Zn	0.6	1.3	3.0	11.8	<0.1	<0.1	<0.1	<0.1	5.0	25
Anions										
Cl^-	2	10	0.8	360	10	2.7	3.6	1.2		
F^-	0.3	3	37	46	0.2	1.2	1.2	0.6		
NO_3^-	–	75	<1	–	66	1.6	<1	0.7		
PO_4^{-3}	<2	<2	<2	2	7	3	0.4	1.8		
SO_4^{-2}	1520	2190	1680	3140	1600	15	1000	560		

[a]US EPA (1980) proposed UMTRAP standards.
[b]Not available.

contaminants present in the conditioned tailings; (3) the general physical characteristics (particle size, surface area); or (4) the structure of the tailings (new mineral forms, crystalline vs amorphous). Evaluating changes in elemental mobility will help to clarify how the conditioned tailings have been modified and whether we might expect the product to retain advantageous characteristics over the long term.

III. SULFURIC ACID EXTRACTION OF MINERAL VALUES AND CONTAMINANTS

One method of conditioning uranium mill tailings involves the removal of radionuclides from the tailings to enable the disposal of a large volume of innocuous waste and the stringent management of a small volume of

highly radioactive residues. The advantages of radionuclide removal can be seen in an evaluation of the long-term radiological hazard posed by tailings with varying radionuclide contents. Such an analysis encourages the development of conditioning techniques that remove a substantial portion of the long-lived radionuclides (i.e., ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb, ^{235}U, ^{231}Pa). Leaching with concentrated sulfuric acid is one method that shows promise. If valuable metals can be recovered as a by-product of a radionuclide removal process, some of the reprocessing costs can be offset.

A. Radionuclide Removal

One of the more difficult technical obstacles in achieving radionuclide removal is the extraction of ^{226}Ra from a sulfate-rich matrix such as tailings. Such extraction can be achieved by multistage leaching with strong nitric acid (Ryon et al. 1977), hydrochloric acid, or chelating agents (Borrowman and Brooks 1975). The approach for ^{226}Ra removal, which we have investigated, has much in common with early radium extraction methods using concentrated sulfuric acid (Landa 1981).

Table VI presents the percentage extraction of radionuclides from tailings fines by both concentrated and 10N H_2SO_4. The extraction (see Appendix A.4. for procedure) observed seems consistent with the proposition that concentrated H_2SO_4 is an effective solvent for aqueously insoluble sulfate salts, such as $BaSO_4$, $RaSO_4$, and $PbSO_4$ (Williams et al. 1981). Concentrated sulfuric acid also extracts substantial U and ^{230}Th, as does 10N acid. These results indicate that concentrated H_2SO_4 is effective in extracting the long-lived radionuclides. A major technical problem is to achieve a solid/liquid separation with a very viscous liquid like concentrated H_2SO_4. Until this technical obstacle and other technical difficulties are resolved, a conceptual radionuclide removal process using this technology cannot be developed.

B. Mineral Values in Tailings

The comparison of the elemental concentrations in these composite tailings solids with the concentrations in shales and soils showed that a number of elements are present at levels much in excess of levels found in typical crustal materials. As examples, the following elements are enriched in the most concentrated tailings by the factors indicated in parentheses: Co (10), Cr (170), Mn (3), Ni (42), Se (13), U (120), V (58), Zn (35). Recovery of these constituents from tailings, particularly if the tailings must be handled in the process of placement in depositories, would be desirable.

An assessment of mineral value recovery from these tailings is summarized in Table VII (see Tables A-XII through A-XV for details). It is apparent that Shiprock tailings contain negligible values, whereas the Salt Lake City fines and ferrophos residues and the Durango tailings contain appreciable values. These results indicate that a more thorough investigation of mineral recovery from these favorable tailings is warranted.

An economic analysis (see Appendix A.5.) of reprocessing the Durango tailings has been performed; percolation H_2SO_4 leaching of tailings in excavated leach tanks was the conceptual process that was evaluated (Thode and Dreesen 1981). It is estimated that $32 million of U and V could be recovered from these tailings with an incremental cost, because of the leaching steps,

TABLE VI

EXTRACTION OF RADIONUCLIDES AND OTHER ELEMENTS FROM TAILINGS BY CONCENTRATED AND 10N H_2SO_4

	U	^{230}Th	^{226}Ra	Ba	^{210}Pb	Pb
% Extracted by Conc. H_2SO_4						
SHIP Fines	0	85	80	70	20	40
SLC 4AB	60	90	75	30	55	30
DGO SP Fines	55	80	70	70	50	55
% Extracted by 10N H_2SO_4						
SHIP Fines	35	55	0	0	20	30
SLC 4AB	70	65	0	0	0	60
DGO SP Fines	90	60	0	0	0	15

TABLE VII

RECOVERABLE MINERAL VALUES FROM TAILINGS COMPOSITES USING STRONG SULFURIC ACID LEACHING

	Maximum Amount Extracted (g/metric ton) Value Extracted ($/metric ton)						
Mineral	SHIP Sands	SHIP Fines	SLC Sands (1AB)	SLC Fines (4AB)	SLC Ferrophos (5AB)	DGO SP Sands	DGO SP Fines
U	5	18	57	130	23	190	430
	a	a	$2.51	$5.72	$1.01	$8.36	$18.92
V	160	680	18	70	1560	450	2140
	a	$3.89	a	a	$8.92	$2.57	$12.24
Mo	43	130	120	1710	150	4	14
	a	$1.79	$1.65	$23.51	$2.06	a	a
Co	1	1	11	8	14	8	75
	a	a	a	a	a	a	$4.45
Cr	1	3	2	82	260	10	37
	a	a	a	a	$2.43	a	a
Mn	5	19	23	50	1340	160	680
	a	a	a	a	$2.06	a	$1.04
Ni	1	8	5	9	370	3	32
	a	a	a	a	$2.85	a	a
Cu	11	16	17	140	600	85	650
	a	a	a	a	$1.10	a	$1.20
Zn	5	13	25	72	33	180	1320
	a	a	a	a	a	a	$1.34
Total Value ($/metric ton)	a	$6.00	$4.00	$29.00	$20.00	$11.00	$39.00

[a]Value less than $1.00.

of $19.5 million. Therefore, over $12 million could be gained to offset the overall cost of remedial action. The net cost of such a reprocessing scenario would be less than the total cost of reshaping, stabilizing, and covering the existing tailings in place.

Reprocessing tailings for *metals recovery* will remove some residual U and ^{230}Th, but not ^{226}Ra; thus, the long-term radiological hazard will not be appreciably reduced. However, reprocessing can remove potential leachable contaminants, such as Mo and U, and therefore lessen

the overall hazard of these materials. In conclusion, if the value of the materials recovered equals or exceeds the incremental cost of adding the leaching step, reprocessing should definitely be considered as part of the overall remedial action.

IV. CHARACTERIZATION OF SALT LAKE CITY TAILINGS COMPOSITE FOR PILOT-SCALE THERMAL STABILIZATION TESTS

Planned scale-up thermal stabilization studies showed that at least 500 kg of raw tailings material would be required to perform these tests. Samples from previous sampling or coring operations (in particular the coring performed by Mountain States Research and Development) would composite to, at most, about 100 kg. Consequently, Los Alamos National Laboratory collected approximately 7000 kg of tailings material from the Salt Lake City (Vitro) tailings pile. This site was selected because it was one of only a few sites where thermal stabilization might be used for remedial action (other sites are Shiprock, New Mexico and Canonsburg, Pennsylvania). Details of sampling and composite preparation are presented in Appendix B.1. The composition of these untreated tailings was determined by NAA and the results are shown in Appendix Table B-III. The average (AVG) agglomerated tailings had higher concentrations of all elements, except Ti, than the sample blended with 10% coal (COAL); the coal acted as diluent of the tailings. The tailings material, which was a composite of agglomerates from different locations (MIX), generally had higher concentrations of most elements than the AVG material, probably because the small subsample selected for NAA was not representative of the bulk material containing large heterogeneous particles (6-19 mm). The composition of these input materials for the pilot-scale thermal stabilization tests was used to determine (1) an estimate of the total loss of volatile species during thermal treatment (H_2O, CO_2, SO_x, halides, volatile metals) from the enrichment of nonvolatile elements (e.g., Na, Al, V, Ca) and (2) the loss of specific volatile components such as Cl, Sb, and As by direct measurement.

Another important criterion for these input materials was how representative they were of average Salt Lake City tailings. We examined site composite tailings prepared by Mountain States Research and Development as the most representative average tailings material available for this site; both total and leachable elemental contents were determined by NAA, AA, ICP, IC, and LF techniques. The results of these analyses are presented in Appendix Table B-IV. The Los Alamos composite (AVG) had greater concentrations in the tailings solids of the following elements: Cl, V, Mn, Sb, U, Cr, Fe. The presence of elevated Cl, V, Mn, Cr, and Fe would indicate that the Los Alamos composite contained a somewhat greater fraction of ferrophos tailings than did the Mountain States composite. The leachate data showed large discrepancies for only a few elements (Cl, Se, Co, U, Mn, and Mg), which were lower in the Los Alamos composite. However, in general, the composition data indicate that the Los Alamos composite of Salt Lake City tailings is reasonably similar to the most representative tailings samples in existence.

V. CHARACTERIZATION AND STATISTICAL ANALYSIS OF TAILINGS SAMPLES COLLECTED BY THE MOUNTAIN STATES ASSAY AND DRILLING PROGRAM

Mountain States Research and Development carried out a drilling and assay program under subcontract to Sandia National Laboratories to assess recoverable mineral values (U, V, and Mo), as well as to better characterize the physical and chemical properties at 12 inactive mill sites. At the completion of Mountain States' assay of tailings, the samples were shipped to Los Alamos National Laboratory as a repository for these archival samples. At the request of Sandia National Laboratories, we performed elemental analyses by instrumental NAA on samples from two sites (Salt Lake City and Shiprock) and obtained more complete characterization of site composites from the following 12 inactive mill locations:

Ambrosia Lake, New Mexico—AML
Riverton, Wyoming—RIV
New Rifle, Colorado—NR
Spook, Wyoming—SPK
Maybell, Colorado—MBL
Mexican Hat, Utah—MH
Salt Lake City (Vitro), Utah—VIT
Shiprock, New Mexico—SHR
Grand Junction, Colorado—GJT
Gunnison, Colorado—GUN
Old Rifle, Colorado—OR
Tuba City, Arizona—TC

A. Characterization Studies—Salt Lake City and Shiprock Sites

The sample collection and preparation procedures are outlined in Appendix C. Individual core samples selected by Sandia National Laboratories were analyzed by neutron activation techniques; a subset of these samples was also analyzed for major gamma-emitting radionuclides (by gamma spectroscopy) and by AA and ICP for a number of priority trace contaminants. The neutron activation data are presented in Appendix Tables C-Ia and C-Ib. The radionuclide and trace contaminant data are presented in Appendix Tables C-II and C-III, respectively.

Summary statistics on elemental concentrations obtained by NAA are reported in Appendix Table C-IV for Salt Lake City and Shiprock samples.

1. Statistical Analysis—Salt Lake City Samples

Examination of the coefficients of variation (CVs) of the elemental concentration data (Table C-IV) provides a means of identifying those elements with the greatest variability. The following elements had CVs greater than 100%: Fe, Cl, Cr, Mn, V, Zn, U, Co, and Sb. The least variable elements, i.e., CV less than 50%, include Al, K, Na, Ti, Ba, Sr, La, Th, Sc, Hf, Dy, Yb, Eu, and Lu.

Those elements exhibiting the greatest relative differences between the mean and median (mean/median >2) have the most skewed distributions, e.g., Cl, Cr, V, Zn, U, and Sb. These elements must have a few very high concentration data points causing this skewed distribution. Agreement between mean and median values was found for Al, K, Na, Ti, Rb, La, Th, Sc, Hf, Cs, Dy, Yb, Eu, and Lu.

Factor analysis was employed to identify those elements highly intercorrelated (see Appendix C.4. for methods). The first five factors that explained more than 75% of the total variance are described in Table VIII. Factor 1 identifies those elements that are highly elevated in the ferrophos vanadium tailings and have a negative correlation with Al and K, which may represent clay minerals. Factor 2 indicates a Mg and Ca correlation and a negative correlation with Ba. Factor 3 seems to represent uranium analog elements (U, Se, As) as well as several elements (Sm, Ce, Lu) that show elevated concentrations, as determined by NAA, caused by fission product interferences from high-U samples. Cluster analysis (see Appendix C.4.) *on variables* (elements) identified interelement correlations similar to those found in factor analysis. A cluster identical to Factor 1 was formed. A cluster containing most elements in Factors 2 and 5 was identified. Uranium and fission product interference elements were identified as a separate cluster similar to Factor 3. Al, La, and Eu made up another cluster resembling Factor 4.

Cluster analysis *on samples* (cases) was used to identify groups of samples having similar elemental concentration patterns. The initial analysis was performed on data normalized to unit variance and unit

TABLE VIII

FACTOR ANALYSIS OF SALT LAKE CITY TAILINGS DATA INTERCORRELATION OF ELEMENTS

Factor No.	1	2	3	4	5
	Cr(0.97)[a]	Mg(0.89)	Sm(0.96)	La(0.87)	Rb(0.91)
	Fe(0.97)	Sc(0.82)	U(0.95)	Na(0.77)	K(0.75)
	Cl(0.91)	Dy(0.71)	Ce(0.93)	Eu(0.69)	W(0.72)
	V(0.91)	Ca(0.69)	Lu(0.81)	Th(0.69)	Cs(0.72)
	Mn(0.90)	Yb(0.55)	Se(0.54)	Al(0.67)	Ti(0.59)
	Co(0.76)		As(0.44)		As(0.45)
	Al(−0.45)	Ba(−0.62)		As(−0.48)	
	K(−0.47)				
% Variance Explained	22	21	15	10	8

[a]Numbers in parentheses are factor loadings.

mean so that the major elements would not greatly outweigh the minor and trace element concentrations in determining minimum distance between cases. The first iteration identified three clusters—two large clusters (60 and 54 cases) and one small cluster (5 cases). Several more iterations split the 54-case cluster into a 34- and a 20-case cluster. Two clusters with 1 and 2 cases each were also generated.

The eight samples contained in the three small clusters (mainly the ferrophos samples) were eliminated from the next round of cluster analysis to better determine clusters among the remaining samples. After several iterations on normalized data, three large clusters were derived containing 19, 35, and 54 cases. The elemental patterns are shown below.

Cluster 1 (19 Cases)

- high Na, Al, La.
- low most elements, especially Sc, As, Ca, Cs, V, Sb, Rb, Lu, Co, U, and Sm.

Cluster 2 (35 Cases)

- high As, V, Ba, Sb, Rb, K, U, W, Hf, Sm, and Se.
- most other elements less than or equal to grand mean.

Cluster 3 (54 Cases)

- all elements greater than or equal to grand mean except Se and Ba.

We have classified these clusters by sample type as follows: Cluster 1 = S (uncontaminated soil), Cluster 2 = T (tailings), and Cluster 3 = P (contaminated soil or precipitate zones). Sample types are identified in Appendix Table C-Ia for each sample. The general pattern shows a transition from T to P to S as progressively deeper samples are examined. The preponderance of P-type samples is probably because an abundance of examined cores are dike material, i.e., contaminated soil. The sample type or categories seem to represent rational sample groupings.

After we examined these analyses, we decided to determine which elements discriminate one category from another (see Appendix C.4. for methods). These results are summarized in Table IX for variance weights, i.e., interclass variance/intraclass variance. The Fisher weights (described in Appendix C.4.) gave the same order of elements in discriminating importance.

These results show that soil (S) can be discriminated from tailings (T) on the basis of high soil concentrations of Na, Al, and La, as well as low soil concentrations of As, Sb, Cs, Zn, V, Rb, and U. Contaminated soil (P) differs from tailings (T) as follows: high in Mg, Sc, Mn, Fe, Al, Ca, Dy, Eu, and Th and low in As. Contaminated soil (P) has high concentrations of Sc, Mg, Cs, Ti, Mn, Ca, Dy, Fe, and Rb, as well as low concentrations of Na, relative to soil (S). Mean elemental concentrations for each of the three sample types are presented in Appendix Table C-V.

TABLE IX

DISCRIMINATION OF SAMPLE TYPES FOR SALT LAKE CITY TAILINGS SAMPLES

	Elements and Variance Weights		
Discrimination:	S from T	P from T	P from S
	Na – 14.8	Mg – 6.0	Na – 7.4
	As – 7.6	Sc – 5.0	Sc – 6.2
	Al – 5.3	Mn – 4.0	Mg – 4.8
	Sb – 3.2	Fe – 3.7	Cs – 4.7
	Cs – 2.6	Al – 3.6	Ti – 4.1
	La – 2.5	Ca – 3.1	Mn – 4.0
	Zn – 2.2	Dy – 2.9	Ca – 3.1
	V – 2.1	As – 2.7	Dy – 2.9
	Rb – 1.9	Eu – 2.5	Fe – 2.9
	U – 1.7	Th – 2.4	Rb – 2.3

[a]S = Soil.
T = Tailings.
P = Contaminated soil or precipitate zone.

Thus, the data analysis has defined the above three major groups of samples plus the ferrophos samples. Our interpretation of what the elemental patterns represent, i.e., soil, tailings, and contaminated soil, may be open to question, but is consistent with the data and has been objectively determined.

2. Statistical Analysis—Shiprock Samples

Summary statistics for the Shiprock samples are reported in Appendix Table C-IV. An approximation of silica content was calculated by subtracting the total elemental content from 100%; this number (SiOX) would include Si, O, S, and other unanalyzed elements, so it is not exclusively related to silica content. Those elements with the highest variability in concentration (CV >100%) include ***Mn, V, Zn, U,*** As, and ***Co*** (italicized elements had similar CV classifications for Salt Lake City samples). Elements exhibiting low CVs (<50%) are as follows: SiOX, Ca, ***Al, K, Na, Ti, Ba,*** Rb, ***Hf,*** Cs, ***Yb,*** and Ta. The only element showing a large difference between mean and median values (mean/median >2) is uranium. Mean and median values were very similar for Ca, ***Al,*** Fe, ***K, Na, Ti,*** Ba, Cr, ***Rb, La, Th, Se, Hf, Dy, Yb, Eu, Lu,*** and Ta.

Highly intercorrelated elements were determined by factor analysis on variables; the first five factors that were identified explained over 75% of the total variance. Those elements making up each factor are reported in Table X. Factor 1 contains many major elements (Al, Mg, K, Na, Ca) and is negatively correlated with SiOX; these elements might be depleted in tailings (sandstone origin) versus soil (shale origin). Factor 2 is basically a cluster of rare earth elements. Uranium is of primary importance in Factor 5.

Cluster analysis *on variables* was also performed as a means of verifying the factor analysis results. A cluster identical to the rare earth elements factor was formed. In addition, those elements negatively correlated in Factor 1 (SiOX and Se) were clustered together. Many elements positively correlated in Factor 1 formed another cluster—Cs, Rb, Ti, Sc, Al, Th, Ta, and K. A small cluster containing La and Co similar to Factor 3 was also identified.

Groups of samples having similar elemental concentration patterns were identified using cluster analysis *on samples.* Numerous analyses were performed on the raw data or normalized data examining major elements only, trace and minor elements only, and all elements. The analysis, which seemed to quickly separate large clusters (43, 44, and 40 cases), used normalized data on the major elements only (i.e., SiOX, Na, Mg, Al, K, Ca, Ti, and Fe). After three more iterations, six major clusters

TABLE X

FACTOR ANALYSIS OF SHIPROCK TAILINGS DATA INTERCORRELATION OF ELEMENTS

Factor No.	1		2	3	4	5
	Cs(0.89)	K(0.69)	Dy(0.88)	Co(0.84)	Fe(0.66)	U(0.89)
	Rb(0.85)	Na(0.69)	Tb(0.87)	V(0.73)	Mn(0.66)	Ba(0.69)
	Ti(0.84)	Ca(0.68)	Eu(0.79)	La(0.64)	As(0.48)	
	Sc(0.84)	Cl(0.65)	Yb(0.74)			
	Al(0.83)	Yb(0.55)	Lu(0.59)			
	Hf(0.80)	Cr(0.47)				
	Th(0.79)					
	Ta(0.79)	SiOX(–0.84)				
	Mg(0.71)	Se(–0.56)				
% Variance Explained	49		11	6	6	5

[a]Numbers in parentheses are factor readings.

were formed; these clusters can be described according to elemental concentration patterns as follows:

Cluster 1 (8 cases)
High—Al, Ca, Fe, Na, Mn, La, Sc, Rb, Th
Low—SiOX, V, As, Se

Cluster 2 (20 cases)
High—Al, Fe, K, Na, Rb
Low—SiOX

Cluster 3 (27 cases)
High—Al, Ca, Fe, Mg, Ti, Sc, Cr, Rb, Cs, Yb, Lu, Hf, Ta, Th
Low—SiOX, Se

Cluster 4 (27 cases)
High—SiOX, Se
Low—Al, Ca, Fe, K, Mg, Na, Ti, Cl, Mn, Dy, La, Sc, Co, Rb, Cs, Eu, Tb, Yb, Lu, Hf, Ta, Th

Cluster 5 (20 cases)
High—SiOX
Low—Al, Ca, Fe, Mg, Ti, Mn, Dy, U, La, Sc, Co, Cs, Eu, Tb, Yb, Lu, Hf, Ta, Th

Cluster 6 (14 cases)
High—Ca, Ti
Low—SiOX, Mn

After examination of the above elemental patterns and the pattern of categories (i.e., clusters) with sample depth and location, we have classified Clusters 1, 2, and 3 as soils and Clusters 4, 5, and 6 as tailings. Cluster 4 includes tailings sands (TS) from quadrants A and B, (high pile) exclusively. Cluster 5 includes tailings fines (TF) from all quadrants. Cluster 6 (TCa) appears to be a different type of tailings high in Ca and Ti and low in SiOX and Mn (all clusters classified as tailings were depleted in Mn). This cluster (TCa) could represent tailings derived from the precipitates produced at the Monument Valley heap leach operations that were reprocessed at the Shiprock mill (Merritt 1971). Clusters 2 and 3 seem to include both contaminated and clean soils (SA and SB). Cluster 1 may represent soils with Fe and Mn precipitates (P).

Discriminant analysis was next performed to determine which elements discriminate one sample type from another. These results are summarized in Table XI for variance weights. Because the categories were based on cluster analysis of the normalized major element data, it is not surprising that the major elements are frequently the most discriminating elements.

Tailings material at Shiprock is well defined relative to soil material on the basis of SiOX content. Tailings sands (TS) are readily discriminated from most other sample types (Table XIa) except for the tailings fines (TF) (Table XIc). The discrimination between tailings sands (TS) and fines (TF) is based on lower concentrations of Al, Na, Rb, Cs, Fe, and Eu and higher SiOX in the sands. High calcium tailings (TCa) and tailings fines (TF) are similar except the TCa material has higher Ca and Ti and lower SiOX concentrations (Table XIb). These two classes of tailings (TCa and TF) are less well defined versus the soils (SA and SB) than are the tailings sands (TS). All three tailings types can be well discriminated (Table XIa) from the soil precipitates (P) on the basis of very high Fe in the precipitates and high SiOX in the tailings.

Soils materials (SA and SB) are fairly well defined versus the other materials, but, not surprisingly, the discrimination between them is not strong. The two soils (SA and SB) differ primarily because of higher Mg in SB. These soils differ from the precipitate (P) because of the high Fe concentrations in P. The high Mg soil (SB) is greatly different from tailings sands and fines (TS and TF) because of the high Mg and Th and low SiOX in the soil. This soil differs from TCa primarily on the basis of high Mg, Cr, Fe, and Th and low SiOX and Se in the soil. High concentrations of Al, La, Fe, and Na and low SiOX in the other soil (SA) discriminate it from TS. Tailings fines (TF) differ from SA because of high SiOX and low Al, Fe, and Th in the tailings. The high calcium tailings (TCa) are discriminated from SA on the basis of high Ca and Ti and low Fe, Na, and K in the tailings.

Examination of the listing of sample types in Appendix Table C-Ib, according to quadrant and sample depth, indicates that lenses of TS and TF are found in most holes in quadrants A and B (the upper tailings pile, Fig. A-2). The high-calcium tailings are generally found deep in the pile in all quadrants. The high-Mg soil (SB) is often found among the deepest samples, particularly those identified as soil cores. The other soil type (SA) is often found in association with SB as soil core samples (S1, etc.). However, in the C and D quadrants, often both SA and SB type materials are identified as tailings cores. An explanation of this contradiction is that soil is covering tailings in these quadrants and that soil and tailings may have been mixed as a result of the significant earth-moving activity on the southern, low pile—quadrants C and D. The precipitate (P) samples seem to occur in the

TABLE XI

ELEMENTS THAT DISCRIMINATE BETWEEN SAMPLE TYPES FOR SHIPROCK TAILINGS SAMPLES

a. Cluster Pairs Strongly Discriminated by Elements

TS vs P	TS vs SB	TF vs P	TS vs SA	TS vs TCa	TCa vs P	TF vs SB
Fe – 79	SiOX – 39	Fe – 38	SiOX – 27	SiOX – 24	Fe – 24	SiOX – 17
SiOX – 49	Th – 24	SiOX – 21	Al – 24	Ti – 24	Mn – 6.2	Mg – 13
Na – 22	Mg – 23	Al – 6.6	La – 16	Ca – 14	Na – 5.7	Th – 9.8
La – 19	Ti – 19	Na – 6.5	Fe – 15	Th – 9.8	SiOX – 2.8	Sc – 76
Al – 18	Sc – 19	Mn – 6.2	Na – 14	Eu – 9.3	Se – 2.5	Fe – 7.0
Ca – 17	Fe – 17	Ca – 5.7	Rb – 13	Na – 8.8	Ca – 2.4	Ti – 6.8
Th – 15	Cs – 13	Th – 5.3	Yb – 11	Dy – 8.5	Sc – 1.6	Cs – 6.1

b. Cluster Pairs Moderately Discriminated by Elements

SA vs P	SB vs P	TCa vs SB	TF vs SA	TF vs TCa
Fe – 11	Fe – 9.9	Mg – 9.6	SiOX – 9.1	SiOX – 8.5
Ba – 3.6	Na – 3.8	Cr – 3.9	Al – 8.4	Ca – 7.6
SiOX – 3.3	Mg – 3.5	Fe – 3.4	Fe – 5.9	Ti – 6.1
Ca – 2.2	Cr – 3.2	Th – 2.9	Th – 4.5	Eu – 3.6
K – 1.9	Hf – 2.2	Se – 2.8	La – 4.2	La – 3.3
Mn – 1.8	Cs – 2.2	SiOX – 2.4	Na – 3.4	Th – 3.3
Na – 1.5	Ti – 2.0	Sc – 1.8	Sc – 3.3	Ta – 2.8

c. Cluster Pairs Weakly Discriminated by Elements

SA vs SB	TS vs TF	TCa vs SA
Mg – 6.9	Al – 5.7	Ca – 4.3
Ti – 2.8	SiOX – 5.6	Fe – 2.8
SiOX – 2.8	Na – 4.5	Na – 2.7
Ca – 2.6	Rb – 3.3	K – 2.4
Cr – 2.1	Cs – 3.3	Ti – 2.1
Yb – 1.9	Fe – 3.1	Se – 2.0
As – 1.8	Eu – 2.7	Sb – 1.9

upper tailings horizons or at the interface (i.e., the first subsoil sample labeled X-000-S1).

Again, our descriptions of the sample types (soil, tailings, etc.) are subjective; however, the separation of these six clusters was based on the results of statistical analysis, not on opinion.

B. Analysis of Composite Samples from 12 Inactive Mill Sites

Hole, quadrant, and site composites were prepared by Mountain States as described in Appendix C.1. At the request of Sandia National Laboratories, we analyzed selected pulverized tailings material by NAA. In addition, site composites were analyzed using gamma spectroscopy to determine radionuclide content. Batch equilibrium leaches (1:5 solid to water ratio) were also performed on the site composite materials, as well as two New Mexico surface soils.

1. Elemental Composition

The neutron activation analysis data for the *hole* composites are presented in Table C-VI; the *quadrant* and *site* composite NAA results are reported in Table C-VII. Table C-VIII summarizes the site composite data for major, minor, and trace element content.

Among the 12 sites, Vitro and Tuba City seem to have the highest elemental concentrations, with Gunnison, Riverton, and Mexican Hat having many elements at above average concentrations. Spook and Grand Junction tend to have lesser concentrations of most elements; Ambrosia Lake, Maybell, and Shiprock have considerable numbers of elements that have less than the average tailings concentration.

The elements showing the most extreme differences compared with soil include the following:

	Median[a] Soil Conc (μg/g)	Maximum Tailings Conc (μg/g)	Site with Maximum Conc
As	6	730	Tuba City
Cl	100	900	Vitro
Co	8	146	Tuba City
Cr	70	770	Vitro
Ga	20	280	Tuba City
Sb	1	18.1	Gunnison
Se	0.4	74	Spook
Th	9	78	Mexican Hat
U	2	310	Old Rifle
V	90	2500	New Rifle
Zn	90	580	Tuba City

[a]Source: Bowen (1979).

A large number of elements appear depleted in tailings versus median soil concentrations (Bowen 1979), including Al, Fe, Ti, Br, Cs, Hf, Mn, Rb, Sc, Dy, Eu, La, and Yb.

The coefficients of variation reported in Table C-VIII show high variability (CVs >100%) for As, Cl, Co, Cr, Ga, Sb, ^{232}Th, and Zn. Other elements generally enriched in tailings show high mean values compared with soils but are not as variable (CV 50 –100% for Se, U, and V). Most of the major elements have CVs from 45 to 60%, with Al and Fe having CVs of ~30%. Low variability is also found for Ba, Hf, Mn, Rb, Sc, and the lanthanide (rare earth) elements, i.e., CVs <60%. Correlations of the concentration of 12 elements (Al, Ca, Fe, K, Mg, Na, As, Co, Mn, Se, U, V) were determined to establish whether certain elements were interrelated. Significant correlations at the 95% confidence level were found between the following pairs of elements:

Positively Correlated (r)	Negatively Correlated (r)
As – Co (0.87)	Al – V (–0.81)
Al – K (0.82)	K – V (–0.68)
Se – K (0.68)	Na – Co (–0.62)
As – Mg (0.66)	
Ca – Mn (0.63)	

Correlations among the 12 sites were also calculated to determine similarities between sites on the basis of all elements analyzed by NAA. The results show that most sites were significantly positively correlated; two groups of sites were generally not correlated. The sites RIV, SPK, MBL, GUN, and TC were highly positively correlated but were not significantly correlated with the group NR, GJT, and OR. This pattern would indicate some dissimilarities between the Wyoming sites and the western Colorado sites.

These data show a substantial variability in major element composition and very large variances for trace and minor elements. The composition of tailings can vary dramatically from site to site, which could influence contaminant mobility and the interaction between the tailings and barrier systems used to isolate tailings from the biosphere.

2. Radionuclide Contents

Natural radionuclide contents by gamma spectroscopy are presented in Table XII. The tailings composites having high ^{238}U progeny (^{210}Pb, ^{226}Ra, ^{230}Th) contents include New Rifle, Mexican Hat, Grand Junc-

TABLE XII

RADIONUCLIDES IN COMPOSITE TAILINGS FROM 12 SITES
(Activity pCi/g)

Site	^{238}U Series					^{235}U Series				^{232}Th Series			Total U				^{238}U Series[e]		
	^{234}Th	^{230}Th	^{226}Ra[a]	^{226}Ra[b]	^{210}Pb	^{231}Pa	^{227}Ac[c]	^{227}Ac[d]	^{227}Th	^{228}Ra	^{228}Th	^{40}K	^{234}Th	^{230}Th / ^{226}Ra[a]	^{226}Ra[a] / ^{210}Pb	^{230}Th / ^{210}Pb	/ ^{235}U Series	^{228}Th / ^{232}Th[f]	^{40}K (mea / ^{40}K (calc
Ambrosia Lake	32	603	492	454	641	47	25	24	27	<3	<2	13.0	1.16	1.23	0.77	0.94	22.3	–	0.86
Riverton	19.2	416	314	311	365	11.9	17	15	16.5	1.9	1.73	23.1	1.45	1.32	0.86	1.13	21.8	0.93	0.98
New Rifle	43	927	708	654	822	42	43	37	39	<3	0.62	5.2	1.16	1.31	0.86	1.13	20.0	1.44	0.88
Spook	35	246	327	354	503	–	17	14	15.1	<3	0.84	26.2	1.06	0.75	0.65	0.49	22.4	1.08	0.95
Maybell	26	169	156	153	202	13.0	9.2	9.5	13.5	0.89	0.46	14.9	1.23	1.08	0.77	0.84	16.0	0.77	1.05
Mexican Hat	37	549	689	670	892	26	32	30	33	7.7	8.5	9.5	1.08	0.80	0.77	0.62	21.8	1.00	1.03
Vitro	39	194	495	508	562	18.9	24	18	26	<3	1.11	14.9	1.21	0.39	0.88	0.35	16.7	0.99	0.85
Shiprock	14.8	316	405	405	511	13.2	18.6	17	20	<2	0.35	11.8	1.42	0.78	0.79	0.62	21.3	0.71	1.18
Grand Junction	42	1003	619	719	738	57	31	27	29	<2	0.30	7.7	1.19	1.62	0.84	1.36	26.2	0.71	1.43
Gunnison	17.3	188	270	249	324	–	12.7	13	15.7	<2	0.35	9.7	1.24	0.70	0.83	0.58	18.4	0.45	1.00
Old Rifle	79	692	581	543	576	29	33	28	25	<2	0.43	5.1	1.32	1.19	1.01	1.20	18.1	1.10	0.78
Tuba City	57	797	805	735	954	40	41	37	37	<3	<2	13.6	1.28	0.99	0.84	0.84	21.8	–	1.01

[a]Activity determined from high-energy gammas ^{214}Pb and ^{214}Bi.
[b]Activity determined from low-energy gamma (53.2 keV) of ^{226}Ra.
[c]Activity determined from high-energy gammas (236 and 256 keV).
[d]Activity determined from low-energy gamma (50.1 keV).
[e]Uranium-238 series = mean of ^{230}Th, ^{226}Ra (high-energy gammas only), and ^{210}Pb activities.
Uranium-235 series = mean of ^{227}Ac (high-energy gammas only) and ^{227}Th activities.
[f]Determined by NAA.
[g]Potassium-40 (meas) = measured activity of ^{40}K.
K (calc) = calculated activity of ^{40}K based on total K and 0.0118% isotopic abundance.

tion, and Tuba City; low activities of these progeny were found for tailings from Riverton, Spook, Maybell, and Gunnison. The ^{226}Ra activities reported in Table XII, compared with the average calculated ^{226}Ra content reported by the EPA (1980), are consistently low by 100 to 400 pCi/g. Such discrepancies may result from considerable soil material being included in the Mountain States composites or from an overestimation of ore grade used in calculating ^{226}Ra activities.

Comparing U determined by NAA and U calculated assuming equilibrium with ^{234}Th (half-life = 24.1 d) shows a consistent underestimation of U by gamma counting of 5 to 45% based on the activation results; generally these differences were in the range of 15 to 30%. These lower values from gamma counting may result from greater self-absorption of this low-energy gamma (63.3 keV) in some samples because of different mineralogical content.

The ratios of ^{230}Th:^{226}Ra range from 0.39 to 1.62. The greatest depletion of ^{230}Th relative to ^{226}Ra is found in the Vitro composite; the greatest enrichment occurs in the Grand Junction composite. Radium-226 is generally depleted relative to ^{210}Pb, with ratios ranging from 0.65 (Spook) to 1.01 (Old Rifle). The $^{230}Th/^{210}Pb$ ratios range from 0.35 to 1.36. If we assume that the ores milled at each of these sites were in secular equilibrium, it appears that both ^{230}Th and ^{226}Ra are depleted in most tailings (SPK, MBL, MH, VIT, SHR, GUN, and TC). For some tailings, ^{230}Th activities are greater than either ^{226}Ra or ^{210}Pb (e.g., RIV, NR, GJT, and OR). Most of the 12 mills used acid leach processes [except for AML and parts of RIV and TC (Merritt 1971)]; however, there is not a consistent trend of ^{230}Th depletion, which might be expected for acid leach tailings. As a possible explanation, it must be remembered that some subsoils were included in these tailings composites; these soils may contain any leached radionuclides thus negating the opportunity to see depletion of radionuclides in the tailings fraction.

The expected ratio of activities of ^{238}U progeny versus ^{235}U progeny based on isotopic abundances and specific activities is 22.0. Our calculations, comparing ratios of these two series, range from 16.0 to 26.2, which is in fair agreement with the expected value considering analytical uncertainties. Other comparisons of ^{228}Th with ^{232}Th and ^{40}K with expected values from total K indicate that the gamma counting is producing reasonable results with no consistent bias.

3. Leachate Composition

The equilibrium leaching experiments showed a number of distinct elemental patterns (see Table XIII) among the 12 sites. Most sites had highly elevated concentrations of U, Mn, As, Mo, SO_4^{-2}, V, Se(IV and VI), Na, and Ca compared with the Grants soil leachate. The leachates of the Tuba City, Mexican Hat, and Gunnison tailings were generally high in Zn, Cu, Ni, Mg, Co, and Cd and low in Se(IV) and Se(VI). In addition, the Gunnison and Ambrosia Lake tailings leachates contained high concentrations of Fe and Al. Gunnison had the only tailings producing a distinctly acid leachate (pH 3.9); the other two leachates (TC and MH) containing high metal concentrations (Zn, Cu, Ni, Co, and Cd) were neutral to slightly alkaline. Another group of elements was not appreciably elevated in any leachates (Pb, Sb, SiO_2, and Cr) or was actually depleted in the tailings leachates (Ba) compared with the Grants soil leachate. Thus, the elements that tend to be geochemical analogs of U in sandstone uranium deposits, As, Mo, V, and Se, are often present in high concentrations in leachates. In addition, Ca and Mn would tend to be mobile over a broad pH range in high-sulfate solutions. The presence of generally high concentrations of Na and SO_4^- probably results from reagents used during U milling (including H_2SO_4, NaCl, $NaClO_3$, $NaHCO_3$, Na_2CO_3). Those elements that are infrequently highly leachable (e.g., Zn, Cu, Co, Ni) require either an acidic environment or the presence of fairly soluble minerals or salts in the tailings; such tailings may all have been derived from ores high in metal sulfides. The low leachability of both Pb and Ba is expected in high-sulfate matrices. The low but consistent leachability of Sb may result from a solubility-controlled mechanism; the tailings have highly variable Sb contents (see Table C-VIII).

Correlations of elemental concentrations in these leachates were calculated to determine intercorrelations in leachable constituents (V, Mo, U, Se, As, Co, pH, Mg, Na, SiO_2, Mn, and Al). Correlation coefficients are presented in Table XIV. Fairly strong positive intercorrelations are apparent for the group Mo, Se, As, Na, SiO_2, and pH. Leachable U and, to some extent, V show some similarities with the above group. Se, As, V, and SiO_2 are negatively correlated with Mg. In addition, V and As are negatively correlated with Mn. In contrast, Co is positively correlated with Mn and Mg and

TABLE XIII

COMPOSITION OF WATER EXTRACTS OF COMPOSITE TAILINGS FROM 12 SITES AND OF 2 NEW MEXICO SURFACE SOILS (mg/ℓ)

Site	Initial pH	Flow pH	SO_4^{-2}	Ca	Mg	Na	SiO_2	Cl^-	Mn	Al	Fe	V	Mo	U
Ambrosia Lake	9.4	8.2	740	4	0.6	390	99	15	0.05	19.5	6.5	6.6	30	8.7
Riverton	6.9	7.8	1750	570	110	83	18	20	1.7	<0.05	<0.02	0.01	3.0	2.0
New Rifle	5.8	6.4	1670	590	25	36	81	12	0.54	<0.05	<0.01	22	4.8	0.004
Spook	6.7	7.6	1660	640	23	27	47	8	0.63	<0.06	<0.02	0.28	<0.02	4.2
Maybell	6.4	5.5	1990	560	40	11	42	<10	37	<0.04	0.04	0.03	0.05	0.12
Mexican Hat	7.1	8.0	1910	570	110	61	21	<10	47	<0.02	<0.01	0.53	1.58	0.47
Vitro	7.3	8.0	1820	640	94	75	57	63	1.8	<0.05	<0.01	1.52	14.6	2.9
Shiprock	7.4	8.0	1810	600	97	47	70	18	1.7	<0.06	<0.02	5.5	4.0	0.78
Grand Junction	7.5	7.6	1770	590	83	57	56	75	0.41	<0.04	<0.02	13.1	2.2	0.63
Gunnison	3.9	3.8	2020	530	98	15	56	<10	12.3	62	26.5	0.69	<0.05	1.7
Old Rifle	7.7	8.1	880	330	29	55	16	11	0.12	0.08	0.03	10.9	0.50	2.8
Tuba City	7.2	8.3	2670	530	240	300	24	27	7.8	<0.03	<0.02	<0.06	1.41	8.5
Grants Soil	7.8	8.2	7.6	36	10	2.8	15	2	<0.01	<0.02	0.10	<0.05	<0.02	0.008
Bluewater Soil	8.3	8.1	50	12	1.5	68	17	9	0.08	0.12	0.11	<0.05	0.06	0.012

TABLE XIII (cont)

Site	Total Se	As	Sb	Co	Ni	Cu	Zn	Ba	Cd	Cr	Pb	Se(IV)	Se(VI)	Other Se
Ambrosia Lake	7.8	0.91	0.15	<0.03	<0.04	0.11	0.04	0.05	<0.002	0.01	0.06	5.9	2.0	NS[a]
Riverton	1.0	0.019	0.18	0.05	0.06	<0.01	0.01	0.01	0.001	<0.01	0.06	0.11	0.30	0.59
New Rifle	2.6	0.79	0.20	0.04	0.11	<0.01	0.07	0.03	0.005	<0.01	<0.03	1.84	0.43	0.32
Spook	3.0	0.015	0.20	0.06	0.04	<0.01	0.01	0.03	0.001	<0.01	0.03	2.08	0.67	0.29
Maybell	0.61	0.011	0.17	0.12	0.17	<0.01	0.15	0.02	0.002	<0.01	0.02	0.14	0.23	0.25
Mexican Hat	<0.3	0.034	0.21	2.45	1.02	0.47	1.12	<0.01	0.001	<0.01	<0.04	<0.01	0.01	NS
Vitro	0.34	0.20	0.27	0.08	0.16	0.03	0.04	0.03	0.005	<0.01	0.04	0.13	0.03	0.18
Shiprock	0.57	0.067	0.20	0.06	0.10	0.01	0.02	0.04	0.014	<0.01	<0.02	0.29	0.09	0.19
Grand Junction	1.11	0.40	0.17	0.06	0.08	0.01	0.02	0.07	<0.002	<0.01	0.05	0.49	0.48	NS
Gunnison	<0.01	0.065	0.19	2.02	2.53	1.06	6.9	0.01	0.109	<0.01	0.06	<0.01	<0.01	NS
Old Rifle	0.31	0.35	0.14	0.05	<0.03	<0.01	0.01	0.07	<0.002	<0.01	<0.04	0.35	0.02	NS
Tuba City	<0.1	0.21	0.22	2.67	4.3	0.45	2.03	0.01	0.039	<0.01	0.04	<0.01	0.06	NS
Grants Soil	<0.1	0.001	0.05	<0.03	<0.01	<0.01	<0.01	0.17	0.002	<0.01	<0.02	<0.01	<0.01	NS
Bluewater Soil	<0.1	0.009	<0.02	<0.05	<0.02	0.01	<0.01	0.04	<0.002	<0.01	<0.02	<0.01	0.01	NS

[a]NS = difference between total Se — [Se(IV) + Se(VI)] not significant.

TABLE XIV

CORRELATION COEFFICIENTS (r) OF LEACHABLE CONSTITUENTS ($r \geq 0.4$ and $r \leq -0.4$) IN TAILINGS FROM 12 INACTIVE SITES[a]

Element	Mo	Se	As	Na	SiO_2	pH	U	V	Co	Mn	Mg	Al
Mo												
Se	0.79											
As	0.67	0.72										
Na	0.70	0.61	0.53									
SiO_2	0.66	0.68	0.66									
pH	0.62	0.52	0.41	0.63								
U	0.54	0.52		0.90		0.50						
V			0.74		0.44							
Co								−0.41				
Mn			−0.42					−0.41	0.51			
Mg		−0.57	−0.42		−0.48			−0.42	0.72			
Al						−0.54						

[a]Only lower diagonal of correlation matrix presented.

negatively correlated with V. The only strong negative correlation with pH occurs for Al.

As with the tailings solids composition data, we calculated correlations between sites on the basis of the leachable constituents. Those sites least similar to the others are AML, NR, and GUN. The high alkalinity (pH = 9.4) of the AML leachate would explain some of these differences. The GUN and NR leachates in contrast were the most acidic leachates (pH = 3.9 and 5.8). All the other leachates had pH values of 6.4 to 7.7.

Correlations and regressions between leachable and total contents of Na, Zn, U, Se, Sb, V, As, Cl, Mg, Co, and Mn were determined. Significant positive correlations at the 95% confidence level were found for Se (with AML deleted), Sb (with GUN deleted), V, Cl, Mg, Co, and Mn. The best regressions [i.e., greatest coefficient of determination (r^2)] fitting the data are as follows for leachate concentrations in mg/ℓ (e.g., V_L) and solid contents in μg/g (e.g., V_s):

$V—[V_L] = 0.009\ [V_s] - 2.252$ ($r^2 = 0.909$) (with AML deleted),

$V—[V_L] = 0.008\ [V_s] - 1.654$ ($r^2 = 0.871$),

$Co—[Cl_L] = 0.773 \log [Co_s] - 1.194$ ($r^2 = 0.789$),

$Se—[Se_L] = 0.019\ [Se_s]^{1.078}$ ($r^2 = 0.723$) (with AML deleted),

$Sb—[Sb_L] = 0.009\ [Sb_s] + 0.162$ ($r^2 = 0.617$) (with GUN deleted),

$Mg—[Mg_L] = 0.015\ [Mg_s] + 3.822$ ($r^2 = 0.403$),

$Cl—[Cl_L] = 13.306 \log [Cl_s] - 43.468$ ($r^2 = 0.349$), and

$Mn—[Mn_L] = 0.077\ [Mn_s] - 11.838$ ($r^2 = 0.337$).

The best fits were found for Se, V, and Co in predicting leachate concentrations from solid elemental contents.

VI. CONCLUSIONS

The results presented in this report show that uranium mill tailings are quite variable regarding composition and mineralogy both between sites and often within one site. These differences between sites most probably reflect differences in the ores being milled and the milling processes. At any site, such differences may reflect different ore types, milling processes, and segregation of wastes during disposal.

Our in-depth examination of tailings from the three sites, Shiprock, Durango, and Salt Lake City, illustrates the extreme differences in major, minor, and trace element composition, leachable constituents, and mineralogy. The radionuclide contents also ranged widely, depending on the type of sample. Of all the parameters

measured, the radon emanation coefficient tended to have less variability than other compositional or structural parameters. These eight composite tailings samples exhibited extremes in texture, composition, and leachable constituents, including pH. Fine-grained acidic tailings produced, in general, the most noxious leachates.

The characterization of tailings from the 12 sites showed generally enriched levels of a number of trace contaminants, including As, Se, U, and V, as well as radionuclides of the ^{238}U and ^{235}U series. It appears, on the basis of these 12 site composites, that the hazards posed by toxic constituents in tailings require a case-by-case evaluation because there are few, if any, contaminants universal to all these tailings. Much the same can be said for leachable constituents; however, it is possible to point to certain elements that may be frequently leachable: U, Mn, As, Mo, SO_4^{-2}, V, Se(IV and VI), Na, and Ca. Some tailings leachates can also contain high concentrations of Zn, Cu, Ni, Mg, Co, and Cd. Here again, leachable components are not universal across tailings; each material requires an evaluation of contaminant leachability. It is also apparent that knowledge of solid elemental contents alone will provide little information regarding degree of leachability.

Our efforts at examining the composition of individual core samples have shown that such data analysis may provide a means of identifying soils, contaminated soils, or tailings. Such information is critical to the assessment of contaminant migration beneath a tailings pile. Neutron activation analysis of a complete sample set from one pile and subsequent data analysis would likely provide a clearer discrimination of sample categories and a more thorough understanding of contaminant migration. Such understanding would aid any assessment of the long-term leaching potential of a tailings pile by determining the degree of movement during and after the termination of milling operations.

Our examination of the reprocessing of mill tailings has pointed out a possible technique of radionuclide removal using concentrated sulfuric acid. Much additional work would be required to verify that such a technology is economically feasible and technically possible. These studies, however, did point to results of a more immediate significance; that is, appreciable U, V, Mo, and Co could be leached from some tailings using strong, aqueous, sulfuric acid. The initial assessment of the economics of such reprocessing has shown that if (1) a tailings pile requires relocation, (2) the tailings are of sufficiently high grade (U >150 μg/g and V >1000 μg/g or Co >100 μg/g or Mo >100 μg/g), and (3) the tailings are amenable to percolation acid leaching (50-75% extraction efficiencies for valuable metals), then the value of the recovered mineral products could exceed the cost of performing the leaching step. Thus, a net economic benefit could be gained by reprocessing as an integral part of a remedial action plan.

APPENDIX A

CHARACTERIZATION OF NEAR-SURFACE TAILINGS SAMPLES

1. Sample Collection and Preparation

During the summer of 1980, Pacific Northwest Laboratory (PNL) personnel, as well as Los Alamos staff, collected tailings samples from three inactive uranium mill sites. PNL sampled the Salt Lake City (SLC) pile using a gasoline-powered auger to obtain 0- to 1-m material (labeled A); using an auger extension, 1- to 2-m material (labeled B) was obtained from the same hole. Figure A-1 shows the six sampling locations for Salt Lake City. The moist-to-saturated samples were placed in 19-ℓ (5-gal.) polyethylene or steel buckets for transport. PNL and Los Alamos personnel collected samples at Shiprock (SHIP) and Durango (DGO). Samples were taken from 11 locations (Figs. A-2 and A-3) at each site, again using an auger; only 0- to 1-m material was collected. The samples were shipped as described above for SLC.

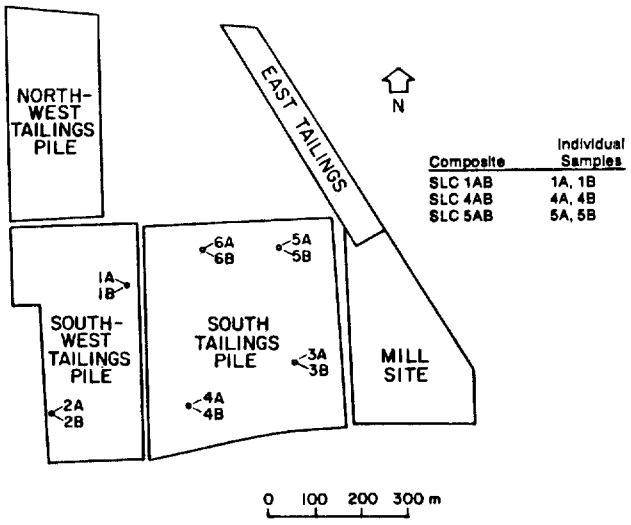


Fig. A-1. Composites from sample locations (1A-6B) at the Salt Lake City, Utah tailings site.

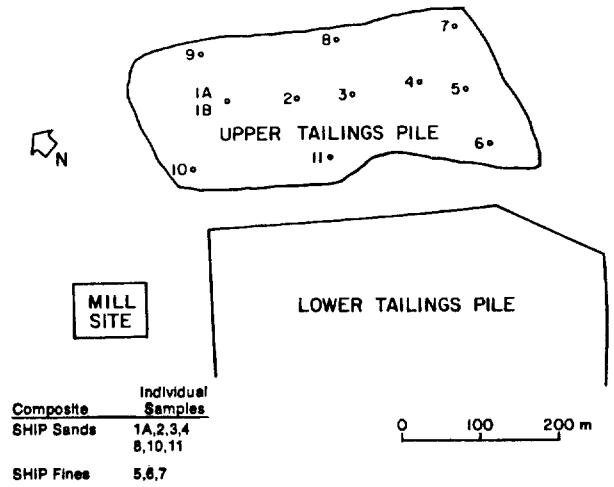


Fig. A-2. Composites from sample locations (1A-11) at Shiprock, New Mexico tailings site.

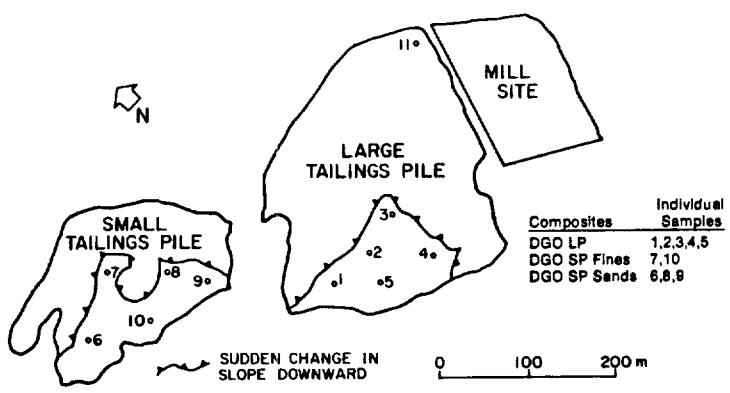


Fig. A-3. Composites from sample locations (1-11) at the Durango, Colorado tailings site.

The Ambrosia Lake, New Mexico sample (AML Fines) represents an aliquot of a large bulk sample collected in the central portion of the pile where slimes predominate.

The as-received samples were split to provide an archival sample as well as a sample for conditioning studies. Tailings sands were divided with a riffle splitter. Slime samples, being too moist to pass through the splitter, were cut into agglomerate pieces smaller than 1 cm and split by long-pile divisions. The archival samples were sealed in polyethylene bags and stored. The samples for conditioning were dried to a constant weight under infrared lamps (<40°C) and a flow of dry air. The aggregates in the dried samples were pulverized to pass through a 20-mesh sieve. The –20–mesh samples were divided into 8 parts of approximately 1 kg each using an eight-way rotary splitter. Each portion was sealed in a polyethylene bag for storage until needed.

A 0.5-kg subsample of the moist, as-received tailings was set aside during the initial riffle splitting operations. These subsamples were used for the characterization of the tailings solids and in the preliminary leaching studies.

2. Analysis of Near-Surface Tailings Samples and Leachates

a. Sample Preparation and Analytical Procedures. Approximately 120 g (two of the 1/8 splits from the 0.5–kg as-received sample) were leached in a 1-ℓ polyethylene bottle with an amount of deionized water to produce a 1:5 solid-to-liquid ratio. The mixtures were agitated for 24 h on a shaker table (3.8 cm stroke and 100 strokes/min). The slurry was vacuum–filtered through Whatman 541 and 0.45–μm membrane filters. Measurements of pH were taken initially and after agitation. The leachate solutions were analyzed for uranium by laser solution fluorimetry (SCINTREX UA-3) and, for the other constituents, by flame atomic absorption spectrophotometry. The solids were dried, pulverized, and submitted for analysis by instrumental thermal neutron activation (NAA) for 39 elements (see Appendix C.2.). Delayed–neutron counting was used for the determination of total uranium from ^{235}U content.

Another 1/8 subsample (~60 g) of the as-received sample was used for a loss-on-drying (LOD) determination. The weighed sample material was dried at 110°C for a minimum of 24 h and reweighed to determine loss of volatile components.

The pH of the as-received, moist tailings was determined from 15 ± 2 g subsamples that had been produced by additional stages of splitting with the rotary splitter. Measurements of pH were made following each of three successive 5.0–mℓ water additions. The initial pH of the solids was found by extrapolating the pH results back to zero mℓ of added water.

The neutralization capacity determination was carried out on the pH subsample described above. The pH was measured after successive incremental additions (100 μℓ) of either 1M NaOH or 1M HCl until the pH reached 7.0. The number of milliequivalents (as either H^+ or OH^-) required to neutralize 1 kg of tailings was calculated from the titration data.

The oxidation-reduction potential of the tailings solids was determined on another 15–g subsample, to which 10 mℓ of deionized (but not de-aereated) water had been added. Direct measurements of the equilibrium steady potential of a platinum electrode versus a silver/silver chloride reference electrode were made according to the ASTM procedure for measurement of redox potential. The ASTM Fe^{+3}/Fe^{+2} reference solution was used, and all results corrected to the potential of the hydrogen electrode.

It must be understood that the redox potential data were obtained from samples that had been in storage for at least 2 months before measurement and thus do not represent true *in situ* redox conditions. However, these data do provide an *upper limit* on the redox condition prevailing in the sampled material and are valuable for interpreting the solubility of various chemical constituents. It should be emphasized that *only* for near-surface material is it *at all* defensible to make off-site measurements of Eh and even for them *in situ* measurement is much preferred.

b. Tables of Data. The pH-Eh diagrams for the as-received tailings samples from the Salt Lake City, Shiprock, and Durango sites are shown in Figs. A-4, A-5, and A-6.

The neutron activation data on the 35 samples from the three sites are presented in Table A-I, along with the pH, Eh, and neutralization capacity data. The overall precision of the NAA analysis was examined by analyzing four replicate samples of Ambrosia Lake, New Mexico mill tailings fines. The coefficients of variation for these analyses are summarized in Table A-II. These results show reasonable precision (CV <10%) for the major elements and for most of the important minor and trace elements.

The data on leachable constituents are shown in Table A-III for the 35 leachate samples. In addition, minimum and maximum leachable values for each tailings site are presented.

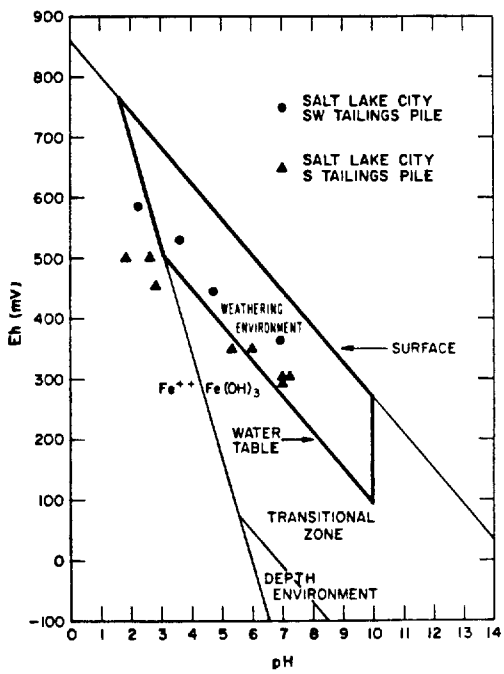


Fig. A-4. pH-Eh diagram for the Salt Lake City tailings samples.

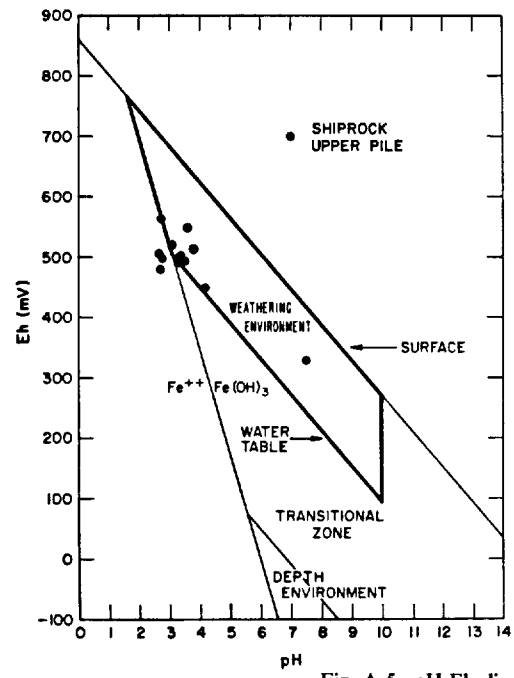


Fig. A-5. pH-Eh diagram for the Shiprock tailings samples.

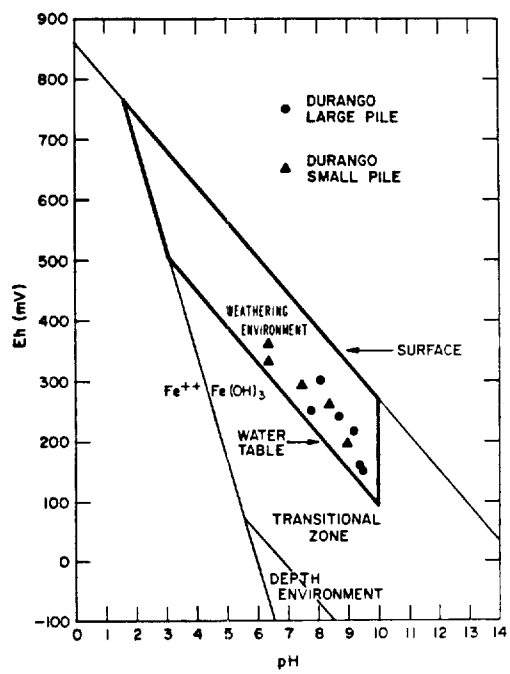


Fig. A-6. pH-Eh diagram for the Durango tailings samples.

TABLE A-I

ELEMENTAL COMPOSITION OF TAILINGS IN μg/g (SiO_2 IN %) BY INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS

(SiO_2 determined by atomic absorption spectrophotometry)

Site	Sample No.	pH	Eh (+mV)	Neut[a] (meq/kg)	Al	As	Au	Ba	Br	Ca	Ce	Cl	Co	Cr	Cs	Dy	Eu	Fe	Ga	Hf	Hg	I
Salt	1 A	3.6	530	<13	35 600	73	<0.012	2380	<1.4	39 400	97	<56	12.7	26	4.5	2.7	0.75	8630	48	6.1	<0.01	<8
Lake	1 B	2.2	585	45	36 200	73	<0.015	2330	<1.6	43 300	84	<56	16.9	26	4.7	3.3	0.91	8310	<19	5.7	<0.02	<9
City,	2 A	6.9	365		30 300	229	<0.016	1520	<1.7	24 800	79	<61	5.5	22	5.7	2.0	0.65	13 000	<20	5.1	<0.04	<10
Utah	2 B	4.7	445	14	38 800	284	0.032	1520	<1.5	26 400	85	<59	6.3	24	6.4	2.6	0.63	13 200	43	5.4	0.05	<9
	3 A	2.6	500	54	44 300	411	0.083	830	4.5	32 200	154	157	14.4	154	10.5	3.7	1.14	21 800	76	7.0	0.13	<14
	3 B	7.2	305	<6	40 900	140	<0.017	675	6.3	42 400	112	<71	19.3	70	5.3	3.7	0.86	17 500	53	6.4	0.10	49
	4 A	2.8	455	309	67 400	354	0.043	893	<2.4	34 700	146	639	10.5	98	15.1	5.2	1.10	24 100	<28	6.0	0.07	<13
	4 B	1.8	500	220	60 000	419	0.038	1040	<2.0	35 500	159	1450	36.4	61	12.4	5.7	1.33	21 100	<24	6.9	0.13	<13
	5 A	7.0	295	<6	19 700	174	0.102	<194	<1.8	76 400	44	6980	42.0	7250	8.0	<1.2		119 000	<22	2.9	<0.02	<25
	5 B	7.0	300	<6	21 600	101	0.038	<209	3.0	81 600	53	6850	39.7	7030	6.3	<1.2	0.49	113 000	<24	3.7	<0.02	<28
	6 A	5.9	350	<6	34 000	150	0.043	554	<2.0	40 000	89	2660	17.7	2670	7.0	3.2	0.65	50 400	<25	5.7	<0.03	<22
	6 B	5.3	350	36	48 500	283	<0.019	1000	<2.0	48 700	97	525	8.8	517	9.4	3.4	1.01	23 000	<24	5.7	<0.03	<15
Shiprock,	1 A	3.3	490	7	13 000	26	<0.006	854	<0.6	12 900	19	45	0.8	26	1.0	2.0	0.38	1740	<8	4.9	<0.02	<5
New	1 B	7.5	330	<8	16 700	21	<0.008	726	<0.8	11 200	34	<30	2.9	29	0.9	1.5	0.35	5500	<11	4.0	<0.02	<7
Mexico	2	2.7	480	28	16 000	70	<0.007	937	<0.8	17 800	26	<31	1.9	18	1.5	1.4	0.60	3670	<9	8.0	<0.02	<6
	3	3.5	495	<6	11 000	28	<0.006	739	0.5	9430	20	71	0.8	25	0.9	0.8	0.39	2010	<8	3.9	<0.02	<5
	4	3.8	515	7	12 900	53	<0.007	781	<0.8	13 300	18	<27	1.2	22	1.1	1.0	0.78	2260	<9	4.6	<0.03	<6
	5	3.1	520	60	41 100	197	<0.015	1150	<1.6	75 900	55	121	3.5	36	4.1	5.9	1.27	19 900	<18	4.3	<0.01	<16
	6	2.7	500	470	42 600	172	<0.016		<1.7	87 300	76	118	4.2	54	4.0	4.4	1.13	11 100	<19	3.5	<0.03	<16
	7	2.7	500	560	42 500	200	<0.016	1240	<1.6	73 800	71	<61	4.9	45	4.0	4.8	1.23	9970	<19	4.7	<0.02	<16
	8	3.6	550	33	18 800	93	<0.009	1210	<0.9	26 200	34	<31	1.3	19	1.7	1.3	0.78	3640	<10	5.7	<0.02	<8
	9	2.7	565	<63	25 000	146	<0.011	968	<1.2	39 000	49	<40	2.7	35	2.2	2.6	0.93	5280	<13	5.8	<0.03	<11
	10	4.2	450	<7	11 800	38	<0.006	836	<0.7	9150	23	<27	1.1	24	1.2	0.6	0.57	2490	<8	6.0	<0.02	<6
	11	3.4	500	7	11 200	46	<0.005	926	<0.6	8810	21	67	0.8	20	1.0	0.6	0.33	2180	<7	6.2	<0.02	<5
Durango,	1	9.4	160	40	50 900	243	<0.036	1400	<4.2	36 800	216	2070	97	3100	3.4	5.4	1.80	41 300	<54	5.3	0.21	<31
Colorado	2	9.2	215	23	43 600	222	<0.029	908	<3.4	30 400	175	1920	73	2420	3.4	4.7	1.44	35 000	<43	5.2	0.19	<25
	3	8.7	240	11	40 700	199	<0.023	1320	<2.6	21 200	205	874	73	344	4.4	5.4	1.50	26 700	123	5.8	0.24	<16
	4	9.5	150	26	49 900	221	<0.027	958	<3.3	24 900	201	1910	91	1440	2.4	6.2	1.74	30 500	95	6.5	<0.02	<22
	5	7.8	250	22	47 100	242	<0.031	1660	<3.7	36 400	187	2760	77	3950	2.6	5.9	1.61	38 700	<47	5.4	<0.02	<27
	6	9.0	195	29	27 200	182	<0.019	1140	<2.1	15 200	123	513	31.5	442	3.0	13.1	0.69	14 500	<27	4.9	0.15	<16
	7	7.5	290	6	49 900	632	<0.029	40 800	<3.3	30 200	253	721	66	236	2.6	5.3	1.43	32 100	<42	8.7	0.29	<20
	8	6.4	330	<6	22 000	79	<0.014	2300	2.6	11 800	120	591	13.6	31	2.3	1.9	0.46	10 200	86	5.9	0.16	<11
	9	6.4	360	<6	20 500	72	<0.015	1370	<1.7	7100	152	562	11.8	25	1.3	1.2	0.67	9600	81	4.7	0.19	<11
	10	8.4	260	59	71 900	310	<0.043	2380	<5.0	57 100	279	914	138	798	5.4	7.1	2.13	37 500	<65	4.6	0.30	<34
	11	8.1	300	<15	13 900	44	<0.010	869	<1.2	7310	77	721	9.2	12	1.9	1.8	0.36	16 300	53	4.1	<0.01	<8

[a]Neutralization capacity.

TABLE A-I (cont)

Site	Sample No.	K	La	Lu	Mg	Mn	Na	Rb	Sb	Sc	Se	Sm	Sr	Ta	Tb	^{232}Th	Ti	U	V	W	Yb	Zn	SiO_2 (%)
Salt	1 A	19 200	17.8	0.30	4580	87	4170	67	10.0	3.5	5.9	10.0	910	1.5	<0.2	4.5	1740	142	158	4.7	<1.1	86	77.5
Lake	1 B	18 100	19.3	0.23	4130	79	3910	67	11.0	4.1	<6.7	8.1	948	<0.8	<0.3	6.6	1900	97	175	4.6	<1.5	43	71.6
City,	2 A	24 600	18.1	0.20	3010	194	7740	79	18.8	3.6	31.8	8.1	306	<0.6	1.3	7.0	1420	107	168	6.3	2.1	<60	75.0
Utah	2 B	23 000	16.3	0.19	4800	185	7010	115	23.6	3.8	13.8	8.2	469	0.8	0.3	8.4	2290	116	193	6.3	1.1	142	73.2
	3 A	17 900	23.3	0.38	4530	179	4540	103	39.2	7.9	59	16.5	<198	1.5	<0.4	10.9	3070	271	1610	13.2	<1.8	95	73.9
	3 b	16 000	22.8	0.32	14 200	392	7580	87	8.6	5.7	14.5	10.0	345	<0.7	<0.3	7.4	1810	159	686	6.1	3.4	118	70.2
	4 A	23 700	35.7	0.33	5740	204	8400	131	54.1	9.5	24.9	14.6	334	<1.0	<0.4	16.7	2860	156	332	18.8	<2.1	25	60
	4 B	22 400	29.8	0.39	7990	292	7780	101	53.5	8.5	68	16.7	402	<1.0	<0.4	11.5	3130	230	468	13.3	4.7	231	62.8
	5 A	12 200	10.9	0.16	<2760	2080	10 100	46	21.8	3.1	12.5	4.5	<377	1.9	<0.3	10.2	2860	63	3040	10.4	<1.6	90	42.5
	5 B	<5220	11.4	<0.11	<3080	1990	9510	59	19.8	3.0	9.9	3.6	<410	1.9	<0.4	8.8	3720	58	2860	9.6	<1.6	87	43.2
	6 A	14 000	14.6	0.46	<2220	1130	9290	61	29.9	4.0	13.0	6.9	<328	1.2	<0.4	28.9	2220	86	1540	10.7	6.3	96	65.7
	6 B	14 200	24.1	0.26	8480	303	6860	87	16.6	6.1	30.5	9.5	<219	<0.8	<0.4	33.1	2330	104	1640	8.1	4.0	<24	64.1
Shiprock,	1 A	8050	20.3	0.24	<833	26	1590	26	1.6	1.4	34	2.0	<78	<0.4	<0.1	2.1	793	25	850	5.1	2.4	29	88.1
New	1 B	6780	26.4	0.12	<1010	114	2630	36	1.2	1.5	23	2.6	<108	<0.4	<0.1	3.4	690	33	796	<1.2	1.5	87	87.5
Mexico	2	8710	27.6	0.13	<971	36	1820	29	2.2	1.9	70	2.8	<91	<0.4	<0.1	1.8	1250	40	1230	<0.05	<0.7	137	86.4
	3	6060	22.3	0.10	<844	26	1290	18	1.5	1.0	44	2.2	<81	<0.4	<0.1	1.8	574	34	709	4.1	<0.6	43	93.9
	4	7100	22.4	0.09	<953	21	1350	23	1.8	1.5	74	2.2	<90	<0.3	1.0	1.4	516	29	987	4.0	<0.7	<17	90.9
	5	18 900	20.3	0.03	6720	60	2220	<20	6.6	6.6	179	7.0	<227	<0.9	4.8	7.0	3130	56	4490	<2.2	3.2	175	54.0
	6	16 700	20.5	0.25	6280	60	1900	79	6.7	6.7	197	83	320	<1.0	5.4	5.9	2950	50	4120	6.0	<1.9	86	50.9
	7	17 200	20.7	0.23	6550	80	.2040	68	6.3	6.9	233	6.2	418	<1.0	<0.4	6.0	2630	56	4440	7.6	4.2	109	53.2
	8	9460	8.1	0.12	2420	31	1360	39	3.1	2.3	93	3.2	<116	<0.5	<1.0	2.3	1110	40	1760	4.7	<1.0	98	82.1
	9	13 000	11.3	0.23	<1760	36	1550	53	4.2	4.1	115	4.1	<165	<0.7	1.7	3.7	1780	49	2640	4.5	1.7	<83	77.5
	10	6130	4.6	0.07	<915	33	1430	25	1.5	1.1	45	2.3	<91	<0.4	<0.1	1.3	471	35	1100	5.1	<0.5	<45	95.1
	11	6130	4.7	0.09	<746	21	1180	25	1.3	1.2	53	2.2	<71	<0.4	<0.1	1.2	819	32	744	4.9	0.5	106	93.4
Durango,	1	<4790	29.0	0.59	6780	1160	35 400	<34	5.8	7.5	<5.7	22.0	<454	<1.4	<0.6	8.4	1990	330	3530	<5.7	4.1	1870	57.8
Colorado	2	<4050	25.2	0.41	7270	969	30 100	<26	6.9	6.4	<4.7	20.3	<354	<1.0	2.2	6.4	2060	275	3100	<4.6	4.9	1490	67.1
	3	6520	23.9	0.66	6610	489	24 900	<22	8.6	5.8	<3.6	24.0	<245	<1.0	0.6	6.1	1250	348	2510	<0.06	3.7	921	73.9
	4	8100	24.9	0.39	9770	715	31 700	<28	5.9	7.2	<1.6	19.7	<335	<1.1	0.6	8.1	2270	294	2840	<4.5	5.0	1050	69.5
	5	<4160	26.8	0.57	8120	940	30 300	<29	4.8	6.9	<5.9	18.0	<391	<1.2	0.8	8.9	3160	259	3240	<5.0	3.2	1140	65.1
	6	3520	14.4	0.26	<1970	461	15 000	<17	<0.5	3.4	<14.4	17.2	<224	1.3	2.3	3.8	<553	258	2240	8.7	3.0	486	83.7
	7	8270	32.0	0.59	7840	511	27 800	<28	10.1	8.4	28.6	31.2	575	<1.2	<0.4	9.6	1680	477	3420	<0.08	<2.1	921	61.4
	8	8300	11.6	0.32	6430	108	9330	<15	3.3	2.6	6.6	17.6	367	<0.8	<0.2	3.2	1290	280	1940	4.7	<1.1	155	88.2
	9	5120	12.2	0.44	4350	91	8050	<15	2.8	2.3	<20.2	18.2	<165	1.9	<0.2	2.5	952	325	1980	6.2	<1.2	173	89.1
	10	<5580	43.8	0.67	<4230	1280	47 200	<39	9.5	8.3	<5.9	34.0	<484	2.6	4.2	7.4	<1170	448	4110	<6.8	5.8	2270	53.5
	11	<1350	8.1	0.21	3720	144	7350	<12	3.4	1.8	<0.7	9.7	<127	<0.5	<0.2	1.9	785	170	1540	<0.05	<0.8	412	90.7

TABLE A-II

COEFFICIENTS OF VARIATION FOR NEUTRON ACTIVATION ANALYSIS OF FOUR REPLICATE MEASUREMENTS ON AMBROSIA LAKE FINES

Coefficient of Variation (%)	Elements
<1	Mn, Na, U,[a] V
1 – 5	Al, As, Ce, Co, Eu, Fe, La, Sc, Se, Sm, Th
5 – 10	Ba, Ca, Dy, Hf, K, Ti
10 – 21	Cr, Cs, Lu, Mg, Rb, Sb, Yb, Zn
Uncertain[b]	Au, Br, Cl, Ga, Hg, I, Sr, Ta, Tb, W

[a]Uranium analyzed by delayed-neutron counting.
[b]Uncertain because of data below detectable concentrations.

TABLE A-III

LEACHABLE CONSTITUENTS IN TAILINGS SOLIDS
(Units are μg of Element Leached from 1 g Dry Tailings by Deionized Water)

Site	Sample	Leach pH	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	Pb	Se	Si	U	V	Zn	SO_4^{-2}	Cl^-
SLC	1.A	5.20	<0.02	<1	3300	0.3	6.4	<1	1	0.4	14	<0.2	45	12	<1	16	3.3	<1	0.2	160	2.4	<1	10	8300	330
	1.B	2.70	0.2	<1	2950	0.3	3.3	<1	6	28	6	<0.2	43	11	<2	12	2.5	1.3	0.1	140	36.5	1	12	18 730	320
	2.A	7.23	0.1	<1	3650	<0.01	0.1	<1	<0.1	<0.6	9	<0.2	105	<0.1	15	200	<0.1	0.3	0.2	210	4.8	<1	<0.06	9310	38
	2.B	5.74	0.02	<1	3300	0.14	1.2	<1	0.8	<0.6	8	<0.2	180	5.7	3	160	2.3	<0.2	0.1	110	0.33	<1	8.3	9370	42
	3.A	3.12	1.3	<1	3300	0.10	0.4	<1	64	15	51	<0.2	70	5.7	12	180	1.4	0.4	0.1	220	0.14	5.8	7.9	10 210	65
	3.B	7.57	1.6	<1	3200	<0.01	<0.1	<1	<0.1	<0.6	76	0.3	250	<0.1	34	110	<0.1	<0.2	0.7	350	1.5	1.3	<0.06	9290	53
	4.A	3.03	0.9	<1	1700	0.21	2.0	<1	33	20	19	0.7	210	18	3	860	2.6	<0.2	0.1	180	<0.02	10	13	24 780	2700
	4.B	2.55	2.9	<1	3300	1.0	7.5	3	130	48	39	1.6	400	32	21	1500	7.4	4.2	0.1	310	<0.01	18	69	20 600	1950
	5.A	7.18	4.2	<1	2900	<0.01	<0.1	<1	<0.1	<0.6	24	<0.2	140	0.7	5	590	0.6	<0.2	0.4	320	<0.01	115	<0.6	8450	68
	5.B	7.15	3.7	<1	3400	<0.01	0.2	<1	<0.1	<0.6	28	<0.2	150	0.8	5	590	0.6	<0.2	0.5	380	<0.01	140	<0.06	9710	116
	6.A	6.19	5.1	<1	3400	<0.01	0.2	<1	0.4	<0.6	24	<0.2	110	15	8	290	2.3	<0.2	0.4	290	<0.01	66	<0.06	8920	90
	6.B	4.71	5.6	<1	2900	<0.01	0.4	<1	2.3	<0.6	48	<0.2	130	9	10	360	2.0	<0.2	0.5	160	0.016	22	1.5	8420	125
SHIP	1.A	3.65	0.3	<1	3300	0.09	<0.1	<1	0.7	0.9	37	<0.2	67	1.2	<1	69	0.2	4.6	1.2	100	0.12	2	1.6	8490	<6
	1.B	7.51	1.2	<1	3400	0.03	<0.1	<1	0.1	<0.6	37	<0.2	150	<0.1	1.5	310	<0.1	0.2	0.8	320	0.01	13	<0.06	9210	120
	2	3.25	0.3	<1	3600	0.45	0.7	<1	9.4	6	8	0.7	240	6	<1	190	0.9	1.7	0.4	80	1.5	13	8.4	11 940	<6
	3	4.09	0.1	<1	2800	0.7	0.2	<1	1	0.2	10	<0.3	37	1.3	<1.5	35	0.7	2.4	0.4	50	0.06	2	1.4	–	<10
	4	3.77	0.7	<1	2500	0.12	<0.1	<1	3	<0.6	30	<0.2	113	1.2	<1	120	1.7	0.8	1.2	180	0.10	2	2.3	14 600	<10
	5	3.62	0.2	<1	3000	0.29	0.7	<1	1.5	0.9	27	0.9	330	9.5	<1	320	2.7	0.9	0.4	260	0.24	2	4.5	10 310	63
	6	2.91	0.2	<1	2800	0.33	0.8	<1	2.6	8	30	0.9	330	10	<1	290	3.7	4.4	0.4	370	6.0	13	4.6	10 990	39
	7	3.04	0.3	<1	2900	0.42	1.1	<1	5.3	4	36	1.2	360	11	<1	360	2.4	3.0	0.5	380	4.2	17	8.5	11 700	<6
	8	3.54	0.4	<1	3000	0.17	0.2	<1	4.6	<0.6	14	0.2	105	3	<1	90	0.3	5.0	1.0	170	0.5	4	3.3	8510	<6
	9	3.13	0.2	<1	1300	0.08	0.2	<1	2.1	4	15	0.3	83	1.6	<1	34	0.5	7.3	0.7	170	0.54	5	2.1	8870	<6
	10	4.78	0.2	<1	3200	0.11	<0.1	<1	0.2	<0.6	7	0.3	50	1.1	<1	20	0.3	<0.3	0.5	120	0.02	<2	2.5	14 480	<10
	11	3.87	0.2	<1	3500	0.27	<0.1	<1	3.8	<0.6	10	0.4	70	1.5	<1	60	0.2	2.3	0.4	110	0.13	<2	3.8	14 820	<10
DGO	1	9.48	1.1	<1	60	0.02	<0.1	<1	0.1	<0.6	40	0.7	43	<0.1	<1	220	0.1	0.3	<0.02	40	0.46	69	<0.05	50	34
	2	9.55	0.9	<1	70	<0.1	<0.2	<1	<0.1	<0.6	19	<0.2	42	0.1	<1	23	0.4	<1	<0.02	40	0.23	51	0.1	–	–
	3	9.31	0.7	<1	100	<0.01	<0.1	<1	<0.1	<0.6	8	0.2	9	0.1	<1	24	0.2	<0.2	<0.02	160	0.37	34	<0.06	<6	12
	4	9.63	1.4	<1	80	<0.01	<0.1	<1	<0.1	<0.6	28	0.6	35	0.1	<1	270	0.2	<0.2	<0.02	40	0.38	73	<0.06	120	45
	5	9.32	1.2	<1	120	<0.01	<0.1	<1	<0.1	<0.6	18	0.2	67	0.1	<1	50	0.1	<0.2	<0.02	40	0.51	55	<0.06	<7	6
	6	8.54	2.4	<1	150	<0.01	<0.1	<1	<0.1	<0.6	16	<0.2	35	0.1	<1	50	0.1	<0.2	0.3	230	1.5	59	<0.06	<7	6
	7	7.62	2.1	<1	3000	<0.01	<0.1	<1	0.13	<0.6	28	<0.2	52	3	1	44	<0.1	<0.2	0.7	240	5.0	43	0.16	7010	127
	8	6.38	0.7	<1	3100	<0.01	<0.1	<1	<0.1	<0.6	21	<0.2	8	0.5	<1	35	<0.1	<0.2	0.8	200	<0.01	28	<0.06	7590	83
	9	6.40	0.4	<1	940	<0.01	<0.1	<1	<0.1	<0.6	6	<0.2	10	<0.1	<1	12	<0.1	<0.2	0.5	180	1.2	16	<0.06	2490	6
	10	8.99	1.3	<1	2400	<0.01	<0.1	<1	<0.1	<0.6	27	0.5	57	<0.1	<1	240	0.2	<0.2	0.1	90	0.27	90	<0.06	1190	60
	11	8.70	0.5	<1	2200	<0.01	<0.1	<1	<0.1	<0.6	6	<0.2	4	<0.1	<1	12	<0.1	0.4	<0.02	100	0.07	10	<0.06	810	60
Min	SLC	2.55	<0.02	<1	1700	<0.01	<0.1	<1	<0.1	<0.6	6	<0.2	43	<0.1	<1	12	<0.1	<0.2	<0.1	100	<0.01	<1	<0.06	8300	38
	SHIP	2.91	0.1	<1	1300	0.03	<0.1	<1	<0.1	<0.6	7	<0.2	37	<0.1	<1	20	<0.1	<0.3	0.4	50	0.01	<2	<0.06	8490	<6
	DGO	6.38	0.4	<1	60	<0.01	<0.1	<1	<0.1	<0.6	6	<0.2	4	<0.1	<1	12	<0.1	<0.2	<0.2	40	<0.01	10	<0.06	<6	6
Max	SLC	7.57	5.6	<1	3650	1.0	7.5	3	130	48	51	1.6	400	32	34	1500	7.4	4.2	0.7	380	36.5	140	69	24 780	2700
	SHIP	7.51	1.2	<1	3600	0.45	1.1	<1	9.4	8	37	1.2	360	11	1.5	360	3.7	7.3	1.2	380	6.0	17	8.5	14 820	120
	DGO	9.63	2.4	<1	3100	0.02	<0.2	<1	0.13	<0.6	40	0.7	67	3	1	270	0.4	0.4	0.8	240	5.0	90	0.16	7590	127

3. Analytical Procedures—Composites of Near-Surface Tailings

a. Neutron Activation Analysis. The NAA data on site composites are presented in Tables A-IV, A-V, and A-VI for major, minor, and trace elements, respectively. The coefficients of variation for replicate analyses are given and indicate good precision (CV $\leq$10%) for Al, Ca, Fe, Na, Mn, V, As, and U. Other elements (Ba, Cl, Cr, Zn, Ce, Co, Sb, Th) have fair reproducibility by NAA.

TABLE A-IV

MAJOR ELEMENT COMPOSITION OF URANIUM MILL TAILINGS DETERMINED BY NEUTRON ACTIVATION ANALYSIS[a]

Site	Composite	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Na (%)
SHIP	Sands	1.27(a)	1.25(b)	0.29(b)	0.80(b)	<0.10	0.14(a)
SHIP	Fines	4.02(a)	7.65(a)	1.22(a)	1.73(c)	0.54(b)	0.20(a)
SLC	1AB	3.35(a)	3.76(a)	0.90(b)	2.06(a)	0.31(d)	0.40(a)
SLC	4AB	5.91(b)	3.40(a)	2.49(b)	2.66(c)	0.59(e)	0.76(a)
SLC	5AB	2.15(b)	7.66(a)	13.1(a)	1.13(e)	<0.31	0.98(a)
DGO	LP	4.97(a)	3.04(b)	3.80(b)	<0.53	0.94(e)	3.17(a)
DGO	SP Fines	6.26(a)	4.16(b)	4.11(a)	0.87(d)	1.08(d)	3.75(a)
DGO	SP Sands	2.47(b)	1.27(b)	1.39(b)	0.75(d)	0.47(e)	1.21(a)
AML	Fines	5.97(a)	3.77(a)	2.52(b)	2.12(b)	0.56(e)	1.33(a)
Shale	Max[b]	7.97	6.99	4.50	2.03	1.58	1.17
Soil	Max[c]	5.80	2.03	2.96	1.87	1.02	0.43

[a]Mean concentration of replicate analysis (n = 3 to 10) presented in %; coefficient of variation (std dev/mean) class denoted by letter:

(a) = 0-5%.
(b) = 5-10%.
(c) = 10-15%.
(d) = 15-20%.
(e) = >20%.
SHIP = Shiprock, New Mexico.
SLC = Salt Lake City, Utah.
DGO = Durango, Colorado.
AML = Ambrosia Lake, New Mexico.
[b]Maximum value for Mancos and Tropic shale.
[c]Maximum value for Grants Mineral Belt soil.

TABLE A-V

MINOR ELEMENT COMPOSITION OF URANIUM MILL TAILINGS DETERMINED BY NEUTRON ACTIVATION ANALYSIS[a]

		(μg/g)						
Site	Composite	Ba	Cl	Cr	Mn	Ti	V	Zn
SHIP	Sands	820 (b)	<30	20 (d)	31 (b)	830 (c)	1000 (a)	100 (d)
SHIP	Fines	1030 (c)	140 (d)	43 (d)	86 (d)	2600 (c)	4130 (a)	180 (b)
SLC	1AB	2170 (a)	<50	20 (d)	79 (a)	1700 (e)	150 (a)	80 (e)
SLC	4AB	820 (b)	2030 (a)	71 (b)	240 (a)	2900 (c)	380 (a)	210 (b)
SLC	5AB	360 (e)	6730 (a)	7880 (a)	2040 (a)	3330 (d)	2970 (a)	97 (b)
DGO	LP	1220 (b)	1870 (a)	2210 (a)	900 (a)	2500 (b)	3150 (a)	1470 (b)
DGO	SP Fines	21 800 (a)	770 (b)	550 (a)	900 (a)	1700 (e)	3790 (a)	1780 (b)
DGO	SP Sands	1690 (a)	630 (a)	220 (c)	290 (a)	1100 (d)	2180 (a)	340 (c)
AML	Fines	670 (c)	<110	22 (d)	460 (a)	1800 (d)	1360 (a)	46 (e)
Shale	Max[b]	440	<60	77	320	3800	200	52
Soil	Max[c]	480	<50	46	640	2900	65	51

[a]Mean concentration of replicate analysis (n = 3 to 10) presented in %; coefficient of variation (std dev/mean) class denoted by letter:

(a) = 0-5%.
(b) = 5-10%.
(c) = 10-15%.
(d) = 15-20%.
(e) = >20%.
SHIP = Shiprock, New Mexico.
SLC = Salt Lake City, Utah.
DGO = Durango, Colorado.
AML = Ambrosia Lake, New Mexico.
[b]Maximum value for Mancos and Tropic shale.
[c]Maximum value for Grants Mineral Belt soil.

TABLE A-VI

TRACE ELEMENT COMPOSITION OF URANIUM MILL TAILINGS DETERMINED BY NEUTRON ACTIVATION ANALYSIS[a]

Site	Composite	As	Ce	Co	Ga	Rb	Sb	Se	^{232}Th	U	W
SHIP	Sands	30 (b)	23 (d)	1.2(c)	<22	31 (c)	1.4(c)	59 (b)	1.7(d)	33 (b)	<7
SHIP	Fines	110 (a)	68 (b)	5.3(d)	<47	81 (b)	5.5(a)	200 (a)	6.7(c)	49 (a)	<14
SLC	1AB	42 (b)	90 (a)	16 (b)	43 (c)	76 (c)	8.1(b)	<10	4.8(b)	110 (a)	17 (b)
SLC	4AB	240 (b)	170 (b)	26 (a)	66 (e)	130 (b)	45 (b)	56 (a)	14 (a)	180 (a)	69 (d)
SLC	5AB	86 (b)	56 (b)	46 (a)	<28	86 (e)	19 (b)	13 (c)	10 (c)	62 (a)	48 (c)
DGO	LP	150 (a)	210 (b)	90 (b)	270 (b)	<42	5.3(b)	<8	7.5(b)	310 (a)	<28
DGO	SP Fines	320 (b)	290 (b)	110 (a)	370 (c)	<56	7.2(b)	29 (e)	11 (b)	470 (a)	<35
DGO	SP Sands	72 (b)	140 (b)	24 (b)	180 (d)	<23	2.7(b)	<23	3.6(d)	290 (b)	<15
AML	Fines	54 (e)	140 (b)	6.7(c)	<67	89 (e)	2.1(c)	36 (b)	7.5(b)	160 (b)	<19
Shale	Max[b]	15	98	13	<39	120	1.5	<15	19	8	<13
Soil	Max[c]	7	80	11	<36	99	0.8	<15	12	4	<12

[a]Mean concentration of replicate analysis (n = 3 to 10) presented in %; coefficient of variation (std dev/mean) class denoted by letter:

(a) = 0-5%.
(b) = 5-10%.
(c) = 10-15%.
(d) = 15-20%.
(e) = >20%.
SHIP = Shiprock, New Mexico.
SLC = Salt Lake City, Utah.
DGO = Durango, Colorado.
AML = Ambrosia Lake, New Mexico.
[b]Maximum value for Mancos and Tropic shale.
[c]Maximum value for Grants Mineral Belt soil.

b. Atomic Absorpton Spectrophotometry. Splits of the same samples analyzed by NAA were dissolved (alkali fusion or acid digestion) and analyzed by atomic absorption spectrophotometric techniques. The results of these analyses are presented in Tables A-VII and A-VIII.

Comparison of the neutron activation and the atomic absorption analyses shows a number of elements that agree: Ca, Fe, Mg, Cr, Mn, V, and Zn. Large discrepancies between these analyses are seen for Ba and Co.

TABLE A-VII

MAJOR AND MINOR ELEMENT COMPOSITION OF URANIUM MILL TAILINGS DETERMINED BY ATOMIC ABSORPTION SPECTROPHOTOMETRY

Site	Composite	Ba (μg/g)	Ca (%)	Cr (μg/g)	Fe (%)	Mg (%)	Mn (μg/g)	V (μg/g)	Zn (μg/g)
SHIP	Sands	520	1.29	38	0.29	0.12	31	850	83
SHIP	Fines	50	7.23	46	0.97	0.52	62	3810	120
SLC	1AB	67	3.46	35	0.79	0.23	71	130	55
SLC	4AB	155	3.07	73	1.80	0.23	200	320	150
SLC	5AB	610	8.16	6890	10.97	0.51	2520	3270	66
DGO	LP	1350	2.96	1310	3.30	0.92	980	3033	1300
DGO	SP Fines	3800	3.76	410	3.21	0.97	920	690	1550
DGO	SP Sands	1690	1.11	170	1.18	0.41	270	400	330
AML	Fines	590	3.61	33	2.08	0.56	470	1300	43
Mean Soil Value[a]		500	1.37	100	3.80	0.50	850	100	50

[a]Bowen (1966)

TABLE A-VIII

TRACE ELEMENT COMPOSITION OF URANIUM MILL TAILINGS DETERMINED BY ATOMIC ABSORPTION SPECTROPHOTOMETRY

		(μg/g)						
Site	Composite	Ag	Cd	Co	Cu	Mo	Ni	Pb
SHIP	Sands	1.3	2.1	66	20	26	16	120
SHIP	Fines	2.9	2.2	4	46	96	49	230
SLC	1AB	<0.5	0.7	12	37	71	7	5
SLC	4AB	1.5	1.3	22	270	800	21	180
SLC	5AB	11.9	<0.1	77	850	70	1670	74
DGO	LP	1.5	13	73	510	7	180	200
DGO	SP Fines	3.7	21	87	730	8	130	200
DGO	SP Sands	0.8	2.9	140	110	11	19	160
AML	Fines	<0.5	<0.1	7	43	11	5	75
Mean Soil Value[a]		0.1	0.06	8	20	2	40	10

[a]Bowen (1966)

c. Gamma Spectroscopy. The natural radioactivity of tailings composites was analyzed by gamma spectroscopy using Ge(Li) detectors (Be window detector for low γ-energies <100 keV). The Canadian Certified Radiometric Material DH-l was used to standardize the detector efficiencies and sample self-absorption at a range of energies from 46 to 609 keV. The important radionuclides of the ^{238}U, ^{235}U, and ^{232}Th series in the tailings composites detected by gamma spectroscopy are reported in Table A-IX. In addition, radionuclide contents are reported for parents from their short-lived progeny such as ^{226}Ra from ^{214}Bi and ^{214}Pb, ^{227}Ac from ^{227}Th and ^{223}Ra, ^{228}Ra from ^{228}Ac, and ^{228}Th from ^{212}Pb.

TABLE A-IX

RADIONUCLIDE CONTENT OF TAILINGS COMPOSITES AND SIZE-FRACTIONED TAILINGS[a] (in pCi/g)

		Uranium-238 Series							Uranium-235 Series		Series Activity Ratio	Thorium-232 Series			Uranium Extraction Efficiency[a]
Site	Composite	^{238}U	^{234}Th	^{230}Th	^{226}Ra	^{210}Pb	$^{230}Th/^{226}Ra$	$^{226}Ra/^{210}Pb$	^{231}Pa	^{227}Ac	$^{226}Ra/^{231}Pa$ or ^{227}Ac	^{232}Th	^{228}Ra	^{228}Th	(%)
SHIP	Sands	11	14 ± 2	182 ± 4	396 ± 13	447 ± 31	0.46	0.89	16 ± 8	13 ± 4	25	0.2	<2	<2	97
SHIP	Fines	16	13 ± 4	1130 ± 110	2020 ± 30	2430 ± 210	0.56	0.83	51 ± 22	74 ± 12	27	0.7	<7	<6	99
SLC	1AB	37	35	408	1180	1390	0.35	0.85	31	50	24	0.5	5	3	97
SLC	4AB	60	63	465	1070	1350	0.43	0.79	22	49	22	1.5	4	5	94
SLC	5AB	21	16	60	316	295	0.19	1.07	<1	16	20	1.1	2	3	93
DGO	LP	103	92	1070	973	708	1.10	1.37	16	45	22	0.8	<3	<3	89
DGO	SP Fines	157	139	2190	1810	1370	1.21	1.32	53	92	20	1.2	4	4	91
DGO	SP Sands	97	102	924	719	616	1.29	1.17	20	35	21	0.4	<2	<2	90
AML	Fines	53	47	1410	1330 ± 245	1540 ± 29	1.06	0.86	41 ±2	73 ± 10	18	0.8	3 ± 1	3 ± 1	96
SHIP	Fines +400 mesh	–	19	270	136	324	1.99	0.42	10	8	17	–	<2	<3	
SHIP	Fines –400 mesh	–	<18	1190 ± 197	2270 ± 86	2830 ± 11	0.52	0.80	47 ± 3	95 ± 1	24	–	<7	<5	

[a]Analytical methods.
^{238}U—delayed-neutron counting after thermal neutron irradiation gives ^{235}U, calculated ^{238}U using natural isotopic abundance.
^{232}Th—thermal neutron activation analysis.
Others—γ-spectroscopy for listed isotope or short-lived progeny: ^{226}Ra from ^{214}Bi and ^{214}Pb.
^{227}Ac from ^{227}Th and ^{223}Ra.
^{228}Ra from ^{228}Ac.
^{228}Th from ^{212}Pb.

[b]$(1.0 - {}^{238}U/{}^{226}Ra) \times 100\%$.

d. Particle Size Analysis. Particle size analyses of composite tailings materials were performed by both wet sieving and by sedimentation. The preliminary sedimentation analyses were carried out on samples dispersed in deionized water, with fairly vigorously shaken suspensions dispersed by ultrasonic agitation. After particle size was determined by sedimentation, these same suspensions were wet-sieved through 200-mesh screens (<75μm) and the size separates (+200- and –200-mesh) were dried and weighed. The results of these determinations are presented in Table A-X, along with the predicted silica (SiO_2) content of each composite.

These results indicate that samples containing a large percentage of fines (SLC 4AB, SHIP FINES, DGO SP-FINES) require vigorous dispersion to break up "sand" aggregates, which are primarily silt but contain some clays. The sandy tailings samples, on the other hand, showed no appreciable difference in particle size analysis by sedimentation when subjected to different degrees of dispersion. For all samples, except SLC 5AB, there is a positive correlation between SiO_2 content and per cent sand. Particle size analysis by wet sieving shows agreement between the +200-mesh fraction and the per cent sands determined by sedimentation with vigorous dispersion.

e. Mineralogical Analysis by Powder X-Ray Diffraction. The mineralogy of the tailings composites (–325 mesh) was assessed on a quantitative basis for quartz, gypsum, clay, illite, kaolinite, and calcite

TABLE A-X

PARTICLE SIZE ANALYSIS OF COMPOSITE TAILINGS BY SEDIMENTATION AND WET-SIEVING TECHNIQUES[a]

[Silica content is predicted from SiO_2 content of individual samples making up the composites.]

Site[a] Composite	SLC 1AB	SLC 4AB	SLC 5AB	SHIP Sands	SHIP Fines	DGO LP	DGO SP Fines	DGO SP Sands
Predicted SiO_2	75	61	43	90	53	67	57	87
Standard Dispersion								
Sand	50	34	64	77	27	55	31	84
Silt	44	58	32	17	67	43	67	16
Clay	6	8	4	6	6	2	2	1
Vigorous Dispersion								
Sand	47	14	64	77	10	47	11	81
Silt	47	76	33	17	78	52	86	19
Clay	6	10	3	6	12	1	3	1
Wet-Sieving								
+200 mesh	41	15	60	76	4	47	13	80
–200 mesh	54	83	39	23	94	50	86	19
Loss	5	2	1	1	2	3	1	1

[a]Values in per cent.

Note: Sand >50 μm (40 s sedimentation).
Silt 2-50 μm (2 h sedimentation).
Clay <2 μm.

and on a qualitative basis for minerals that have not been standardized on the x-ray diffractometer unit. The diffractometer was operated at 40 kV and 20 mA using a copper target. Noise levels and peak heights were determined by visual inspection of the strip chart record of the x-ray intensity response. A computer program was employed to determine the percentage of standardized minerals present in the tailings samples (Williams, 1980).

f. Electron Microprobe Analysis. Six samples of size-fractioned mill tailings particles from Shiprock were submitted for electron microprobe examination. The samples were mounted in epoxy (three samples per mount) using a vacuum-pressure impregnation method. Following grinding and polishing, the specimens were ion etched lightly. A 10- by 10-μm fast-electron microprobe raster was employed for the analysis of all but the smallest size fraction. The small particles required the use of a finely focused (1-μm) electron beam. Elemental analyses were determined by energy dispersive detection of x-ray emissions. The results of the electron microprobe analysis are summarized in Table A-XI and show the elemental

TABLE A-XI

COMPOSITION OF TAILINGS PARTICLES DETERMINED BY ELECTRON MICROPROBE[a]

(Shiprock Fines)

	Particle Classification					
	Silicates	Organic	Potassium Aluminosilicates	Other Aluminosilicates	Iron Oxide	Calcium Sulfate
Si	M	om,o	M	M	o	om,o
O	(M)		(M)	(M)	M	(M)
C	?	M	?	?		?
S		M	o			M
Al	o	om,o	M	M	o	o
K		om,o	M	om,o	o	o
Fe	o	om,o	o	om,o	M	o
Ca		om,o	o	om		M
Mg	o	o	o		o	
V	o	om,o	o		o	o
Ti	o	o	o			o
P		om,o			o	
Cl		o				
Na			o	om,o		
Ni			o			
Mn					om,o	
F						o
Inferred Mineral	Quartz	Coalified Humic Substance	Feldspar, Illite, Clay	Feldspar, Kaolinite, Clay	Iron Oxide	Gypsum

[a]M = constant major component.
om = occasional major component.
o = occasional minor component.
? = carbon from epoxy resin on occasional basis.

Values in parentheses indicate variable oxygen response.

distributions found in 36 particles from the size-fractionated SHIP Fines: fraction A (particles >355 μm); fraction B (250 μm < particles <355 μm); fraction C (150 μm < particles <250 μm); and fraction F (particles <38 μm).

The six particles analyzed in fraction A are shown in photomicrographs (Figs. A-7 through A-12). The elemental distributions in these six particles are presented in the following table:

Particle	C	O	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	V	Mn	Fe
1		M			M									
2		M		L	L				L			L	L	M
3		M			L	L			L				L	M
4	M						M	L		L				
5		M	L		M	M			M	L				L
6				L	M	M							L	M

M = major element.
L = low-concentration element.

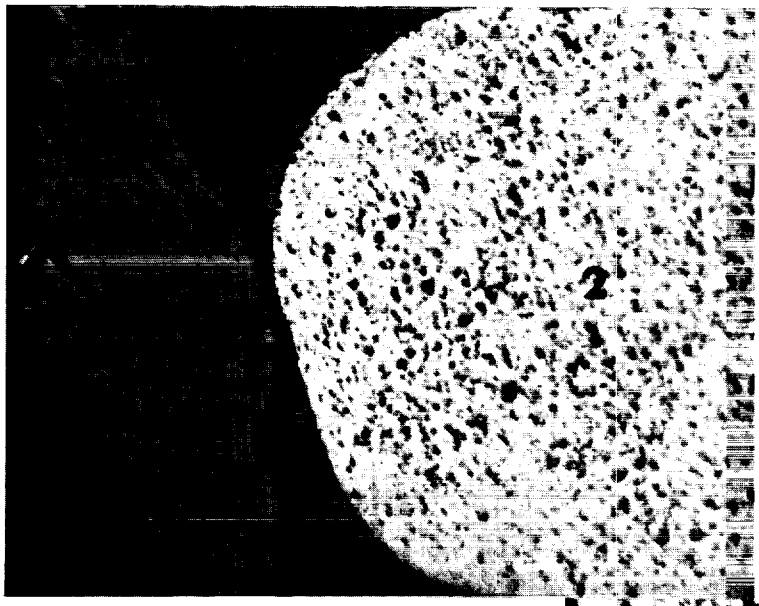


Fig. A-7. Photomicrograph of Particles 1 and 2 from Fraction A (150X).

Fig. A-8. Photomicrograph of Particle 3 from Fraction A (75X).

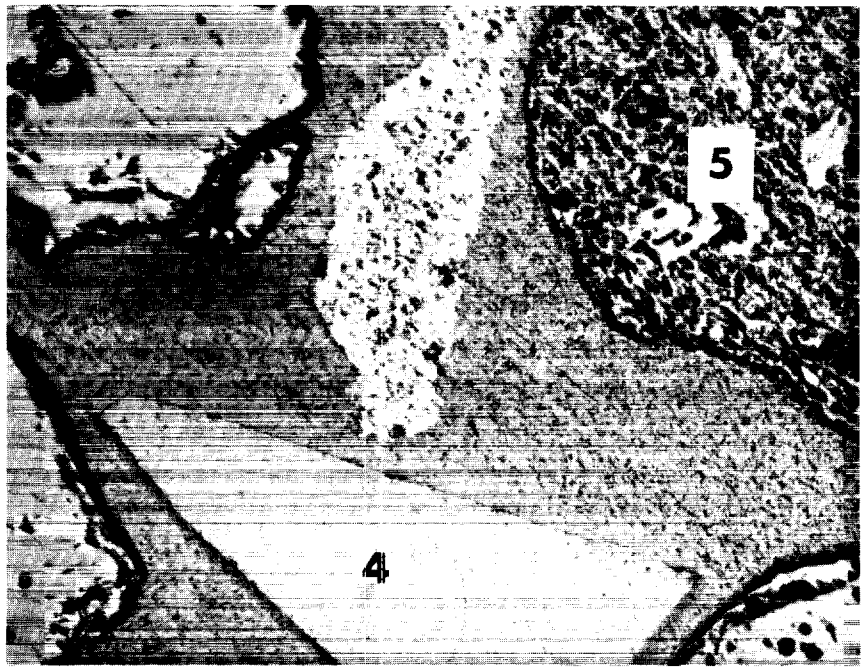


Fig. A-9. Photomicrograph of Particles 4 and 5 from Fraction A (150X).

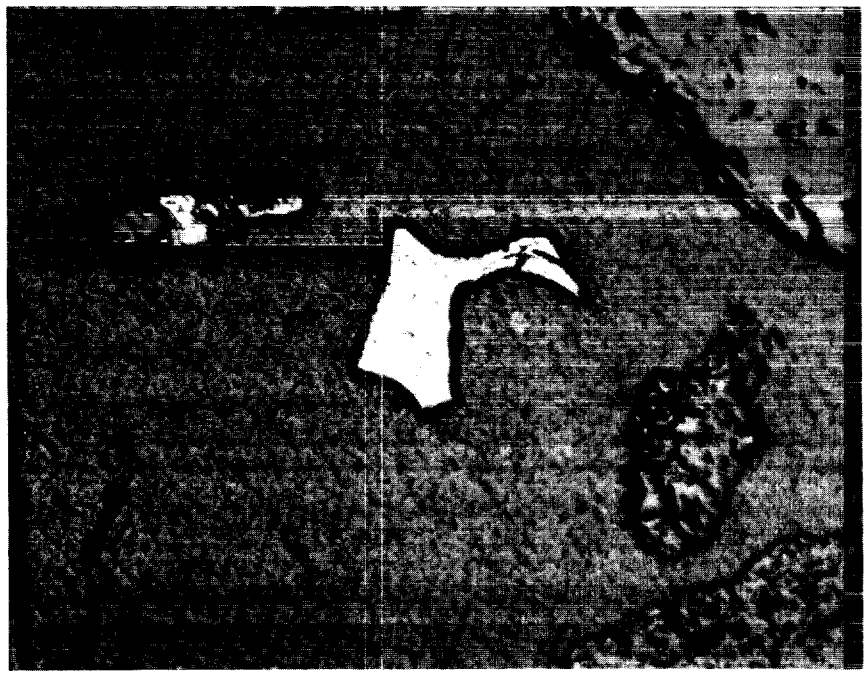


Fig. A-10. Photomicrograph of Fraction A (150X).

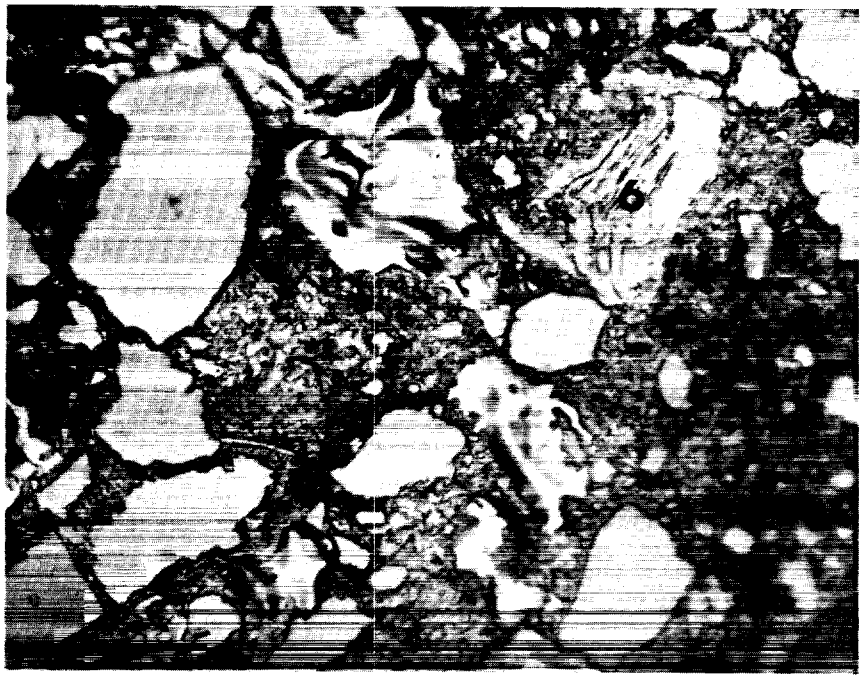


Fig. A-11. Photomicrograph of Particle 6 from Fraction A (600X).

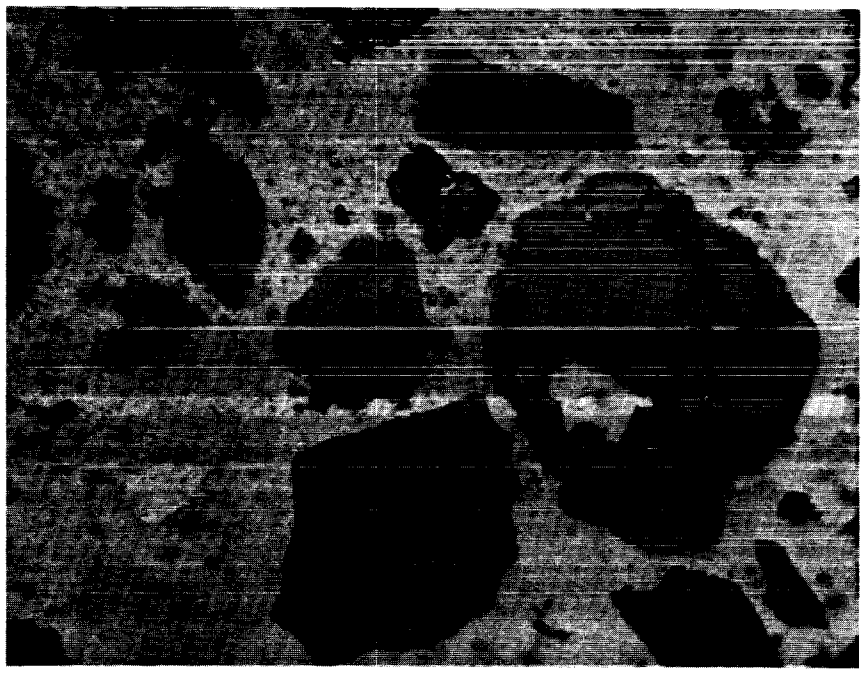


Fig. A-12. Photomicrograph of Fraction A (600X).

A specimen-current image and a backscattered-electron image of the particles in the photomicrograph (Fig. A-11) are shown in Figs. A-13 and A-14, respectively. Two-dimensional x-ray distributions (single element distributions) of this same particle grouping are given for Al, Si, K, Fe, Mg, Ti, Na, O, and C in Figs. A-15 through A-23, respectively. Similarly, Figs. A-24 and A-25 are the specimen-current and backscattered-electron images, respectively, of another particle grouping from fraction A, shown in Fig. A-12. The distributions of Al, Si, K, Fe, O, and C are presented in Figs. A-26 through A-31.

The particles analyzed in fraction B are shown in Figs. A-32 through A-35. The elemental distributions found in these particles are as follows:

Particle	C	O	Na	Mg	Al	Si	S	Cl	P	Ca	Ti	V	Cr	Mn	Fe	Ni	K
1	M					L	M										
2	L	L			L	M	M			M					L		
3		M		L	L	L	L		L					M	M		
4	M			L	M	M	M		M	M		M			L		M
5		M	L		M	M									L	L	M
6		M				L									M		
7	M		L	L	M	M	M					L			L		M
8	M				M	L	M		L	M	L	L			M		
9		M			L	M						L			L		
10		M			M	M	L			M				L	M		

M = major element.
L = low-concentration element.

Fig. A-13. Specimen-current image of Fig. A-11 (500X).

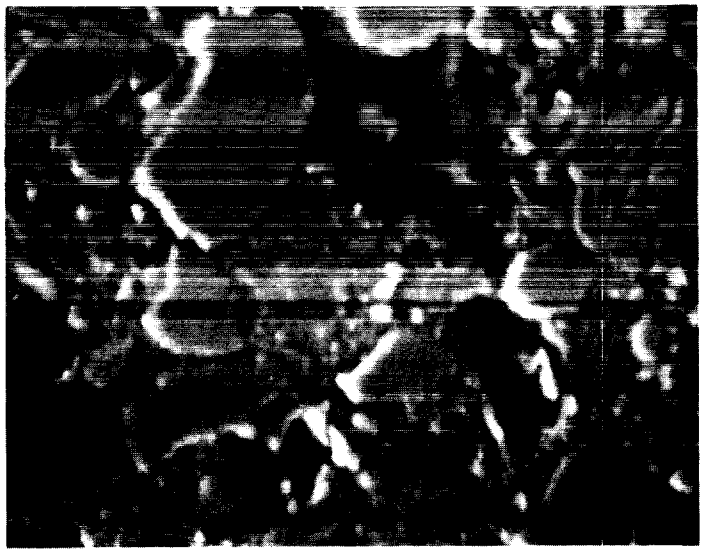


Fig. A-14. Backscattered-electron image of Fig. A-11 (500X).

Fig. A-15. Al distribution.

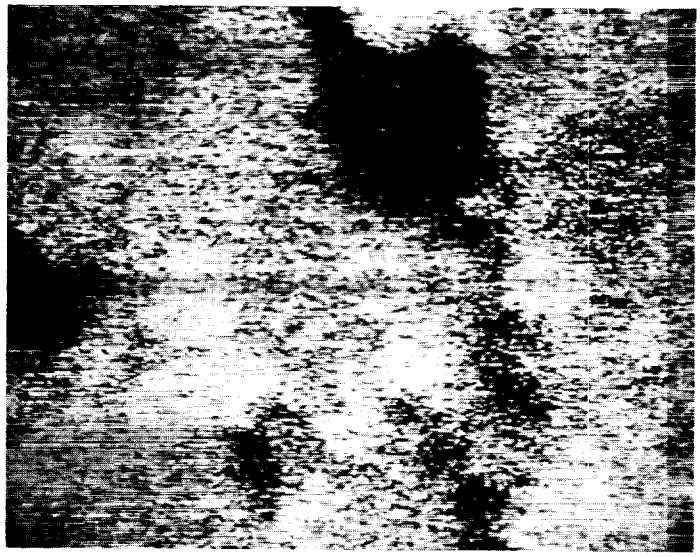


Fig. A-16. Si distribution.

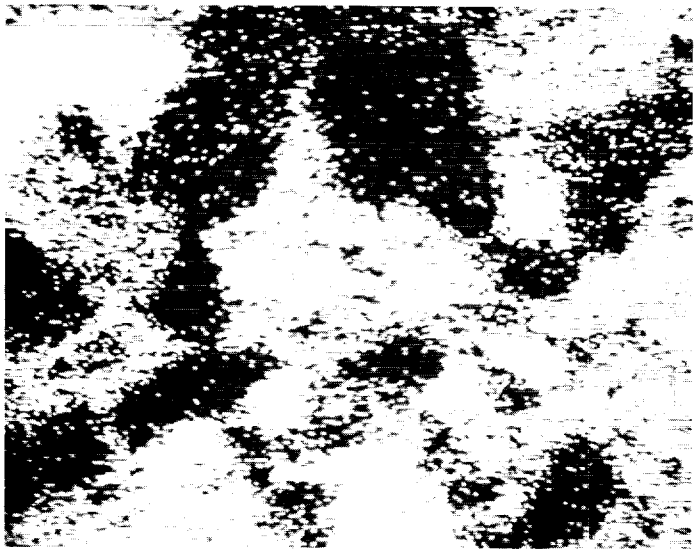


Fig. A-17. K distribution.

Fig. A-18. Fe distribution.

Fig. A-19. Mg distribution.

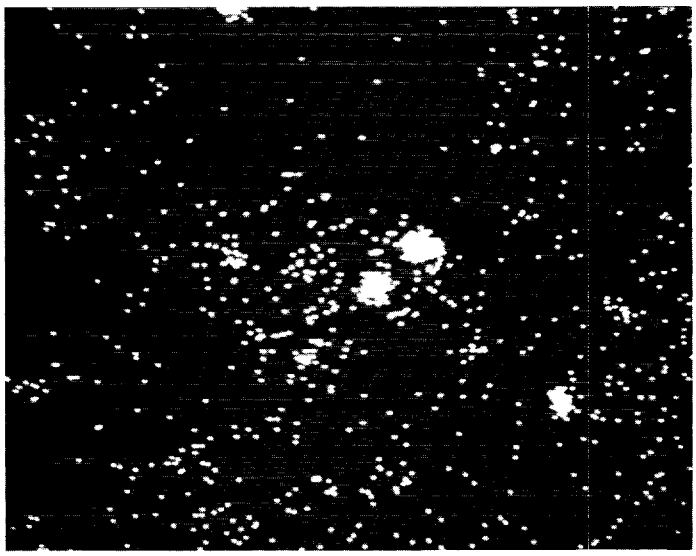


Fig. A-20. Ti distribution.

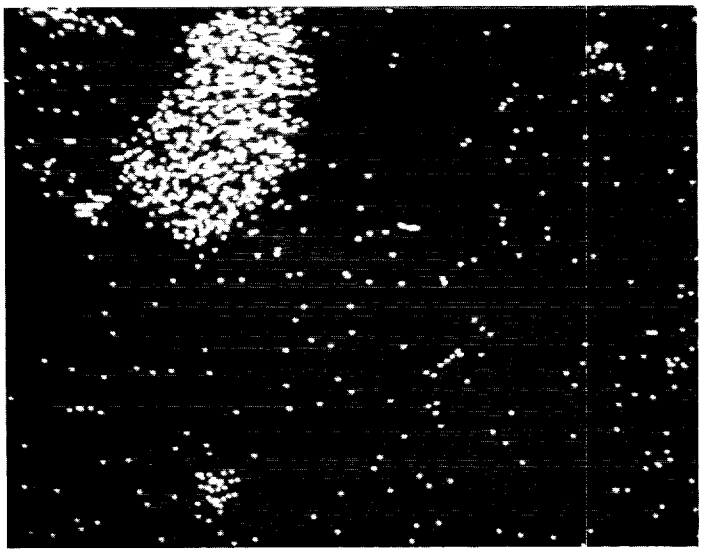


Fig. A-21. Na distribution.

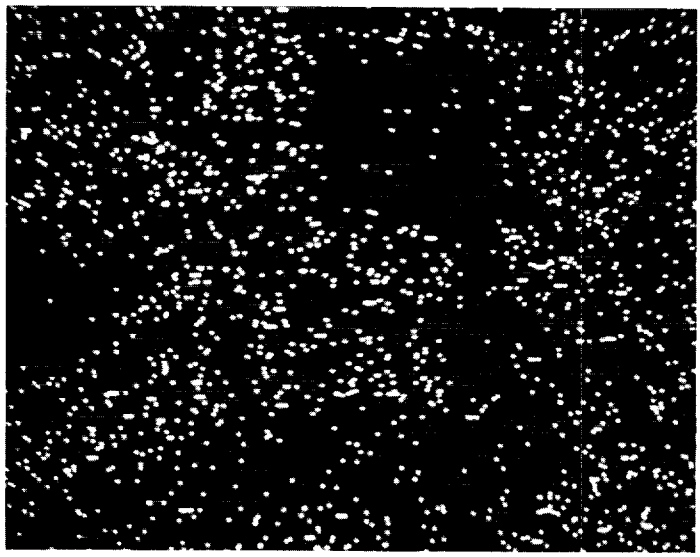


Fig. A-22. O distribution.

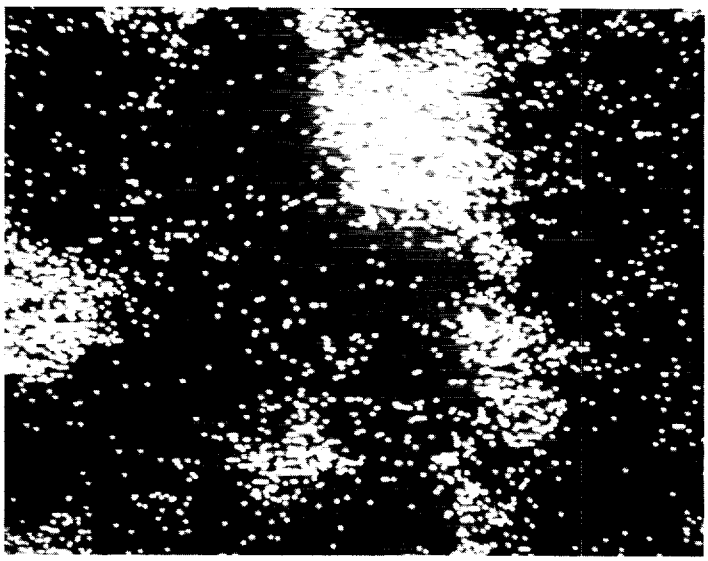


Fig. A-23. C distribution.

Fig. A-24. Specimen-current image of Fig. A-12 (500X).

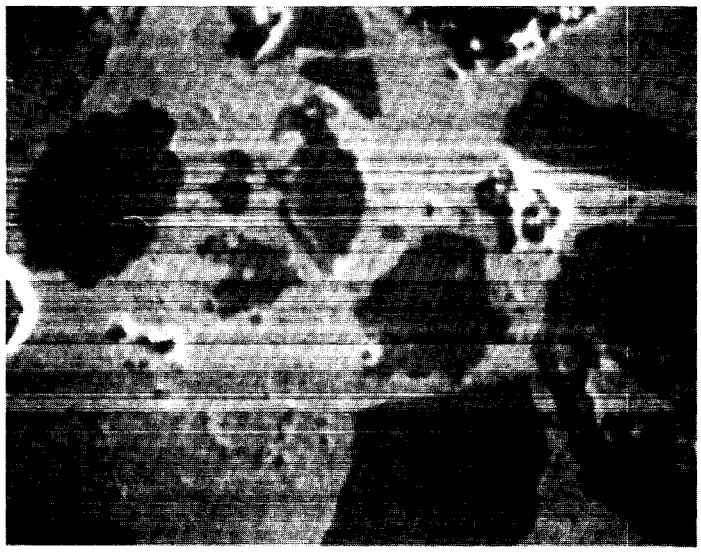


Fig. A-25. Backscattered-electron image of Fig. A-12 (500X).

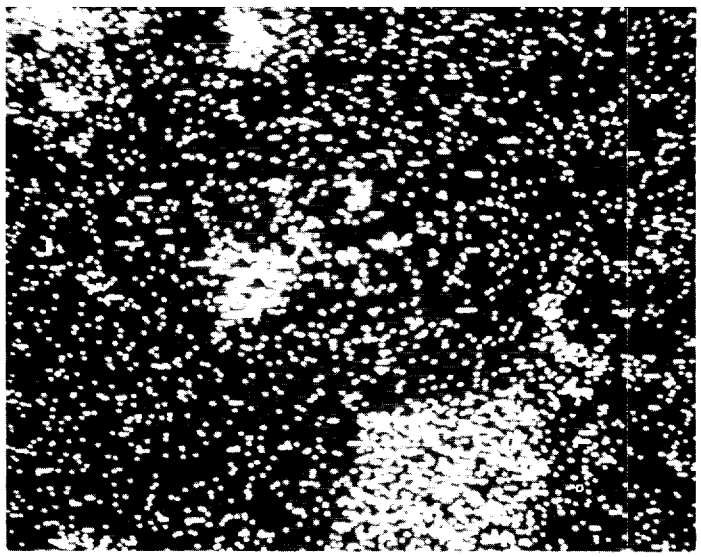


Fig. A-26. Al distribution.

Fig. A-27. Si distribution.

Fig. A-28. K distribution.

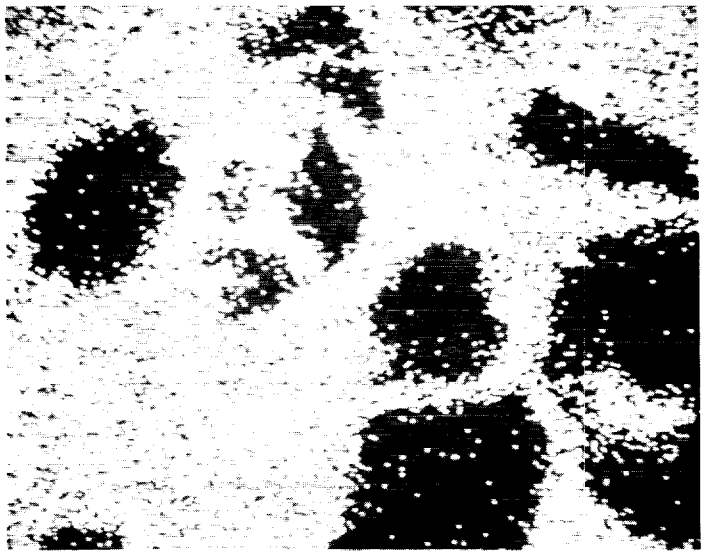


Fig. A-29. Fe distribution.

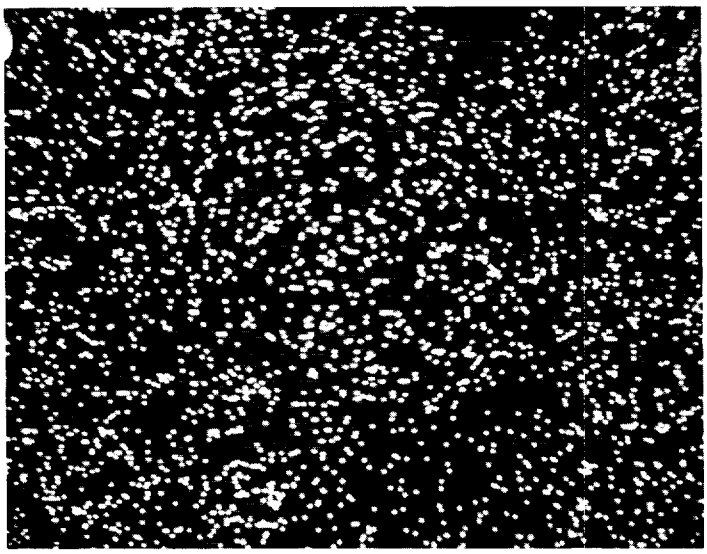


Fig. A-30. O distribution.

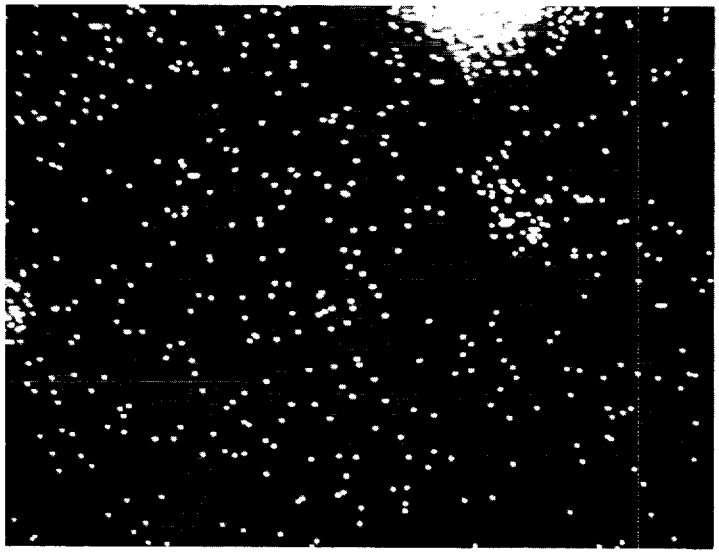


Fig. A-31. C distribution.

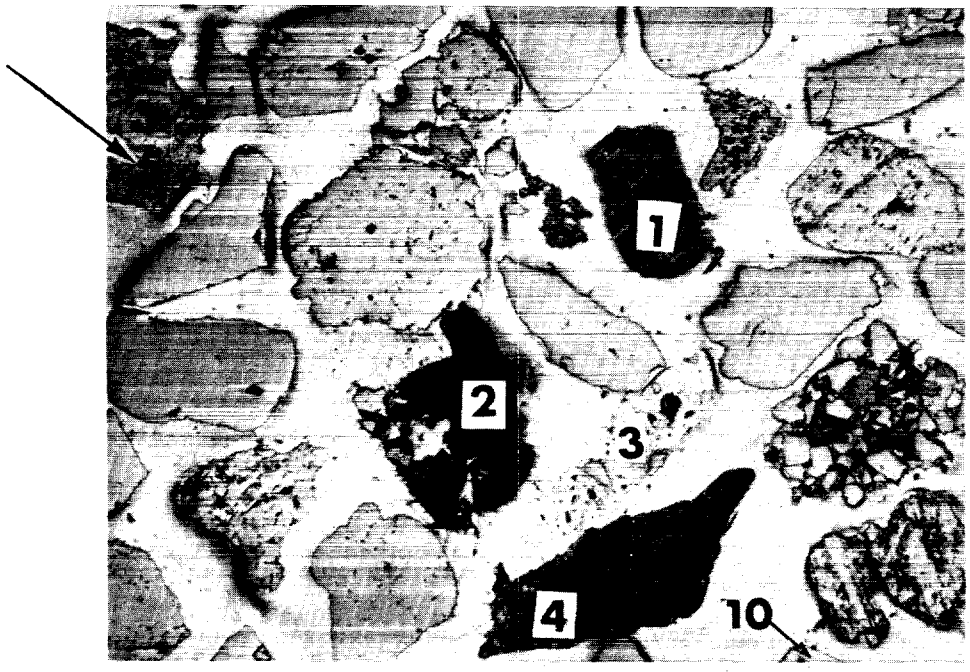


Fig. A-32. Photomicrograph of Particles 1, 2, 3, 4, 5, and 10 from Fraction B (75X).

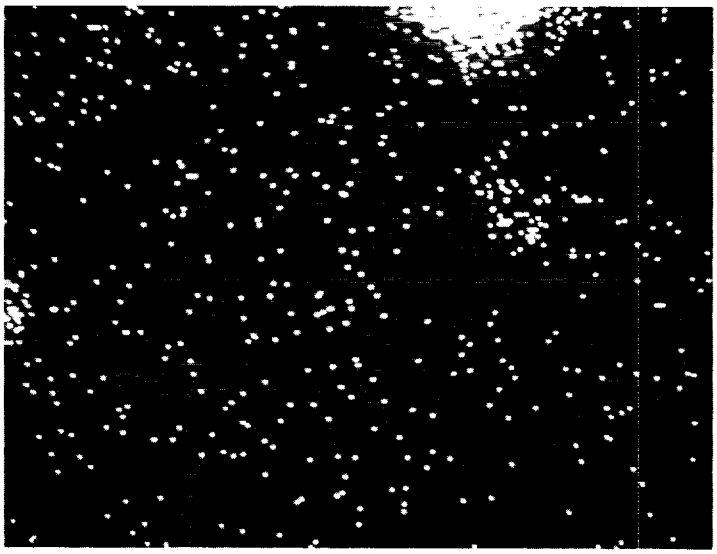


Fig. A-31. C distribution.

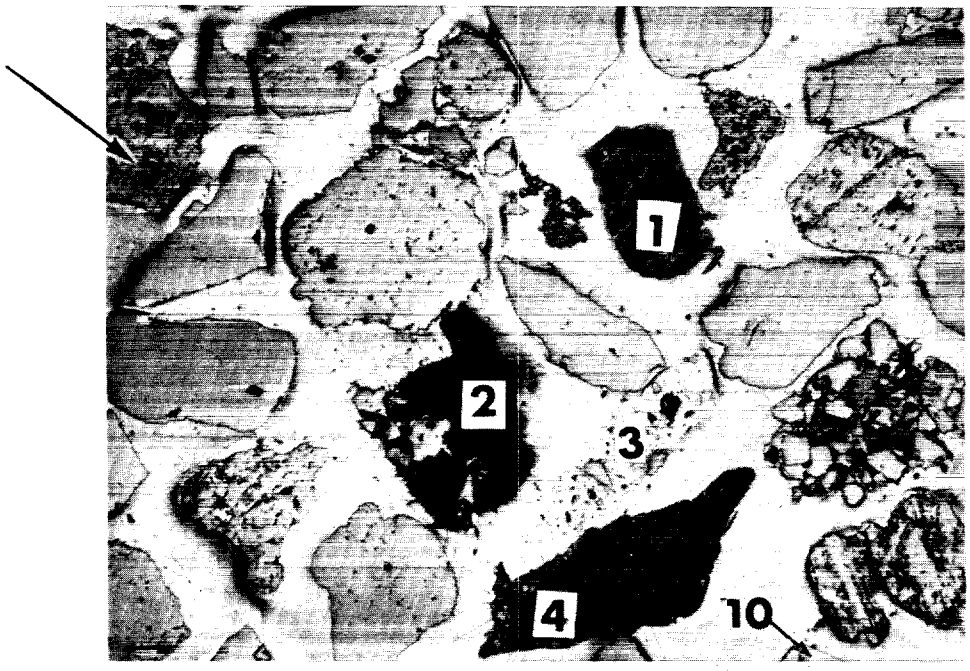


Fig. A-32. Photomicrograph of Particles 1, 2, 3, 4, 5, and 10 from Fraction B (75X).

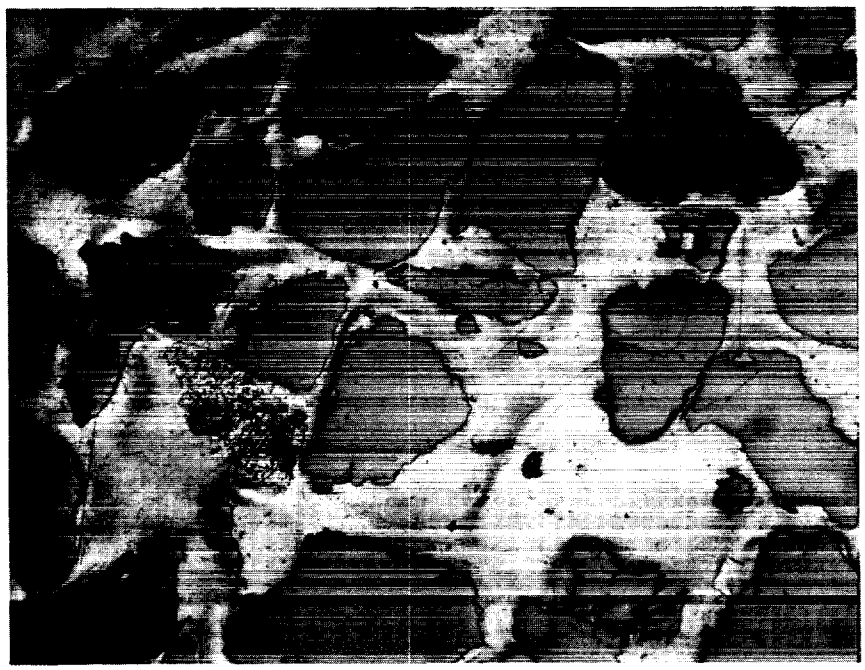


Fig. A-35. Photomicrograph of Fraction B (75X).

In addition, 10 particles from fraction C were analyzed (see Figs. A-36 through A-39). The elemental contents of these particles are shown below:

Particle	C	O	Na	Mg	Al	Si	P	S	K	Ca	Ti	V	Cr	Mn	Fe
1		M		L	M	M			M	M	L				L
2		M				M									
3		M	M		M	M									
4	M					L		M			L				
5	L	M		L	M	M			L			L			L
6	L	L						M		M					
7	M							M							
8	L	L		L	M	M			M			L	L		L
9	M					L		M							
10		M	L		M	M			M						

M = major element.
L = low-concentration element.

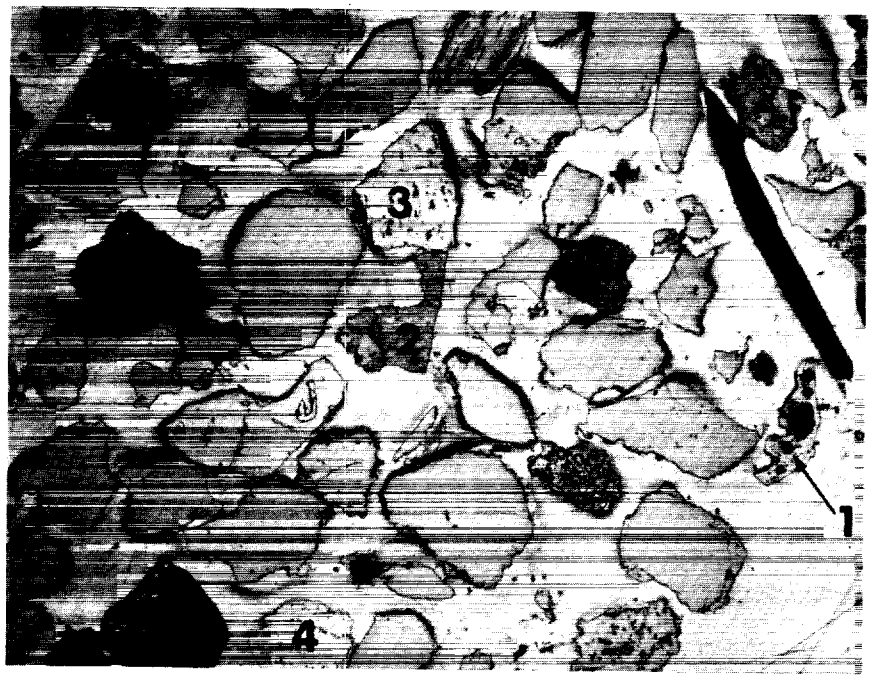


Fig. A-36. Photomicrograph of Particles 1, 2, 3, and 4 from Fraction C (75X).

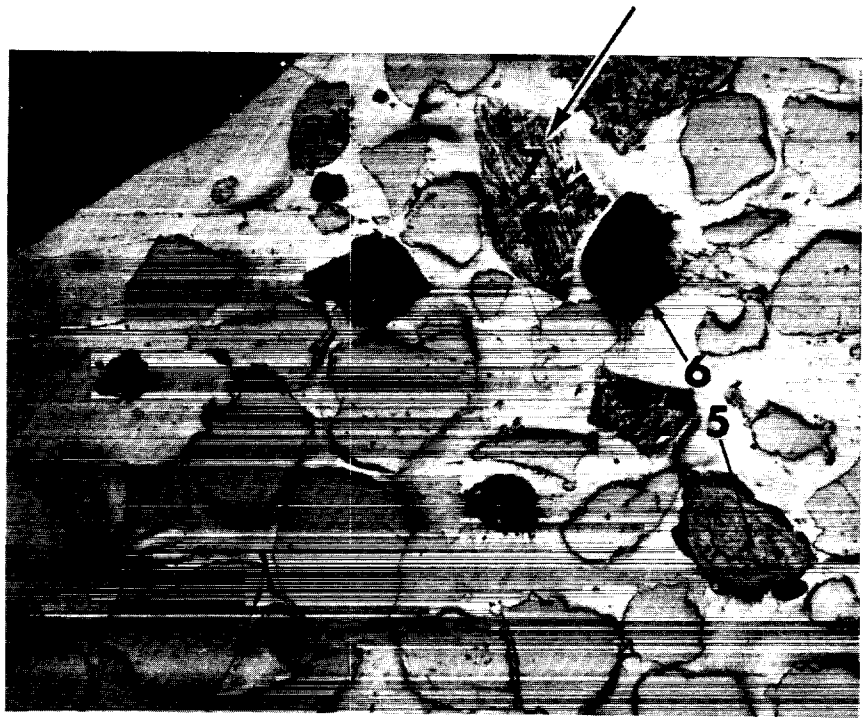


Fig. A-37. Photomicrograph of Particles 5, 6, and 7 from Fraction C (75X).

Fig. A-38. Photomicrograph of Particles 8 and 9 from Fraction C (75X).

Fig. A-39. Photomicrograph of Particle 10 from Fraction C (75X).

Finally, 10 particles from fraction D (<38 μm) were analyzed; photomicrographs showing these particles are in Figs. A-40 and A-41. The following table describes the elemental distribution of these particles:

Particle	C	O	F	Na	Mg	Al	Si	K	Ca	S	Ti	V	Fe
1		M			L	L	M						L
2	L	L			L	M	M	M			L	L	L
3	L	L			L	M	M	M			L	L	L
4	L	L		L	L	M	M	M	L	L	L	L	L
5	M				L	L	M	L	M	M	L	L	L
6	L	L			L	L	M				L	L	L
7	L		L			L	M	L	M	M		L	L
8	M	L				M	M			L	L		L
9	L	M		L		M	M	M	L		L	L	L
10	L	L	L			L	L	L	M	M	L		

M = major element.
L = low-concentration element.

Fig. A-40. Photomicrograph of Particles 1, 2, 3, 4, and 5 from Fraction D (150X).

Fig. A-41. Photomicrograph of Particles 6, 7, 8, 9, and 10 from Fraction D (150X).

g. Leaching Tests. The experimental procedure consisted of adding 30 g of tailings to 150 mℓ of deionized water in a 250-mℓ polyethylene bottle and shaking for 1 day. After shaking, the samples were centrifuged (~18 000 rpm) and filtered through 0.45-μm micropore filters. These filtrates were analyzed for major and trace constituents by atomic absorption spectrophotometry and for anions by ion chromatography.

4. Sulfuric Acid Extraction Procedure and Results

The composite tailings from the Shiprock, Salt Lake City, and Durango sites were acid-leached with 0.001N, 0.01N, 1.0N, 10N, and concentrated H_2SO_4 at a solid-to-liquid *mass* ratio of 1 to 5. The suspensions were centrifuged (~18 000 rpm) and filtered through 0.45-μm micropore filters. Analyses of the leachates for most elements were performed by atomic absorption spectrophotometry. Uranium was determined by laser fluorescence and anions by ion chromatography.

Tables A-XII, A-XIII, and A-XIV show results of the sulfuric acid and water leaches in terms of grams of element extracted per metric ton of tailings for each composite material. These numbers are five-fold higher than the corresponding concentrations (mg/ℓ) in the leachates for the H_2O, 0.0001N, 0.01N, and 0.1N solutions. Factors for conversion back to liquid concentration require dividing by 4.85 for 1.0N, 3.89 for 10N, and 2.73 for concentrated H_2SO_4. Division by the appropriate concentration in the tailings solids (Tables A-IV through A-VIII) gives the fraction of the total element extracted.

The effectiveness of elemental leaching by different concentrations of sulfuric acid appears to vary according to the quantity of the element present in the tailings and the equilibrium pH of the slurry. Those tailings that have inherent alkalinity do not become as acidic as those with little or no alkalinity. The elements Al, Fe, Co, Cr, Cu, Mn, Ni, U, V, and Zn were most extractable by 1.0N or 10N H_2SO_4. These extractions had sufficient acid concentration to reduce the pH of the slurry to 1 or less. In some cases, the solute concentrations were quite high. For example, Zn concentrations in 1.0N leachates from DGO LP and SP Fines were 203 and 273 mg/ℓ, respectively, and V concentration in one leachate (10N DGO SP Fines) was 550 mg/ℓ.

TABLE A-XII

MASS OF ELEMENTAL CONSTITUENTS EXTRACTED FROM SHIPROCK TAILINGS BY SULFURIC ACID SOLUTIONS[a]

Site	Composite	Initial Sulfuric Acid Conc	Al	Ba	Ca	Fe	K	Mg	Na	pH	Be	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Se	U	V	Zn
SHIP	Sands	Conc	290	440	10 650	560	140	96	660	–	<1	–	–	–	11	<3	27	<3	<5	14	<1	96	–
		10N	260	<1	500	760	200	130	190	–	<1	<1	<1	<1	9	5	43	<1	74	14	5	160	5
		1.0N	130	<1	3730	240	49	97	–	0.9	<1	<1	<1	<1	6	4	19	<1	34	12	3	110	3
		0.1N	80	<1	2750	73	20	85	65	1.2	<1	<1	<1	<1	5	3	8	<1	15	5	3	56	3
		0.01N	60	<1	3600	19	20	85	65	2.3	<1	<1	<1	<1	4	3	3	<1	7	1	3	26	3
		0.001N	40	<1	3450	1	20	85	65	3.3	<1	<1	<1	<1	3	3	<1	<1	2	<1	1	5	3
		H_2O	30	<1	3550	<1	20	85	65	3.5	<1	<1	<1	<1	3	3	<1	<1	1	<1	<1	1	3
SHIP	Fines	Conc	980	710	7180	240	420	440	180	–	<1	–	–	–	16	19	68	<3	90	27	1	330	–
		10N	1250	<1	560	3420	740	1320	470	–	<1	<1	<1	3	16	19	130	8	74	22	18	680	13
		1.0N	730	<1	3690	1010	170	570	–	0.9	<1	<1	1	1	10	19	53	5	34	16	15	500	9
		0.1N	390	<1	2750	37	85	490	380	1.3	<1	<1	1	<1	7	15	21	4	13	5	12	250	8
		0.01N	290	<1	2550	27	70	470	370	2.5	<1	<1	1	<1	5	15	3	4	9	1	8	63	7
		0.001N	210	<1	2550	5	65	470	370	3.1	<1	<1	1	<1	3	15	1	4	2	1	3	7	7
		H_2O	80	<1	2600	4	65	460	370	3.2	<1	<1	1	<1	3	15	<1	4	1	1	3	5	7

[a]All concentrations in terms of grams of element extracted per metric ton of tailings; 500 g/MT = 1 lb/ton.

TABLE A-XIII

MASS OF ELEMENTAL CONSTITUENTS EXTRACTED FROM SALT LAKE CITY TAILINGS BY SULFURIC ACID SOLUTIONS[a]

Site	Composite	Initial Sulfuric Acid Conc	Al	Ba	Ca	Fe	K	Mg	Na	pH	Be	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Se	U	V	Zn
SLC	1AB	Conc	550	1170	7640	330	150	74	270	–	2	–	–	–	14	14	55	<3	16	<5	41	14	–
		10N	890	<1	540	2400	320	220	39	–	3	<1	11	2	17	23	120	5	59	<1	49	18	25
		1.0N	410	<1	3730	1480	68	87	–	0.8	3	<1	9	<1	12	20	110	4	29	<1	55	9	22
		0.1N	210	<1	2800	735	35	60	15	1.2	2	<1	7	<1	9	16	55	3	25	<1	57	5	17
		0.01N	170	<1	3200	240	30	55	15	2.3	2	<1	5	<1	7	14	5	3	7	<1	57	2	13
		0.001N	150	<1	3250	22	25	55	15	3.1	2	<1	6	<1	7	14	<1	3	1	<1	50	<1	15
		H_2O	140	<1	3250	65	25	55	15	3.2	2	<1	5	<1	7	14	<1	3	1	<1	43	<1	15
SLC	4AB	Conc	1090	250	7370	660	380	420	1230	–	<1	–	–	–	82	41	600	<3	52	<5	110	55	–
		10N	1320	<1	590	8170	740	740	2060	–	<1	<1	7	14	140	50	1710	9	110	3	130	70	72
		1.0N	1550	<1	3590	2670	120	550	–	0.8	<1	<1	8	9	130	20	620	9	34	3	97	45	65
		0.1N	1200	<1	2800	1350	70	490	1770	1.3	<1	<1	7	6	110	39	260	8	14	1	90	33	59
		0.01N	950	<1	2150	400	60	470	1750	2.3	<1	<1	7	3	110	36	65	8	25	<1	60	26	57
		0.001N	900	<1	2150	250	60	490	1740	2.7	<1	<1	7	3	110	37	29	8	10	<1	40	17	59
		H_2O	900	<1	2200	230	60	490	1720	2.7	<1	<1	7	2	110	37	27	8	6	<1	40	16	59
SLC	5AB	Conc	300	160	8460	1940	160	590	3820	–	<1	–	–	–	140	460	68	25	<3	<5	22	930	–
		10N	350	<1	630	13 400	580	3540	6300	–	<1	<1	14	260	600	1340	150	370	51	<1	23	1560	33
		1.0N	410	<1	3780	1290	110	1750	–	1.9	<1	<1	5	43	450	750	24	140	<1	<1	23	1060	20
		0.1N	70	<1	3700	33	50	550	1030	2.3	<1	<1	1	6	170	140	10	26	<1	<1	5	355	7
		0.01N	<1	<1	3400	<1	30	170	650	6.5	<1	<1	<1	<1	1	11	13	3	<1	<1	<1	130	<1
		0.001N	<1	<1	3350	<1	30	150	630	7.1	<1	<1	<1	<1	<1	1	17	<1	<1	<1	<1	130	<1
		H_2O	<1	<1	3400	<1	30	160	650	7.2	<1	<1	<1	<1	<1	<1	17	<1	<1	<1	<1	120	<1

[a]All concentrations in terms of grams of element extracted per metric ton of tailings; 500 g/MT = 1 lb/ton.

TABLE A-XIV

MASS OF ELEMENTAL CONSTITUENTS EXTRACTED FROM DURANGO TAILINGS BY SULFURIC ACID SOLUTIONS[a]

Site	Composite	Initial Sulfuric Acid Conc	Al	Ba	Ca	Fe	K	Mg	Na	pH	Be	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Se	U	V	Zn
DGO	LP	Conc	710	710	11 470	1010	190	900	760	–	<1	–	–	–	350	190	<14	16	71	<5	160	1150	–
		10N	4280	<1	590	1560	410	3150	2330	–	<1	14	41	76	420	630	5	32	23	<1	300	1670	1010
		1.0N	1520	<1	3100	570	260	2470	–	0.9	<1	16	38	50	420	290	2	25	4	<1	200	1450	980
		0.1N	<1	<1	3100	<1	65	910	410	6.5	<1	1	11	2	<1	100	1	6	<1	<1	4	270	12
		0.01N	<1	3	1650	<1	35	130	130	8.1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	33	31	<1
		0.001N	<1	<1	100	<1	30	50	110	9.1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	11	43	<1
		H_2O	<1	<1	55	<1	25	30	110	9.4	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	9	54	<1
DGO	SP Fines	Conc	610	15 290	9830	680	200	490	600	–	<1	–	–	–	260	340	<14	<3	110	11	270	1200	–
		10N	4790	<1	620	4440	530	2410	1950	–	<1	20	63	37	650	660	14	32	31	6	430	2140	–
		1.0N	1530	<1	3050	1820	260	1600	–	1.1	<1	22	75	33	650	680	1	27	5	8	280	1840	1320
		0.1N	310	<1	2900	200	70	280	150	1.7	<1	2	5	9	80	120	<1	3	3	1	61	340	170
		0.01N	<1	<1	3700	<1	40	120	160	8.2	<1	<1	<1	<1	<1	2	3	<1	<1	1	15	61	<1
		0.001N	<1	<1	2700	<1	35	90	150	7.9	<1	<1	<1	<1	<1	<1	3	<1	<1	<1	7	49	<1
		H_2O	<1	<1	2600	<1	35	90	150	7.9	<1	<1	<1	<1	<1	<1	3	<1	<1	<1	5	50	<1
DGO	SP Sands	Conc	380	550	3930	850	120	280	150	–	<1	–	–	–	68	130	<14	<3	63	<5	110	290	–
		10N	1440	<1	560	1070	290	700	510	–	<1	2	8	10	82	150	4	3	23	3	190	400	180
		1.0N	600	<1	3730	640	140	400	–	1.2	<1	2	7	10	85	160	2	3	5	3	170	450	180
		0.1N	<1	<1	3650	<1	50	360	285	7.7	<1	1	4	<1	<1	73	3	3	<1	1	21	190	27
		0.01N	<1	1	2550	<1	15	55	35	7.7	<1	<1	<1	<1	<1	5	<1	<1	<1	<1	3	35	<1
		0.001N	<1	<1	1800	<1	15	30	30	8.1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	3	26	<1
		H_2O	<1	<1	1650	<1	15	30	25	8.1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	29	<1

[a]All concentrations in terms of grams of element extracted per metric ton of tailings; 500 g/MT = 1 lb/ton.

Table A-XV lists the maximum mass of each of 11 potentially valuable elements and 6 major constituents extracted by variable sulfuric acid solutions. In every case but one (U in SLC 1AB), the H_2SO_4 concentrations giving these maxima were greater than or equal to 1.0N. These data show which tailings materials have the greatest potential for recovery of specific mineral values. The three composites, SLC 5AB, DGO LP, and DGO SP Fines, have high extractable quantities for many elements. Of the remaining five composites, four appear to contain appreciable extractable values for a few elements: SHIP Fines for Mo, Se, and V; SLC 1AB for Mo; SLC 4AB for Mo; and DGO SP Sands for V. The mineralogy of the three tailings composites with the greatest potential for mineral recovery (SLC 5AB, DGO LP, DGO SP Fines) appears to be quite different from the others. The two Durango composites have high concentrations of plagioclase feldspars and nonaluminosilicates. The SLC 5AB tailings appear to have considerable α-hematite and chloroapatite. In addition, these tailings contain appreciable concentrations of Fe, Mn, and Na, which may be of significance regarding extractable constituents.

The concentrations of anions (mg/ℓ) in the sulfuric acid leachates are reported in Table A-XVI. Particularly noteworthy are the high chloride concentrations in the Salt Lake City and DGO LP leachates for the 10N and 1N solutions. It seems probable that some chloride-containing minerals are being dissolved from these tailings. A similar occurrence is seen for fluoride in SLC 5AB. In contrast, fluoride in SLC 1AB and SLC 4AB is highly leachable in all the leaching solutions.

High nitrate concentrations are seen for the Shiprock tailings and SLC 5AB. The dissolution of phosphate minerals seems apparent in strong acids (10N and 1N) for composites SLC 5AB, DGO LP, and DGO SP Fines. A chloroapatite mineral was identified in SLC 5AB; the high concentrations of both chloride and phosphate would indicate the dissolution of this mineral. It would appear from these results that both DGO LP and DGO SP Fines also contain a (chloro/fluoro) phosphate mineral prone to sulfuric acid attack.

The sulfate data show that certain tailings composites are precipitating sulfate from solution (DGO LP —1N and lesser acid concentration), whereas others are generally dissolving sulfate salts (SLC 4AB). For all composites, the 1N H_2SO_4 solution had an initial sulfate concentration that promoted precipitation. In contrast, the calcium concentrations were always at their minimum for the 10N solutions (except DGO LP). The controlling factor would appear to be the solubility product constant of calcium sulfate.

5. Economic Analysis of Mineral Recovery—Durango Site

The general criterion for conducting leaching for mineral recovery as a part of a remedial action program requires that the economic benefits be at least equal to the incremental cost of adding the leaching step to the design scheme. A more specific problem is whether it is economically feasible to recover mineral values from tailings as part of a remedial action program. The preliminary answer is *yes* for the Durango site, as explained in the following paragraphs.

In the late 1970s, only two sites of the locations available for study by Ranchers Exploration and Development Corporation (REDC) were deemed worthy of mineral recovery; these were Durango and Naturita, Colorado (Deuel 1979). REDC was convinced that it could transport the Durango tailings to the Long Hollow Site, process them in excavated "leach tanks," cover them with 0.6 m of compacted Mancos shale, and make a profit. Based on 1978 prices and our current analysis and recovery data, the authors have estimated that REDC expected to gross at least $40 million from the venture. Considering the risks involved, a profit margin of about $8 million was probably used by REDC in 1978. This leaves a "production cost" of $32 million, which includes both leaching costs and hauling/excavation costs.

An independent engineering firm has reported the various costs of a hypothetical 2-million-ton heap-leaching plant in southern Colorado or northern New Mexico (Mountain States Research and Development 1980). Interpreting their figures liberally (high) for the Long Hollow disposal site and assuming 1.6 million tons of Durango tailings, we estimate a 1981 leaching cost of $20.8 million, from which credit can be taken for about $1.3 million of health physics work that would have to be done as part of remedial action. Thus, the net leaching cost is $19.5 million.

TABLE A-XV

MAXIMUM MASS EXTRACTED BY SULFURIC ACID FROM EACH TAILINGS COMPOSITE FOR POTENTIALLY VALUABLE METALS[a]

		Cd*	Co	Cr*	Cu*	Fe*	Mn*	Mo*	Ni*	Se	U	V	Zn*	Al	Ca*	K	Mg*	Na
SHIP	Sands	<1	<1	<1	11 a	760 b	5 b	43 b	<3	14 a	5 b	160 b	5 b	290 a	10 650 a	200.b	130 b	660 a
					(55 %)	(26 %)	(16 %)	(~100 %)		(24 %)	(15 %)	(16 %)	(6 %)	(2 %)	(83 %)	(3 %)	11 %)	(47 %)
SHIP	Fines	<1	1 c	3 b	16 a	3420 b	19 b	130 b	8 b	27 a	18 b	680 b	13 b	1250 b	7180 a	740 b	1320 b	470 b
			(19 %)	(7 %)	(35 %)	(35 %)	(31 %)	(~100 %)	(16 %)	(14 %)	(37 %)	(16 %)	(11 %)	(3 %)	(10 %)	(4 %)	(25 %)	(24 %)
SLC	1AB	<1	11 b	2 b	17 b	2400 b	23 b	120 b	5 b	<5	57 d	18 b	25 b	890 b	7640 a	320 b	220 b	270 a
			(69 %)	(6 %)	(46 %)	(30 %)	(32 %)	(~100 %)	(71 %)		(52 %)	(12 %)	(45 %)	(3 %)	(22 %)	(2 %)	(10 %)	(7 %)
SLC	4AB	<1	8 c	14 b	140 b	8170 b	50 b	1710 b	9 b	<5	130 b	70 b	72 b	1550 c	7370.a	740 b	740 b	2060 b
			(31 %)	(19 %)	(52 %)	(45 %)	(25 %)	(~100 %)	(43 %)		(72 %)	(18 %)	(48 %)	(3 %)	(24 %)	(3 %)	(32 %)	(27 %)
SLC	5AB	<1	14 b	260 b	600 b	13 400 b	1340 b	150 b	370 b	<5	23 b	1560 b	33 b	410 c	8460 a	580 b	3540 b	6300 b
			(30 %)	(4 %)	(71 %)	(12 %)	(53 %)	(~100 %)	(22 %)		(37 %)	(53 %)	(50 %)	(2 %)	(10 %)	(5 %)	(69 %)	(64.%)
DGO	LP	16 c	41 b	76 b	420 b	1560 b	630.b	5 b	32 b	<5	310 b	1670 b	1010 b	4280 b	11 470 a	410 b	3150 b	2330 b
		(~100 %)	(46 %)	(6 %)	(82 %)	(5 %)	(64 %)	(71 %)	(18 %)		(97%)	(53 %)	(78 %)	(9 %)	(39 %)	–	(34 %)	(7 %)
DGO	SP	22 c	75 c	37 b	650 b	4440 b	680 c	14 b	32 b	11 a	280 c	2140 b	1320 c	4790 b	9830 a	530 b	2410 b	1950 b
	Fines	(95 %)	(68 %)	(9 %)	(89 %)	(14 %)	(74 %)	(~100 %)	(25 %)	(38 %)	(60%)	(56 %)	(85 %)	(8 %)	(26 %)	(6 %)	(25 %)	(5 %)
DGO	SP	2 b	8 b	10 b	85 c	1070.b	160 c	4 b	3 b	<5	190 b	450.c	180 b	1440 b	3930.a	290.b	700 b	510 b
	Sands	(69 %)	(33 %)	(6 %)	(77 %)	(9 %)	(59 %)	(36 %)	(16 %)		(~100 %)	(21 %)	(55 %)	(6 %)	(35.%)	(4 %)	(17 %)	(4 %)

[a]Grams of element extracted per metric ton of tailings (or μg/g);
500 g/MT = 1 lb/ton.

Letter denotes the sulfuric acid concentration that extracted the maximum mass:
a = concentrated
b = 10N
c = 1N
d = 0.1N
(%) indicated percentage in tailings extractable based on atomic absorption results,* otherwise on neutron activation analysis.
~100% indicates more mass extracted than present in tailings.

TABLE A-XVI

CONCENTRATION OF ANIONS EXTRACTED FROM TAILINGS BY SULFURIC ACID SOLUTIONS

Site	Composite	Initial Sulfuric Acid Conc	(mg/ℓ) Cl	F	NO_3^-	PO_4^{-3}	SO_4^{-2}	pH
SHIP	Sands	1.0N	9	<10	18	<10	40 000 [a]	–
		0.1N	<10	<10	15	<10	6360 [b]	0.9
		0.01N	3	0.3	–	<1	1920 [b]	1.2
		H_2O	2	0.3	–	<2	1520 [b]	3.5
SHIP	Fines	1.0N	70	<10	110	<10	43 000 [a]	–
		0.1N	22	<10	75	<10	6420 [b]	0.9
		0.01N	12	1	75	<2	2550 [b]	1.3
		H_2O	10	3	75	<2	2190 [b]	3.2
SLC	1AB	10N	1000	–	–	–	769 000 [a]	–
		1.0N	38	28	<5	<10	40 000 [a]	–
		0.1N	<10	22	<5	<10	6400 [b]	0.8
		0.01N	<1	19	<5	<5	1850 [b]	1.2
		H_2O	0.8	37	<1	<2	1680 [b]	3.2
SLC	4AB	10N	1400	–	–	<500	530 000 [b]	–
		1.0N	290	54	<10	290	40 000[a]	–
		0.1N	350	61	<10	22	6400 [b]	0.8
		0.01N	300	41	–	<5	3900 [b]	1.3
		H_2O	360	46	–	2	3140 [b]	2.7
SLC	5AB	10N	2400	300	–	29 000	448 000 [a]	–
		1.0N	980	58	<10	14 300	10 500 [a]	–
		0.1N	150	19	65	1840	1990 [a]	1.9
		0.01N	<10	<1	61	185	1500 [b]	2.3
		H_2O	10	0.2	66	7	1600 [b]	7.2
DGO	LP	10N	1200	–	–	3300	508 000 [b]	–
		1.0N	290	30	<5	3100	26 600 [a]	–
		0.1N	34	1.8	<5	<10	2350 [a]	0.9
		0.01N	3.7	1.2	1.6	2.7	450 [a]	6.5
		H_2O	2.7	1.2	1.6	3	15 [a]	9.4

[a]Sulfate precipitating (initial conc > final conc).
[b]Sulfate leaching (final conc > initial conc).

TABLE A-XVI (cont)

Site	Composite	Initial Sulfuric Acid Conc	(mg/ℓ) Cl	F	NO_3^-	PO_4^{-3}	SO_4^{-2}	pH
DGO	SP	10N	–	–	–	1100	–	–
	Fines	1.0N	62	39	22	540	25 500 [a]	–
		0.1N	<20	7	<10	148	4260	1.1
		0.01N	3.6	1.3	<1	1.7	1350 [b]	1.7
		H_2O	3.6	1.2	<1	0.4	1000 [b]	7.9
DGO	SP	10N	–	–	–	–	–	–
	Sands	1.0N	23	10	<5	<10	37 000 [a]	–
		0.1N	<10	<10	<10	<10	1600 [a]	1.2
		0.01N	0.9	1.3	<1	3.3	870 [b]	7.7
		H_2O	1.2	0.6	0.7	1.8	560 [b]	8.1

Using current (1981) prices and our analytical data, the uranium and vanadium extracted from the 1.6 million tons of Durango tailings would be worth $32.2 million, after discounting for the cost of off-site solution processing subsequent to heap leaching. The difference between the $19.5 million leaching cost and the $32.2 million mineral value would produce $12.7 million in contribution margin to be applied to other costs of remedial action. If the only other costs are those listed by Ford, Bacon and Davis Utah Inc. (1981) in their Durango report, then the following advantages apply:

- Leaching would pay for 58% of the $21.8 million cost of remedial action (other than leaching) with disposal at Long Hollow Site.
- The *net* cost would be less than that of reshaping, stabilizing, and covering the pile in place.
- Leaching and disposal at Long Hollow Site would be $12 million less expensive than conventional off-site disposal (such as at Bodo Canyon)

Conventional off-site disposal would make leaching and recovery of the strategic mineral values very difficult, if not impossible, both now or at some future time. The high dollar and energy costs of earth moving mean that potentially recoverable strategic minerals must be recovered as part of the conditioning process or that disposal should be carried out in a manner that will facilitate later recovery.

Whether sulfuric acid leaching of the tailings is conducted as part of an immediate uranium mill tailings remedial action program or is deferred to a later time will depend on the market prices for the mix of heavy metals in any given pile during the active remedial action phase. All the technology for the leaching process and subsequent separations of uranium and vanadium is available and well known, requiring only a relatively modest amount of applications research and development to adapt to the characteristics of any given tailings. However, technology for cobalt and other strategic mineral recovery needs to be developed. Any decision to use or not to use a leaching process should be determined on a basis of incremental benefit to the remedial action program and total recovery of strategic heavy metals. In other words, if the value of the materials recovered equals or exceeds the incremental cost of adding the leaching step, then leaching should be performed as part of the tailings treatment. All strategic metals present in substantial concentrations in the acid leachates should be separated and recovered if the technology is available or can be quickly developed.

APPENDIX B

SALT LAKE CITY COMPOSITE TAILINGS FOR THERMAL STABILIZATION STUDIES

Sample Collection and Composite Preparation

The five disposal areas (Mountain State quadrants A, B, C, D, and E) at the Vitro site are depicted in the map in the upper left of Fig. B-1. The small circles represent holes cored by Mountain States. A crude (because of the number of points available) surface contour map of each area is also given. The elevations correspond to the number of feet over 4200. Areas C and D are relatively flat and were fairly dry when sampled. Area B has several mounded areas and what would appear to be an associated "dug-out" area. This area was somewhat muddy when sampled. Area A is somewhat lower than the former three. Most of the lower (below the 40-ft mark) areas in quadrant A were water covered (with a thin layer of ice) during the sampling period. Water from the adjacent sewage treatment plant (denoted by the eight large circles in Fig. B-1) was actively being pumped into the area. Area E is characterized by very irregular terrain. This complex topography corresponds to ore storage pits and areas occupied by the old mill. Most of the northeast triangle was dry when sampled. Many of the low-lying areas (especially the pits) were muddy.

For our sampling, we assigned a distribution of barrels as described in Table B-I. Our desire was to minimize the number of holes dug and yet reasonably represent the site. The hole locations are shown by the darkened circles on the map at the upper left of Fig. B-2. [A contour map (based on the Mountain States drilling) of the depth of each tailings area is also given.] In addition to the barrels collected above, we collected "composite" barrels. These barrels were prepared so that a composite sample could be made by drying and mixing only five barrels of material. A description of the contents of each composite barrel is given in Table B-II. A barrel of soil was collected to evaluate the "top soil" in the area. In all, forty-two 30-gal. barrels containing 15 000 pounds were collected and shipped by truck to Los Alamos.

The sample holes were dug by a very experienced operator using a trencher (backhoe) able to reach a depth of 4 m. The 9-ft^3 bucket trencher generally was able to make a hole only 0.75 to 1 m wide by 3-4 m long. Cave-ins occurred during excavation of the sandy holes (ALA2, CLA, and DLA3) and the very wet hole (ALA1). As the operator reached a new depth, he piled one bucketful representing this depth to one side of the hole. Generally, eight piles representing eight depths were set aside. The remainder was placed on the other side of the hole. When the digging was completed, the barrels assigned to each hole were filled by shovel. Equal amounts from each pile were added to each barrel. The remaining tailings were then back-filled into the hole. Any original cover had been set aside and was replaced.

After the samples arrived in Los Alamos, they were prepared for pilot-scale conditioning tests. The lids were removed from the barrels and the wettest samples (ALAC1 and ALAC2) were placed in trays to facilitate drying. Agglomeration and drying were accomplished by tumble drying each barrel of tailings in a 9-ft^3 cement mixer heated by two 100 000-Btu kerosene heaters. During heating and mixing, the tailings material was homogenized, first into large clumps and then into smaller agglomerated balls. The degree of agglomeration and size of the balls were very operation dependent. Indeed, a fine powder could be produced in some modes of operation. Generally, however, the tailings formed balls about 0.5 to 1.3 cm in diameter (Table B-II). Drying required from 1 to 2 days per barrel.

The tailings materials were sieved to separate large agglomerates from the finer fractions. Two basic composites were prepared; one composite represents tailings from the entire SLC site and was composed of composited large agglomerates (MIX); the second composite is a site composite of fine material, which was blended and then agglomerated into small balls (AVG). Variations of these composite samples with admixtures of fluxing agents (NaOH) and COAL [to achieve an oxygen-starved system] were also prepared in 50-lb batches as feed to the rotary slagger used for the pilot-scale thermal stabilization tests. The elemental composition of these composites is presented in Table B-III. Table B-IV compares the composition of our AVG composite with the Mountain States Vitro site composite.

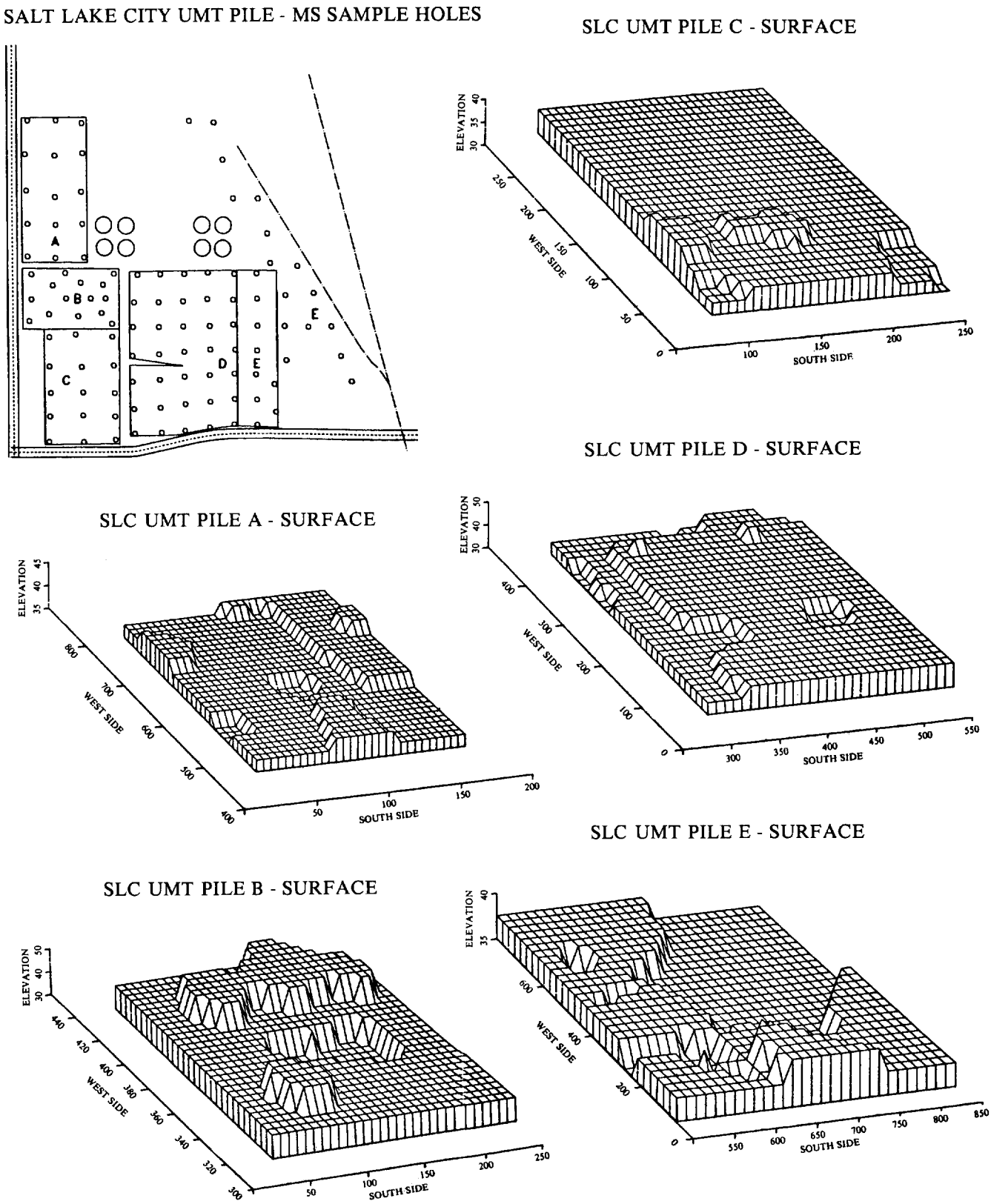
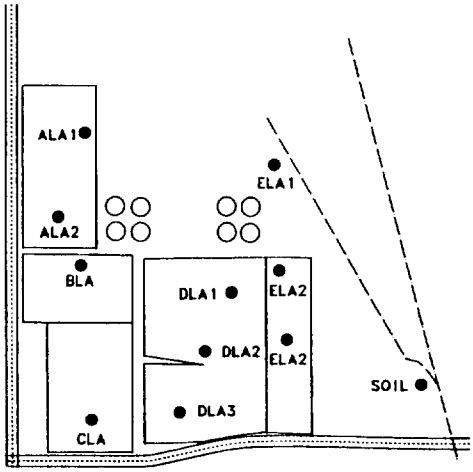
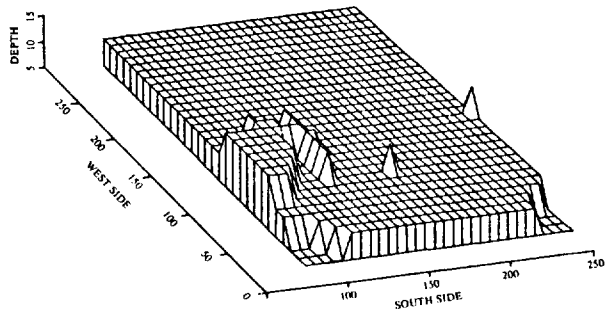


Fig. B-1. Surface topography at the Salt Lake City Vitro site [based on elevations obtained by Mountain States (MS)].

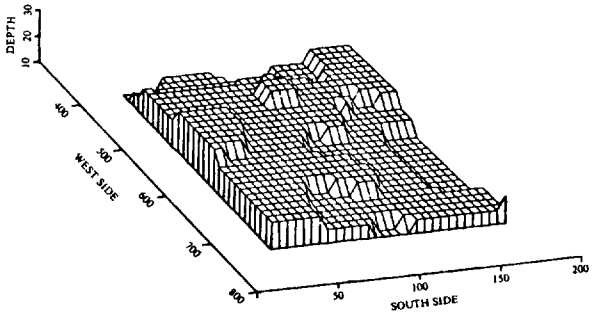
SALT LAKE CITY UMT PILE - LOS ALAMOS SAMPLE HOLES



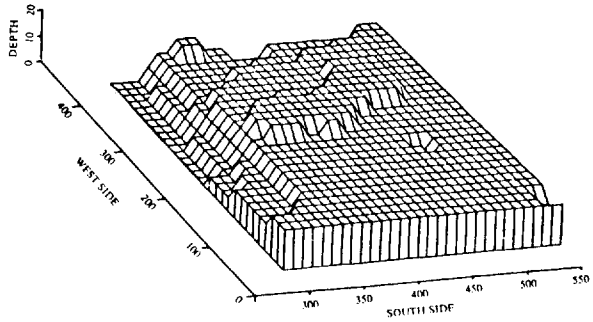
SLC UMT PILE C - DEPTH



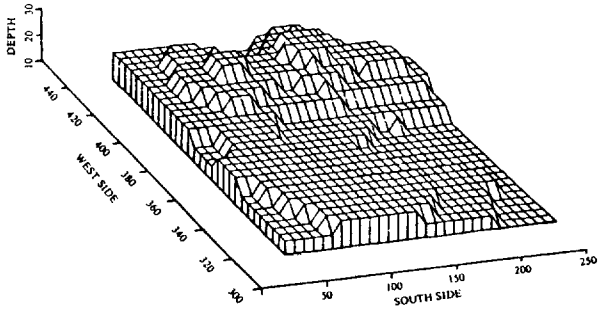
SLC UMT PILE A - DEPTH



SLC UMT PILE D - DEPTH



SLC UMT PILE B - DEPTH



SLC UMT PILE E - DEPTH

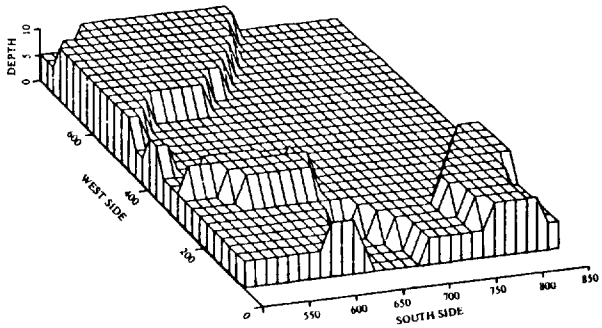


Fig. B-2. Depth of tailings at the Salt Lake City Vitro site (based on depths obtained by Mountain States).

TABLE B-I

DISTRIBUTION OF BARRELS FOR SAMPLING AT VITRO SITE[a]

Sampling Area	Fraction of[b] Total Tailings (%)	Number of Barrels			Fraction of Total Barrels (%)
		Hole 1	Hole 2	Hole 3	
A	26	4	4	–	24
B	12	4	–	–	12
C	13	4	–	–	12
D	42	5	5	5	45
E	7	1	0.5	0.5	6
Soil	–	1	–	–	

[a]30-gal. barrels.
[b]As reported by Mountain States Research and Development.

TABLE B-II

SALT LAKE CITY FIELD-COMPOSITED SAMPLES

Composite[a]	Holes Composited[b]	Dry Wt kg	+ 1/4 in. (%)	−1/4 in. (%)
ALAC1	1/2 ALA1 + 1/2 ALA2	132	33	67
ALAC2	1/2 ALA1 + 1/2 ALA2	131	71	29
BCLAC1	1/2 BLA + 1/2 CLA	129	80	20
BCLAC2	1/2 BLA + 1/2 CLA	113	72	28
DLAC1	1/3 DLA1 + 1/3 DLA2 + 1/3 DLA3	120	33	67
DLAC2	1/3 DLA1 + 1/3 DLA2 + 1/3 DLA3	128	68	32
DLAC3	1/3 DLA1 + 1/3 DLA2 + 1/3 DLA3	144	91[c]	9[c]
ELAC	1/2 ELA1 + 1/2 ELA2	110	64	36

[a]30-gal. barrel.
[b]As collected in the field.
[c]Reagglomerated; original drying gave >90% minus 1/8 in. powder.

TABLE B-III

COMPOSITION OF SALT LAKE CITY COMPOSITE MATERIALS USED IN PILOT-SCALE THERMAL STABILIZATION TESTS

Tailings Material	AVG	MIX	COAL
Element[a]			
Na (%)	0.63 ± 0.02	0.62 ± 0.02	0.57 ± 0.01
Mg (%)	0.48 ± 0.10	0.58 ± 0.08	0.38 ± 0.11
Al (%)	3.52 ± 0.08	3.72 ± 0.19	3.30 ± 0.09
Cl (%)	0.15 ± 0.01	0.16 ± 0.02	0.14 ± 0.01
K (%)	1.68 ± 0.14	1.85 ± 0.26	1.60 ± 0.09
Ca (%)	4.03 ± 0.17	4.47 ± 0.13	3.67 ± 0.17
Ti (%)	0.21 ± 0.03	0.27 ± 0.04	0.23 ± 0.03
Fe (%)	3.15 ± 0.24	3.35 ± 0.44	2.83 ± 0.14
V	863 ± 11	923 ± 59	763 ± 14
Mn	501 ± 10	480 ± 24	462 ± 63
Ba	1160 ± 90	1260 ± 300	1070 ± 170
As	148 ± 3	167 ± 8	130 ± 3
Sb	19.2 ± 0.7	21.2 ± 0.9	17.1 ± 0.5
La	32.0 ± 3.6	35.8 ± 2.3	28.8 ± 3.0
U	223 ± 9	282 ± 26	188 ± 12
Sc	4.3 ± 0.3	4.9 ± 0.2	3.9 ± 0.2
Cr	1600 ± 100	1800 ± 360	1420 ± 90
Co	50 ± 10	26 ± 2	35 ± 5
Se	12.2 ± 1.1	14.0 ± 1.8	10.9 ± 0.6
Rb	89 ± 9	87 ± 5	79 ± 12
Cs	5.0 ± 0.6	5.2 ± 0.6	4.5 ± 0.2
^{232}Th	12.4 ± 1.1	13.5 ± 2.1	11.3 ± 0.7

[a]Mean ± 95% confidence limits (n = 6, except Co, where n = 3).

TABLE B-IV

COMPARISON OF LOS ALAMOS[a] SLC COMPOSITE AND THE MOUNTAIN STATES[b] VITRO COMPOSITE
(Total and Leachable Constituents)

	Tailings Solids % or μg/g		Leachate[c] (mg/ℓ)	
Element[b]	SLC	Vitro	SLC	Vitro
Na (%)	0.63	0.71	42	75
Mg (%)	0.48	0.84	75	94
Al (%)	3.52	4.1	<0.03	<0.05
Cl (%)	0.15	0.09		
K (%)	1.68	2.1		
Ca (%)	4.03	3.9	620	640
Ti (%)	0.21	0.25		
V	863	640	1.28	1.52
Mn	501	420	0.98	1.8
Ba	1160	1100	<0.02	0.03
As	148	117	0.27	0.20
Sb	19	12	0.24	0.27
La	32	32		
U	223	140	0.30	2.9
Sc	4.4	4.8		
Cr	1630	770	<0.01	<0.01
Fe (%)	3.23	2.76	<0.01	<0.01
Co	18.6	15.2	<0.04	0.08
Zn	240	130	0.03	0.04
Se	12.5	13	0.25	0.34
Rb	87	84		
Cs	5.2	5.0		
Th	12.6	10.2		
Cd	–	–	0.003	0.005
Mo	–	–	15.0	14.6
Pb	–	–	0.04	0.04
Cu	–	–	0.02	0.03
Ni	–	–	0.12	0.16
pH	–	–	7.3	7.3
SiO_2	–	–	58	57
SO_4^{-2}	–	–	1720	1820
Cl^-	–	–	27	63

[a]SLC composite used in pilot-scale kiln tests.
Vitro composite from Mountain States drilling and assay program.
[b]Values in μg/g unless otherwise noted.
[c]Leachates from 1:5 tailings to water.

APPENDIX C

CHARACTERIZATION AND STATISTICAL ANALYSIS OF MOUNTAIN STATES TAILINGS SAMPLES

1. Sample Collection and Preparation*

Most tailings were sampled by Mountain States Research and Development using a 6-in. hollow stem auger and split spoon system to obtain cores 30 in. in length. Split spoon samplers of both ~1.4 and ~2.4 in. i.d. were employed; most samples were obtained using the ~2.4-in. spoon. A few samples were obtained using Shelby tubes (3-in.-o.d. thin wall). From 56 to 113 holes were drilled at each site; the surface area of tailings ranged from about 5 to 100 acres (Brewer et al. 1982). At Mountain States, the individual samples were dried, crushed to less than 10 mesh, mixed, and split. Reject splits were packaged as archives; 500 g of each individual sample from one hole were composited to create a hole composite. The hole composites were multiply split to achieve the desired weight to create a quadrant composite and finally a site composite.

Neutron activation analysis was carried out on 4 cm^3 (3-6 g of tailings) of the individual reject splits. In addition, pulverized quadrant, site, and selected hole composites were analyzed by NAA.

Selected individual samples were analyzed by gamma spectroscopy for major gamma-emitting radionuclides (e.g., ^{40}K, ^{226}Ra, ^{227}Ac) and by AA and ICP for priority trace contaminants (Ag, Ba, Cd, Cr, Pb, Mos, As, Se).

The sample identification code used by Mountain States is as follows: the first letter represents a quadrant or section of a tailings site; the three-digit number is the hole number; the two-digit number represents the sample depth; i.e., 01 is the core from 0 to 30 in., 02 is the core from 30 to 60 in., etc.; if a core depth number is preceded by an S, it indicates that the drilling crew identified the sample as a subsoil sample below the tailings interface; e.g., S1 represents the first core containing subsoil, is 30 in. long, and is contiguous with preceding tailings cores. Finally, if numbers or D follow the depth code, the samples represent Los Alamos analytical replicate samples. The codes for the various tailings sites are as follows:

AML—Ambrosia Lake, New Mexico
RIV—Riverton, Wyoming
NR—New Rifle, Colorado
SPK—Spook, Wyoming
MBL—Maybell, Colorado
MH—Mexican Hat, Utah
VIT—Salt Lake City, Utah
SHR—Shiprock, New Mexico
GJT—Grand Junction, Colorado
GUN—Gunnison, Colorado
OR—Old Rifle, Colorado
TC—Tuba City, Arizona
GRS—Grants, New Mexico ***Soil***

2. Neutron Activation Analysis

The automated neutron activation system at Los Alamos' Omega West Reactor has been described by Garcia et al. (1982) and Minor et al. (1982). The irradiation and counting parameters were altered for tailings analysis to the following:

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*This information provided by J. Teel, Mountain States Research and Development, 1982.

	Delayed–Neutron Counting	Short Half–Life Products	Intermediate Half–Life Products	Long Half–Life Products
Elements	U	Na, Mg, Al, Cl, K, Ca, Ti, V, Mn, Sr, Dy	U, Ga, As, Br, Sb, W	Sc, Cr, Fe, Co, Zn, Rb, Cs, Ce, Eu, La, Sm, Tb, Yb, Lu, Hf, Ta, Th
Irradiation	20 s	0 s	220 s	220 s
Decay Times	10 s	20 m	4.5 – 5.5 d	20 – 25 d
Count Times	30 s	480 s	30 m	2 h
Counting Geometry				
Distance	–	~70 cm	7 cm	0.5 cm

The sample mass placed in the 4–cm^3 vials for irradiation varied from about 2.5 to 7.5 g; however, generally, sample mass was about 4.5 to 5.0 g.

3. Analytical Data—Salt Lake City and Shiprock Tailings

Tables C-Ia and C-Ib present the NAA results for Salt Lake City and Shiprock tailings, respectively. The tables are arranged to present first the major and minor elements along with U, V, and ^{232}Th. The trace elements are found in alphabetical order, in later sections.

The data from the analysis of selected trace elements by AA and ICP techniques are shown in Table C-II.

The radionuclide content and gross gamma counts of selected tailings and subsoil samples are presented in Table C-III for both Salt Lake City and Shiprock. These measurements were made with a Ge(Li) detector; the gross gamma counts were based on total counts minus background for the energy region 170 to 360 keV.

Table C-IV reports the summary statistics for the elemental concentration (NAA) data from both the Salt Lake City and Shiprock sites. Table C-V reports the mean compositions of clusters identified by cluster analysis. Table C-VI presents NAA data for hole composites; Table C-VII presents NAA data for section and site composites. Table C-VIII summarizes elemental composition of site composite samples.

TABLE C-Ia

NEUTRON ACTIVATION ANALYSES OF SALT LAKE CITY TAILINGS SAMPLES AND CLUSTER ANALYSIS CLASSIFICATION

				Major and Minor Elements plus Uranium and Thorium									
Sample ID	Cluster Class[b]	Non–NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
A–001 01	P	81.8	4.5	7.4	1.90	1.9	1.41	608	0.660	0.23	10.00	79	7.5
A–001 03	P	81.4	4.1	8.7	1.79	1.4	1.34	581	0.76	0.14	4.21	51	7.1
A–001 04	P	81.9	4.0	8.1	1.63	1.7	1.49	559	0.703	0.22	6.33	51	7.1
A–001 06	P	76.8	4.9	11.5	2.31	1.9	1.39	570	0.67	0.24	9.27	56	10.7
A–001 07	P	75.0	5.3	11.6	2.98	2.3	1.58	665	0.77	0.26	8.95	66	11.4
A–001 S1	S	85.3	6.3	1.8	1.75	2.1	0.40	169	2.02	0.12	2.37	35	13.3
A–004 01	T	88.6	4.4	1.2	1.47	2.7	0.27	215	0.96	0.19	23.04	143	8.2
A–004 02	T	90.2	3.48	1.1	1.22	2.5	0.17	135	0.763	0.20	34[a]	190	9.6
A–004 03	T	90.9	3.50	1.1	1.07	2.2	<0.10	130	0.80	0.18	28[a]	139	6.0
A–004 05	T	88.7	4.5	2.0	1.46	1.7	0.44	137	0.65	0.17	153[a]	510	8.6
A–004 06	P	83.9	5.7	2.2	2.99	2.6	1.16	300	0.98	0.29	40[a]	145	12.1
A–004 07	P	84.3	5.6	2.8	2.34	2.1	1.11	295	1.22	0.28	18.48	108	11.7
A–004 08	S	86.4	5.4	1.8	1.53	2.2	0.55	214	1.72	0.19	3.19	38	9.1
A–004 S1	S	85.7	5.6	2.4	1.64	1.8	0.68	215	1.82	0.14	2.90	35	14.4
A–008 01	T	90.3	3.9	1.2	0.96	2.3	0.19	118	0.72	0.17	33[a]	257	7.2
A–008 02	T	92.4	2.88	1.2	0.69	1.67	0.17	98	0.606	0.159	27[a]	238	4.4
A–008 04	P	79.8	5.3	7.7	2.44	2.0	1.28	546	0.80	0.29	174[a]	298	10.7
A–008 S1	P	80.3	6.5	5.0	2.87	2.5	1.23	853	1.00	0.28	12.80	87	13.4
A–008 S2	P	81.1	7.2	3.4	3.17	2.4	1.01	519	1.09	0.34	6.26	77	18.1
A–011 04	P	78.5	5.2	9.5	1.96	2.0	1.30	561	0.93	0.24	6.17	66	9.9
A–011 05	O	78.2	7.8	4.2	4.19	2.9	1.23	541	0.95	0.28	6.43	126	18.0

[a]Uranium analyzed by neutron activation, not delayed-neutron counting.
[b]S = soil.
P = precipitate.
T = tailings.
F = ferrophos.
O = other.
[c]TC = test charge or quadrant composite.

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
A-011 07	P	82.6	5.5	4.0	2.54	2.2	1.62	335	1.02	0.32	3.04	64	12.5
A-011 08	P	81.1	6.0	5.2	2.48	2.3	1.30	447	1.05	0.29	4.41	73	14.2
A-011 S1	S	86.7	4.9	2.6	1.10	1.9	0.88	180	1.52	0.19	2.80	40	8.2
A-011 S2	S	86.8	5.4	2.2	1.06	1.8	0.51	160	1.82	0.18	2.72	32	8.6
A-011 S3	S	86.4	5.6	2.2	1.09	2.1	0.48	168	1.84	0.14	3.01	34	8.0
A-011 S4	S	86.1	5.8	1.9	1.08	2.4	0.44	147	2.00	0.13	2.52	27	7.3
B-016 02	P	80.4	6.1	5.1	2.50	2.5	1.66	406	1.21	0.34	4.15	63	13.9
B-016 03	P	81.7	6.7	3.3	2.74	2.4	1.54	341	1.14	0.29	4.31	66	15.9
B-016 04	P	81.0	5.9	5.2	2.18	2.4	1.68	368	1.05	0.28	6.12	65	11.5
B-016 06	P	81.8	5.9	4.2	2.44	2.4	1.50	362	1.07	0.33	7.84	68	14.2
B-017 03	P	83.5	5.6	2.7	3.13	2.2	0.63	255	1.81	0.29	9.03	80	19.3
B-017 04	S	83.7	6.0	2.7	2.79	2.0	0.44	232	2.01	0.14	4.20	59	17.3
B-017 05	S	84.5	6.3	2.4	1.20	2.6	0.54	193	2.11	0.15	44[a]	64	7.1
B-017 S1	S	85.3	6.1	2.0	1.22	2.5	0.46	168	2.05	0.15	3.81	28	7.9
B-017 S2	S	87.0	5.4	1.9	1.05	2.1	0.35	172	1.81	0.11	3.11	32	7.4
B-017 S3	S	87.5	5.3	1.3	1.25	2.3	0.34	149	1.69	0.10	2.69	37	8.3
B-022 01	T	89.5	3.64	2.3	0.92	2.4	0.28	140	0.499	0.153	89[a]	210	53
B-022 02	T	91.7	2.76	1.4	0.79	2.3	0.16	115	0.439	0.15	46[a]	170	4.4
B-022 04	T	90.5	3.10	2.3	0.81	2.1	0.40	161	0.360	0.17	127[a]	335	3.6
B-022 05	P	85.7	4.3	4.4	1.46	2.1	0.74	325	0.514	0.28	493[a]	261	7.9
B-022 06	P	79.9	5.8	6.2	2.60	2.4	1.68	591	0.92	0.28	34[a]	89	12.0
B-022 07	P	84.1	5.0	4.3	1.72	2.0	1.37	286	1.07	0.24	143[a]	111	8.9
B-022 S1	S	86.7	5.1	2.3	1.69	1.8	0.60	180	1.54	0.21	5.87	44	10.8
B-022 S2	P	85.4	4.8	3.1	2.67	1.5	0.77	234	1.39	0.19	10.38	69	16.0
B-022 S3	S	86.1	5.3	2.2	1.69	2.0	0.53	187	1.66	0.18	5.30	52	11.6
C-025 01	T	87.7	3.60	3.3	1.30	2.6	0.47	177	0.680	0.15	80[a]	89	5.0
C-025 02	P	83.2	4.9	5.8	1.73	2.0	0.82	530	1.07	0.19	96[a]	67	7.6
C-025 S1	P	77.8	4.7	9.9	2.19	1.7	2.3	651	0.90	0.22	30[a]	51	10.6
C-025 S2	P	79.9	5.1	6.8	2.19	2.1	2.46	577	0.89	0.27	5.22	59	10.6
C-025 S3	P	82.6	4.8	5.7	2.17	1.8	1.52	519	0.95	0.24	12.02	62	10.9
C-025 S4	P	79.8	5.6	6.7	2.42	2.4	1.59	590	0.93	0.27	9.66	73	11.5
C-025 S5	P	78.8	6.0	6.9	2.59	2.4	1.8	586	0.94	0.27	4.09	80	12.7
C-025 S6	P	77.72	6.4	7.5	2.91	2.6	1.88	607	0.84	0.30	5.78	83	11.9
C-025 S7	P	76.0	5.9	9.8	2.53	2.5	1.89	649	0.72	0.31	4.51	79	11.6
C-025 S8	P	77.9	5.8	8.4	2.51	2.2	1.80	580	0.83	0.30	4.80	70	12.5
C-025 S9	P	81.0	4.7	7.3	2.19	2.1	1.62	476	0.73	0.17	3.36	51	11.2
C-029 01	T	90.7	2.91	1.8	0.84	2.4	0.37	137	0.502	0.102	210[a]	138	4.3
C-029 02	T	92.5	2.67	1.0	0.57	2.2	0.20	74	0.424	0.174	49[a]	121	2.9

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	Non–NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
C–029 03	T	87.9	4.5	1.3	1.02	3.7	0.13	100	0.96	0.29	55 [a]	105	5.5
C–029 04	T	89.0	2.9	4.2	0.86	1.8	<0.1	71	0.449	0.28	941 [a]	236	8.7
C–029 S5	P	73.9	5.0	13.1	2.34	2.0	2.29	821	0.78	0.27	3.92	66	10.5
C–029 S8	P	83.5	4.6	5.3	1.63	2.0	1.23	371	1.17	0.27	12.87	45	8.6
C–029 S9	S	85.6	4.1	4.7	1.32	1.6	0.88	297	1.17	0.24	7.38	39	7.2
C–039 01	T	85.2	3.9	5.6	1.56	1.9	0.71	348	0.78	0.13	21.60	59	7.6
C–039 04	T	91.1	3.19	1.4	0.47	2.7	0.18	58.1	0.495	0.138	50 [a]	80	3.3
C–039 S3	S	85.0	5.4	3.4	1.34	2.1	0.64	343	1.71	0.18	8.97	32	8.2
C–039 S5	S	88.9	4.9	1.4	0.56	1.9	0.35	92	1.69	0.07	2.39	19	4.9
C–039 S6	S	87.9	5.0	2.1	0.92	1.9	0.26	130	1.70	0.10	6.36	19	6.3
C–039 S7	S	90.0	3.94	1.6	0.62	1.8	0.34	89	1.37	0.061	1.75	18	5.8
C–060 01	T	86.5	4.2	4.2	1.17	2.3	0.57	116	0.338	0.24	188 [a]	298	6.3
C–060 02	T	86.2	4.4	3.5	1.35	2.5	0.76	322	0.89	0.19	145 [a]	66	7.4
C–060 03	T	86.8	4.3	3.3	1.24	2.4	0.60	256	0.83	0.17	134 [a]	85	6.0
C–060 S1	P	84.9	5.7	2.5	1.89	2.6	0.87	302	0.91	0.31	116 [a]	135	9.7
D–047 01	T	91.9	2.60	2.0	0.88	1.5	0.19	123	0.557	0.110	112 [a]	301	3.4
D–047 02	T	90.3	3.52	1.2	1.01	2.5	0.13	137	0.80	0.18	117 [a]	206	4.4
D–047 03	T	88.5	4.1	1.3	1.98	2.3	<0.1	322	1.10	0.32	75 [a]	290	5.6
D–047 04	T	90.1	3.51	1.1	1.46	2.2	0.16	199	0.87	0.31	90 [a]	317	5.4
D–047 05	T	91.6	3.21	0.8	1.08	2.0	0.17	86	0.610	0.21	173 [a]	690	5.8
D–047 06	T	92.7	2.55	0.48	0.99	2.0	0.31	69	0.449	0.19	170 [a]	532	5.7
D–047 07	T	90.7	3.4	1.0	1.30	2.2	0.22	89	0.586	0.17	270 [a]	730	7.0
D–047 S1	P	75.6	4.7	11.8	2.42	2.0	2.11	548	0.73	0.19	135 [a]	160	9.9
D–047 S2	P	81.3	4.2	8.1	1.62	2.0	1.32	805	0.94	0.21	5.80	42	8.1
D–054 01	T	88.6	4.1	2.2	1.20	2.2	0.22	232	0.95	0.28	60 [a]	283	16.2
D–054 04	T	87.4	4.0	3.8	1.56	1.6	0.59	136	0.481	0.14	206 [a]	1110	7.8
D–054 S2	P	74.6	4.6	13.2	2.35	1.7	2.50	570	0.574	0.18	19.62	89	9.6
D–054 S3	P	70.6	4.1	18.2	1.90	1.6	2.4	691	0.57	0.26	5.54	56	8.5
D–054 S5	P	75.7	4.9	12.1	1.90	2.0	2.10	626	0.83	0.22	5.72	52	9.0
D–063 01	O	80.4	4.9	6.5	3.58	1.9	1.17	569	0.97	0.20	6.29	68	10.6
D–063 03	O	77.0	3.25	8.1	7.55	1.3	0.95	845	0.644	0.17	20.53	104	6.0
D–063 04	T	86.4	3.52	3.4	3.06	1.7	0.43	576	0.72	0.17	84 [a]	760	9.6
D–063 S1	T	92.1	1.77	3.3	0.64	0.92	0.82	101	0.220	0.094	87 [a]	171	4.2

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
D-063 S2	P	87.1	4.3	3.7	1.11	1.2	1.2	162	0.527	0.36	774 [a]	1190	15.2
D-063 S6	P	76.9	6.2	7.9	2.55	2.5	2.26	653	1.11	0.31	10.09	88	11.9
D-063 S7	P	77.3	5.9	8.2	2.83	2.0	2.10	639	1.11	0.29	14.90	124	12.8
D-073 01	F	61.6	1.7	12.4	17.4	<0.9	1.0	3240	1.18	0.36	68 [a]	3550	4.5
D-073 03	F	57.3	1.5	13.9	19.8	<0.8	<0.4	2440	1.24	0.52	82 [a]	6060	12.7
D-073 06	O	81.7	6.9	1.0	2.72	5.1	0.42	195	1.32	0.50	90 [a]	288	18.8
D-073 S1	P	81.1	5.4	6.4	2.39	2.2	0.97	406	0.81	0.24	407 [a]	1080	14.2
D-073 S2	P	79.1	4.4	8.3	3.13	1.6	2.14	1170	0.73	0.25	23.89	71	9.4
E-081 01	T	93.0	2.43	0.8	1.18	1.6	<0.1	79	0.355	0.16	214 [a]	1330	5.4
E-081 S1	P	83.4	4.7	5.7	1.86	2.0	1.12	392	0.699	0.23	282 [a]	720	8.7
E-081 S2	P	80.7	3.9	8.9	1.51	1.7	2.00	407	0.84	0.19	12.75	57	6.6
E-087 01	T	91.0	3.37	0.86	1.35	2.1	0.14	183	0.575	0.26	166 [a]	630	7.8
E-087 02	T	91.9	3.2	0.67	1.35	1.8	<0.09	115	0.529	0.22	129 [a]	540	6.8
E-087 03	P	90.5	3.38	1.0	1.35	2.3	<0.1	150	0.541	0.33	1013 [a]	1060	6.4
E-087 S1	P	82.1	4.8	6.2	1.77	2.2	1.21	390	1.27	0.26	51 [a]	109	10.6
E-087 S2	P	78.3	4.7	10.1	2.00	2.0	1.49	587	0.90	0.23	70 [a]	232	9.4
E-090 01	O	82.1	4.2	6.8	2.46	1.9	1.33	430	0.64	0.20	134 [a]	386	9.0
E-090 02	T	87.6	3.7	3.4	1.60	1.6	0.75	198	0.612	0.19	230 [a]	790	7.9
E-090 03	F	74.2	1.4	6.9	13.0	<1.0	<0.5	3200	0.48	<0.2	329 [a]	8500	13.0
E-090 S1	P	8.22	4.8	6.1	1.84	2.1	1.50	410	1.07	0.26	9.11	87	9.3
E-090 S2	P	80.6	5.2	6.7	2.09	1.8	2.22	476	0.95	0.26	8.48	95	9.5
E-094 01	P	82.3	4.4	6.1	2.61	1.4	1.8	501	0.532	0.32	842 [a]	650	12.9
E-094 03	P	81.1	4.1	8.2	1.87	1.5	1.75	493	0.85	0.20	520 [a]	490	9.5
E-094 S1	P	81.4	4.8	6.4	1.88	1.9	2.06	503	1.01	0.26	33 [a]	65	9.3
E-096 01	F	69.7	2.4	10.4	11.5	<0.6	0.8	1580	1.41	0.30	151 [a]	5370	9.9
E-096 02	F	62.7	1.1	13.5	16.0	<1.0	<0.5	3460	1.27	<0.2	93 [a]	5120	19.3
E-096 05	O	78.8	2.9	8.0	5.86	<0.5	1.1	1760	1.14	0.24	24.02	1700	6.4
SLC-TC A[c]		83.9	4.8	4.9	1.85	2.3	0.82	375	1.01	0.23	25.02	169	9.5
SLC-TC B		86.1	4.8	3.4	1.46	2.4	0.59	198	0.77	0.14	105 [a]	202	8.5
SLC-TC D		85.8	3.8	3.8	2.75	1.9	0.42	512	0.72	0.24	152 [a]	970	12.6
SLC-TC E		84.8	3.6	4.1	3.22	2.0	0.61	588	0.68	0.22	369	[a]1730	9.5
SLC-TC Site		84.8	4.2	4.3	2.34	2.3	0.54	430	0.74	0.27	143 [a]	690	10.0

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
				Trace Elements (A to H)									
A–001 01	P	46.9	470	12.5	66	<80	7.7	72	5.3	3.3	870	<10	4.1
A–001 03	P	29.1	360	16.1	52	1360	7.7	70	3.6	2.3	890	<10	4.4
A–001 04	P	34.7	350	15.6	53	1060	6.8	74	3.6	3.8	710	<12	4.7
A–001 06	P	10.5	460	9.0	67	270	10.3	57	6.0	3.2	820	<10	3.6
A–001 07	P	15.5	620	7.8	71	280	9.6	54	10.1	3.2	900	11	2.9
A–001 S1	S	<2	1120	<2	110	270	4.2	23	2.1	1.8	1000	<20	4.0
A–004 01	T	55.2	1110	2.6	52	<60	3.2	28	6.5	1.7	540	<13	5.8
A–004 02	T	123	1540	2.5	57	<60	3.1	23	4.5	1.4	490	<12	5.9
A–004 03	T	118	1070	2.6	42	<60	2.8	23	5.8	1.5	470	<10	5.4
A–004 05	T	106	1470	3.7	125	<60	13.2	29	5.9	2.5	780	<10	4.8
A–004 06	P	58	890	5.4	98	80	20.0	48	7.4	4.2	1010	14	4.6
A–004 07	P	22.3	820	1.6	102	110	12.3	37	6.3	4.1	1290	12	6.7
A–004 08	S	4.4	940	<2	90	<90	5.1	22	2.3	2.4	760	<20	4.8
A–004 S1	S	<2	890	<2	124	<90	4.9	24	2.1	2.4	1250	<20	4.8
A–008 01	T	92	880	<1.3	53	<60	2.8	26	8.6	1.3	700	<20	5.8
A–008 02	T	89	1150	1.2	46	<50	1.3	19	5.8	1.1	380	<12	4.5
A–008 04	P	69	650	10.1	139	160	32.5	58	5.6	5.3	1200	<20	4.3
A–008 S1	P	18.1	690	3.9	92	<90	14.2	51	8.1	4.5	1040	12	4.5
A–008 S2	P	11.1	880	2.8	106	<100	12.6	58	10.6	4.3	1300	<20	5.3
A–011 04	P	24.6	750	8.8	74	180	8.4	46	7.3	3.1	800	<20	3.1
A–011 05	O	47	560	5.1	115	200	15.3	69	12.5	3.6	1300	<20	4.8
A–011 07	P	8.9	720	2.8	97	140	10.7	49	5.8	4.5	1100	<10	6.1
A–011 08	P	12.1	810	2.3	90	140	10.7	56	6.6	3.9	970	<20	5.0
A–011 S1	S	2.5	700	<1.6	91	150	5.2	22	2.0	2.8	760	<20	5.5
A–011 S2	S	4.1	770	<2	91	<80	4.5	17	2.1	1.7	840	<20	4.3
A–011 S3	S	7.1	1030	<1.5	72	100	3.8	18	1.3	2.3	730	<20	4.1
A–011 S4	S	8.1	1160	<1.7	72	150	3.8	17	1.5	2.0	720	<20	3.2
B–016 02	P	5.8	760	3.2	101	450	11.6	47	7.9	4.1	1200	23	5.5
B–016 03	P	5.7	560	3.2	111	480	12.8	65	8.0	3.9	1400	<20	5.8
B–016 04	P	11.3	640	1.7	85	580	9.5	41	4.8	4.4	1020	<10	5.6
B–016 06	P	12.4	740	3.1	96	660	10.8	58	7.5	4.5	1070	<20	5.8

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
B–017 03	P	5.2	900	3.1	196	230	6.0	31	2.2	4.0	1480	<20	10.4
B–017 04	S	1.7	740	<2	163	230	5.3	28	1.7	2.9	1370	<20	7.4
B–017 05	S	10.5	1130	2.2	88	350	7.2	19	2.4	2.1	900	<20	3.4
B–017 S1	S	2.2	1060	<2	87	430	3.8	18	2.0	2.3	910	<20	2.9
B–017 S2	S	2.4	1080	<2	83	420	4.4	16	1.9	1.7	620	<20	2.8
B–017 S3	S	<1	1030	2.6	80	350	5.1	15	1.2	1.3	720	<20	3.4
B–022 01	T	103	1800	2.4	71	90	8.9	22	3.7	2.6	900	<10	4.4
B–022 02	T	108	2190	1.8	41	<50	3.7	17	2.6	1.4	500	<10	4.1
B–022 04	T	131	1990	1.6	76	80	20.1	17	1.8	2.3	690	28	3.8
B–022 05	P	128	1910	34	238	<70	79	29	4.0	3.3	1200	53	5.4
B–022 06	P	37.8	810	5.6	91	150	17.0	42	6.4	4.1	900	<10	4.8
B–022 07	P	40.0	960	<1.5	121	150	18.5	33	4.3	4.0	920	40	5.7
B–022 S1	S	3.0	720	<2	109	130	4.5	27	2.0	2.7	960	<20	6.2
B–022 S2	P	3.3	650	<1.6	149	210	6.3	32	1.7	3.1	1280	<20	9.0
B–022 S3	S	3.5	940	<1.5	100	240	4.5	27	2.4	2.8	880	<20	5.1
C–025 01	T	37.1	1690	2.3	55	<70	3.7	22	2.3	1.8	570	<12	4.3
C–025 02	P	19.2	880	4.5	99	90	10.3	31	4.2	3.0	870	<20	5.2
C–025 S1	P	21.8	630	3.9	92	<90	10.3	42	5.7	2.6	760	<20	4.5
C–025 S2	P	20.6	620	2.7	80	200	7.8	43	6.2	3.8	920	<10	4.4
C–025 S3	P	23.3	740	3.0	78	150	8.8	43	5.3	2.9	930	<10	5.4
C–025 S4	P	28.3	720	1.9	85	140	10.1	53	6.6	3.5	990	<20	4.4
C–025 S5	P	26	570	<1.5	86	<90	10.6	54	7.1	2.5	1000	<20	4.6
C–025 S6	P	24	660	2.6	92	150	10.7	64	8.0	4.1	1000	<10	3.3
C–025 S7	P	29.2	650	3.4	73	170	10.3	65	7.5	4.3	1000	<20	2.9
C–025 S8	P	28.6	720	2.5	92	140	10.0	57	7.1	3.7	1200	<20	4.1
C–025 S9	P	12.1	460	<1.3	78	<80	9.3	49	4.6	2.9	1000	<10	5.4
C–029 01	T	82	1850	1.8	85	<50	9.9	18	2.5	1.8	490	<10	3.7
C–029 02	T	34.7	1690	1.8	33	<50	2.1	17	2.7	0.89	390	<10	5.5
C–029 03	T	63	1300	3.3	49	160	1.8	22	5.7	1.5	630	<10	6.0
C–029 04	T	151	2120	<1.4	362	<60	14.0	31	2.4	2.1	1000	<10	5.9
C–029 S5	P	11.1	600	3.0	57	370	9.7	50	7.0	3.0	1000	<10	2.5
C–029 S8	P	21.5	720	2.2	67	1170	6.8	29	3.6	3.3	990	<20	6.3
C–029 S9	S	12.5	670	1.9	70	1770	6.2	24	3.5	2.7	730	<20	4.9
C–039 01	T	48	600	3.4	59	<70	5.2	34	3.9	1.7	720	<10	5.0
C–039 04	T	40.4	2200	1.5	33	80	4.3	17	2.6	1.40	450	<10	3.8

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
C–039 S3	S	5.6	900	<1.6	83	110	7.4	18	1.8	2.6	790	<20	3.6
C–039 S5	S	6.1	1100	<2	43	140	2.7	11	1.2	1.1	460	<20	2.6
C–039 S6	S	4.9	870	<1.6	64	190	3.8	14	1.1	1.4	670	<20	3.2
C–039 S7	S	4.4	870	<1.3	51	490	1.9	11	0.8	1.2	430	<10	2.6
C–060 01	T	123	1980	<1.3	118	<60	27.8	41	6.2	3.5	1020	32	4.0
C–060 02	T	26.3	1380	10.3	109	<70	13.2	26	3.8	2.8	710	30	5.4
C–060 03	T	39	1310	5.9	94	<70	6.7	40	2.4	1.3	700	<20	4.9
C–060 S1	P	84	1330	5.0	111	<70	13.7	38	6.0	3.4	900	<10	5.2
D–047 01	T	95	970	<1.0	62	<60	8.1	15	1.8	1.2	430	29	3.2
D–047 02	T	80	1190	2.0	74	<60	7.6	23	2.7	2.0	700	<10	4.4
D–047 03	T	83	950	<1.4	64	<70	7.2	41	4.8	1.3	800	<20	9.8
D–047 04	T	58.4	840	<1.1	52	80	5.6	53	3.7	1.2	600	29	7.0
D–047 05	T	121	900	2.1	81	90	8.4	62	3.7	1.6	590	38	4.3
D–047 06	T	78	850	2.0	78	970	8.7	46	3.8	1.5	470	35	6.4
D–047 07	T	119	880	<1.2	120	930	12.2	68	5.8	1.3	800	29	6.3
D–047 S1	P	43.4	500	5.1	118	990	37.9	46	7.0	3.9	960	39	3.9
D–047 S2	P	6.9	570	<1.3	62	370	11.5	32	3.3	2.4	850	<20	5.4
D–054 01	T	68	960	3.7	59	230	3.9	175	3.7	3.7	660	30	5.8
D–054 04	T	110	960	5.1	131	180	21.4	33	7.6	3.1	990	<10	4.1
D–054 S2	P	10.9	460	6.3	56	620	17.9	42	8.7	2.2	600	<20	1.6
D–054 S3	P	7.7	530	3.0	46	610	8.8	45	5.3	2.7	800	<20	1.8
D–054 S5	P	11.9	590	2.1	68	510	8.2	39	5.9	2.7	650	<20	2.7
D–063 01	O	42	890	<1.5	78	<90	9.0	80	4.2	2.7	910	<20	4.6
D–063 03	O	117	1100	3.4	59	270	7.6	77	3.1	2.5	700	<10	3.6
D–063 04	T	96	1010	2.4	75	1680	11.4	1230	4.6	2.3	630	<10	4.4
D–063 S1	T	33.6	340	1.0	59	90	9.1	50	1.6	2.7	510	<9	3.2
D–063 S2	P	69	990	<1.4	333	180	28.8	47	3.0	4.4	1100	<10	6.0
D–063 S6	P	46.1	550	1.8	80	480	10.2	67	7.4	4.4	960	<20	3.6
D–063 S7	P	26.6	710	2.4	87	670	13.8	61	8.4	4.3	980	<20	3.6
D–073 01	F	18.2	<300	<2	54	12 400	61	17 700	ND	<2	400	<20	2.1
D–073 03	F	41	<300	<2	67	15 600	77	18 200	2.5	<2	500	<20	1.6
D–073 06	O	200	1050	5.3	92	330	6.0	111	12.2	2.9	1160	<20	7.0
D–073 S1	P	48.1	920	5.6	222	190	16.1	121	5.7	7.2	1400	71	4.6
D–073 S2	P	23.3	410	<1.4	73	300	48.1	73	3.8	3.1	820	<20	3.8

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
E-081 01	T	78	820	2.0	93	110	16.7	94	3.5	0.8	600	28	5.6
E-081 S1	P	83	530	5.9	174	170	34.2	91	4.8	4.7	1080	56	4.6
E-081 S2	P	17.6	520	1.9	58	630	7.2	36	2.7	3.0	740	11	3.6
E-087 01	T	110	780	<1.3	94	110	11.3	87	5.2	2.2	570	42	5.7
E-087 02	T	93	640	11.9	77	<50	9.0	90	4.9	1.0	590	<10	5.8
E-087 03	P	152	1100	5.8	334	110	8.5	114	7.3	1.7	660	<10	5.3
E-087 S1	P	13.6	700	3.0	98	180	7.3	50	3.9	3.4	980	<20	6.7
E-087 S2	P	26.0	590	6.4	100	180	12.1	95	5.0	3.4	730	<20	4.7
E-090 01	O	43.4	480	5.3	107	400	18.8	74	4.3	3.7	790	42	3.7
E-090 02	T	75	740	3.8	137	550	20.1	106	4.5	3.1	750	54	4.7
E-090 03	F	69	<300	<1.4	141	700	55	8900	4.2	<2	380	50	3.9
E-090 S1	P	12.9	660	3.9	76	550	8.0	65	4.3	3.0	800	<20	5.4
E-090 S2	P	11.2	620	2.7	70	520	9.5	64	5.1	3.2	900	<20	4.4
E-094 01	P	62	1350	<1.4	322	350	20.8	250	4.2	4.4	730	<10	5.0
E-094 03	P	30.5	1490	5.3	212	360	29.5	225	2.9	2.9	800	<20	4.0
E-094 S1	P	10.6	650	1.8	77	280	16.5	45	4.4	3.0	660	<20	4.0
E-096 01	F	23.2	300	<2	86	11 200	44.8	9900	2.6	2.4	510	<20	3.2
E-096 02	F	12.2	<300	<2	65	14 400	68	12 000	ND	<2	ND	<20	1.4
E-096 05	O	8.0	430	3.4	54	6600	24.2	3750	2.3	2.3	580	<20	3.6
SLC-TC A		148	810	5.6	83	220	8.0	59	7.8	2.7	880	<20	4.6
SLC-TC B		88	1320	<1.5	110	<70	14.4	30	4.1	1.7	1100	<20	6.1
SLC-TC D		98	920	<1.3	102	1510	17.9	1180	4.7	3.0	900	44	4.3
SLC-TC E		96	630	4.1	166	1980	21.6	1600	4.8	2.7	800	70	4.4
SLC-TC Site		96	1010	2.7	121	1010	15.2	800	5.1	3.3	870	<20	4.7

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	I (ppm)	La (ppb)	Lu (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
			Trace Elements (I to Z)										
A–001 01	P	21	25.6	290	60	50.1	6.5	7	4.6	<200	1.5	2.3	85
A–001 03	P	<10	27.0	350	56	9.2	6.3	6.3	4.4	<200	<2	2.2	99
A–001 04	P	28	24.1	310	62	10.6	6.0	5.8	4.1	330	<1	2.2	60
A–001 06	P	22	28.8	310	100	3.7	7.5	5.4	4.5	660	3.3	1.8	100
A–001 07	P	<20	32.0	<100	100	3.8	7.6	<4	5.5	560	5.2	2.1	86
A–001 S1	S	<10	55.8	190	68	5.0	3.03	34	3.6	450	3.8	1.6	37
A–004 01	T	<9	24.1	200	113	13.0	3.21	10.3	2.82	290	5.0	1.5	28
A–004 02	T	<8	20.6	<70	118	7.6	2.76	11.8	2.9	270	5.2	1.7	41
A–004 03	T	<9	18.3	220	91	7.7	2.60	9.9	2.8	190	3.6	1.2	40
A–004 05	T	<10	37.1	300	100	14.8	4.8	11	10.2	<100	7.5	1.9	120
A–004 06	P	<10	41.0	330	110	2.5	7.3	<3	6.7	<200	8.7	2.5	180
A–004 07	P	<10	42.8	330	90	6.2	6.3	8.2	6.1	310	7.5	2.4	100
A–004 08	S	<10	38.6	170	68	0.7	3.65	6.0	5.0	340	4.1	1.6	34
A–004 S1	S	<10	54.6	210	64	<0.4	4.19	5.1	5.3	290	<2	2.5	59
A–008 01	T	<9	22.8	200	120	28.4	3.18	16	5.3	<100	3.5	2.2	23
A–008 02	T	<7	18.2	150	73	11.5	2.40	12.8	2.58	<100	3.3	0.8	35
A–008 04	P	27	43.2	440	80	2.5	7.4	<4	11.8	700	2.8	2.9	680
A–008 S1	P	<20	39.1	350	120	1.6	8.7	<3	5.9	<200	8.9	2.5	135
A–008 S2	P	<20	43.0	430	150	1.6	10.5	6	6.4	380	6.9	3.0	134
A–011 04	P	28	30.9	260	81	2.9	6.3	<4	4.8	570	3.3	1.9	93
A–011 05	O	<20	47.0	320	180	3.6	12.0	7	6.6	400	7.8	3.0	130
A–011 07	P	<10	40.4	320	100	1.6	8.2	7	5.0	250	5.2	2.8	99
A–011 08	P	<10	38.7	310	100	1.7	7.9	<3	4.7	450	3.7	3.1	82
A–011 S1	S	<10	35.7	250	49	<0.3	3.56	9.7	4.5	380	2.0	1.5	30
A–011 S2	S	<10	43.4	190	66	0.4	3.05	45	3.7	420	<2	1.5	24
A–011 S3	S	<10	33.7	200	61	0.8	2.92	4.9	3.3	380	2.0	1.8	30
A–011 S4	S	<11	35.3	130	70	<0.3	2.49	4.2	3.2	530	2.3	1.1	15
B–016 02	P	15	41.4	390	130	1.2	8.1	6.2	5.8	600	7.0	2.7	105
B–016 03	P	<10	45.4	480	120	1.0	10.5	<4	6.3	<200	4.6	2.9	120
B–016 04	P	<10	38.6	320	100	0.8	7.4	<3	5.6	370	6.9	2.6	95
B–016 06	P	<10	42.1	290	110	1.08	8.7	7	6.1	330	5.1	2.8	84

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	I (ppm)	La (ppb)	Lu (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
B–017 03	P	<10	84.2	310	56	<0.4	3.95	12.9	8.6	350	8.2	2.6	32
B–017 04	S	<10	80.3	250	61	<0.4	3.75	56	6.9	<200	6	2.5	<10
B–017 05	S	<10	34.4	310	82	0.9	3.19	<10	4.9	500	2.7	1.5	59
B–017 S1	S	<10	36.8	170	81	<0.3	3.04	3.7	4.2	400	3.1	1.4	18
B–017 S2	S	<10	34.6	110	73	0.33	2.60	3.6	3.0	380	3.1	0.9	21
B–017 S3	S	<9	38.6	140	67	<0.3	2.55	31	3.4	330	<2	1.3	15
B–022 01	T	<7	21.4	270	80	8.4	3.25	15	6.0	460	3.7	1.8	140
B–022 02	T	<7	14.3	190	83	9.3	1.92	10.1	<0.06	390	1.8	1.0	85
B–022 04	T	<9	18.2	280	51	8.5	2.62	15	8.2	480	2.7	0.9	119
B–022 05	P	<10	42.9	640	120	12.9	5.7	14	25	490	4.4	2.2	240
B–022 06	P	31	38.0	320	120	2.0	7.5	<3	6.3	440	5.1	2.3	125
B–022 07	P	<10	38.4	370	70	2.1	5.4	8.8	10.5	380	4.4	2.3	91
B–022 S1	S	<10	44.4	250	59	<0.3	3.76	5.6	5.4	280	5.9	1.8	26
B–022 S2	P	<11	75.5	330	60	<0.3	4.35	9.9	7.9	280	8.9	3.1	28
B–022 S3	S	<9	45.5	190	66	<0.3	3.53	<2	4.0	370	5.0	1.8	43
C–025 01	T	<9	17.9	270	79	3.3	2.82	6.3	5.0	600	2.9	1.1	86
C–025 02	P	68	32.2	310	73	1.6	4.73	5.8	8.2	620	2.4	1.5	78
C–025 S1	P	42	35.2	290	90	<0.3	6.6	42	7.8	380	3.1	1.8	90
C–025 S2	P	29	34.4	370	77	1.1	6.9	5.7	4.4	390	2.8	2.3	60
C–025 S3	P	23	32.3	380	95	1.5	6.2	<3	4.2	450	3.7	2.7	98
C–025 S4	P	<20	36.3	390	94	1.1	7.6	4.5	5.9	380	4.9	2.5	125
C–025 S5	P	<10	42.7	250	100	<0.3	8.4	43	6.0	<200	5.8	2.3	80
C–025 S6	P	<10	37.6	290	120	1.2	9.4	<4	5.6	340	4.5	3.0	120
C–025 S7	P	<20	35.2	340	110	1.2	8.7	4.8	5.3	570	3.0	3.0	74
C–025 S8	P	<20	36.7	440	110	1.4	8.4	4.5	5.7	600	4.5	2.9	115
C–025 S9	P	<10	33.8	350	80	1.1	7.4	51	4.6	<200	3.7	2.5	57
C–029 01	T	<8	18.2	240	100	6.0	2.14	<30	10.5	660	2.9	1.0	61
C–029 02	T	<7	11.0	<70	100	4.8	2.13	8.3	2.80	550	4.3	0.8	27
C–029 03	T	<9	15.5	290	140	14.9	3.72	11.1	4.0	450	13.5	1.6	60
C–029 04	T	<10	34.4	660	80	7.5	3.79	37	43	660	<2	1.4	48
C–029 S5	P	<20	29.2	240	80	1.0	6.8	<3	4.0	960	3.2	2.0	96
C–029 S8	P	<10	31.2	310	82	0.66	5.11	6.6	4.1	350	2.4	1.6	58
C–029 S9	S	<10	28.0	290	62	0.41	4.29	6.6	4.4	280	<2	1.6	46

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	I (ppm)	La (ppb)	Lu (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
C–039 01	T	<10	24.9	<90	73	5.9	4.54	6.4	5.7	<200	2.2	1.6	210
C–039 04	T	<6	12.4	190	92	4.0	2.40	5.9	3.4	760	4.6	<0.5	32
C–039 S3	S	<10	37.6	170	60	0.69	3.19	4.1	4.3	380	3.7	1.9	36
C–039 S5	S	<10	22.7	80	54	1.0	1.53	2.6	2.0	280	<2	1.5	14
C–039 S6	S	<9	31.0	100	57	0.5	2.26	28	3.3	290	<2	0.8	22
C–039 S7	S	<8	23.8	170	58	0.89	1.49	<2	1.45	<100	<2	1.1	12
C–060 01	T	<9	33.8	340	80	18.4	4.71	15	<0.1	620	5.4	2.6	130
C–060 02	T	16	29.7	370	74	6.7	4.27	7.4	10.1	490	4.2	1.8	120
C–060 03	T	<11	27.6	450	90	7.7	3.58	8.6	8.3	480	<2	1.1	66
C–060 S1	P	<10	34.9	290	93	11.0	6.4	14	8.7	440	3.2	1.6	105
D–047 01	T	<8	15.1	210	58	5.8	2.12	13.8	6.1	340	1.9	<0.5	121
D–047 02	T	<9	14.3	200	88	7.9	3.01	12.5	7.0	740	5.0	0.7	122
D–047 03	T	<10	17.7	230	106	11.7	3.86	16.9	5.2	400	6.7	0.7	160
D–047 04	T	<9	16.4	200	78	6.7	3.20	17.3	5.1	320	4.8	1.3	113
D–047 05	T	<9	17.0	210	110	6.1	3.52	25	8.1	<100	4.3	1.0	166
D–047 06	T	<8	14.7	340	77	5.5	3.54	19	9.4	210	6.1	1.3	114
D–047 07	T	<9	24.9	290	130	8.2	4.43	26	13.8	<100	6.4	1.2	200
D–047 S1	P	38	34.3	480	110	2.1	7.0	8	9.5	700	3.4	1.6	420
D–047 S2	P	<20	28.8	240	71	0.87	4.79	4.7	4.1	600	1.9	2.1	72
D–054 01	T	<10	17.3	630	80	27.5	4.02	23	5.4	360	8.8	4.0	160
D–054 04	T	<10	38.2	300	80	7.7	4.4	32	12.6	<200	6.0	1.7	120
D–054 S2	P	80	24.0	410	100	1.6	6.6	<4	4.2	930	3.3	2.0	140
D–054 S3	P	72	22.4	<100	90	0.80	6.0	<3	3.1	1020	1.9	1.5	100
D–054 S5	P	16	28.0	280	80	0.84	6.0	4.8	4.6	920	4.7	2.0	90
D–063 01	O	<20	35.8	260	70	13.4	6.6	<4	4.9	230	3.9	1.8	1530
D–063 03	O	<10	29.1	190	70	35.4	4.58	<4	3.8	360	14.0	1.3	6660
D–063 04	T	<10	27.3	330	74	13.5	3.82	18	6.3	350	6.4	1.8	270
D–063 S1	T	<8	18.5	300	24	2.8	2.53	8.9	6.1	<100	2.0	1.1	83
D–063 S2	P	<10	53.7	930	60	6.0	5.7	17	37	360	3.3	3.6	450
D–063 S6	P	28	37.2	330	100	1.2	8.6	<3	5.5	<200	7.5	2.3	123
D–063 S7	P	22	35.5	330	90	1.3	8.8	4.9	5.1	430	6.3	3.2	130
D–073 01	F	<50	14.0	<300	<40	2.9	2.77	<12	4.6	<700	5.3	<2	80
D–073 03	F	<40	14.4	<300	<50	7.4	3.14	11	8.8	<600	6.1	<2	30
D–073 06	O	<10	31.6	260	270	24.3	8.8	17	6.9	500	21.8	2.0	138
D–073 S1	P	<10	47.6	580	84	2.1	8.2	<50	22.8	330	2.8	3.3	270
D–073 S2	P	<20	28.2	340	71	0.81	5.6	34	5.1	<300	2.4	2.1	190

TABLE C-Ia (cont)

Sample ID	Cluster Class[b]	I (ppm)	La (ppb)	Lu (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
E-081 01	T	<9	17.6	180	80	8.6	3.15	35	10.5	<100	4.9	1.4	110
E-081 S1	P	22	46.4	600	55	5.4	5.9	51	16.4	400	4.3	2.4	490
E-081 S2	P	29	24.6	280	66	0.88	4.91	4.8	3.4	<200	2.0	1.8	42
E-087 01	T	<11	19.6	230	100	8.3	4.39	33	9.5	170	6.1	1.0	131
E-087 02	T	<8	19.8	170	90	9.3	4.29	32	6.7	<100	5.3	0.6	63
E-087 03	P	<10	31.0	670	90	7.9	5.4	44	43	320	7.5	<1.0	73
E-087 S1	P	<10	40.8	360	81	1.0	5.01	9.6	6.0	560	4.2	2.8	68
E-087 S2	P	<20	34.0	280	68	1.8	6.0	9.7	7.5	480	<2	1.6	53
E-090 01	O	27	29.6	330	90	3.9	5.9	13	8.6	400	2.8	1.9	1230
E-090 02	T	<10	28.8	380	76	4.2	4.62	27	13.3	420	3.3	1.6	340
E-090 03	F	<50	22.0	<200	80	9.6	4.35	13	15.7	<700	9.3	3.4	130
E-090 S1	P	35	29.8	280	90	1.7	5.7	<3	4.1	460	1.9	2.0	64
E-090 S2	P	28	32.2	280	90	0.63	6.4	5.3	4.2	450	3.3	2.0	56
E-094 01	P	<10	41.2	870	70	5.8	6.6	64	42	<200	5.1	1.9	130
E-094 03	P	59	31.6	510	70	2.8	4.59	9	23.6	<200	3.6	1.3	250
E-094 S1	P	37	31.3	270	90	1.4	5.7	4.5	4.8	400	3.0	1.5	151
E-096 01	F	<30	19.0	<200	60	2.8	2.90	<10	8.7	<500	6.3	3.0	83
E-096 02	F	<50	15.0	<300	<40	1.9	2.02	<10	8.7	<700	4.2	4.2	70
E-096 05	O	<20	22.5	270	50	0.93	3.07	<5	3.4	<300	3.0	<1.1	59
SLC-TC A[c]		<10	33.1	280	100	12.5	5.4	5.5	5.2	330	4.3	1.7	53
SLC-TC B		<11	37.4	270	90	11.6	5.3	13	13.6	510	4.2	1.3	60
SLC-TC D		<10	26.4	320	80	12.3	4.52	24	9.0	360	7.1	2.9	180
SLC-TC E		<20	29.3	330	100	6.6	4.67	32	17.1	<200	6.4	1.9	240
SLC-TC Site		<20	29.5	320	90	11.4	4.76	18	10.0	590	5.2	1.9	160

TABLE C-Ib

NEUTRON ACTIVATION ANALYSES OF SHIPROCK TAILINGS SAMPLES AND CLUSTER ANALYSIS CLASSIFICATION

				Major and Minor Elements plus Uranium and Thorium									
Sample ID	Cluster Class[a]	Non–NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
B–003 03	P	86.1	3.6	4.3	3.05	1.3	0.38	290	0.79	0.17	68	830	8.7
B–003 04	SA	88.2	4.2	2.6	2.14	1.5	0.40	94	0.46	0.18	35	2150	9.8
B–003 S1	SB	86.1	3.9	4.2	2.42	1.4	0.99	330	0.48	0.22	61	181	10.3
B–012 01	TS	96.0	1.24	1.2	0.264	0.69	0.16	36	0.149	0.082	35	830	1.65
B–012 04	TF	92.1	2.11	3.1	0.67	1.10	0.29	117	0.211	0.13	30	1690	4.4
B–012 06	TS	95.0	1.67	1.6	0.287	0.81	0.15	22	0.105	0.086	34	1650	2.10
B–012 09	TCa	87.3	3.5	5.2	1.03	1.6	0.41	81	0.45	0.22	22.8	1170	5.3
B–016 01	TS	96.2	1.22	1.1	0.275	0.64	<0.1	53	0.129	0.088	48	960	1.82
B–016 04	TS	95.1	1.54	1.5	0.45	0.78	0.10	63	0.218	0.083	34	1050	2.5
B–016 05	TS	96.3	1.25	1.01	0.198	0.72	0.14	28	0.142	0.081	32	780	1.39
B–016 06	TS	96.7	1.17	0.59	0.188	0.88	<0.08	27	0.159	0.070	19.9	580	1.60
B–016 07	TS	95.3	1.38	1.5	0.234	0.85	0.27	21	0.129	0.076	23.5	1030	2.05
B–016 08	TS	94.3	1.83	1.8	0.36	0.98	<0.1	28	0.121	0.096	28	1570	2.5
B–016 09	TS	94.6	1.82	1.8	0.35	0.76	<0.1	31	0.118	0.088	71	1430	2.11
B–016 10	TS	93.9	1.97	2.2	0.38	0.97	<0.1	33	0.132	0.106	26	1720	2.4
B–016 11	TS	94.6	1.74	1.5	0.30	1.16	0.16	36	0.182	0.107	18.6	1080	1.87
B–016 12	TF	94.3	1.77	1.5	0.34	1.26	0.20	48	0.34	0.102	8.9	400	2.03
B–016 13	TF	90.9	2.9	3.0	0.58	1.4	0.33	66	0.49	0.17	12.2	630	3.5
B–016 14	TS	94.1	1.82	2.0	0.30	1.1	0.18	45	0.273	0.12	9.8	390	1.77
B–016 16	TS	95.5	1.45	1.1	0.232	1.14	0.14	40	0.220	0.078	9.5	370	1.47

[a]P = soil with precipitate.
SA = soil.
SB = soil with high magnesium, calcium.
TS = tailings sands.
TF = tailings fines.
TCa = tailings high calcium.
[b]TC = test charge or quadrant composite.
[c]A - 030 is a hole composite.
[d]D = analytical replicate.

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
B-016 17	TS	94.3	1.60	2.1	0.29	1.09	<0.1	44	0.244	0.084	11.3	570	2.01
B-016 S1	SB	84.9	5.4	3.8	2.13	1.7	0.9	460	0.51	0.25	220	1460	9.6
B-016 S2	SB	85.0	4.5	3.8	2.41	1.7	1.5	620	0.67	0.30	31	157	9.0
B-016 S3	SB	86.2	4.3	3.6	2.02	1.4	1.2	560	0.74	0.26	9.0	130	7.0
A-031 04	TS	96.2	1.31	0.89	0.32	0.72	<0.10	50	0.131	0.091	28	810	2.2
A-031 05	TS	96.4	1.18	0.9	0.215	0.75	<0.09	25	0.104	0.073	38	870	1.91
A-031 06	TS	95.3	1.41	1.5	0.28	0.92	<0.1	25	0.099	0.083	35	1380	2.4
A-031 08	TF	93.2	2.31	1.8	0.66	1.02	<0.1	125	0.37	0.14	34	1240	3.3
A-031 10	TS	93.9	2.04	2.0	0.34	0.99	<0.1	29	0.125	0.12	33	1690	3.0
A-031 11	TF	93.2	2.20	2.1	0.43	1.28	<0.09	50	0.43	0.14	12.0	530	2.5
A-031 12	TF	92.5	2.19	2.8	0.45	1.28	<0.1	50	0.38	0.12	12.0	520	2.5
A-031 13	TCa	88.2	2.5	6.2	0.59	1.4	0.29	52	0.35	0.21	22.5	1080	3.7
A-031 S1	SB	82.6	5.6	5.4	2.48	1.9	0.9	810	0.53	0.26	150	1330	9.5
A-034 01	TS	97.0	1.00	0.61	0.173	0.73	<0.07	30	0.149	0.065	26	490	1.21
A-034 02	TF	92.5	1.90	2.8	0.81	1.05	0.25	197	0.235	0.16	28	880	2.5
A-034 03	TS	96.2	1.32	0.92	0.227	0.84	<0.10	28	0.160	0.065	29	770	1.66
A-034 04	TF	91.6	2.7	2.7	0.60	1.1	<0.2	51	0.38	0.18	53	2300	4.9
A-034 05	TF	97.0	1.03	0.62	0.163	0.77	0.12	22	0.111	0.058	22.8	540	1.22
A-034 06	TF	92.6	2.4	2.4	0.50	1.09	<0.2	44	0.252	0.17	54	1900	3.4
A-034 08	TS	94.5	1.62	1.8	0.30	1.09	0.18	31	0.189	0.096	28	1300	1.54
A-034 09	TS	94.8	1.55	1.7	0.265	1.13	0.15	42	0.242	0.095	14.1	580	1.32
A-034 11	TF	92.2	2.39	2.5	0.55	1.42	0.18	66	0.44	0.15	19.6	530	3.2
A-034 12	TS	94.1	1.80	1.8	0.32	1.21	0.22	39	0.292	0.111	10.0	460	1.92
A-034 13	TS	94.7	1.65	1.6	0.28	1.21	0.16	43	0.241	0.078	11.1	460	1.79
A-034 14	TS	95.5	1.46	1.1	0.259	1.12	0.13	39	0.235	0.079	10.6	430	1.80
A-034 15	TS	95.7	1.39	1.1	0.218	1.11	<0.10	37	0.222	0.069	11.8	440	1.49
A-034 16	SB	81.9	7.5	3.5	1.26	2.6	1.3	84	0.59	0.30	150	5800	7.7
D-042 01	TF	91.2	2.6	2.4	1.08	1.28	0.66	290	0.43	0.15	140	710	4.3
D-042 S1	TCa	89.2	3.4	3.3	1.35	1.2	0.53	270	0.58	0.22	86	420	5.6
D-042 S2	TF	90.6	2.8	2.8	1.01	1.16	0.50	227	0.43	0.24	120	490	5.1
D-042 S3	SA	89.5	4.1	2.2	0.81	1.8	<0.1	90	1.07	0.20	2.46	37	4.9
D-048 S1	P	84.8	4.3	4.0	3.41	1.4	0.83	660	0.72	0.26	21.7	520	7.4
D-048 S2	TCa	86.6	4.2	5.1	1.15	1.6	0.40	105	0.54	0.30	10.5	410	5.3
D-048 S3	TCa	87.4	3.9	4.4	1.24	1.6	0.24	110	0.68	0.29	3.9	72	5.5
D-048 S4	P	85.5	3.4	4.2	4.0	1.5	<0.2	630	0.81	0.13	6.8	250	4.7
D-048 S5	SB	85.1	4.4	4.3	1.98	1.6	1.4	290	0.68	0.27	4.5	103	8.6

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
D-051 S1	SA	88.1	3.7	3.4	1.51	1.6	0.61	270	0.66	0.17	89	760	6.7
D-051 S3	SB	85.6	4.4	4.0	1.68	1.6	1.7	260	0.67	0.24	14.4	98	8.2
D-051 S4	SB	85.5	4.2	4.5	1.59	1.6	1.7	231	0.60	0.25	17.8	117	7.5
D-051 S5	SB	85.1	4.2	4.2	2.12	1.4	1.6	300	0.85	0.27	9.0	72	7.6
D-067 01	TCa	87.1	4.1	4.3	1.43	1.5	0.60	270	0.65	0.25	17.1	430	6.0
D-067 02	TCa	86.5	4.2	4.9	1.26	1.6	0.53	260	0.57	0.27	6.2	260	6.4
D-067 S1	TCa	86.8	3.9	5.7	0.95	1.4	0.36	80	0.51	0.22	7.7	280	4.7
D-067 S2	SA	88.2	4.5	2.6	1.38	1.7	0.33	103	0.82	0.24	6.1	320	7.2
D-067 S3	SA	89.6	4.2	1.6	1.26	1.8	0.34	107	0.89	0.23	6.6	230	7.2
C-072 01	SA	86.9	3.6	3.7	2.27	1.6	0.89	480	0.61	0.19	66	390	6.4
C-072 02	SA	87.0	4.2	3.4	1.78	1.7	0.70	360	0.69	0.22	76	1440	7.7
C-072 03	TF	90.1	2.8	2.6	1.37	1.5	0.70	300	0.53	0.13	100	890	4.5
C-072 04	TF	92.5	3.0	0.87	0.61	1.9	<0.1	70	0.66	0.08	39	1030	2.6
C-072 05	SA	88.9	3.3	3.6	0.93	1.8	0.30	102	0.51	0.18	130	2700	3.2
C-072 06	TCa	87.8	3.4	4.2	1.19	1.4	0.7	144	0.39	0.21	290	2500	4.3
C-072 07	TCa	87.2	3.3	5.0	0.97	1.5	0.7	159	0.37	0.26	710	3500	6.1
C-072 08	SB	84.2	4.8	5.1	1.95	1.8	1.03	430	0.57	0.24	87	940	9.1
C-072 09	SA	85.3	5.2	3.5	1.94	1.8	1.00	400	0.81	0.22	58	350	8.2
C-072 S2	SA	86.3	4.4	3.2	1.97	2.0	0.87	1640	0.76	0.20	12.8	97	8.3
C-073 S1	P	85.9	4.3	3.3	3.06	1.4	0.70	770	0.86	0.18	32	730	6.2
C-073 S2	SA	85.8	4.6	3.9	1.90	2.0	0.55	213	0.73	0.23	15.3	1100	7.7
C-073 S3	SA	86.5	4.8	3.4	1.85	1.6	0.48	168	0.65	0.25	46	3200	6.7
C-073 S5	SA	87.1	4.4	3.4	1.71	1.5	0.51	150	0.64	0.26	32	1590	7.2
C-084 01	SA	88.6	3.8	3.0	1.49	1.3	0.78	400	0.55	0.16	140	1170	6.1
C-084 02	SB	85.0	5.2	4.2	1.58	1.5	1.4	320	0.59	0.27	45	188	8.3
C-084 03	SB	86.0	4.4	3.9	1.71	1.6	1.4	390	0.56	0.26	30	230	7.1
C-084 05	SB	86.9	3.8	4.1	1.51	1.3	1.4	196	0.48	0.26	14.1	67	7.5
C-084 06	SB	86.9	3.6	4.2	1.34	1.6	1.5	181	0.46	0.24	22.9	67	7.0
C-084 07	SB	87.4	3.6	3.8	1.32	1.5	1.5	171	0.47	0.23	12.9	57	7.1
C-084 S1	SB	83.4	3.4	7.3	1.69	1.4	1.9	290	0.41	0.24	10.5	48	6.5
C-094 03	SA	88.5	3.7	3.1	1.55	1.6	0.45	370	0.63	0.13	100	1430	6.1
C-094 04	TF	89.9	3.1	2.9	1.12	1.3	0.6	390	0.52	0.11	240	1290	5.0
C-094 05	SA	87.1	3.8	4.0	1.96	1.6	0.47	260	0.64	0.19	78	660	4.2

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
C-100 01	P	86.6	3.3	3.2	3.6	1.4	0.52	1200	0.79	0.17	52	230	6.6
C-100 03	P	84.2	4.2	4.5	3.28	1.3	1.1	1110	0.86	0.21	56	620	5.2
C-100 04	SA	86.1	4.4	3.4	2.17	1.9	0.78	400	0.79	0.20	20.7	470	7.2
C-100 05	SA	86.8	4.1	3.3	2.06	1.8	0.58	450	0.92	0.18	26	550	5.9
C-100 06	SA	88.4	3.7	2.5	2.03	1.7	0.42	340	0.84	0.13	18.5	440	5.8
C-100 07	TCa	88.6	2.6	5.7	0.44	1.2	<0.2	83	0.52	0.22	73	2800	5.2
C-100 08	TCa	88.8	2.2	6.1	0.37	1.3	<0.2	72	0.50	0.23	91	1730	6.5
C-100 09	TCa	88.2	2.2	6.1	0.80	1.2	<0.2	130	0.41	0.27	1200	1660	9.1
C-100 10	SB	85.2	4.6	3.9	2.09	1.6	1.3	550	0.70	0.35	9.1	92	9.0
C-100 S1	SB	84.5	4.6	4.7	1.82	1.6	1.7	320	0.63	0.31	6.0	88	8.7
C-100 S2	SB	86.1	4.3	4.0	1.52	1.6	1.6	250	0.56	0.26	5.3	69	8.6
C-100 S3	SB	86.0	3.0	6.0	1.32	1.30	1.39	290	0.49	0.23	4.7	37	5.7
C-100 S4	SA	87.2	3.4	4.0	1.76	1.6	0.77	1160	0.82	0.18	5.1	35	5.8
D-104 03	P	83.1	5.1	3.9	3.32	1.9	0.91	870	1.21	0.31	74	490	6.7
D-104 04	P	83.9	4.4	4.5	2.85	1.5	1.3	730	0.90	0.18	71	390	7.3
D-104 05	TF	91.9	2.42	2.3	0.75	1.4	0.43	197	0.42	0.11	150	1250	2.9
D-104 06	TF	92.5	2.27	2.2	0.73	1.12	0.34	181	0.38	0.13	140	1170	3.1
D-104 07	TF	93.5	2.30	1.3	0.46	1.42	<0.2	84	0.39	0.09	52	1810	1.73
D-104 08	TF	92.8	3.0	0.72	0.37	2.0	<0.1	64	0.73	0.058	46	860	1.89
D-104 09	TF	92.9	2.5	1.4	0.49	1.39	0.27	64	0.55	0.10	190	1520	2.0
D-104 10	TCa	83.4	4.4	7.0	1.53	1.5	0.8	231	0.39	0.24	150	3400	6.4
D-104 S1	SB	84.1	5.4	3.7	2.13	1.8	1.2	530	0.69	0.36	900	670	9.8
D-104 S2	SB	82.4	5.8	4.7	2.24	1.7	2.0	440	0.68	0.36	11.5	87	10.0
D-104 S3	SB	84.7	4.2	5.0	1.71	1.6	1.8	250	0.52	0.29	7.3	60	8.7
D-104 S4	SB	86.6	3.4	4.7	1.25	1.6	1.5	221	0.48	0.23	4.2	49	7.0
D-104 S5	SB	85.5	3.3	6.1	1.40	1.4	1.4	280	0.47	0.21	4.7	40	6.6
D-104 S6	SB	84.7	3.7	5.3	2.24	1.5	1.5	2020	0.49	0.28	13.1	96	6.3
SHIP-TC[b] A[c]		94.0	1.75	2.0	0.45	1.12	0.14	63	0.242	0.10	33 [a]	950	2.6
SHIP-TC B		91.3	2.56	3.2	0.89	1.2	<0.1	166	0.12	44 [a]	1580	4.7	
SHIP-TC C		88.1	3.56	3.4	1.59	1.7	0.43	349	0.643	106 [a]	1210	5.3	
SHIP-TC D		87.7	3.8	3.6	1.69	1.7	0.49	366	0.611	0.18	73 [a]	1050	5.6
SHIP-TC Site		89.2	3.01	3.5	1.24	1.4	0.63	357	0.496	0.16	82 [a]	1280	4.7
A-030[c]		94.7	1.70	1.5	0.40	1.01	<0.1	41	0.235	0.093	30	960	2.6
A-031 06 D[d]		95.3	1.43	1.6	0.274	0.75	<0.1	34	0.103	0.086	37	1420	1.99
A-031 06 D		95.3	1.50	1.5	0.283	0.84	0.16	23	0.096	0.072	43	1410	2.3

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	Non–NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
A–031 06 D		95.5	1.52	1.4	0.265	0.80	<0.1	24	0.101	0.077	34	1380	1.82
A–031 06 D		95.1	1.54	1.7	0.33	0.78	<0.1	23	0.100	0.093	33	1570	2.6
A–031 06 D		95.1	1.45	1.6	0.277	0.93	<0.1	26	0.099	0.09	35	1390	2.05
A–034 13 D		94.7	1.57	1.6	0.252	1.20	0.19	40	0.243	0.085	10.7	470	1.62
A–034 13 D		94.7	1.57	1.5	0.30	1.24	0.20	41	0.243	0.097	11.1	460	2.06
A–034 13 D		94.5	1.59	1.9	0.29	1.10	0.19	39	0.240	0.106	11.4	480	2.2
A–034 13 D		94.9	1.55	1.5	0.29	1.14	<0.10	42	0.238	0.078	11.1	470	1.95
A–034 13 D		94.2	1.66	1.9	0.275	1.3	0.21	43	0.252	0.087	11.3	500	1.97
A–034 15 D		95.1	1.54	1.5	0.223	1.09	<0.10	37	0.220	0.099	13.0	510	1.47
A–034 15 D		95.4	1.49	1.2	0.216	1.11	<0.09	39	0.223	0.088	11.9	460	1.27
A–034 15 D		95.4	1.46	1.2	0.233	1.20	<0.08	37	0.216	0.076	12.2	450	1.46
A–034 15 D		95.6	1.48	1.1	0.211	1.12	<0.09	37	0.220	0.069	11.3	420	1.47
A–034 15 D		95.4	1.48	1.1	0.210	1.30	<0.10	38	0.221	0.086	11.8	430	1.34
C–072 02 D		87.0	4.0	3.6	1.89	1.5	0.75	390	0.67	0.18	81	1270	7.7
C–072 02 D		87.4	4.1	3.3	1.83	1.4	0.77	370	0.68	0.22	91	1310	7.4
C–072 02 D		86.8	4.0	3.5	2.01	1.6	0.9	590	0.67	0.16	87	1370	7.3
C–072 02 D		87.0	4.2	3.3	1.88	1.6	0.73	460	0.72	0.19	76	1380	6.9
C–072 02 D		86.8	4.0	3.7	1.96	1.6	0.71	430	0.67	0.18	85	1320	7.8
C–084 S1 D		84.4	3.3	6.8	1.73	1.02	1.9	270	0.41	0.26	10.6	49	8.0
C–084 S1 D		83.8	3.5	7.1	1.57	1.3	1.8	360	0.41	0.21	10.7	54	7.2
C–084 S1 D		84.1	3.5	6.8	1.55	1.4	1.8	260	0.44	0.22	11.2	49	6.9
C–084 S1 D		83.9	3.5	6.9	1.75	1.4	1.8	500	0.43	0.22	10.8	50	6.4
C–084 S1 D		84.3	3.4	6.7	1.58	1.21	1.9	227	0.41	0.21	10.6	50	6.8
D–104 S2 D		82.7	5.5	4.5	2.31	1.9	1.9	430	0.66	0.33	11.2	87	9.5
D–104 S2 D		82.9	5.4	4.4	2.41	2.0	1.8	420	0.65	0.31	11.5	78	10.0
D–104 S2 D		82.9	5.5	4.5	2.24	1.8	1.8	420	0.66	0.29	11.1	85	9.7
D–104 S2 D		82.5	5.7	4.7	2.32	1.6	2.0	440	0.67	0.29	10.9	84	10.4
D–104 S2 D		82.9	5.5	4.3	2.34	1.9	1.9	420	0.65	0.28	12.1	91	10.1

TABLE C-Ib (cont)

			Trace Elements (A to H)										
Sample ID	Cluster Class[a]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
B-003 03	P	125	960	<1.5	78	<60	3.6	42	3.3	4.5	750	<20	7.8
B-003 04	SA	27	440	2.6	54	<50	3.9	58	3.6	3.7	770	<11	8.6
B-003 S1	SB	7.0	780	4.5	95	<50	8.8	38	2.7	17.3	3800	21	7.2
B-012 01	TS	28	840	<0.7	19.9	40	0.90	18	0.87	0.98	240	<7	4.7
B-012 04	TF	24	880	<0.9	41	40	3.0	27	1.9	3.2	530	<9	4.5
B-012 06	TS	33	630	<0.7	28	<20	2.9	16	1.2	1.8	350	<6	4.0
B-012 09	TCa	17	760	<1.1	56	40	4.0	32	3.6	3.0	810	<11	5.4
B-016 01	TS	24	840	<0.7	25.3	44	0.85	25	0.97	1.07	210	4	5.0
B-016 04	TS	28	800	<0.9	28	40	2.9	30	1.04	1.5	310	<8	4.8
B-016 05	TS	16.6	730	<0.7	17.2	40	1.78	27	0.85	1.2	210	<6	4.5
B-016 06	TS	13.1	650	<0.6	17.8	40	1.20	20	0.98	0.90	200	<6	4.6
B-016 07	TS	25	820	<0.7	19.9	70	1.01	15	0.90	1.2	280	<7	3.8
B-016 08	TS	31	890	<0.8	35	60	2.03	35	1.1	1.5	430	<7	5.6
B-016 09	TS	33	910	<0.8	39	<30	8.7	120	0.99	1.4	350	<7	4.5
B-016 10	TS	27	790	<0.7	32	<30	3.9	58	1.5	2.2	500	12	4.6
B-016 11	TS	18	650	<0.9	21.5	70	1.51	37	1.1	1.4	380	<9	4.3
B-016 12	TF	6.4	590	<1.0	16.8	<40	1.04	16	1.3	1.4	330	<10	5.3
B-016 13	TF	6.5	630	<1.3	30	<40	4.5	21	2.2	2.5	540	<10	5.5
B-016 14	TS	4.8	560	<1.0	17.0	<40	2.8	13	1.3	1.2	320	<11	4.7
B-016 16	TS	4.5	530	1.3	12.4	60	2.8	11	0.99	0.88	200	<9	4.4
B-016 17	TS	6.2	520	1.5	14.0	30	1.83	11	1.3	1.3	270	<9	3.6
B-016 S1	SB	13.0	820	2.6	132	<70	19.5	45	4.1	9.7	1740	50	6.4
B-016 S2	SB	4.9	540	1.6	91	90	22.2	48	4.0	9.8	2060	<10	8.9
B-016 S3	SB	6.8	690	1.9	45	120	6.6	40	3.5	3.9	840	<20	7.0
A-031 04	TS	17.1	820	<0.7	21.7	50	1.77	32	0.94	1.0	270	<7	5.3
A-031 05	TS	22	810	<0.6	22.4	40	2.09	24	0.88	0.8	210	<6	4.9
A-031 06	TS	24	840	<0.7	30	60	1.85	27	1.2	1.0	370	<6	5.2
A-031 08	TS	22	910	<1.2	36	<40	3.2	28	1.3	1.7	440	<12	4.7
A-031 10	TS	33	840	<0.9	30	<30	1.64	20	1.2	1.7	440	<8	4.1
A-031 11	TF	9.3	640	<0.9	24.5	60	2.8	15	1.4	1.8	440	<10	5.8
A-031 12	TF	6.5	580	<1.1	21.8	60	2.5	15	1.7	1.5	420	<12	4.4
A-031 13	TCa	11.1	730	<1.3	52	<50	13.6	17	2.2	2.3	740	<10	3.8
A-031 S1	SB	17	760	2.6	111	<80	19.8	45	4.8	6.8	1650	<10	5.6

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
A–034 01	TS	11.9	770	1.1	16.5	<20	0.62	13	0.70	0.68	140	<6	5.0
A–034 02	TF	28	1000	1.8	31	<50	2.19	17	1.3	2.0	420	<10	4.3
A–034 03	TS	19	760	<0.8	21.1	24	1.29	15	0.99	1.2	240	<8	4.9
A–034 04	TF	39	1300	<1.4	57	100	5.2	70	1.9	2.6	780	<10	5.1
A–034 05	TS	13.7	620	<0.5	15.2	43	0.91	20	0.78	0.81	220	<6	5.3
A–034 06	TF	47	1300	<1.1	51	70	4.4	108	1.6	2.7	660	<11	6.1
A–034 08	TS	26	590	<0.9	24	<30	1.10	14	1.2	0.9	310	<9	3.7
A–034 09	TS	14.7	440	<0.9	13.0	<30	0.90	11	0.97	0.85	270	<9	4.6
A–034 11	TF	7.1	550	<1.0	27.0	50	5.9	19	1.9	1.2	450	<11	6.5
A–034 12	TS	4.8	610	<1.0	19.6	<40	6.0	11	1.2	1.2	350	<11	4.5
A–034 13	TS	5.7	560	<1.0	15.6	50	4.5	12	1.2	1.0	270	<10	5.3
A–034 14	TS	4.8	530	<0.7	13.5	28	4.8	12	0.96	1.1	250	<8	4.8
A–034 15	TS	5.6	480	<0.8	10.2	<40	1.31	8.7	1.01	0.84	210	<9	4.1
A–034 16	SB	27	1800	4	270	<80	126	49	2.9	8.0	3100	50	5.3
D–042 01	TF	10.9	730	1.9	80	100	3.8	28	2.2	2.5	530	34	6.6
D–042 S1	TCa	13.1	710	2.9	62	140	5.2	27	2.9	2.9	800	<20	7.1
D–042 S2	TF	8.9	3300	2.5	73	150	5.2	31	2.9	2.2	700	38	7.3
D–042 S3	SA	25	730	<2	37	120	1.90	17	2.4	2.3	710	<20	7.6
D–048 S1	P	14.9	870	2.6	57	160	9.0	36	3.9	3.7	1190	<10	7.4
D–048 S2	TCa	54	740	2.1	52	<60	2.5	38	5.9	2.6	870	<20	7.3
D–048 S3	TCa	67	740	3.3	53	<60	2.6	34	5.1	2.7	760	<20	8.9
D–048 S4	P	149	1300	<1.6	35	<70	3.7	16	1.7	1.9	540	<20	5.1
D–048 S5	SB	6.5	690	4.2	61	300	7.2	44	5.1	4.0	1170	<10	8.1
D–051 S1	SA	19	760	2.0	62	140	4.9	29	2.8	3.1	690	50	6.5
D–051 S3	SB	8.3	560	3.4	58	260	5.3	43	3.8	4.4	780	<20	8.5
D–051 S4	SB	11.8	440	2.6	55	230	4.9	44	3.5	3.7	790	<20	8.3
D–051 S5	SB	27	660	2.4	56	290	5.7	41	3.3	4.1	900	<20	9.3
D–067 01	TCa	18	640	2.8	45	170	4.6	36	3.4	3.4	690	<20	7.6
D–067 02	TCa	22	560	3.3	52	140	4.6	39	4.1	3.3	640	<20	8.5
D–067 S1	TCa	19	510	2.7	39	150	2.08	33	3.7	2.3	490	<20	9.0
D–067 S2	SA	14.3	770	2.2	50	100	3.3	33	3.2	2.8	650	<20	7.4
D–067 S3	SA	36	830	<2	44	<70	3.5	26	2.8	2.7	690	<20	7.3
C–072 01	SA	11.7	790	2.5	73	190	5.4	35	3.0	3.1	680	<20	7.5
C–072 02	SA	19	580	1.2	71	240	5.2	38	3.0	3.1	710	<20	7.2

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
C-072 03	TF	12.9	620	1.5	60	200	3.7	21	2.1	2.4	560	31	5.9
C-072 04	TF	19	840	<1.3	33	<50	1.42	11	2.0	1.0	460	<20	4.9
C-072 05	SA	24	820	<1.3	73	<50	3.8	18	1.6	2.1	640	18	3.9
C-072 06	TCa	21	1300	<1.2	148	<50	7.5	23	1.9	3.4	950	<12	5.4
C-072 07	TCa	24	1400	4.1	238	<70	4.5	27	2.5	2.8	750	<20	4.6
C-072 08	SB	7.6	730	3.7	104	80	8.2	47	4.5	5.2	1140	<20	9.1
C-072 09	SA	4.7	710	2.5	79	<70	8.1	37	4.8	4.0	1120	<20	8.7
C-072 S2	SA	7.1	610	<1.3	59	<90	12.3	43	3.8	4.0	920	<10	8.1
C-073 S1	P	13.3	1000	1.8	55	190	9.0	34	3.0	3.3	1010	<20	5.8
C-073 S2	SA	19	790	4.2	60	480	6.0	42	5.0	3.4	990	<10	8.7
C-073 S3	SA	13.0	620	3.6	67	360	9.2	38	4.2	4.4	1040	<12	7.9
C-073 S5	SA	15.9	720	2.8	60	300	11.5	41	3.8	3.7	760	<10	8.1
C-084 01	SA	12.1	680	3.6	78	150	5.7	29	3.0	3.0	670	38	6.4
C-084 02	SB	5.2	560	1.7	71	130	5.9	45	3.5	4.1	820	24	8.1
C-084 03	SB	8.2	610	3.0	56	130	5.4	42	3.5	3.9	740	<12	8.5
C-084 05	SB	5.2	570	4.3	51	140	4.5	47	3.5	3.6	750	<10	8.4
C-084 06	SB	5.8	580	4.2	46	120	4.1	42	3.4	3.6	770	<12	8.0
C-084 07	SB	3.9	430	2.4	51	120	3.7	42	3.1	3.8	720	<12	9.0
C-084 S1	SB	4.1	820	2.0	46	130	4.0	41	2.9	4.0	710	<10	7.6
C-094 03	SA	26	920	<1.4	61	<60	5.8	26	2.5	3.3	620	33	6.5
C-094 04	TF	17	1000	3.1	106	140	5.2	27	2.3	2.7	630	45	6.2
C-094 05	SA	31	690	2.1	68	110	6.1	42	2.6	2.8	670	<10	6.8
C-100 01	P	21	1100	<1.5	56	<100	6.7	21	2.0	2.8	700	<10	4.9
C-100 03	P	12.3	900	2.5	54	170	11.8	30	2.1	3.8	760	30	5.2
C-100 04	SA	48	660	<1.4	60	200	8.4	32	2.9	3.5	750	<10	7.0
C-100 05	SA	70	740	2.2	49	160	6.4	28	2.1	2.9	660	20	5.3
C-100 06	SA	65	740	<1.5	44	100	6.7	28	2.1	2.9	710	<20	5.3
C-100 07	TCa	10.3	1000	<1.5	66	110	5.7	19	1.6	4.6	940	<10	5.5
C-100 08	TCa	10.1	1200	<1.4	82	80	4.3	16	1.6	3.0	880	28	6.6
C-100 09	TCa	10.0	1800	5.0	430	110	4.0	32	2.0	3.4	960	<10	5.0
C-100 10	SB	5.8	710	3.1	61	<70	9.1	48	3.9	4.3	1000	<20	9.4
C-100 S1	SB	4.3	570	2.0	51	70	5.9	47	3.9	4.4	890	<10	8.1
C-100 S2	SB	5.5	460	<1.3	58	<50	4.8	49	3.7	4.4	840	<10	12
C-100 S3	SB	4.1	1500	<1.0	39	<50	4.3	32	2.0	3.5	610	<11	10.6
C-100 S4	SA	3.2	570	<1.4	47	<90	14.6	25	2.2	4.1	830	<20	7.3

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
D–104 03	P	14.3	1200	<2	64	140	8.7	32	2.2	3.4	900	<20	5.6
D–104 04	P	14.3	1600	2.5	78	190	7.1	35	2.6	3.6	810	<20	7.1
D–104 05	TF	11.3	840	3.1	74	90	3.3	16	1.6	1.7	450	34	5.4
D–104 06	TF	9.8	1200	<1.1	63	100	3.1	16	1.6	1.8	430	40	5.6
D–104 07	TF	9.2	750	<1.1	29	<40	2.19	10	1.4	0.8	270	<11	4.3
D–104 08	TF	12.7	830	<1.3	31	<50	1.10	7.1	1.3	0.8	350	<10	4.2
D–104 09	TF	11.5	980	<1.1	73	<40	1.96	8.2	1.1	1.5	330	41	4.3
D–104 10	TCa	29	1000	3.0	118	<70	7.6	36	3.2	4.1	1200	50	5.3
D–104 S1	SB	8.3	1700	6.2	330	<80	7.9	56	4.6	5.7	990	<20	8.5
D–104 S2	SB	7.6	530	1.8	71	<60	7.4	54	5.2	4.7	960	<20	7.1
D–104 S3	SB	5.0	510	<1.4	56	80	5.2	51	4.4	4.3	850	<10	7.8
D–104 S4	SB	3.6	380	<1.3	41	110	5.0	43	3.3	3.7	690	<10	8.0
D–104 S5	SB	3.7	420	<1.2	44	180	9.4	40	2.9	3.4	650	<10	6.6
D–104 S6	SB	5.6	440	<1.2	71	120	23.4	40	3.4	6.4	1160	<12	6.2
SHIP–TC A[c]		18.3	670	<0.9	34	50	5.0	28	1.7	1.4	360	<10	4.5
SHIP–TC B		30.4	950	<1.0	52	<50	5.8	39	1.9	2.1	640	<11	4.0
SHIP–TC C		19.1	670	1.9	76	110	5.8	23	2.2	3.0	890	26	4.5
SHIP–TC D		24.5	790	1.9	68	150	5.7	37	3.5	3.0	670	<10	5.2
SHIP–TC Site		21.2	690	2.1	77	90	5.8	28	2.9	2.2	670	31	4.1
A–030[c]		15.9	930	<0.9	32	70	11.0	25	1.5	1.8	440	<9	5.0
A–031 06 D[d]		27	820	<0.7	26.8	<30	1.67	19	0.99	1.5	410	<7	4.6
A–031 06 D		26	830	<0.8	36	<30	1.84	21	1.07	1.4	370	<7	4.6
A–031 06 D		27	820	<0.7	26	<30	1.80	17	0.95	1.3	390	<7	4.5
A–031 06 D		29	800	<0.7	31	50	2.02	23	1.2	1.4	450	<6	5.0
A–031 06 D		29	720	<0.8	29	40	1.63	18	1.04	1.5	390	15	4.5
A–034 13 D		5.9	660	<0.9	14.4	<30	4.4	11	1.0	1.0	260	<10	4.9
A–034 13 D		6.2	590	<0.8	15.5	<30	4.2	12	1.01	1.1	290	<8	5.8
A–034 13 D		5.8	620	<0.9	16.1	<40	4.1	12	1.2	0.97	330	<10	5.1
A–034 13 D		5.9	670	<0.9	16.1	<30	4.4	11	1.05	0.8	240	<10	5.5
A–034 13 D		7.3	560	<0.9	13.9	<30	4.7	11	1.2	0.9	260	<10	5.1
A–034 15 D		6.1	500	<0.9	12.7	<30	1.34	8.9	1.1	1.1	200	<9	3.9
A–034 15 D		5.6	470	<0.8	9.7	<30	1.23	9.5	0.92	0.8	180	<9	4.1
A–034 15 D		6.0	440	<0.7	11.7	40	1.35	9.3	1.03	1.1	240	<8	4.1
A–034 15 D		4.9	490	<0.8	9.8	33	1.16	11	1.01	0.88	180	<9	4.3
A–034 15 D		5.1	430	<0.9	10.6	<30	1.20	8.6	0.89	0.8	180	<10	4.2

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
C–072 02 D		17	620	2.4	74	240	5.7	38	3.3	3.8	770	<10	7.8
C–072 02 D		19	780	2.7	68	240	5.4	35	3.1	3.7	730	<20	7.7
C–072 02 D		19	840	2.5	77	240	5.6	39	3.2	3.6	740	<20	7.4
C–072 02 D		19	760	2.3	68	250	5.7	44	3.1	3.9	650	30	7.1
C–072 02 D		18	680	2.5	76	210	6.0	39	3.4	3.4	780	<10	7.9
C–084 S1 D		5.5	840	2.3	51	160	4.4	48	3.5	3.7	790	<12	8.7
C–084 S1 D		2.8	840	<1.2	46	150	4.1	43	3.3	3.6	800	<11	7.6
C–084 S1 D		4.9	730	2.4	50	180	3.8	38	3.4	3.6	690	<12	7.4
C–084 S1 D		5.4	960	1.8	46	130	4.2	39	3.3	3.5	710	<10	7.6
C–084 S1 D		4.1	1000	2.1	48	140	3.9	40	3.2	3.6	680	<12	8.0
D–104 S2 D		5.6	770	2.3	68	<60	7.6	50	4.8	4.7	920	<10	7.2
D–104 S2 D		6.4	680	1.8	69	<70	8.0	59	5.7	5.1	1040	<20	8.0
D–104 S2 D		6.0	510	2.5	59	<60	7.4	56	5.4	4.7	1010	<20	7.1
D–104 S2 D		5.0	650	2.3	74	<60	7.5	58	5.6	4.3	950	<20	7.7
D–104 S2 D		5.6	650	2.0	69	80	8.0	54	5.3	5.3	950	<10	8.0

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
			Trace Elements (I to Z)										
B–003 03	P	<10	24.0	430	51	1.3	4.55	12.4	7.0	<200	<2	2.7	41
B–003 04	SA	<9	22.2	290	59	0.86	4.77	11.0	5.3	250	<1	2.15	41
B–003 S1	SB	<9	32.6	710	55	0.76	5.54	4.4	16.6	<200	<1	6.2	100
B–012 01	TS	<6	9.4	140	27	1.09	1.25	50	2.5	190	<0.8	1.14	41
B–012 04	TF	<9	17.1	260	42	1.9	2.59	59	3.6	240	<1.1	2.50	52
B–012 06	TS	<6	12.2	100	31	1.29	1.38	31	3.0	170	<0.7	0.86	51
B–012 09	TCa	<7	23.6	240	67	1.9	5.6	39	4.6	210	<1	2.1	35
B–016 01	TS	<6	8.6	140	24	1.09	1.28	58	3.2	150	<0.8	0.99	110
B–016 04	TS	<7	9.7	180	31	1.47	1.46	42	2.7	180	<0.9	1.20	58
B–016 05	TS	<5	8.1	110	22	1.15	1.00	26	2.2	<80	0.8	0.86	31
B–016 06	TS	<4	7.4	120	29	0.82	1.00	21	1.60	<70	<0.7	0.81	31
B–016 07	TS	<6	10.2	100	29	1.12	1.22	29	2.3	140	<0.8	0.85	44
B–016 08	TS	<8	13.8	140	33	1.30	1.76	32	2.9	<100	<0.9	1.37	54
B–016 09	TS	<7	13.3	170	29	1.08	1.40	28	4.7	<100	<0.8	0.87	42
B–016 10	TS	<7	15.2	140	33	1.27	1.75	32	3.2	210	<0.8	1.13	54
B–016 11	TS	<7	10.2	130	38	1.11	1.52	30	2.3	200	<1.0	1.08	23
B–016 12	TF	<6	8.3	160	41	0.62	1.55	18	1.7	<100	<1.2	0.94	11
B–016 13	TF	<7	17.0	210	52	1.0	3.47	18	3.1	180	<1	1.48	15
B–016 14	TS	<7	8.8	110	40	0.8	1.76	23	1.8	<100	<1.2	1.05	12
B–016 16	TS	<5	5.8	140	36	0.90	1.70	21	1.23	<90	<1.0	0.95	15
B–016 17	TS	<6	6.7	90	43	0.92	1.47	43	1.5	<100	<1.1	0.92	9
B–016 S1	SB	<10	40	540	68	0.7	5.8	7.8	17	<200	<2	3.6	110
B–016 S2	SB	<10	36.2	560	68	0.6	6.6	5.3	9.7	<200	<2	4.4	80
B–016 S3	SB	<10	25.7	330	68	0.9	5.6	5.7	4.8	<200	<2	2.31	54
A–031 04	TS	<6	8.5	130	29	1.63	1.13	26	2.4	<100	<0.8	0.87	80
A–031 05	TS	<5	9.0	100	25	1.37	0.99	30	2.6	<90	<0.7	0.74	100
A–031 06	TS	<6	11.7	140	29	1.3	1.38	41	3.0	<100	<0.7	0.93	58
A–031 08	TF	<9	15.3	160	40	1.8	2.93	36	3.4	220	1.7	1.28	60
A–031 10	TS	<7	16.0	100	35	1.5	1.60	40	3.7	170	<1.0	1.01	48
A–031 11	TF	<6	11.4	170	44	0.94	2.15	22	2.3	<90	<1.2	1.49	23
A–031 12	TF	<7	12.1	160	50	1.4	2.50	27	2.4	210	<1	1.25	19
A–031 13	TCa	<9	22.9	230	47	1.8	4.85	60	4.8	250	<2	2.0	30
A–031 S1	SB	<20	39.8	470	78	1.1	7.2	11.1	13.7	<300	<2	3.1	100

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
A–034 01	TS	<4	6.0	100	26	0.97	0.79	21	1.8	<70	<0.7	0.66	31
A–034 02	TF	<9	12.9	150	36	1.8	1.96	57	2.9	210	<1.2	1.54	45
A–034 03	TS	<6	8.1	120	31	1.09	1.01	36	2.2	<100	<0.9	1.04	53
A–034 04	TF	<10	24.7	180	32	6.1	2.89	86	5.9	330	4.4	1.6	510
A–034 05	TS	<4	6.4	120	28	0.92	0.95	17	1.8	<70	<0.6	0.82	90
A–034 06	TF	<9	20.1	220	40	4.4	2.50	50	4.7	260	2.8	1.67	190
A–034 08	TS	<8	9.2	130	34	1.32	1.50	38	2.4	170	<1.0	1.05	43
A–034 09	TS	<6	6.4	90	35	1.0	1.31	32	1.6	150	<1.1	0.71	14
A–034 11	TF	<6	12.1	230	50	0.9	4.40	16	2.8	<100	<1	1.63	29
A–034 12	TS	<6	11.0	130	43	0.94	1.93	20	2.1	<100	<1.2	0.93	26
A–034 13	TS	<6	7.3	140	36	1.07	1.63	29	1.6	<100	<1.1	0.90	24
A–034 14	TS	<5	6.5	150	37	0.98	1.94	25	1.41	<80	<0.9	1.15	19
A–034 15	TS	<6	4.7	90	38	0.95	0.96	38	1.16	<90	<1.0	0.76	10
A–034 16	SB	<20	128	560	58	1.0	8.5	3.3	24	390	<3	3.8	110
D–042 01	TF	<9	19.0	320	54	0.8	3.08	15	8.9	170	<1.2	1.54	45
D–042 S1	TCa	<10	24.2	310	54	0.87	4.63	11.5	7.3	<200	<2	1.97	90
D–042 S2	TCa	<10	19.3	290	52	0.88	3.78	14	8.1	230	<1	1.75	35
D–042 S3	SA	<8	21.2	220	63	0.4	2.99	4.5	2.7	250	<2	1.74	<3
D–048 S1	P	<10	26.3	370	69	1.4	6.7	14	5.0	270	<2	2.5	53
D–048 S2	TCa	<9	29.6	320	68	2.1	4.95	19	4.0	<100	<2	2.26	30
D–048 S3	TCa	<8	24.0	330	66	1.4	4.41	12.2	3.4	210	<2	2.4	21
D–048 S4	P	<10	20.8	220	63	1.8	3.62	10.2	3.4	<200	<2	1.37	21
D–048 S5	SB	<9	28.4	340	70	0.70	7.0	3.6	4.9	230	<2	2.5	46
D–051 S1	SA	<10	24.8	290	58	2.1	4.56	12.3	7.6	<200	<2	1.99	58
D–051 S3	SB	<10	27.0	400	73	1.4	6.1	4.5	5.9	270	<2	2.7	41
D–051 S4	SB	<10	26.8	370	62	3.5	5.7	2.8	6.1	<200	<2	2.4	32
D–051 S5	SB	<10	26.0	420	73	9.7	6.7	6.3	5.2	<200	<2	2.5	38
D–067 01	TCa	<10	2.50	310	68	0.8	5.6	8.4	4.5	<200	<2	2.31	45
D–067 02	TCa	<10	25.2	320	67	0.7	5.8	9.4	4.1	<200	<2	2.3	30
D–067 S1	TCa	<7	22.5	240	71	1.1	6.5	10.7	3.6	<100	<2	1.79	<3
D–067 S2	SA	<7	24.7	260	75	1.0	5.20	3.3	4.1	240	<2	2.02	33
D–067 S3	SA	<9	24.9	300	74	0.8	3.84	3.3	3.9	<100	1.3	1.99	39
C–072 01	SA	<10	24.0	370	57	0.9	4.93	6.7	6.7	<200	<2	2.2	34
C–072 02	SA	<10	26.1	340	62	0.8	5.02	6.9	7.4	300	<2	2.3	3.6

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
C–072 03	TF	<10	19.6	260	53	1.0	3.06	17	7.6	<200	<2	1.68	39
C–072 04	TF	<8	12.0	130	71	1.0	1.46	43	3.0	<100	<2	1.12	12
C–072 05	SA	<10	23.0	210	55	1.6	3.04	49	8.8	<200	<2	1.39	23
C–072 06	TCa	<10	32.9	410	56	1.5	3.93	48	18	550	<1	2.2	33
C–072 07	TCa	<10	38.2	510	61	1.9	3.55	45	39	<200	<2	2.0	30
C–072 08	SB	<10	34.5	550	68	0.9	7.0	11.9	9.4	<200	<2	3.3	49
C–072 09	SA	<10	31.5	440	66	0.48	7.1	4.8	7.2	<200	<2	2.6	49
C–072 S2	SA	<20	27.0	360	76	0.57	6.3	3.0	5.0	<300	<2	2.5	56
C–073 S1	P	<20	26.7	260	61	0.9	6.6	5.5	5.3	<300	<2	2.0	80
C–073 S2	SA	<10	29.8	380	65	0.8	6.5	7.2	5.7	430	<2	2.5	45
C–073 S3	SA	<10	28.1	340	60	0.55	5.9	5.6	6.5	<200	<2	2.3	54
C–073 S5	SA	<10	28.7	330	69	0.9	5.45	6.1	5.3	<200	<2	2.3	80
C–084 01	SA	<10	23.6	320	63	1.0	4.70	23	10.1	<200	<2	2.01	62
C–084 02	SB	<10	29.5	400	61	<0.3	5.8	5.5	6.5	<200	<2	2.8	37
C–084 03	SB	<10	27.7	340	65	0.65	5.9	5.3	5.9	<200	<1	2.7	25
C–084 05	SB	<9	24.7	300	64	0.63	5.53	6.1	4.4	170	<2	2.2	37
C–084 06	SB	<9	24.3	300	60	0.40	5.03	3.7	4.9	<100	<1	2.5	41
C–084 07	SB	<8	24.0	330	60	<0.3	4.89	3.4	5.1	<100	<1	2.5	33
C–084 S1	SB	<8	23.0	290	53	0.30	5.31	5.2	4.3	360	<1.2	2.02	23
C–094 03	SA	<10	24.2	310	53	0.95	4.17	12.2	8.0	<200	<2	2.1	70
C–094 04	TF	<10	24.1	360	55	0.54	3.45	16	13.8	<200	<1	1.7	55
C–094 05	SA	<9	21.9	320	58	1.1	9.5	23	7.0	<200	<2	1.7	<5
C–100 01	P	<20	24.6	250	61	6.6	5.04	2.5	6.0	<300	<2	1.8	52
C–100 03	P	<20	23.0	330	55	1.0	8.2	7.6	6.3	<300	<2	2.1	7
C–100 04	SA	<10	27.7	290	71	1.6	5.51	4.0	4.8	<200	<2	2.1	70
C–100 05	SA	<10	22.8	240	49	1.0	4.14	5.7	4.8	<200	<2	1.57	49
C–100 06	SA	<10	21.8	250	62	1.2	3.94	4.4	4.3	<200	<2	1.8	63
C–100 07	TCa	<10	29.0	700	40	1.8	2.56	33	7.7	<200	<2	5.0	55
C–100 08	TCa	<9	29.1	480	41	1.9	2.19	53	8.2	280	<2	3.7	60
C–100 09	TCa	<10	52	900	44	1.8	3.52	49	62	370	2.4	2.8	48
C–100 10	SB	<10	31.0	430	69	0.69	6.8	3.6	5.1	<200	<2	3.1	44
C–100 S1	SB	<10	28.8	450	68	0.68	6.6	5.4	5.3	320	<2	3.2	46
C–100 S2	SB	<9	27.9	430	67	<0.3	5.8	4.0	4.5	170	<2	3.1	41
C–100 S3	SB	<8	21.4	290	47	0.57	3.78	6.3	4.0	330	<1.3	1.90	24
C–100 S4	SA	<20	23.1	330	62	<0.3	3.95	2.5	4.4	<300	<2	2.3	160

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
D–104 03	P	<20	28.8	330	67	1.2	8.3	4.6	7.6	<300	<2	2.4	70
D–104 04	P	<20	26.7	370	63	0.8	6.1	5.0	7.1	<200	<2	2.2	45
D–104 05	TF	<9	16.5	240	44	0.94	2.40	20	9.0	<100	<1.1	1.2	19
D–104 06	TF	<9	15.8	210	50	0.89	2.32	20	8.6	<200	<1	1.16	19
D–104 07	TF	<9	8.8	150	45	1.01	1.35	29	3.6	<200	<1	0.87	7
D–104 08	TF	<8	10.5	100	65	0.8	0.92	38	3.2	<100	<1	0.80	13
D–104 09	TF	<8	14.3	170	53	0.81	1.51	23	10.7	<100	<1	0.77	15
D–104 10	TCa	<10	41	350	63	2.6	6.3	70	12.0	640	<2	2.4	34
D–104 S1	SB	<20	51	820	84	0.6	7.4	7.8	51	<300	2.9	3.8	70
D–104 S2	SB	<10	34.6	420	87	0.8	8.2	5.2	6.5	<200	<2	3.0	56
D–104 S3	SB	<10	28.6	390	79	<0.3	6.6	5.5	5.2	360	<2	2.9	44
D–104 S4	SB	<9	22.6	340	62	0.47	4.79	5.7	4.1	280	<2	2.34	<3
D–104 S5	SB	<9	21.7	250	50	0.41	4.56	5.3	3.9	420	<1	2.0	48
D–104 S6	SB	<20	35.4	430	58	0.40	5.11	4.0	7.3	<400	<1	2.9	110
SHIP–TC A		<8	11.7	140	49	1.22	1.83	48	3.1	150	<1.1	1.1	69
SHIP–TC B		<10	19.7	180	41	2.0	3.49	56	6.1	<100	<1.2	1.5	61
SHIP–TC C		<10	21.6	340	51	1.31	4.21	25	7.3	260	<1	1.7	37
SHIP–TC D		<10	22.0	340	56	1.00	4.47	24	5.4	280	<1	2.1	60
SHIP–TC Site		<10	19.5	260	50	1.19	3.79	40	6.3	<200	<1	1.8	44
A–030[c]		<6	13.8	200	39	1.46	2.00	32	3.3	140	<1.1	1.21	70
A–031 06 D[d]		<7	12.5	130	28	1.21	1.26	42	3.0	170	<0.9	1.08	53
A–031 06 D		<7	12.3	120	32	1.18	1.28	42	3.6	160	<0.8	0.92	62
A–031 06 D		<6	12.3	100	27	1.31	1.23	37	3.0	<100	<0.8	0.91	53
A–031 06 D		<6	13.9	110	36	1.01	1.47	43	3.3	130	<0.8	1.04	58
A–031 06 D		<7	12.5	90	28	1.12	1.27	40	3.2	<100	<0.9	1.03	80
A–034 13 D		<6	7.6	130	35	0.87	1.53	27	1.5	<100	<1.1	0.85	13
A–034 13 D		<5	7.3	120	40	1.02	1.68	33	1.7	110	<0.9	1.08	18
A–034 13 D		<6	8.1	130	40	1.13	1.63	31	1.7	<100	<1.1	1.07	23
A–034 13 D		<6	7.5	130	40	1.05	1.60	33	1.5	<100	<1.1	0.99	23
A–034 13 D		<6	8.1	130	35	1.2	1.61	33	1.5	<100	<1.1	0.85	29
A–034 15 D		<6	5.3	90	39	1.03	1.07	39	1.30	<100	<1.0	0.74	5
A–034 15 D		<5	5.2	70	34	1.15	0.95	34	1.17	<90	<1.0	0.56	<0.02
A–034 15 D		<5	4.8	80	44	1.10	1.02	36	1.14	<80	<0.9	0.94	7

TABLE C-Ib (cont)

Sample ID	Cluster Class[a]	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
A–034 15 D		<5	4.5	80	37	0.98	0.94	34	1.13	<90	<1.0	0.70	6
A–034 15 D		<6	4.6	110	37	0.85	0.96	37	1.15	<100	<1.1	0.90	6
C–072 02 D		<10	25.2	360	62	0.81	5.31	7.3	7.5	<200	<2	1.91	39
C–072 02 D		<10	27.0	320	69	0.9	5.15	10.2	7.6	<200	<2	2.3	53
C–072 02 D		<20	26.9	370	62	1.0	5.12	7.1	7.9	<300	<2	2.4	42
C–072 02 D		<10	26.0	320	53	0.58	4.94	6.9	7.1	<200	<2	2.00	36
C–072 02 D		<10	25.5	370	73	0.7	5.54	7.3	7.7	<200	1.5	2.2	44
C–084 S1 D		<9	24.2	300	53	0.49	5.7	5.3	4.7	330	<1	2.3	36
C–084 S1 D		<10	24.0	310	61	<0.2	5.42	5.7	4.4	370	<1	2.5	47
C–084 S1 D		<9	25.4	310	58	0.7	5.09	5.7	5.3	300	<1	2.3	47
C–084 S1 D		<10	24.0	290	50	0.39	5.28	5.0	4.5	340	<1.2	2.1	<4
C–084 S1 D		<9	24.2	320	58	0.38	5.37	5.6	4.5	360	<1	2.2	32
D–104 S2 D		<10	33.7	370	92	0.6	8.2	32	6.6	<200	<2	3.1	<5
D–104 S2 D		<10	35.0	440	90	0.74	8.6	5.4	5.8	<200	<2	3.1	100
D–104 S2 D		<10	33.7	440	83	0.70	8.1	3.8	6.4	<200	<2	3.0	61
D–104 S2 D		<10	34.1	440	93	<0.3	8.5	5.8	6.5	<200	<2	3.3	100
D–104 S2 D		<10	32.6	410	78	0.6	8.4	4.9	6.5	280	<2	3.2	<5

TABLE C-II

TRACE ELEMENT ANALYSIS OF MOUNTAIN STATES SAMPLES BY AA AND ICP TECHNIQUES

				Conc (μg/g)							
Site	Quad	Hole	Interval	Ag	Cd	Cr	Pb	Ba	Mo	As	Se
VIT	A		Comp	1	1.5	50	65	740	27	82	5
	A	008	Comp	<1	3	27	90	800	49	82	5
	B	Comp		1	1	27	165	1300	93	160	5
	C	060	Comp	1	1.5	40	240	1400	80	56	4
	C	060	S1	2	1	30	240	1050	186	78	7
	C	039	S3	<1	<1	14	<50	790	8	7	0.3
	D	Comp		1	1	1120	240	730	204	90	21
	D	063	Comp	2	<1	460	970	815	104	60	6
	D	063	S1+S2	<1	2	44	160	470	123	56	5
	D	063	S6+S7	<1	<1	51	85	550	5	32	<0.3
	E	Comp		2	1	1210	170	590	215	90	21
	E	090	Comp	1	<1	2520	70	570	116	26	5
	E	090	S1	<1	<1	64	<50	570	9	13	0.3
	E	090	S2	<1	<1	56	<50	565	7	10	<0.3
				2	1.5	–	190	–	–	90	23
SHR	A	030	Comp	<10	<5	15	130	660	38	13	40
	C	080	1	<10	<5	10	20	610	56	13	41
	C	080	2	<10	<5	15	20	520	46	14	26
	C	080	3	<10	<5	12	20	540	51	19	80
	C	080	4	<10	<5	15	40	560	69	18	130
	C	080	5	<10	<5	16	50	640	82	15	129
	C	080	6	<10	<5	31	30	430	43	28	7
	C	080	7	<10	<5	16	30	550	60	17	74

TABLE C-III

RADIONUCLIDE CONTENT OF SELECTED SAMPLES FROM SALT LAKE CITY AND SHIPROCK

(Activity in pCi/g)

Site	Quad	Hole	Interval	^{226}Ra	^{40}K	^{227}Ac	^{228}Ra	^{228}Th	Gross Gamma[a]
VIT	A	001	01	27	17	1.2	1.0	1.0	73
			06	1.1	15	–	1.1	1.1	17
			07	1.4	16	<0.1	1.0	1.2	18
			S1	0.6	18	<0.1	0.7	0.6	12
	A	004	01	200	22	7.0	1.4	0.6	450
			02	200	18	8.1	1.4	0.9	450
			03	170	18	8.4	–	0.8	390
			05	650	19	31	–	0.9	1370
			06	45	19	4.2	0.9	1.2	120
			07	98	16	4.2	1.1	0.9	220
			08	7.9	17	0.5	0.7	1.0	30
			S1	1.4	14	<0.1	1.1	1.1	17
	A	008	02	220	9.2	9.5	–	0.5	490
			S1	3.9	18	0.3	1.2	1.2	26
	A	011	04	11	16	0.5	1.1	0.9	39
			05	12	22	0.6	1.8	1.6	43
			07	1.8	16	0.1	1.2	1.2	17
			08	7.0	16	0.4	1.3	1.2	30
			S1	0.8	13	–	0.8	0.9	13
			S2	0.8	15	–	0.8	0.8	13
			S3	1.5	16	0.1	0.8	0.9	14
			S4	0.9	17	0.1	0.6	0.6	12
	B	016	03	1.7	20	0.2	1.4	1.5	19
	B	017	03	12	13	0.7	1.6	1.6	40
			05	68	19	4.1	0.6	0.7	170
	B	022	04	1070	15	46	<1.3	0.5	2260
	C	060	Comp	820	19	34	–	1.1	1760
	E	090	01	90	14	4.9	1.2	0.6	130
			02	230	12	12	<1.1	1.0	470
			03	240	11	10	2.0	1.1	530
	A	Comp		130	18	5.9	0.9	1.0	290
	B	Comp		800	18	37	<1.5	0.8	1710
	D	Comp		580	17	26	<3.2	2.1	1250
	E	Comp		350	15	17	–	0.8	790
	Site	Comp		490	15	22	1.1	1.0	1050

[a]Counts/s/g $\times 10^3$ for gamma energy range from 170 to 360 keV.

TABLE C-III (cont)

Site	Quad	Hole	Interval	^{226}Ra	^{40}K	^{227}Ac	^{228}Ra	^{228}Th	Gross Gamma[a]
SHR	B	003	04	70	15	4.4	1.1	1.0	150
			S1	13	11	1.3	1.0	0.9	34
	B	012	09	690	15	31	<3	1.1	1370
	B	016	16	310	9	14	<1.4	0.4	630
			17	470	10	19	1.1	0.4	940
			S1	95	–	7.8	–	–	–
			S2	8.7	14	0.6	0.8	0.9	22
	A	031	13	970	16	60	<1	0.5	2390
			S1	310	13	18	1.3	1.0	650
	A	034	16	2210	21	100	–	0.5	4170
	D	042	01	210	8.2	1.3	1.4	0.4	440
			S2	150	11	11	0.7	0.7	330
	D	051	S1	140	12	15	<0.7	0.8	300
			S3	11	15	0.7	1.0	0.8	28
	C	072	6	1010	12	52	1.9	0.7	2040
			S2	13	14	0.7	0.9	0.9	32
	C	084	6	8.9	12	0.3	0.9	0.7	23
			S1	1.5	12	0.1	0.7	0.6	7
	D	104	6	340	8.2	20	<1.3	0.4	710
			S3	1.2	13	0.1	0.8	0.8	5
	A	030	Comp	370	7.6	17	<0.5	0.2	740

TABLE C-IV

STATISTICS ON ELEMENTAL CONCENTRATION DATA FROM NAA OF SALT LAKE CITY AND SHIPROCK SAMPLES

Salt Lake City

Element	Mean (μg/g)	Coefficient of Variation (%)	Median (μg/g)	Minimum (μg/g)	Maximum (μg/g)	n[a]
SiOX	834 100	7.6	–	573 000	930 000	
Ca	49 500	73.6	40 000	4 800	182 000	
Al	45 400	28.1	47 000	11 000	78 000	
Fe	24 600	121	17 700	4 700	199 000	
K	21 100	22.7	20 900	9 200	51 000	
Mg	10 300	65.2	8 850	1 300	25 000	110
Na	9 760	44.4	9 000	2 200	21 100	
Ti	2 250	34.5	2 200	610	5 200	117
Cl	1 030	275	245	80	15 600	88
Ba	911	45.3	823	300	2 200	
Cr	606	425	44.7	11.0	18 200	
Mn	463	123	325	58.1	3 460	
Sr	452	37.1	401	170	1 020	89
V	451	265	88.0	18.0	8 500	
Zn	185	342	90.0	12.0	6 600	
Ce	96.3	59.9	83.3	33.0	362	
U	94.9	188	23.9	1.75	1 010	
Rb	86.3	88.2	80.4	24.0	270	
As	45.2	93.1	28.6	1.74	200	116
La	31.9	39.5	31.6	11.0	84.2	
Se	15.6	88.2	9.87	2.58	64.0	92
Co	13.5	106	9.30	1.34	79.0	
Th	9.44	38.8	8.95	2.86	19.3	
Sm	7.71	96.7	5.49	1.45	43.0	117
Sb	5.87	129	2.88	0.33	50.1	107
Sc	5.08	43.8	4.59	1.49	12.0	
W	4.80	58.2	4.30	1.48	21.8	107
Hf	4.64	31.5	4.61	1.41	10.4	
Cs	4.61	51.8	4.26	0.85	12.5	117
Dy	2.80	40.2	2.78	0.77	7.16	115
Yb	1.96	37.7	1.84	0.62	4.18	113
Eu	0.83	29.9	0.81	0.38	1.48	118
Lu	0.31	44.9	0.29	0.08	0.93	109

[a] n =119 unless otherwise indicated; n is the number of valid cases, i.e., greater than detection limit.

[b] n = 116 unless otherwise indicated.

[c] Insufficient data for statistics.

Shiprock

Element	Mean (μg/g)	Coefficient of Variation (%)	Median (μg/g)	Minimum (μg/g)	Maximum (μg/g)	n[b]
SiOX	893 700	4.7	881 900	819 900	970 400	
Ca	32 100	48.1	33 000	5 900	73 000	
Al	32 100	40.6	34 000	10 000	75 000	
Fe	12 500	71.1	12 400	1 630	40 000	
K	13 800	25.0	14 000	6 400	26 000	
Mg	7 580	68.9	6 050	1 000	20 000	90
Na	4 920	49.0	4 910	990	12 100	
Ti	1 830	42.6	1 800	580	3 600	
Cl	125	67.2	110	24.0	480	73
Ba	808	45.4	737	380	3 300	
Cr	31.8	53.8	31.3	7.08	120	
Mn	263	122	169	21	2 020	
Sr[c]						43
V	871	101	580	35	5 800	
Zn	51.4	103	43.5	7.0	510	112
Ce	59.7	95	52.0	10.2	430	
U	69.6	222	28.0	2.46	1 200	
Rb	53.2	28.7	55.3	22.0	87.0	
As	19.1	107	13.1	3.17	149	
La	22.3	62.2	23.0	4.68	128	
Se	20.3	86	14.0	2.49	86	
Co	6.37	188	4.51	0.62	126	
Th	5.17	51.0	5.33	1.21	10.3	
Sm	6.62	62.2	4.75	1.16	62	
Sb	1.29	93.4	0.99	0.30	9.69	111
Sc	4.02	54.2	3.95	0.79	9.46	
W[c]						7
Hf	6.29	27.3	5.83	3.59	12.0	
Cs	2.49	49.9	2.21	0.70	5.91	
Dy	3.03	70.5	2.83	0.68	17.3	
Yb	1.96	48.1	1.99	0.66	6.22	
Eu	0.71	69.3	0.69	0.14	3.78	
Lu	0.29	53.7	0.29	0.09	0.95	
Tb	0.38	77.5	0.33	0.09	2.45	107
Ta	0.55	44.6	0.56	0.18	1.30	113

TABLE C-V

MEANS OF SALT LAKE CITY TAILINGS SAMPLE TYPES GROUPED BY CLUSTER ANALYSIS[a]

(Mean Conc μg/g)

Element	Cluster 1 5 (soil) (n=19)	Cluster 2 T (tailings) (n=35)	Cluster 3 P (contaminated soil) (n=54)
Ca	22 600	20 200	71 000
Al	53 600	34 600	51 700
Fe	31 100	11 900	22 500
K	20 500	21 400	20 600
Mg	5090	3080	15 800
Na	17 500	6310	9170
Ti	1460	1930	2600
Cl	304	191	335
Ba	933	1240	723
Cr	19.5	78.8	59.6
Mn	183	162	512
Sr	352	348	435
V	36.0	377	157
Zn	29.0	109	135
Ce	87.9	90.0	106
U	6.07	161	84.2
Rb	64.5	87.9	89.5
As	4.64	86.3	28.2
La	39.7	21.7	37.2
Se	13.9	18.0	11.5
Co	4.65	9.06	15.0
Th	9.02	6.39	11.1
Sm	3.99	8.63	8.22
Sb	0.75	9.43	3.37
Sc	3.06	3.46	6.83
W	3.03	4.73	4.23
Hf	4.16	5.10	4.72
Cs	1.87	4.25	5.70
Dy	2.11	1.87	3.64
Yb	1.56	1.36	2.34
Eu	0.82	0.64	0.97
Lu	0.19	0.28	0.36

[a]Cluster analysis of samples after deletion of 8 atypical samples (ferrophos, etc.).

TABLE C-VI

NEUTRON ACTIVATION ANALYSES OF HOLE COMPOSITE SAMPLES FROM 12 INACTIVE MILL SITES

		Major and Minor Elements plus Uranium and Thorium										
Sample ID	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
NR C 005	90.5	1.85	1.2	3.54	<0.3	0.6	730	1.13	0.17	110	2700	2.6
NR C 015	90.4	2.00	1.2	3.5	0.5	0.53	540	1.16	0.14	90	2320	2.7
NR D 025	85.3	2.9	3.3	4.7	0.5	0.7	760	1.72	0.15	100	3400	4.4
NR D 035	91.5	1.83	1.0	2.93	0.53	0.54	460	1.07	0.13	91	2290	2.0
NR D 045	91.0	2.5	1.6	2.00	0.58	0.53	310	0.97	0.19	260	2600	3.2
NR B 055	90.7	2.9	1.6	1.78	0.67	0.39	69	1.39	0.14	190	2180	4.2
NR A 065	89.8	3.0	1.8	2.16	0.64	0.51	59	1.50	0.15	180	2420	5.0
NR A 075	90.5	2.9	1.8	1.63	0.60	0.75	74	1.26	0.10	190	2500	4.2
NR A 085	88.0	3.4	2.4	2.31	0.68	0.8	87	1.56	0.19	170	2900	5.5
NR A 095 1	90.7	2.9	1.7	1.67	0.55	0.6	58	1.36	0.11	180	2360	4.1
NR A 095 2	90.5	2.9	1.6	1.73	0.70	0.53	60	1.33	0.13	180	2270	4.4
NR A 095 3	90.4	2.9	1.6	1.67	0.68	0.84	54	1.31	0.12	190	2250	4.4
RIV D 005	81.9	6.5	3.6	2.43	2.3	1.0	350	1.73	0.21	14.9	76	14.3
RIV B 015	82.3	6.0	3.8	2.19	2.0	1.3	370	1.54	0.20	5.5	58	15.1
RIV B 025	84.0	7.0	1.9	2.16	2.5	0.45	152	1.53	0.17	64	167	18.0
RIV B 035	84.7	6.5	1.6	2.13	2.5	0.50	130	1.46	0.17	43	171	18.1
RIV B 045	81.6	6.5	3.7	2.52	2.0	1.4	400	1.44	0.26	32	98	16.3
RIV A 055	84.5	6.1	2.0	2.23	2.6	0.49	196	1.54	0.16	31	81	15.0
RIV A 065	86.1	5.6	1.5	1.97	2.8	<0.2	88	1.47	0.07	40	173	13.5
RIV C 075	83.9	6.1	2.0	2.50	3.0	0.33	164	1.42	0.18	130	370	22.6
RIV D 085	85.3	5.8	1.6	2.02	2.8	0.47	206	1.51	0.11	60	168	13.4
RIV C 095	85.8	6.4	1.2	1.95	2.8	<0.2	123	1.50	0.09	95	164	16.3
RIV C 105	85.0	6.5	1.5	2.24	2.6	0.37	147	1.48	0.14	68	117	19.5
MBL D 005	90.0	4.3	1.2	0.98	1.7	0.29	400	1.12	0.08	94	44	4.8
MBL D 015	86.4	5.3	1.8	2.34	2.1	0.55	570	1.15	0.07	130	82	6.5
MBL D 025	88.6	4.8	1.5	1.44	1.7	0.38	310	1.19	0.09	61	50	5.7
MBL B 035	87.8	5.0	1.7	1.85	1.6	0.59	200	1.04	0.10	78	80	6.7
MBL A 045	89.5	4.6	1.4	1.01	1.7	0.34	118	1.12	0.10	83	48	5.5
MBL C 055	86.0	5.3	1.9	2.45	1.9	0.72	580	1.12	0.17	110	85	7.3
MBL A 065	88.5	5.0	1.5	1.33	1.7	0.38	390	1.15	0.09	55	51	5.6
MBL C 075	84.9	6.0	2.9	2.32	1.5	1.0	810	0.78	0.24	190	177	9.1
MBL A 085	85.8	5.9	2.7	2.02	1.4	0.83	760	0.85	0.18	120	128	8.2
MBL B 095	87.1	4.6	2.0	2.09	2.2	0.6	340	0.95	0.20	660	72	6.7

TABLE C-VI (cont)

Sample ID	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
MBL C 105 1	83.5	6.3	4.1	2.62	0.9	1.6	1510	0.43	0.18	140	200	9.6
MBL C 105 2	84.1	6.0	4.3	2.38	0.8	1.5	1490	0.42	0.16	150	190	8.3
MBL C 105 3	83.3	6.4	4.3	2.59	0.9	1.5	1490	0.42	0.20	140	178	9.3
AML B 005	86.8	4.6	3.6	1.47	1.8	<0.2	350	1.18	0.12	100	540	5.5
AML B 015	86.8	3.6	4.5	1.29	2.2	0.20	370	1.13	<0.05	100	450	4.3
AML D 025	85.6	4.6	4.5	1.45	1.9	0.52	340	1.08	0.14	120	430	5.7
AML B 035	87.8	3.7	3.4	1.33	2.0	<0.2	370	1.18	0.10	120	500	3.0
AML D 045	86.3	3.5	5.7	1.25	1.7	0.24	340	1.06	0.08	99	400	4.2
AML C 055	85.9	4.0	5.1	1.17	2.0	0.33	350	1.08	0.10	130	540	3.6
AML C 065	86.5	3.7	5.0	1.03	2.1	0.27	370	1.12	0.09	97	440	3.6
AML C 075	85.5	3.9	5.5	1.43	1.9	<0.2	390	1.15	0.07	110	510	3.6
AML C 085	87.3	3.9	3.9	1.07	2.1	<0.1	340	1.24	0.10	110	420	3.5
AML D 105	85.2	3.9	5.5	1.51	2.1	<0.2	370	1.17	0.13	140	540	4.2
SPK C 014	88.6	4.9	0.88	0.97	3.2	0.29	134	0.85	0.053	120	202	7.4
SPK D 005	88.3	5.3	0.9	1.07	3.0	0.27	134	0.85	0.08	120	150	7.6
SPK D 015	88.8	4.9	0.75	1.02	3.1	0.29	116	0.85	0.079	130	179	7.2
SPK D 025	88.7	4.9	0.83	1.08	3.2	0.25	137	0.78	0.08	110	174	8.6
SPK D 035	88.3	5.1	0.8	1.15	3.3	0.24	121	0.85	<0.03	94	185	8.2
SPK C 045	88.1	4.9	1.0	1.51	3.0	0.35	187	0.80	0.067	150	187	8.0
SPK B 055	87.4	4.7	1.1	2.09	2.8	0.32	250	1.15	0.11	16.8	50	9.8
OR A 015	93.4	1.84	1.00	1.16	0.62	0.65	103	0.86	0.041	230	1410	2.9
OR C 035	91.0	2.5	1.7	1.57	0.8	0.9	162	0.98	0.09	220	1330	3.6
OR A 045	90.1	2.7	1.7	2.26	1.1	0.69	202	0.90	0.14	220	1340	4.9
OR D 055	88.9	3.9	1.3	1.44	0.8	0.73	320	2.11	0.11	380	1290	7.3
OR A 065	89.8	3.0	2.3	1.44	0.9	0.8	161	1.15	0.16	330	1560	3.9
VIT A 005	84.2	5.1	4.0	2.26	2.0	1.06	300	0.82	0.22	45	230	10.3
VIT C 025	86.1	4.0	3.9	1.91	2.0	0.71	350	0.82	0.25	86	62	6.0
VIT B 035	84.6	5.0	5.0	1.43	2.1	0.85	140	0.38	0.27	150	340	7.9
VIT D 045	89.1	3.4	2.2	1.88	1.9	0.53	184	0.55	0.21	170	580	6.9
VIT D 055	84.1	5.0	4.2	2.43	2.2	0.78	310	0.68	0.24	160	380	11.4
VIT D 065	90.1	3.1	1.2	2.25	1.8	0.5	192	0.43	0.19	280	1630	6.9
VIT D 075	85.3	4.2	2.7	3.56	2.1	0.6	500	0.79	0.21	95	810	23.7
VIT E 085	87.8	3.4	2.6	2.27	1.8	1.0	280	0.53	0.28	220	780	6.8
VIT D 095 1	83.9	4.2	4.2	3.47	1.9	0.70	370	0.67	0.25	260	1330	7.9
VIT D 095 2	84.0	4.0	4.1	3.42	2.0	0.9	370	0.67	0.28	250	1330	8.6
VIT D 095 3	83.5	4.1	4.7	3.5	1.9	0.63	380	0.69	0.24	250	1370	8.0

TABLE C-VI (cont)

Sample ID	Non–NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
SHR B 005	83.5	4.3	5.9	2.76	1.5	0.9	620	0.41	0.24	35	2260	7.9
SHR B 015	89.4	3.3	2.7	1.52	1.3	0.91	270	0.41	0.20	43	760	6.5
SHR B 025	90.1	2.8	3.5	1.32	1.1	0.29	202	0.34	0.15	44	1600	4.3
SHR A 035	94.3	1.56	1.4	1.02	1.08	0.18	143	0.220	0.070	28	810	1.75
SHR D 045	85.4	4.9	3.9	2.15	1.8	0.64	240	0.66	0.23	22.9	580	6.7
SHR D 065	86.6	3.9	4.1	2.08	1.4	0.62	350	0.64	0.23	33	1200	6.5
SHR D 075	89.5	3.2	2.5	2.01	1.3	0.32	350	0.62	0.19	100	1160	4.7
SHR D 085	84.9	4.5	3.7	3.22	1.5	0.75	720	0.81	0.24	27	1090	7.2
SHR C 095	85.2	4.0	3.4	3.47	1.6	0.94	810	0.77	0.22	75	370	6.3
MH A 005	91.9	3.3	1.2	1.46	1.16	0.28	164	0.172	0.19	53	460	5.2
MH B 015	80.5	2.9	12.3	2.21	<0.4	<0.3	1380	0.29	<0.10	170	2030	87
MH A 025	74.5	1.9	18.4	3.14	<0.4	<0.3	1190	0.264	0.17	75	2100	1190
MH C 045	89.7	4.0	2.0	1.46	1.4	0.29	250	0.49	0.25	130	790	116
MH D 055	93.2	3.4	0.16	1.03	1.0	0.33	206	0.277	0.16	110	750	47
MH D 065	89.5	5.5	0.26	1.46	1.8	0.38	253	0.308	0.32	160	1210	98
MH D 075	89.2	5.8	0.44	1.31	1.7	0.55	760	0.36	0.23	130	180	80
MH D 085	89.5	5.6	0.19	1.54	1.6	0.51	433	0.39	0.28	150	650	246
MH C 095	94.6	2.25	0.10	1.27	0.9	<0.1	259	0.273	0.14	85	470	47
MH D 105 1	93.9	2.80	0.09	1.27	0.95	0.21	102	0.198	0.21	100	620	12.8
MH D 105 2	94.0	2.7	0.09	1.29	0.9	0.26	102	0.208	0.17	97	640	13.7
MH D 105 3	94.1	2.77	0.09	1.18	1.0	0.13	105	0.202	0.17	100	640	12.1
GUN C 005	86.2	6.6	0.9	2.38	1.7	0.67	260	0.92	0.31	42	68	10.1
GUN A 015	85.2	6.5	1.3	2.73	1.9	0.56	300	1.27	0.30	25	70	11.6
GUN A 025	92.4	3.6	0.48	1.58	0.97	0.18	107	0.43	0.21	36	36	4.7
GUN C 035	90.8	4.4	0.63	1.81	1.01	0.42	191	0.40	0.22	42	56	5.9
GUN C 045	90.4	5.2	0.36	1.67	1.1	0.38	127	0.46	0.19	81	49	7.0
GUN C 055	91.7	4.6	0.16	1.96	0.84	0.23	70	0.145	0.17	110	44	7.0
GUN A 065	90.6	4.1	0.84	1.95	1.07	0.38	205	0.68	0.18	47	47	5.0
GUN B 075	87.4	5.6	1.1	2.92	1.1	0.48	340	0.63	0.39	56	72	6.1
GUN D 085	90.0	4.8	0.46	1.86	1.4	0.44	131	0.59	0.21	56	46	7.2
GUN D 095	87.4	6.0	0.9	2.17	1.8	0.40	217	0.85	0.26	70	50	8.3
GUN D 105	87.2	5.6	1.6	2.08	1.5	0.62	280	0.98	0.22	27	57	6.7

TABLE C-VI (cont)

Sample ID	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	Na (%)	Ti (%)	U (ppm)	V (ppm)	Th (ppm)
GJT D 005	95.1	1.47	0.85	0.97	0.57	0.25	61	0.42	0.061	98	1530	2.2
GJT C 015	94.5	1.61	0.79	1.17	0.59	0.43	88	0.42	0.060	120	1450	2.3
GJT C 025	94.7	1.75	0.90	0.80	0.57	0.41	51	0.46	0.063	120	1680	2.5
GJT B 035	93.0	2.08	1.4	1.32	0.70	0.43	115	0.65	<0.04	120	1420	2.6
GJT B 045	91.2	2.4	1.5	2.23	0.83	0.67	192	0.59	0.16	140	1640	4.1
GJT A 055	87.9	4.1	2.6	1.92	1.3	0.93	198	0.62	0.22	84	1280	6.8
GJT A 065	95.8	1.07	0.52	1.39	0.47	0.24	106	0.138	0.07	100	1700	1.48
GJT D 075	79.3	7.2	4.2	3.8	1.0	<0.4	127	3.12	0.23	290	2800	8.0
GJT D 085 1	83.5	5.3	3.1	3.18	1.0	0.8	134	2.31	0.20	330	2600	7.2
GJT D 085 2	83.3	5.3	3.3	3.29	0.8	0.8	133	2.31	0.18	300	2600	7.4
GJT D 085 3	82.6	5.4	3.3	3.39	1.0	1.0	132	2.28	0.21	310	2600	7.5
GJT D 095	93.9	173	1.0	1.40	0.64	0.47	104	0.44	0.09	120	1640	2.1
TC C 005	89.9	4.5	0.30	1.67	2.0	0.57	208	0.38	0.15	190	270	5.6
TC C 015	89.3	4.7	0.69	1.98	1.7	0.57	132	0.181	0.15	200	470	7.2
TC B 025	87.7	5.6	0.19	1.64	2.9	0.63	156	0.53	0.20	190	210	6.7
TC B 035 1	92.3	2.86	0.40	1.18	1.3	0.89	165	0.40	0.18	500	250	4.0
TC B 035 2	92.1	2.87	0.44	1.11	1.4	0.96	168	0.41	0.14	480	250	3.7
TC B 035 3	91.8	3.0	0.44	1.26	1.4	0.95	173	0.42	0.14	490	260	4.0
TC B 045	93.0	1.90	0.71	0.91	0.84	1.9	232	0.211	0.09	200	115	2.7
TC B 055	90.3	3.8	0.61	1.49	1.1	1.7	288	0.258	0.14	230	200	6.2
TC B 065	88.2	4.0	0.77	2.01	1.5	2.1	337	0.38	0.20	190	5.5	

TABLE C-VI (cont)

		Trace Elements (A to H)										
Sample ID	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
NR C 005	99	410	<2	41	200	5.8	730	ND	1.1	220	30	4.6
NR C 015	98	540	<2	39	220	7.1	560	0.7	<0.9	220	<20	4.6
NR D 025	270	670	<2	59	330	7.8	610	ND	1.0	480	<20	4.2
NR D 035	106	490	<1.6	38	180	5.6	490	ND	<0.7	290	15	5.4
NR D 045	107	1100	3.0	111	400	8.2	480	0.9	2.3	470	70	4.9
NR B 055	137	840	<2	75	540	5.7	58	0.8	2.4	520	60	4.3
NR A 065	149	870	<2	90	470	6.5	65	1.2	2.7	690	50	4.6
NR A 075	126	890	<2	83	590	7.0	67	0.9	2.5	630	60	5.1
NR A 085	190	1100	4.7	96	580	7.8	80	ND	3.4	690	<20	4.8
NR A 095 1	132	740	<2	82	480	5.6	57	ND	3.0	540	<20	5.2
NR A 095 2	128	1200	2.2	86	500	6.2	63	0.7	2.4	560	50	4.9
NR A 095 3	136	920	4.3	82	460	6.0	60	0.8	2.3	500	60	5.4
RIV D 005	39	1100	9.4	81	110	8.0	76	3.7	3.6	770	<20	5.3
RIV B 015	7.7	1200	7.6	83	<80	8.5	76	2.3	2.9	870	<20	5.7
RIV B 025	142	870	3.7	85	120	6.3	58	5.9	4.2	610	<20	5.2
RIV B 035	107	880	5.4	78	<70	5.8	63	6.3	4.7	690	<20	5.8
RIV B 045	40	1100	5.7	81	90	10.3	85	3.6	3.9	1120	<20	5.9
RIV A 055	69	1000	<2	83	<80	5.7	64	5.2	3.0	760	<20	5.0
RIV A 065	173	840	<2	63	<70	3.3	36	3.8	2.7	330	<20	4.1
RIV C 075	240	1100	3.4	113	130	11.4	61	5.6	5.1	820	40	5.4
RIV D 085	130	970	<2	65	190	<0.13	51	3.0	3.2	510	<20	3.8
RIV C 095	176	790	<2	88	<80	6.5	39	4.8	3.8	500	<20	4.5
RIV C 105	163	870	3	91	100	6.4	60	6.5	4.1	560	<20	5.5
MBL D 005	19	880	4.8	63	<80	2.9	19	1.6	2.1	680	<20	3.5
MBL D 015	26	1000	7.4	96	<80	4.5	56	2.0	2.3	690	<20	3.6
MBL D 025	21	910	48	57	<70	2.9	34	1.5	1.8	620	<20	3.2
MBL B 035	28	850	48	65	70	3.0	42	1.9	1.1	580	<20	3.0
MBL A 045	23	970	41	52	<70	1.93	20	1.6	1.3	530	<20	3.0
MBL C 055	33	1100	19	86	<90	4.8	58	2.2	2.3	680	<20	3.3
MBL A 065	22	1000	25	54	<70	2.7	25	1.7	1.4	640	<20	3.2
MBL C 075	72	800	122	97	120	5.7	31	2.6	2.5	770	<20	3.4
MBL A 085	44	870	18	88	80	4.7	31	2.3	2.2	700	<20	3.3
MBL B 095	13.2	1200	8.8	250	<80	5.0	46	2.3	2.5	650	<20	4.1
MBL C 105 1	58	690	17	98	<90	6.7	34	2.2	3.1	850	39	3.4
MBL C 105 2	58	680	17	88	<110	6.3	32	2.0	3.2	770	40	2.9
MBL C 105 3	58	690	19	106	<90	6.4	40	2.9	3.3	810	40	3.4

TABLE C-VI (cont)

Sample ID	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
AML B 005	22	670	6.1	75	<80	4.0	20	2.4	2.8	770	<20	4.1
AML B 015	34	760	3.3	68	<80	3.4	23	1.5	2.3	670	<20	3.5
AML D 025	39	840	4.9	72	<90	4.7	23	2.6	3.2	870	40	3.5
AML B 035	24	830	5.2	63	<80	2.3	25	1.4	1.7	560	<20	3.2
AML D 045	30	710	7.5	64	100	3.4	22	1.7	2.8	640	<20	3.6
AML C 055	33	690	5.9	68	<90	3.9	17	1.6	2.6	760	50	3.2
AML C 065	36	780	3.9	69	<80	3.1	13	1.4	2.2	710	<20	3.2
AML C 075	40	870	4.2	69	<80	5.4	24	1.3	2.2	650	40	3.3
AML C 085	31	840	3.7	68	<70	3.2	16	1.6	2.0	670	<10	3.6
AML D 105	31	750	3.8	74	70	3.3	29	1.8	3.0	710	<20	3.0
SPK C 014	6.0	800	<1.5	70	110	2.6	30	0.9	380	<20	4.4	
SPK D 005	7.9	820	2.6	70	110	2.8	32	1.1	2.3	370	40	4.5
SPK D 015	6.9	710	<2	67	90	2.6	33	1.1	2.1	340	<20	4.2
SPK D 025	7.4	800	1.7	72	<50	3.1	32	1.1	2.3	380	<20	4.3
SPK D 035	6.6	940	<1.6	63	<60	2.7	33	0.68	2.5	380	40	3.8
SPK C 045	8.1	830	<1.5	78	80	2.9	51	1.0	2.1	370	<20	4.2
SPK B 055	7.7	780	1.7	32	140	3.9	40	1.1	2.1	370	<20	3.5
OR A 015	92	1000	<1.6	98	480	5.9	43	0.82	1.7	420	46	5.5
OR C 035	124	830	<1.7	94	460	7.5	57	1.4	2.2	590	40	5.4
OR A 045	90	750	<1.4	104	440	7.7	52	1.9	2.6	600	47	5.3
OR D 055	290	900	6.9	167	640	23.4	89	1.0	7.4	1670	110	4.8
OR A 065	146	1400	<2	134	480	8.8	40	1.5	2.8	680	70	5.2
VIT A 005	47	930	6.9	84	190	9.8	50	6.9	3.1	880	<20	6.3
VIT C 025	32	1300	2.7	61	<80	6.6	36	2.7	2.6	670	<20	5.6
VIT B 035	169	1600	4.2	129	150	18.3	41	5.7	4.5	1240	40	5.7
VIT D 045	94	1000	3.2	90	140	13.4	93	4.3	2.6	660	45	6.2
VIT D 055	155	760	6.6	131	1400	21.2	60	6.3	4.3	1010	60	6.3
VIT D 065	133	790	4.0	107	140	12.2	190	4.8	2.1	560	70	5.6
VIT D 075	168	820	<2	81	1210	12.3	1200	7.4	3.3	640	30	5.8
VIT D 085	91	570	6.2	125	130	15.2	130	4.4	3.2	780	18	6.9
VIT D 095 1	142	760	2.1	122	1560	19.0	1200	5.2	3.3	820	<20	5.7
VIT D 095 2	134	770	<2	143	1570	18.6	1200	5.2	2.9	820	70	6.0
VIT D 095 3	140	1400	3.8	135	1700	19.4	1200	5.2	2.8	840	60	6.0

TABLE C-VI (cont)

Sample ID	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
SHR B 005	47	1200	1.2	66	70	7.2	70	3.5	4.4	1190	<10	4.6
SHR B 015	20	650	2.0	49	<50	8.5	44	2.8	4.6	750	<10	7.5
SHR B 025	31	1000	2.9	56	<50	6.8	40	2.1	2.4	700	<10	4.7
SHR A 035	19	770	1.1	24.8	<30	3.6	38	1.1	1.3	320	<9	4.8
SHR D 045	31	790	2.2	64	170	8.2	54	4.1	3.6	800	<20	7.7
SHR D 065	23	630	3.9	47	170	5.2	43	3.3	3.3	670	<20	7.2
SHR D 075	18	910	<1.4	66	150	4.8	39	2.0	2.1	520	31	5.5
SHR D 085	13.6	890	2.3	58	170	8.1	50	2.9	4.2	890	<20	6.8
SHR C 095	25	1200	4.1	52	200	7.8	69	2.6	3.5	710	40	5.4
MH A 005	101	640	<1.1	73	30	57	43	2.9	3.1	670	<11	6.2
MH B 015	580	<200	<2	114	290	80	52	1.6	13.0	2300	30	3.9
MH A 025	730	700	2.9	101	<100	40	52	1.2	27	3200	<20	2.0
MH C 045	97	1500	<2	90	<70	85	40	2.3	7.8	970	<20	8.0
MH D 055	66	1140	3.3	79	<40	80	26	2.1	4.9	860	140	6.4
MH D 065	103	1700	<3	146	<70	128	52	4.6	7.6	1700	<120	7.2
MH D 075	82	1160	<3	115	<70	91	54	3.7	7.0	1290	<110	5.4
MH D 085	119	1280	3.5	132	<60	103	50	3.3	10.8	1230	200	6.7
MH C 095	56	1130	3.6	70	<50	69	38	1.5	3.9	580	<70	6.6
MH D 105 1	72	970	4	71	<30	75	31	2.1	3.1	670	170	5.4
MH D 105 2	73	1000	2.0	73	<40	76	39	1.9	2.5	630	<70	5.5
MH D 105 3	73	1050	<2	62	<40	69	31	2.0	2.9	520	<70	5.3
GUN C 005	143	920	4.1	108	90	12.8	28	8.3	4.8	1140	<20	6.2
GUN A 015	132	880	2.8	94	110	14.7	40	5.1	4.1	1010	<20	6.4
GUN A 025	136	740	3.3	50	<50	7.9	25	3.6	2.4	590	<10	4.1
GUN C 035	210	960	5.0	71	<40	11.5	23	7.7	3.4	710	<10	4.5
GUN C 045	210	830	3.5	92	<50	12.1	21	6.9	3.4	790	16	
GUN C 055	480	740	3.8	102	<30	27.3	21	7.2	3.5	860	<10	5.1
GUN A 065	166	1100	<1.5	54	60	10.4	25	5.7	3.0	670	<20	4.2
GUN B 075	153	950	3.6	87	<60	28.0	38	7.0	4.3	1010	<20	5.5
GUN D 085	187	960	3.0	84	50	13.9	24	5.9	3.2	930	<10	5.4
GUN D 095	210	890	4.8	86	<70	21.5	29	6.2	3.8	980	<20	5.4
GUN D 105	83	760	<2	73	100	9.5	22	4.5	3.5	920	<20	5.4

TABLE C-VI (cont)

Sample ID	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
GJT D 005	85	500	<0.9	48	160	4.5	35	0.78	1.0	320	28	4.2
GJT C 015	91	540	0.9	45	180	5.8	51	0.96	1.5	350	36	4.2
GJT C 025	84	540	<1.2	55	220	5.7	39	1.1	1.4	330	34	4.0
GJT B 035	87	850	<1.4	64	230	6.6	47	1.0	1.8	520	32	5.2
GJT B 045	56	570	1.4	83	380	5.9	62	1.8	2.5	590	<10	6.0
GJT A 055	48	610	2.6	66	650	6.3	63	4.2	3.3	650	30	5.1
GJT A 065	41	560	<0.8	44	190	2.6	44	0.95	0.53	180	22	3.7
GJT D 075	590	1100	<4	148	1020	27.6	150	1.2	4.9	1480	100	4.3
GJT D 085 1	430	1000	<3	142	670	23.6	120	1.3	4.6	1420	80	4.5
GJT D 085 2	390	1200	23	170	630	24.0	130	1.1	4.5	1460	80	4.8
GJT D 085 3	390	1400	<3	170	680	24.4	140	1.3	4.5	1480	<30	4.9
GJT D 095	90	680	<1.1	49	120	5.5	50	0.9	1.1	310	19	4.0
TC C 005	590	2600	5	102	110	133	31	2.1	3.7	830	300	4.9
TC C 015	1100	2300	<3	121	<50	187	57	3.4	5.6	1270	270	5.3
TC B 025	610	3200	5	102	150	111	27	3.1	4.1	890	300	5.0
TC B 035 1	630	1700	5.9	189	80	86	35	2.8	2.7	660	<80	5.9
TC B 035 2	610	2100	7	168	80	82	36	2.6	3.1	530	<90	5.4
TC B 035 3	650	1900	7	188	100	90	33	3.1	3.2	840	<90	6.0
TC B 045	450	1000	3.0	79	150	109	36	1.9	3.3	740	200	5.2
TC B 055	650	2100	7	125	110	157	49	3.7	4.7	1120	280	5.3
TC B 065	930	1700	6	117	210	244	73	4.9	5.6	1300	380	5.5

TABLE C-VI (cont)

	Trace Elements (I to Z)											
Sample ID	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
NR C 005	<20	9.7	170	<10	1.6	2.31	15	5.9	<300	<2	0.58	90
NR C 015	<20	9.3	190	23	2.0	2.50	16	5.4	<300	<2	1.0	130
NR D 025	<20	16.0	230	<10	3.3	3.45	52	7.0	<300	<3	0.9	270
NR D 035	<10	8.4	200	16	1.8	2.20	16	5.2	<200	<2	0.7	110
NR D 045	<20	17.5	410	23	2.6	3.23	30	15	<300	<2	1.3	90
NR B 055	<10	17.3	350	25	2.8	3.05	29	11.0	<200	<2	0.9	35
NR A 065	<10	17.5	360	25	2.5	3.61	45	11.1	<200	<2	1.4	53
NR A 075	<10	19.6	400	<10	3.0	3.48	51	11.2	<200	<2	1.5	40
NR A 085	<20	21.4	400	<10	3.8	4.15	71	11.0	<300	<3	2.2	43
NR A 095 1	<10	18.5	370	13	2.6	3.50	32	10.7	<200	<2	1.4	33
NR A 095 2	<11	16.9	360	22	2.1	3.55	36	10.7	<200	<2	1.6	40
NR A 095 3	<10	18.7	370	19	2.2	3.39	33	10.3	<200	<2	1.5	40
RIV D 005	<10	46	240	78	1.0	6.2	20	6.2	<200	<3	1.8	<8
RIV B 015	<10	43	240	<10	<0.4	6.3	4.4	5.1	530	<2	1.8	2300
RIV B 025	<10	45	270	93	<0.5	6.1	85	7.0	<200	3.5	2.6	2300
RIV B 035	<9	38.4	300	107	0.9	6.1	90	6.1	<200	4.2	3.0	2300
RIV B 045	<10	48	260	69	<0.5	7.5	28	7.5	520	<3	2.5	2700
RIV A 055	<10	36.2	260	97	0.9	5.3	44	5.2	<200	<3	2.7	1900
RIV A 065	<9	32.2	280	109	<0.4	3.25	54	4.9	<200	<2	2.2	1200
RIV C 075	<10	39.6	330	111	2.9	5..9	69	11.0	<200	3.5	2.9	2200
RIV D 085	<10	35.4	240	97	1.9	3.84	51	5.8	<200	<3	1.9	1400
RIV C 095	<10	39.9	340	109	<0.4	4.23	90	8.5	<200	2.6	2.8	<4
RIV C 105	<10	40	240	120	1.6	5.6	68	7.6	<200	4.6	2.5	23
MBL D 005	<10	25.3	160	60	1.0	2.05	24	7.3	270	<2	1.44	26
MBL D 015	<20	26.2	190	75	1.2	3.26	58	9.1	500	<2	1.6	18
MBL D 025	<10	23.9	110	58	1.2	2.41	28	5.0	450	<2	1.09	13
MBL B 035	<10	20.5	120	71	1.6	3.57	63	5.6	360	<2	1.4	31
MBL A 045	<9	22.6	120	67	0.9	2.31	42	6.1	340	<2	1.20	15
MBL C 055	<20	26.2	220	66	2.0	3.70	68	8.4	<300	<2	1.7	33
MBL A 065	<10	22.6	<60	61	0.9	2.59	50	4.7	<200	<2	1.11	14
MBL C 075	<20	32.9	190	61	1.7	5.9	135	13.0	<300	<3	2.1	58
MBL A 085	<20	27.9	<100	65	1.7	5.4	130	9.1	600	<2	2.1	70
MBL B 095	<10	38.6	350	73	1.1	3.36	10.2	35	400	<2	1.4	19
MBL C 105 1	<20	31.5	220	49	2.0	7.9	150	10.9	<400	<2	2.6	90
MBL C 105 2	<30	33.3	140	42	2.2	7.1	134	11.4	<400	<2	2.3	60
MBL C 105 3	<30	31.8	170	31	2.1	7.9	150	11.2	<500	<2	2.9	100

TABLE C-VI (cont)

Sample ID	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
AML B 005	<10	24.3	220	81	0.8	3.69	53	7.7	<200	<2	2.3	42
AML B 015	<10	19.2	180	84	1.1	1.93	56	7.3	<200	<2	1.73	25
AML D 025	<10	26.1	190	70	1.5	3.58	45	9.1	<200	<2	2.0	38
AML B 035	<10	18.1	120	72	1.0	1.49	55	8.0	<200	<2	1.36	7
AML D 045	<10	19.0	140	78	1.4	1.99	43	7.2	<200	<2	1.6	24
AML C 055	<10	23.6	140	60	1.1	2.16	42	9.5	<200	<2	1.73	29
AML C 065	<10	19.1	210	71	1.1	1.71	50	7.0	<200	<2	1.9	14
AML C 075	<10	20.7	200	73	1.2	1.92	41	7.8	<200	<2	1.9	18
AML C 085	<10	19.2	140	84	1.0	1.79	49	7.5	<200	<2	1.43	14
AML D 105	<10	22.5	190	78	1.3	2.30	44	8.4	<200	<2	1.70	<0.03
SPK C 014	<9	20.0	160	110	0.59	2.35	73	7.4	<200	<2	1.7	15
SPK D 005	<9	22.2	180	116	0.8	2.88	58	7.9	<200	<2	1.6	13
SPK D 015	<9	20.6	170	115	0.7	2.42	79	8.2	<200	<2	1.73	<0.04
SPK D 025	<9	23.0	210	114	0.7	2.49	60	7.5	<200	<2	1.78	16
SPK D 035	<9	23.9	130	111	0.7	2.38	58	6.7	<100	<2	1.6	15
SPK C 045	<9	21.3	140	123	0.8	2.46	68	9.4	<200	<2	1.8	42
SPK B 055	<10	21.4	160	81	0.7	2.96	8.1	3.3	<200	<2	1.20	22
OR A 015	<10	14.7	210	21	2.3	2.20	7.0	13.1	170	<2	1.11	48
OR C 035	<10	19.0	170	18	2.0	2.87	6.7	13.0	<200	<2	1.6	27
OR A 045	<10	20.2	280	38	2.1	3.69	6.7	12.8	240	<2	1.6	90
OR D 055	<20	32.5	460	31	3.1	4.19	6.5	25	<300	<3	4.2	540
OR A 065	<10	27.1	230	32	3.2	3.51	12.4	18	<200	<2	1.31	47
VIT A 005	<10	37.3	430	113	7.2	6.5	5.3	6.9	390	5.4	1.9	140
VIT C 025	33	28.2	190	78	3.3	3.71	3.2	6.7	540	2.9	1.65	70
VIT B 035	<10	41	320	79	23.7	6.4	12.0	13.2	640	7	2.3	130
VIT D 045	<10	24.0	130	98	7.8	4.77	14	10.9	290	5.0	1.4	150
VIT D 055	<10	41	300	103	28	7.4	28	13.2	530	8	2.6	190
VIT D 065	<10	24.8	220	91	10.8	4.47	38	15.1	<200	10	1.6	200
VIT D 075	<20	28.3	260	98	30	5.6	14	7.5	<300	7.3	1.8	100
VIT E 085	<10	36.7	220	92	6.1	4.67	18	14.0	<200	4.4	1.8	210
VIT D 095 1	<20	32.9	280	96	11.0	5.9	39	16.2	<300	6.9	1.8	130
VIT D 095 2	<20	32.1	330	96	10.3	5.9	38	16	<300	7.1	2.5	140
VIT D 095 3	<10	32.9	220	84	10.0	6.2	37	16	<200	5.8	1.7	140

TABLE C-VI (cont)

Sample ID	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
SHR B 005	<20	32.0	250	55	3.0	6.1	62	6.8	<300	<2	3.3	180
SHR B 015	<10	23.6	310	54	1.0	4.17	10.5	5.6	<200	<1	2.19	80
SHR B 025	<10	20.5	240	43	1.9	4.30	56	5.0	<200	<2	2.1	90
SHR A 035	<8	9.4	130	31	1.5	1.46	28	2.5	180	<1.0	0.73	40
SHR D 045	<10	29.1	340	71	1.2	5.4	7.5	5.4	<200	<2	2.5	130
SHR D 065	<10	26.8	240	55	1.4	4.78	11.2	5.0	<200	<2	2.13	<3
SHR D 075	<10	20.7	180	52	1.3	3.53	12.6	7.2	<200	<2	1.6	22
SHR D 085	<10	27.0	290	68	1.2	6.5	6.2	5.5	600	2.2	2.2	80
SHR C 095	<20	26.5	360	56	2.5	6.1	6.2	7.4	<300	<2	2.0	70
MH A 005	<9	24.5	250	47	2.5	4.51	4.6	5.6	290	<1	2.1	130
MH B 015	<30	27.3	730	<20	<0.4	13.4	22	18	<400	<2	6.2	130
MH A 025	<20	24.6	<200	<20	5.9	11.9	<3	22	1000	3.5	5.1	90
MH C 045	<10	33.9	900	40	5.5	4.17	5.1	10.1	310	9	5.1	70
MH D 055	<9	30.3	450	39	2.9	3.50	4.8	9.5	240	<3	2.8	100
MH D 065	<10	52	670	54	6.6	6.6	<2	17	430	10	4.5	60
MH D 075	<20	47	470	57	4.3	6.5	<3	11.7	600	4	2.9	50
MH D 085	<10	47	650	53	6.5	6.6	<3	14.9	<200	<5	4.3	44
MH C 095	<10	22.5	510	21	2.7	2.49	5.1	7.1	260	6	2.8	100
MH D 105 1	<9	25.1	310	27	2.4	3.14	13	<0.2	<100	<3	1.6	130
MH D 105 2	<8	25.7	340	37	2.2	3.18	6.3	7.9	<100	<3	1.9	120
MH D 105 3	<8	24.9	300	36	2.2	2.96	5.6	8.0	180	<3	1.7	170
GUN C 005	<10	43	460	76	20.3	10.0	3.4	8.5	690	10	3.2	80
GUN A 015	<10	42	320	82	12.6	7.9	31	8.8	430	6.2	2.6	80
GUN A 025	<7	26.0	260	37	15.7	3.60	2.6	4.7	450	6.2	1.73	80
GUN C 035	<9	27.9	290	43	18.9	6.9	3.9	6.2	440	9	2.3	59
GUN C 045	<8	37.1	260	52	18.6	5.7	4.4	8.7	550	6.7	2.2	50
GUN C 055	<5	34.0	380	40	24.1	5.8	2.7	10.0	590	10	2.2	130
GUN A 065	<9	25.6	290	45	13.6	5.9	3.1	5.9	420	4.6	1.83	80
GUN B 075	<10	31.1	390	39	15.2	11.5	5.1	7.6	670	6.8	2.9	90
GUN D 085	<7	32.6	320	57	16.1	5.8	4.1	7.4	500	7.4	2.5	90
GUN D 095	<10	38.3	380	56	18.9	7.0	3.0	9.0	680	7.4	2.8	100
GUN D 105	<10	34.3	280	70	11.2	6.2	4.1	6.1	400	4.3	1.83	49

TABLE C-VI (cont)

Sample ID	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
GJT D 005	<7	9.8	<50	21	1.48	1.62	29	5.7	<100	<1.1	0.87	61
GJT C 015	<9	11.9	130	26	2.1	1.69	24	7.2	<100	<1	1.08	70
GJT C 025	<9	11.7	180	26	1.4	1.73	27	7.3	180	<1	0.96	70
GJT B 035	<9	16.5	140	19	1.4	2.40	10.6	8.1	<200	<2	1.23	47
GJT B 045	<10	19.2	240	34	1.7	3.17	17	9.5	<200	<1	1.66	80
GJT A 055	<10	26.0	200	54	1.9	5.9	15	7.0	<200	<2	1.88	150
GJT A 065	<9	8.2	<60	22	1.43	1.13	32	5.5	<100	<0.9	0.73	80
GJT D 075	<20	34.9	330	<20	<0.7	6.7	47	20	700	<4	2.7	80
GJT D 085 1	<20	29.8	320	34	5.2	5.23	39	19	<300	<4	3.2	100
GJT D 085 2	<20	29.1	360	22	5.5	5.5	42	19	500	<3	3.1	130
GJT D 085 3	<20	29.1	260	23	8.4	5.5	41	20	400	<3	2.9	90
GJT D 095	<9	11.1	<60	17	1.9	1.59	27	6.8	<100	<1	0.86	60
TC C 005	<10	33.1	320	51	6.5	4.00	33	13.2	410	<5	2.3	260
TC C 015	<10	34	380	68	11.0	4.7	27	15	<200	<5	2.5	380
TC B 025	<9	36	380	59	6.1	4.9	5.8	13.3	330	<4	2.3	650
TC B 035 1	<10	35.9	450	57	5.5	2.63	44	28	<200	<4	1.8	290
TC B 035 2	<10	34.3	400	54	5.6	2.51	41	28	<200	6	1.5	290
TC B 035 3	<10	36.1	480	54	5.8	2.68	6.7	29	<200	5	1.4	310
TC B 045	<9	19.8	250	28	4.3	2.29	4.5	13.4	<100	<3	1.3	270
TC B 055	<10	32.0	450	<20	7.4	4.36	36	16.1	<200	<5	2.6	230
TC B 065	<20	30.2	380	<30	9.0	4.6	<2	19	<300	<6	2.4	440

TABLE C-VII

NEUTRON ACTIVATION ANALYSES OF SITE AND SECTION COMPOSITE SAMPLES

		Major and Minor Elements plus Uranium and Thorium										
Sample ID	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (ppm)	Mn (%)	Na (%)	Ti (ppm)	U (ppm)	V (ppm)	Th (ppm)
AML A	86.1	3.3	3.4	1.28	1.9	0.28	350	1.15	0.13	110	590	4.3
AML B	86.9	4.0	4.0	1.42	1.9	0.23	340	1.12	0.12	110	490	4.7
AML C	86.4	3.8	4.7	1.38	1.9	0.37	370	1.11	1.10	120	510	3.9
AML D	86.1	4.1	4.9	1.27	1.8	0.32	360	1.19	0.09	110	470	3.2
AML SITE	86.6	3.8	4.3	1.62	1.8	0.29	370	1.11	0.15	110	470	4.4
RIV A	85.2	5.6	2.0	2.35	2.6	0.49	181	1.41	0.09	87	270	17.2
RIV B	83.2	6.8	2.3	2.51	2.5	0.78	232	1.45	0.22	72	163	19.5
RIV C	83.8	6.5	1.7	2.69	2.7	0.70	180	1.44	0.13	89	230	21.8
RIV D	84.8	6.1	1.9	2.21	2.4	0.65	212	1.43	0.21	68	138	17.7
RIV SITE	84.4	6.2	2.0	2.15	2.8	0.62	191	1.42	0.17	83	230	17.0
NR A	89.0	3.1	2.2	2.41	0.56	0.54	102	1.49	0.14	180	2500	5.0
NR B1	90.1	2.7	1.7	2.29	0.7	0.60	121	1.27	0.08	180	2190	4.3
NR B2	89.9	2.9	1.7	2.23	0.70	0.60	123	1.29	0.11	180	2190	4.1
NR B3	89.8	2.8	1.8	2.23	0.67	0.7	118	1.33	0.10	170	2250	4.1
NR C	87.6	2.6	2.2	4.4	0.5	0.61	630	1.29	0.13	150	2900	3.9
NR D	89.6	2.06	1.5	3.40	0.7	0.8	550	1.21	0.19	100	2500	2.7
NR SITE	88.7	2.7	1.8	3.36	0.7	0.64	340	1.33	0.12	150	2500	3.9
SPK A	88.1	5.1	1.0	1.28	3.2	0.26	169	0.80	<0.03	120	164	6.9
SPK B	88.6	4.8	1.0	1.35	3.0	0.24	161	0.78	0.067	110	170	7.5
SPK C	88.9	4.7	0.97	1.25	2.8	0.28	167	0.81	0.070	150	220	7.3
SPK D	88.1	4.9	0.9	1.15	3.3	0.45	154	0.84	0.09	130	189	7.1
SPK SITE	88.3	4.9	0.87	1.30	3.3	0.23	147	0.81	0.062	110	167	7.1
MBL A	87.4	5.0	1.9	1.79	2.0	0.57	480	1.00	0.14	88	74	6.1
MBL B	89.5	4.2	1.2	1.62	1.9	0.29	250	1.07	0.09	70	47	5.0
MBL C	87.4	5.2	2.2	1.68	1.4	0.71	550	0.99	0.14	110	99	6.3
MBL D	88.1	4.6	1.5	1.75	1.9	0.72	330	1.11	0.10	85	56	5.7
MBL SITE	88.3	4.6	1.9	1.77	1.7	0.40	440	1.01	0.12	97	69	5.5

TABLE C-VII (cont)

Sample ID	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (ppm)	Mn (%)	Na (%)	Ti (ppm)	U (ppm)	V (ppm)	Th (ppm)
MH A	89.5	2.7	4.2	1.84	0.8	<0.2	600	0.145	0.11	120	680	270
MH B	87.8	2.7	4.9	2.44	1.0	<0.2	890	0.145	0.10	160	1070	93
MH C	90.1	4.1	1.8	1.45	1.3	0.22	320	0.322	0.25	120	750	74
MH D	92.4	2.9	1.2	1.52	0.90	0.25	219	0.283	0.15	92	660	53
MH SITE	90.6	3.3	2.6	1.53	1.1	<0.2	440	0.254	<0.05	120	820	78
VIT A	83.9	4.7	4.6	2.23	2.2	1.04	360	0.93	0.22	25	141	9.9
VIT B	86.8	4.5	3.1	1.61	2.0	0.79	191	0.68	0.24	110	191	8.0
VIT C	85.9	4.1	4.7	1.54	2.0	0.66	240	0.52	0.21	160	197	6.7
VIT D	85.1	3.8	3.9	3.5	1.6	0.62	520	0.70	0.21	140	920	12.8
VIT E	84.6	3.5	4.1	3.7	1.5	0.9	580	0.65	0.22	280	1440	10.6
VIT SITE	84.9	4.1	3.9	2.76	2.1	0.84	420	0.71	0.25	140	640	10.2
SHR A1	94.2	1.82	1.8	0.53	0.95	0.21	80	0.231	0.096	30	950	2.0
SHR A2	94.0	1.75	1.8	0.63	1.00	0.25	82	0.230	0.093	28	950	2.9
SHR A3	94.2	1.73	1.7	0.54	1.03	0.22	79	0.228	0.114	30	940	2.1
SHR B	91.1	2.6	3.1	1.04	1.19	0.31	182	0.289	0.12	39	1520	3.9
SHR C	88.7	3.4	3.1	1.87	1.4	0.53	380	0.61	0.12	110	1120	4.6
SHR D	87.1	3.9	3.6	2.05	1.5	0.80	370	0.60	0.22	65	1020	6.6
SHR SITE	89.9	3.0	3.1	1.46	1.19	0.52	250	0.41	0.18	64	1250	4.5
GJT A	93.3	2.09	1.2	1.29	0.80	0.44	125	0.49	0.078	160	1520	3.0
GJT B	88.4	3.7	2.5	1.87	0.79	0.65	123	1.45	0.14	190	1760	4.7
GJT C	92.2	2.37	1.4	1.39	0.62	0.70	87	0.81	0.11	140	1680	3.0
GJT D	92.5	2.27	1.4	1.47	0.73	0.35	89	0.81	0.10	140	1740	3.1
GJT SITE	91.7	2.6	1.5	1.65	0.64	0.60	110	0.89	0.10	150	1720	3.8
GUN A	89.4	5.0	0.79	2.16	1.21	0.37	196	0.62	0.24	49	56	7.9
GUN B	90.1	4.7	0.68	2.23	0.94	0.28	228	0.56	0.30	59	61	5.4
GUN C	90.5	4.9	0.51	1.78	1.15	0.28	137	0.46	0.18	72	54	6.6
GUN D	89.7	5.2	0.56	2.05	1.10	0.38	165	0.47	0.25	75	51	5.7
GUN SITE	90.0	4.7	0.63	2.39	1.16	0.21	174	0.50	0.23	63	47	7.0

TABLE C-VII (cont)

Sample ID	Non-NAA (%)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (ppm)	Mn (%)	Na (%)	Ti (ppm)	U (ppm)	V (ppm)	Th (ppm)
OR A	90.1	2.8	1.8	1.80	1.1	0.79	182	1.08	0.11	280	1540	3.7
OR B	92.6	2.07	1.1	1.72	0.58	0.40	164	0.98	0.12	350	1660	3.4
OR C	92.1	2.24	1.2	1.83	0.64	0.57	172	0.93	0.09	260	1410	3.4
OR D	91.0	2.7	1.6	1.66	0.70	0.69	198	1.09	0.12	430	1580	3.5
OR SITE1	91.6	2.5	1.3	1.90	0.78	0.50	190	1.00	0.10	310	1530	3.1
OR SITE2	91.5	2.4	1.4	1.92	0.8	0.41	192	1.03	0.08	310	1580	3.7
OR SITE3	91.5	2.4	1.4	2.03	0.73	0.42	187	1.00	0.13	320	1530	3.9
TC A	87.8	5..5	0.65	1.73	1.4	1.7	370	0.36	0.18	340	430	7.8
TC B	91.0	3.2	0.61	1.43	1.2	1.4	257	0.320	0.13	250	180	4.9
TC C	90.1	4.0	0.39	2.17	1.7	0.46	186	0.320	0.16	200	290	5.9
TC SITE	89.9	3.9	0.52	1.81	1.6	1.1	232	0.323	0.15	220	260	5.5
GRS SOIL1	92.3	3.7	0.52	1.40	0.93	0.67	194	0.206	0.18	1.43	32	6.7
GRS SOIL2	92.3	3.7	0.60	1.32	0.96	0.63	201	0.218	0.16	1.51	31	6.3
GRS SOIL3	92.9	3.4	0.55	1.32	0.79	0.60	188	0.198	0.16	1.33	31	6.5
GRS SOIL4	92.4	3.7	0.67	1.26	0.85	0.64	195	0.215	0.15	1.40	34	6.1
GRS SOIL5	92.0	3.8	0.63	1.52	0.89	0.64	205	0.223	0.19	1.50	30	7.7
GRS SOIL6	92.7	3.6	0.60	1.23	0.81	0.62	194	0.211	0.18	1.42	33	6.2

TABLE C-VII (cont)

	Trace Elements (A to H)											
Sample ID	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
AML A	33	840	3.0	68	<80	3.6	18	1.7	2.4	680	<20	3.3
AML B	30	760	1.9	75	<70	3.9	23	2.2	2.9	740	33	4.0
AML C	31	840	4.0	77	<80	3.9	25	1.4	2.4	730	<20	3.3
AML D	31	840	5.2	63	<80	3.2	18	1.4	2.1	630	40	3.1
AML SITE	29	690	4.5	71	<80	4.0	32	2.0	1.8	690	<20	3.9
RIV A	200	900	4.3	100	130	8.7	63	4.0	4.0	570	<20	4.8
RIV B	138	860	6.0	102	<90	8.7	79	6.6	4.2	750	<20	5.5
RIV C	173	880	4.7	114	80	9.4	71	7.1	4.4	790	<20	5.2
RIV D	123	880	4.5	89	110	6.8	63	5.2	3.6	690	<20	4.9
RIV SITE	173	1000	2.7	92	100	7.8	61	5.0	4.0	680	<20	4.5
NR A	148	1000	<2	85	510	7.3	81	0.9	2.2	660	50	4.5
NR B1	121	930	<2	71	500	6.8	86	ND	2.1	560	50	4.9
NR B2	122	1100	<2	80	550	6.2	82	0.7	2.2	430	<20	4.6
NR B3	122	1200	<2	78	540	6.7	80	1.0	2.2	<20	4.6	
NR C	172	760	<1.6	72	270	8.8	620	ND	2.2	570	44	4.6
NR D	125	650	<2	45	270	6.3	560	0.6	<0.8	260	40	4.5
NR SITE	140	1000	<2	75	450	7.0	300	0.9	1.8	450	<20	4.5
SPK A	7.2	840	<1.4	66	80	2.5	39	0.7	1.6	430	27	4.3
SPK B	8.6	820	2.9	71	80	2.6	45	1.0	1.9	370	26	4.4
SPK C	6.5	710	1.5	73	<60	3.1	39	0.9	2.4	350	52	4.7
SPK D	7.2	690	1.7	67	90	2.8	34	1.1	1.9	360	27	4.0
SPK SITE	6.2	830	1.8	68	90	2.7	44	0.7	1.7	400	<12	3.8
MBL A	25	930	16.1	65	<90	3.3	36	1.8	2.0	670	17	3.0
MBL B	14.9	890	9.5	60	50	2.7	42	1.5	1.4	580	31	3.3
MBL C	28	890	33	77	<70	3.8	29	2.1	1.9	680	<20	3.6
MBL D	19	900	7.5	68	<70	3.2	47	1.7	2.3	640	<10	3.3
MBL SITE	24	820	14.6	66	70	3.3	38	1.6	2.0	620	33	3.4

TABLE C-VII (cont)

Sample ID	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
MH A	210	590	<1.2	96	<50	62	49	2.1	9.1	1310	21	4.6
MH B	280	730	2.6	98	290	80	65	1.5	7.0	1370	29	3.9
MH C	86	1500	3.2	96	<60	94	49	2.7	5.9	990	35	6.4
MH D	71	1100	2.9	79	<40	75	48	1.9	4.6	700	24	6.6
MH SITE	145	900	3.6	84	<50	80	43	2.0	6.1	980	27	6.2
VIT A	164	880	6.1	74	210	7.5	66	7.2	3.3	830	<10	6.5
VIT B	89	1600	3.8	96	100	12.8	36	4.4	3.6	910	<20	6.0
VIT C	116	1500	3.3	106	200	16.3	41	4.2	3.9	830	43	4.8
VIT D	109	790	2.9	87	1390	16.9	1200	4.6	3.0	610	40	5.5
VIT E	91	610	3.8	140	1780	20.77	1600	4.5	2.9	800	46	6.5
VIT SITE	117	1100	3.4	97	900	15.2	770	5.0	3.3	750	40	5.6
SHR A1	17	730	1.4	28	70	5.1	23	1.1	1.6	360	<8	4.2
SHR A2	17.0	690	1.1	34	50	6.1	34	1.5	1.5	420	<7	5.2
SHR A3	17.0	750	1.1	28	<40	5.0	24	1.4	1.5	420	<8	4.0
SHR B	31	820	1.5	45	70	5.1	34	1.9	2.8	600	<11	4.8
SHR C	21	820	1.5	72	80	5.8	28	2.4	2.6	630	<10	5.9
SHR D	27	760	3.4	69	170	5.9	50	3.8	3.1	770	23	6.6
SHR SITE	26	880	2.4	53	110	6.1	38	2.1	2.5	650	<12	5.3
GJT A	59	700	1.4	73	310	4.4	37	1.6	2.0	400	33	5.2
GJT B	200	1000	<2	94	590	9.6	58	1.3	3.3	910	60	5.3
GJT C	150	690	<1.5	61	290	7.4	52	1.3	1.9	610	39	4.3
GJT D	156	660	<1.5	67	280	7.9	53	0.8	2.0	510	33	4.2
GJT SITE	145	740	<1.5	74	350	8.1	56	1.1	2.0	530	43	4.8
GUN A	200	850	2.9	83	<50	17.0	23	6.3	3.7	860	<12	5.4
GUN B	230	1000	2.2	66	<50	17.3	21	6.2	3.6	800	25	4.4
GUN C	260	1100	4.6	78	<40	15.2	20	6.4	3.4	740	<10	5.0
GUN D	300	830	2.7	83	<40	16.7	22	6.1	3.5	760	<10	5.0
GUN SITE	250	880	<1.3	92	<50	17.9	29	6.8	3.4	870	22	5.1

TABLE C-VII (cont)

Sample ID	As (ppm)	Ba (ppm)	Br (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppb)	Ga (ppm)	Hf (ppm)
OR A	139	1100	<2	107	500	8.0	54	1.2	2.6	620	60	5.0
OR B	113	1100	30	127	460	7.3	71	0.8	2.3	520	60	5.1
OR C	110	870	3.1	112	500	7.5	66	1.1	2.8	600	60	5.9
OR D	145	1100	<2	143	490	8.7	58	1.1	3.3	660	80	5.2
OR SITE1	121	1000	2.6	125	520	7.4	66	1.0	2.7	600	70	5.4
OR SITE2	124	1200	4	116	550	7.5	65	0.9	2.3	580	70	4.8
OR SITE3	122	1100	2.0	129	510	8.4	73	1.1	2.5	580	70	5.7
TC A	610	1170	9	181	200	171	47	4.4	7.4	1500	460	4.9
TC B	730	1700	5.0	106	200	149	43	3.2	4.1	930	330	4.8
TC C	840	2900	<3	104	90	146	47	2.8	3.8	930	180	5.0
TC SITE	730	2200	3.9	110	130	146	44	2.8	4.2	1000	280	4.8
GRS SOIL1	1.9	350	11.8	45	<30	4.6	25	2.5	2.6	600	<8	5.8
GRS SOIL2	3.4	330	13.2	35	<40	4.1	22	2.3	3.0	560	<9	6.0
GRS SOIL3	3.2	320	11.9	45	<30	4.1	24	2.3	2.7	510	<9	5.4
GRS SOIL4	2.8	280	12.6	41	<30	4.0	22	2.6	2.7	520	<9	5.7
GRS SOIL5	3.1	300	12.6	43	<30	4.8	30	2.8	2.8	660	<8	7.1
GRS SOIL6	3.0	240	12.8	40	<30	4.2	24	2.3	2.8	530	<10	5.3

TABLE C-VII (cont)

Sample ID	Trace Elements (I to Z)											
	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
AML A	<10	24.1	220	71	0.9	2.61	51	8.2	<200	<2	2.0	20
AML B	<10	21.7	190	76	1.4	2.73	58	7.8	<200	<2	1.8	21
AML C	<10	20.8	240	81	1.0	2.07	52	8.3	<200	<2	1.8	24
AML D	<10	21.5	160	70	1.2	2.02	40	7.5	<200	<2	1.26	13
AML SITE	<10	20.4	240	80	1.1	2.23	49	7.5	<200	<2	1.8	33
RIV A	<10	37.9	420	120	2.7	4.11	61	8.2	<200	3.0	2.3	54
RIV B	<10	46	340	104	<0.5	7.1	60	8.2	<200	<3	2.1	<10
RIV C	<10	39.9	380	143	1.9	6.6	85	8.8	230	4.1	2.6	39
RIV D	<10	43	310	103	2.0	5.5	59	7.1	<200	<2	2.4	28
RIV SITE	<10	38.6	370	94	2.0	5.20	59	8.2	<200	2.5	2.2	39
NR A	<10	20.1	410	17	3.5	3.79	53	10.6	<200	2.6	1.6	46
NR B1	<10	18.0	360	19	2.9	3.39	38	10.6	<200	<2	1.5	47
NR B2	<10	17.6	340	24	2.9	3.27	42	10.5	<200	<2	1.8	80
NR B3	<10	17.4	330	15	2.8	3.32	38	10.1	<200	<2	1.4	38
NR C	<20	15.2	330	26	2.6	3.43	44	9.3	<300	<2	1.4	150
NR D	<20	11.4	210	24	2.2	2.63	24	6.3	<300	<2	0.70	100
NR SITE	<20	16.4	350	29	3.4	3.23	42	9.3	<300	<2	1.5	100
SPK A	<9	21.1	300	109	0.8	2.24	74	7.4	<100	<2	1.5	18
SPK B	<8	20.2	310	119	1.1	2.53	79	7.2	<100	<1	1.7	13
SPK C	<9	22.8	320	107	0.9	2.62	72	9.2	<100	<2	1.7	11
SPK D	<9	22.6	290	104	0.9	2.47	66	8.3	<100	<2	1.6	<5
SPK SITE	<7	19.1	280	128	0.68	2.33	74	7.0	<100	<1	1.1	<1
MBL A	<10	25.5	230	61	1.2	3.34	61	6.8	400	<2	1.7	30
MBL B	<11	21.9	220	64	1.0	2.06	23	5.5	360	<2	1.1	21
MBL C	<10	27.3	260	57	1.1	3.60	58	8.3	510	<2	1.2	18
MBL D	<10	23.3	230	64	1.2	2.28	31	6.2	320	<2	1.5	25
MBL SITE	<10	25.1	250	72	1.4	2.82	42	7.3	310	<2	1.6	<2

TABLE C-VII (cont)

Sample ID	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
MH A	<20	24.0	450	36	3.0	5.3	<3	12.7	400	1.3	3.4	100
MH B	<20	24.8	530	20	4.3	6.3	27	12.9	<300	1.7	3.1	150
MH C	<10	35.5	540	51	5.0	4.48	6.5	10.0	<200	5.0	3.5	60
MH D	<10	24.5	530	31	3.5	3.32	32	8.0	<200	4.3	3.2	90
MH SITE	<10	29.3	480	37	3.7	4.36	29	11.0	<200	3.9	25	90
VIT A	<11	34.4	260	102	13.1	5.7	5.0	5.3	410	4.2	2.0	110
VIT B	<10	39.2	440	78	11.2	5.0	8.4	9.3	520	4.1	2.5	150
VIT C	<10	33.3	400	85	13.9	4.87	9.9	12.1	720	6.0	2.0	110
VIT D	<10	30.2	360	80	13.3	4.60	16	10.2	500	6.5	1.3	220
VIT E	<10	30.7	520	84	7.3	5.3	23	16.6	<200	6.0	1.5	160
VIT SITE	<10	32.1	370	84	12.0	4.78	13	9.5	400	5.8	1.6	130
SHR A1	<6	12.8	120	36	1.37	1.83	28	3.0	<100	0.9	0.77	52
SHR A2	<6	12.3	150	41	1.50	2.16	36	2.9	200	1.1	1.2	54
SHR A3	<7	12.9	160	36	1.45	1.89	29	3.1	<100	<1.0	1.04	60
SHR B	<11	18.2	210	45	2.1	3.19	44	4.5	<200	<1	1.8	57
SHR C	<10	24.0	360	55	1.3	4.20	18	7.5	<200	<2	1.5	27
SHR D	<10	24.4	370	66	1.10	4.87	19	6.4	220	2.0	1.8	54
SHR SITE	<10	21.5	280	54	1.6	3.61	31	5.4	<200	<1	1.7	90
GJT A	<9	15.3	370	31	1.7	2.45	32	9.3	<200	<1	1.2	100
GJT B	<10	24.6	440	34	2.5	4.12	17	12.3	<200	<2	1.8	70
GJT C	<10	16.0	260	25	2.7	2.36	28	8.7	<200	<2	1.3	70
GJT D	<10	14.6	300	23	2.2	2.39	30	8.6	210	<2	1.3	60
GJT SITE	<10	17.2	300	25	2.6	2.84	28	9.1	<200	<2	1.2	90
GUN A	<8	33.6	370	52	17.8	7.0	3.0	7.0	390	7.9	2.6	90
GUN B	<9	31.5	320	44	16.4	7.6	3.5	7.3	490	7.5	1.9	100
GUN C	<8	33.8	390	55	19.4	6.0	4.9	7.2	580	9	2.2	60
GUN D	<8	35.1	360	49	18.5	6.5	5.6	8.0	630	9	2.2	70
GUN SITE	<7	32.9	410	55	18.1	7.1	5.6	7.7	420	7.6	2.4	90

TABLE C-VII (cont)

Sample ID	I (ppm)	La (ppm)	Lu (ppb)	Rb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sm (ppm)	Sr (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)
OR A	<10	22.6	480	25	3.8	3.08	13	14.9	<200	<2	1.7	38
OR B	<10	19.2	520	23	3.0	2.40	9.5	19	<200	<2	1.1	40
OR C	<10	17.6	460	30	2.4	2.78	8.3	14.6	<200	<2	1.3	45
OR D	<10	23.6	570	24	3.0	2.91	7.6	25	<200	<2	2.0	90
OR SITE1	<10	19.5	490	21	3.2	2.68	9.6	18	<200	<2	1.5	50
OR SITE2	<10	20.3	480	28	2.9	2.66	9.0	18	<200	<2	1.2	53
OR SITE3	<10	19.9	540	26	2.8	2.90	10.3	18	<200	<2	1.5	60
TC A	<20	46	600	60	9.1	6.5	4.2	24	<300	<6	2.8	210
TC B	<10	28.1	440	50	6.9	3.62	23	17	<200	<5	1.5	300
TC C	<10	30.4	340	57	8.0	3.75	4.9	13.4	310	<5	2.1	410
TC SITE	<10	30.9	330	51	7.1	3.94	<2	15.5	<200	<4	2.4	580
GRS SOIL1	<7	21.3	250	45	<0.2	4.72	3.7	3.2	<100	<1.0	1.95	35
GRS SOIL2	13	22.4	230	44	0.47	4.44	3.7	3.2	<100	<1.2	1.79	28
GRS SOIL3	<8	20.6	250	43	0.48	4.41	3.9	2.9	<100	<1.1	1.88	23
GRS SOIL4	12	25.1	250	37	<0.2	4.37	3.7	3.2	<100	<1.1	1.56	<4
GRS SOIL5	11	22.3	350	49	0.32	5.11	5.1	3.4	180	<1.0	2.1	41
GRS SOIL6	<8	22.0	330	45	0.38	4.18	3.7	3.1	<100	<1.2	1.53	<4

TABLE C-VIII

ELEMENTAL COMPOSITION OF TAILINGS COMPOSITES FROM 12 INACTIVE SITES

Site	SiO_x[a]	Al	Ca	Fe	K	Mg	Na	Ti	As	Ba	Br	Cl	Co	Cr	Cs	Ga	Hf
Ambrosia Lake	86.6	3.8	4.3	1.62	1.8	0.29	1.11	0.15	29	690	4.5	<80	4.0	32	2.0	<20	3.9
Riverton	84.4	6.2	2.0	2.15	2.8	0.62	1.42	0.17	173	1000	2.7	100	7.8	61	5.0	<20	4.5
New Rifle	88.7	2.7	1.8	3.36	0.7	0.64	1.33	0.12	140	1000	<2	450	7.0	300	0.9	<20	4.5
Spook	88.3	4.9	0.87	1.30	3.3	0.23	0.81	0.062	6.2	830	1.8	90	2.7	44	0.7	<12	3.8
Maybell	88.3	4.6	1.9	1.77	1.7	0.40	1.01	0.12	24	820	14.6	70	3.3	38	1.6	33	3.4
Mexican Hat	90.6	3.3	2.6	1.53	1.1	<0.2	0.254	<0.05	145	900	3.6	<50	80	43	2.0	27	6.2
Vitro	84.9	4.1	3.9	2.76	2.1	0.84	0.71	0.25	117	1100	3.4	900	15.2	770	5.0	40	5.6
Shiprock	89.9	3.0	3.1	1.46	1.19	0.52	0.41	0.18	26	880	2.4	110	6.1	38	2.1	<12	5.3
Grand Jct	91.7	2.6	1.5	1.65	0.64	0.60	0.89	0.10	145	740	<1.5	350	8.1	56	1.1	43	4.8
Gunnison	90.0	4.7	0.63	2.39	1.16	0.21	0.50	0.23	250	880	<1.3	<50	17.9	29	6.8	22	5.1
Old Rifle	91.5	2.4	1.4	1.95	0.77	0.44	1.01	0.10	123	1100	2.9	530	7.8	68	1.0	70	5.7
Tuba City	89.9	3.9	0.52	1.81	1.6	1.1	0.323	0.15	730	2200	3.9	130	146	44	2.8	280	4.8
Minimum	84.4	2.4	0.52	1.30	0.64	<0.2	0.254	<0.05	6.2	690	<1.3	<60	2.7	29	0.7	<12	3.4
Maximum	91.7	6.2	4.3	3.36	3.3	1.1	1.42	0.25	730	2200	14.6	900	146	770	6.8	280	6.2
Mean	88.7	3.85	2.04	1.98	1.57	0.507	0.815	0.140	159	1012	3.72	243	25.5	127	2.58	50	4.80
Std dev	2.4	1.13	1.22	0.60	0.83	0.274	0.385	0.061	194	396	3.57	265	43.5	216	1.97	74	0.84
CV (%)	2.7	29	60	30	53	54	47	44	122	39	96	109	171	170	76	148	17
95% Confidence Interval	1.5	0.72	0.78	0.38	0.53	0.174	0.245	0.039	123	251	2.27	169	27.6	137	1.25	47	0.53

[a]Total of all elements not detected by NAA, including Si, O, and S.

TABLE C-VIII (cont)

Site	SiO_x[a]	Mn	Rb	Sb	Sc	Se	Th	U	V	Zn	Ce	Dy	Eu	La	Lu	Sm	Yb
Ambrosia Lake	86.6	370	80	1.1	2.23	49	4.4	110	470	33	71	1.8	0.69	20.4	0.24	7.5	1.8
Riverton	84.4	191	94	2.0	5.20	59	17.0	83	230	39	92	4.0	0.68	38.6	0.37	8.2	2.2
New Rifle	88.7	340	29	3.4	3.23	42	3.9	150	2500	100	75	1.8	0.45	16.4	0.35	9.3	1.5
Spook	88.3	147	128	0.68	2.33	74	7.1	110	167	<20	68	1.7	0.40	19.1	0.28	7.0	1.1
Maybell	88.3	440	72	1.4	2.82	42	5.5	97	69	<30	66	2.0	0.62	25.1	0.25	7.3	1.6
Mexican Hat	90.6	440	37	3.7	4.36	29	78	120	820	90	84	6.1	0.98	29.3	0.48	11.0	2.5
Vitro	84.9	420	84	12.0	4.78	13	10.2	140	640	130	97	3.3	0.75	32.1	0.37	9.5	1.6
Shiprock	89.9	250	54	1.6	3.61	31	4.5	64	1250	90	53	2.5	0.65	21.5	0.28	5.4	1.7
Grand Jct	91.7	110	25	2.6	2.84	28	3.8	150	1720	90	74	2.0	0.53	17.2	0.30	9.1	1.2
Gunnison	90.0	174	55	18.1	7.1	5.6	7.0	63	47	90	92	3.4	0.87	32.9	0.41	7.7	2.4
Old Rifle	91.5	190	25	3.0	2.75	9.6	3.6	310	1550	54	123	2.5	0.59	19.9	0.50	18	1.4
Tuba City	89.9	232	51	7.1	3.94	–	5.5	220	260	580	110	4.2	1.00	30.9	0.33	15.5	2.4
Minimum	84.4	110	25	0.68	2.23	5.6	3.6	64	47	<20	53	1.7	0.40	16.4	0.24	7.0	1.1
Maximum	91.7	440	128	18.1	7.1	74	78	310	2500	580	123	6.1	1.00	38.6	0.50	18	2.5
Mean	88.7	275	61.2	4.72	3.77	34.7	12.54	135	810	112	83.7	2.94	0.684	25.3	0.347	9.63	1.78
Std dev	2.4	120	31.6	5.27	1.42	21.2	20.96	70	784	151	20.0	1.33	0.191	7.3	0.085	3.66	0.48
CV (%)	2.7	44	52	112	38	61	167	52	97	135	24	45	28	29	25	38	27
95% Confidence Interval	1.5	76	20.1	3.35	0.90	14.2	13.32	45	498	96	12.7	0.84	0.121	4.6	0.054	2.33	0.31

4. **Data Analysis Methods**

1. Factor Analysis

- statistics package BMDP4M (Dixon and Brown 1979)
- routine FACTOR ANALYSIS
- based on intercorrelation of variables.

2. Cluster Analysis on Variables

- statistics package BMDP1M (Dixon and Brown 1979)
- routine CLUSTER ANALYSIS ON VARIABLES
- based on clustering by minimum distance method.

3. Clustering of Cases

- statistics package BMDPKM (Dixon and Brown 1979)
- routine CLUSTERING OF CASES
- based on clustering by minimum distance method.

4. Discrimination of Categorized Data

- statistics package ARTHUR (Harper et al. 1977)
- routine WEIGHT
- based on variance weight (interclass variance/intraclass variance) or Fisher weight [(difference in category means)^2/intraclass variance]
- routine SELECT
- based on selection of variables of decreasing discriminating importance; after selection, remaining variables (elements) are decorrelated before next iteration.

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