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Baseline Geochemistry of Soil and Bedrock Tshirege Member of the Bandelier Tuff at MDA-P

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Baseline Geochemistry of Soil and Bedrock Tshirege Member of the Bandelier Tuff at MDA-P

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ABSTRACT

We collected 18 samples of soil and 23 samples of bedrock tuff to provide a baseline chemical characterization of 3 sites near MDA-P. These sites, planned for use in the remediation of MDA-P, are the Segregation Area, Decontamination Pad, and Staging Area 1. All samples were analyzed for the HNO_3-leachable fraction of 28 chemical elements, and the soil samples were also analyzed for the total concentrations of 25 of these elements. The analyses of these 41 baseline samples represent locations that might have been contaminated from operations near MDA-P to compare with previously reported background analyses of samples that represent soil and bedrock near MDA-P that were sampled where contamination was not expected.

Soil profiles were sampled at five locations in one of the sites at MDA-P, and profiles of fill were sampled at several locations in the other two sites. Concentrations of HNO_3-leachable Ba in soil layers sampled within the Segregation Area and Decontamination Pad are generally two to five times greater than Ba concentrations in background MDA-P soil A horizons and LANL-wide combined soil horizons. Concentrations of total Ba are also above site-specific MDA-P screening background levels for most of the samples collected from the Segregation Area and Decontamination Pad. Concentrations of acid-leachable and total Ba are within the background range for samples collected from the Staging Area.

Total element and nitric acid-leachable abundances and the abundances of primary (phenocryst) minerals within Unit 4 of the Tshirege Member of the Bandelier Tuff at MDA-P vary strongly in a systematic pattern that reflects a primary (magmatic) reverse zonation in bedrock. This zonation results in chemical variations for some elements within Unit 4 within a factor of three and variations for some phenocryst abundances that exceed two orders of magnitude. Because of this effect, accurate chemical comparisons for bedrock are possible only when the stratigraphic level within Unit 4 is accurately known, and large standard deviations can result from simple statistical analyses of data from Unit 4. The problem of distinguishing chemical excursions from this extreme chemical variation within Unit 4 is addressed by examining plots of data versus stratigraphic level. At MDA-P, perfectly horizontal attitudes for units of the Tshirege Member are a fortunate consequence of geologic structure, allowing the equation of stratigraphic level to sample elevation. From plots of data versus sample elevation, recognizable chemical excursions are attributed to analytical errors, hydrologically transmissive zones and extreme chemical mobility, extreme weathering, and contamination from anthropogenic activities at MDA-P. On the other hand, no differences in general chemistry were recognized that could be attributed to rock alteration (glassy versus vitric), general weathering, or to burial (exposed tuff versus tuff covered with soil).

The data contained in this report, taken together with the results of previously reported background studies for MDA-P, indicate that wind-borne contamination is widespread from burning pits located south of the waste pile at MDA-P. Near this contaminating source, both amounts of HNO_3-leachable Ba and fractions of HNO_3-leachable Ba relative to total Ba are highly enriched in both soil and bedrock. Near source, both amounts and relative fractions of HNO_3-leachable Pb and Ag are also significantly enriched in soils, and either amounts or relative fractions of HNO_3-leachable U, Cu, and Ca are significantly enriched. Farther from the source, background soil samples show the same enrichment patterns for Ba, Pb, and U, indicating widespread wind-borne contamination for these elements.

1.0. INTRODUCTION

This report provides "baseline" geochemistry for soils (including fill), and for bedrock within three specific areas that are planned for use in the remediation of Material Disposal Area P (MDA-P) at Technical Area 16 (TA-16). The baseline chemistry includes leachable element concentrations for both soils and bedrock and total element concentrations for all soil samples and for two selected bedrock samples. Bedrock near MDA-P consists of Units 3 through 5 of the Tshirege Member of the Bandelier Tuff. Petrographic analyses for selected samples of this bedrock provide important supplementary data that allow recognition of unusual and pronounced geochemical zonation inherent within Unit 4. This large, naturally occurring intraunit variation must be recognized to accurately assess the cause for chemical variations among samples of Unit 4.

MDA-P operated from the early 1950s to 1984 as a landfill for rubble and debris generated by the burning of high explosives (HE) at the TA-16 Burning Ground, HE-contaminated equipment and material, barium nitrate sand, building materials, and trash (Los Alamos National Laboratory: Technical Area 16, Material Disposal Area P Closure Plan, Revision 0, February 1995). Previous reports provided "background" geochemistry for soils and colluvium (McDonald et al., 1996) and for bedrock (Broxton et al., 1996) to characterize the region surrounding MDA-P. The background geochemistry was obtained from sample locations that avoided known sources of contamination. In contrast, contamination is expected for the two sites near the TA-16 Burning Ground sampled for this report.

The aim of this report is to establish causes for recognizable chemical differences between the background and baseline data sets. In many cases, we conclude that recognizable differences represent natural enrichments. In other cases, differences are best attributed to analytical problems. But most importantly, the comparison of background and baseline geochemistry demonstrates significant contamination for several elements not only at the two remedial sites near the TA-16 Burning Ground, but also within the entire region of the background study. This contamination is highly localized very near to the surface in soil and fill, and probably also in bedrock; consequently, upper tolerance limits (UTLs) calculated as upper 95% confidence limits of the 95th percentile are of little value and thus are not provided. This report instead provides basic statistical summaries and graphical comparisons for background and baseline samples to guide strategies for remediation of the three sites to be used in the restoration of MDA-P.

2.0. SAMPLING SITES AND FIELD METHODS

During November and December, 1995, 18 samples of soil and 23 samples of bedrock tuff were collected for baseline study from 3 sites planned for use during the remediation of MDA-P (Table 1; Figs. 1, 2, and 3). Soil within the Segregation Area and fill within the Decontamination Pad were sampled from hand-excavated soil pits, and fill within the Staging area was sampled from holes excavated using a soil-bucket auger. Soils and fill were sampled vertically by genetic horizon or layer with a single, representative bulk sample of approximately 1 to 2 kilograms (kg) collected for each horizon. Depths and numbers of individual soil horizons or layers sampled varied among sample sites. Soil was continuously sampled between the surface (excluding O horizons) to the top of the underlying tuff (depths varied from 4 to 37 cm) within the Segregation Area and Decontamination Pad. Fill was sampled from selected 10- to 15-cm intervals within 62 to 112 cm of the surface within the Staging area.

Table 1. Soil Samples collected for MDAP Baseline Area (TA-16).

FIMAD Sample #	Field Sample #	Site #	Area	Sample Depth (cm)	Tuff or Soil Horizon/Layer
0816-96-0001		RW16PA1	Segregation Area	0	Tuff
0816-96-0002		RW16PA10	Segregation Area	0	Tuff
0816-96-0003		RW16PA11	Segregation Area	0	Tuff
0816-96-0004		RW16PC1	Staging Area 1	25-30	Tuff
0816-96-0005		RW16PC2	Staging Area 1	25-30	Tuff
0816-96-0006		RW16PC3	Staging Area 1	0	Tuff
0816-96-0007		DCN1-R	Decon Area	20-25	Tuff
0816-96-0008		DCN2-R	Decon Area	25-30	Tuff
0816-96-0009		DCN3-R	Decon Area	20-25	Tuff
0816-96-0010		NUS1-R	Segregation Area	15-40	Tuff
0816-96-0011		SUS1-R	Segregation Area	15-40	Tuff
0816-96-0012		RW16PA2	Segregation Area	0	Tuff
0816-96-0013		SLS1-R	Segregation Area	40	Tuff
0816-96-0014		NLS1-R	Segregation Area	35-45	Tuff
0816-96-0015		GB1-R	Segregation Area	40-50	Tuff
0816-96-0016		SA1/1-0.84	Segregation Area	76-84	Tuff
0816-96-0017		RW16PA3	Segregation Area	0	Tuff
0816-96-0018		RW16PA4	Segregation Area	0	Tuff
0816-96-0019		RW16PA5	Segregation Area	0	Tuff
0816-96-0020		RW16PA6	Segregation Area	0	Tuff
0816-96-0021		RW16PA7	Segregation Area	0	Tuff
0816-96-0022		RW16PA8	Segregation Area	0	Tuff
0816-96-0023		RW16PA9	Segregation Area	0	Tuff
0816-96-0024	FS-2309	SUS-1-A	Segregation Area	0--15	A
0816-96-0025	FS-2310	SLS-1-A1	Segregation Area	0--11	A1
0816-96-0026	FS-2311	SLS-1-A2	Segregation Area	11--28	A2
0816-96-0027	FS-2312	NLS-1-A1	Segregation Area	0--8	A1
0816-96-0028	FS-2313	NLS-1-A2	Segregation Area	8--34	A2
0816-96-0029	FS-2314	GB-1-A1	Segregation Area	0--21	A1
0816-96-0030	FS-2315	GB-1-A2	Segregation Area	21--37	A2
0816-96-0031	FS-2316	NUS-1-A1	Segregation Area	0--9	A1
0816-96-0032	FS-2317	NUS-1-A2	Segregation Area	9--25	A2
0816-96-0033	FS-2318	SA1/1-0.15	Staging Area 1	0--15	Fill
0816-96-0034	FS-2319	SA1/1-0.70	Staging Area 1	60--70	Fill
0816-96-0035	FS-2320	SA1/2-0.15	Staging Area 1	0--15	Fill
0816-96-0036	FS-2321	SA1/2-1.12	Staging Area 1	96--112	Fill
0816-96-0037	FS-2322	SA1/3-0.15	Staging Area 1	0--15	Fill
0816-96-0038	FS-2323	SA1/3-0.62	Staging Area 1	50--62	Fill
0816-96-0039	FS-2324	DCN-1	Decon Area	0--7	Fill/Tuff
0816-96-0040	FS-2325	DCN-2	Decon Area	0--12	Fill
0816-96-0041	FS-2326	DCN-3	Decon Area	0--4	Fill/Tuff

Most of the baseline samples were collected from or immediately outside the 200- by 200-ft Segregation Area, which has its western boundary 100 ft southeast from MDA-P (Fig. 2). Three sites were sampled for fill and bedrock within the 20- by 20-ft Decontamination Pad, <100 ft southwest of the Segregation Area (Fig. 2), and three sites were sampled for fill and four for bedrock within or immediately outside Staging Area 1, an irregular area somewhat larger than the Decontamination Pad, and about 1000 ft south from MDA-P (Fig. 3). The Run-on Control Trench for MDA-P prohibits runoff from MDA-P from reaching most of the sample sites of the baseline study, except for four bedrock sites within the drainage of this trench in or immediately outside the Segregation Area (Table 2).

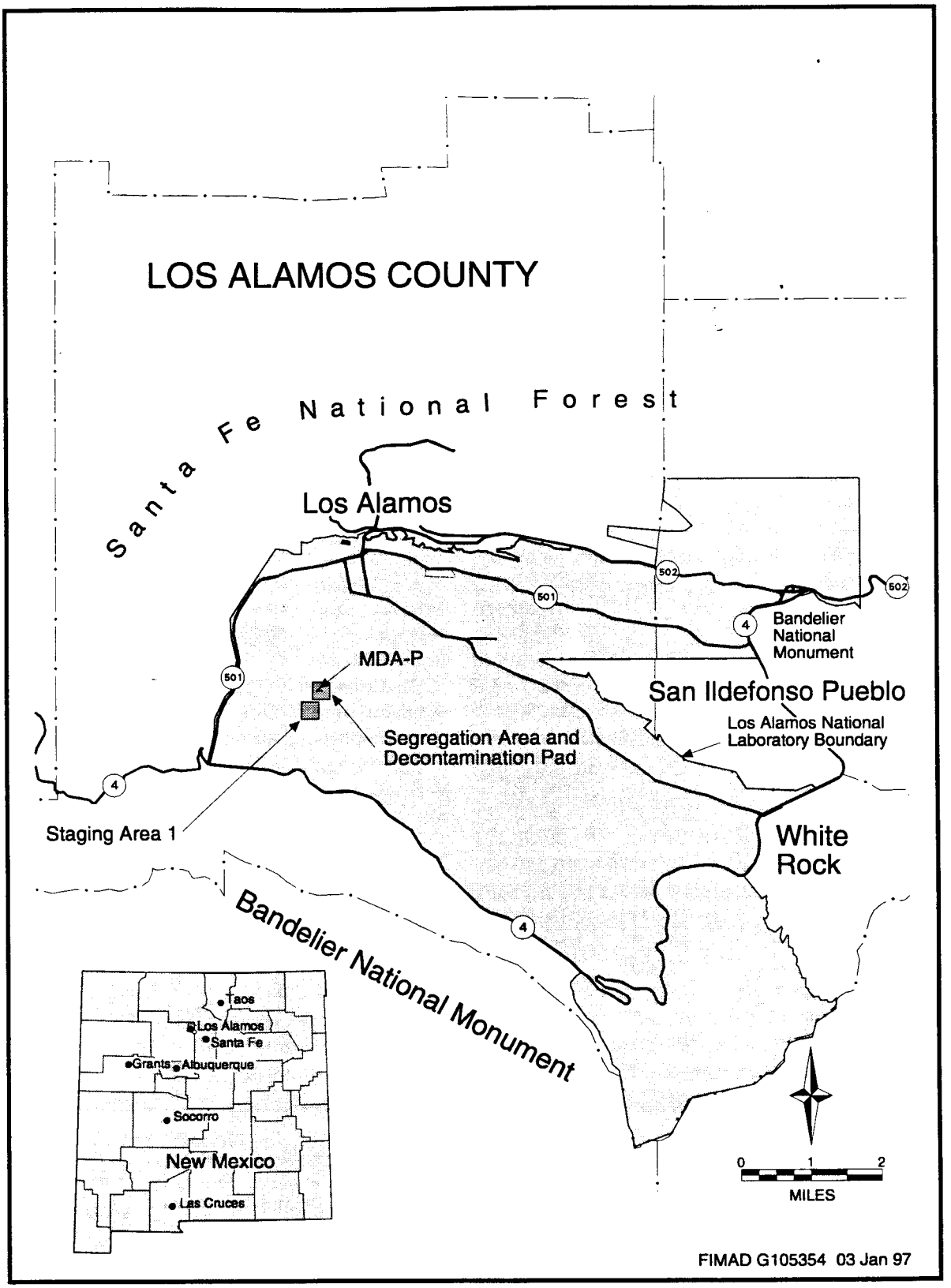

Fig. 1. Location of remediation sites at MDA-P within Los Alamos County, New Mexico.

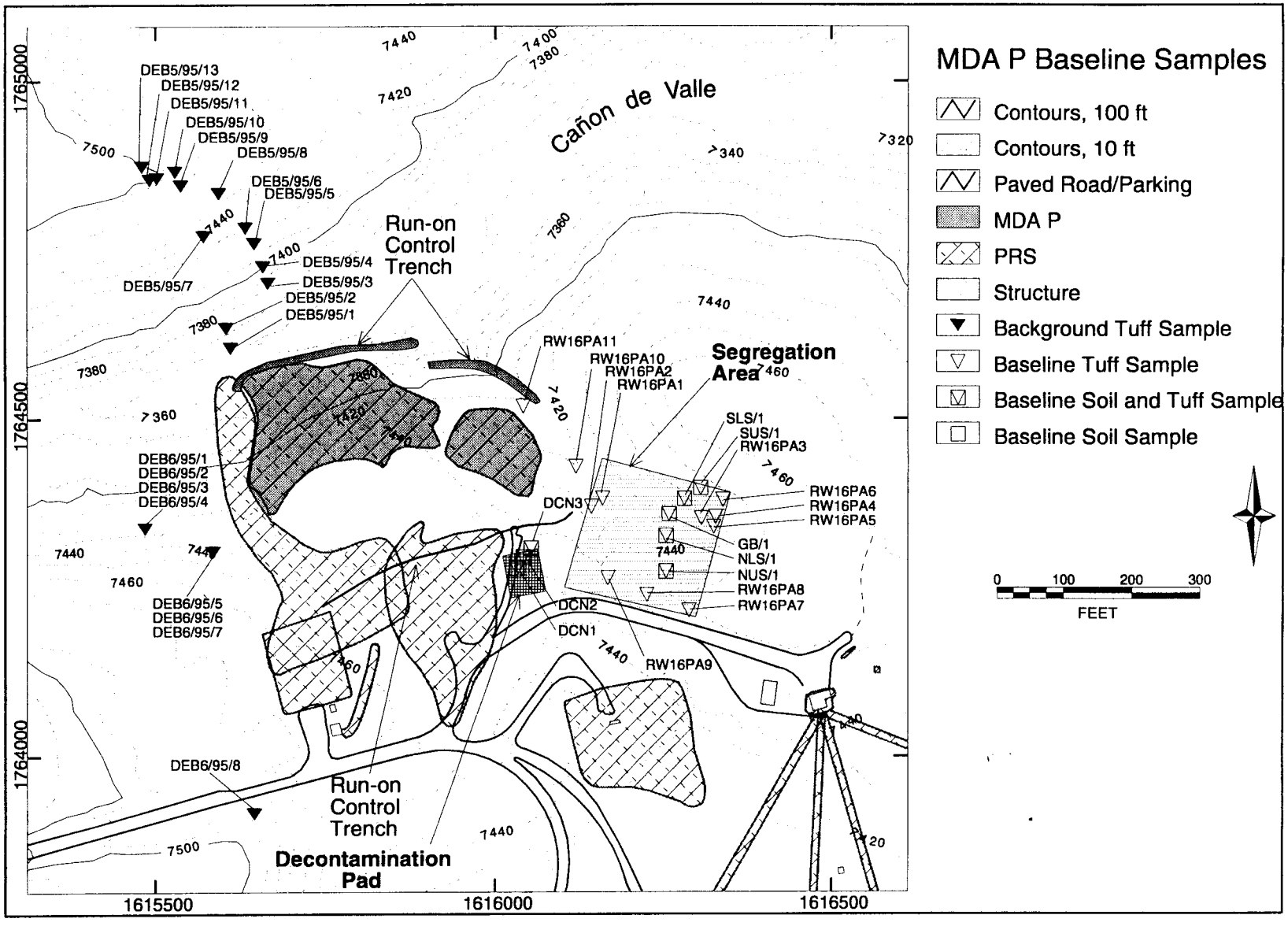

Fig. 2. Location of baseline samples and background bedrock samples, and the Segregation Area and Decontamination Pad at MDA-P. See Figure 1 for general location of area.

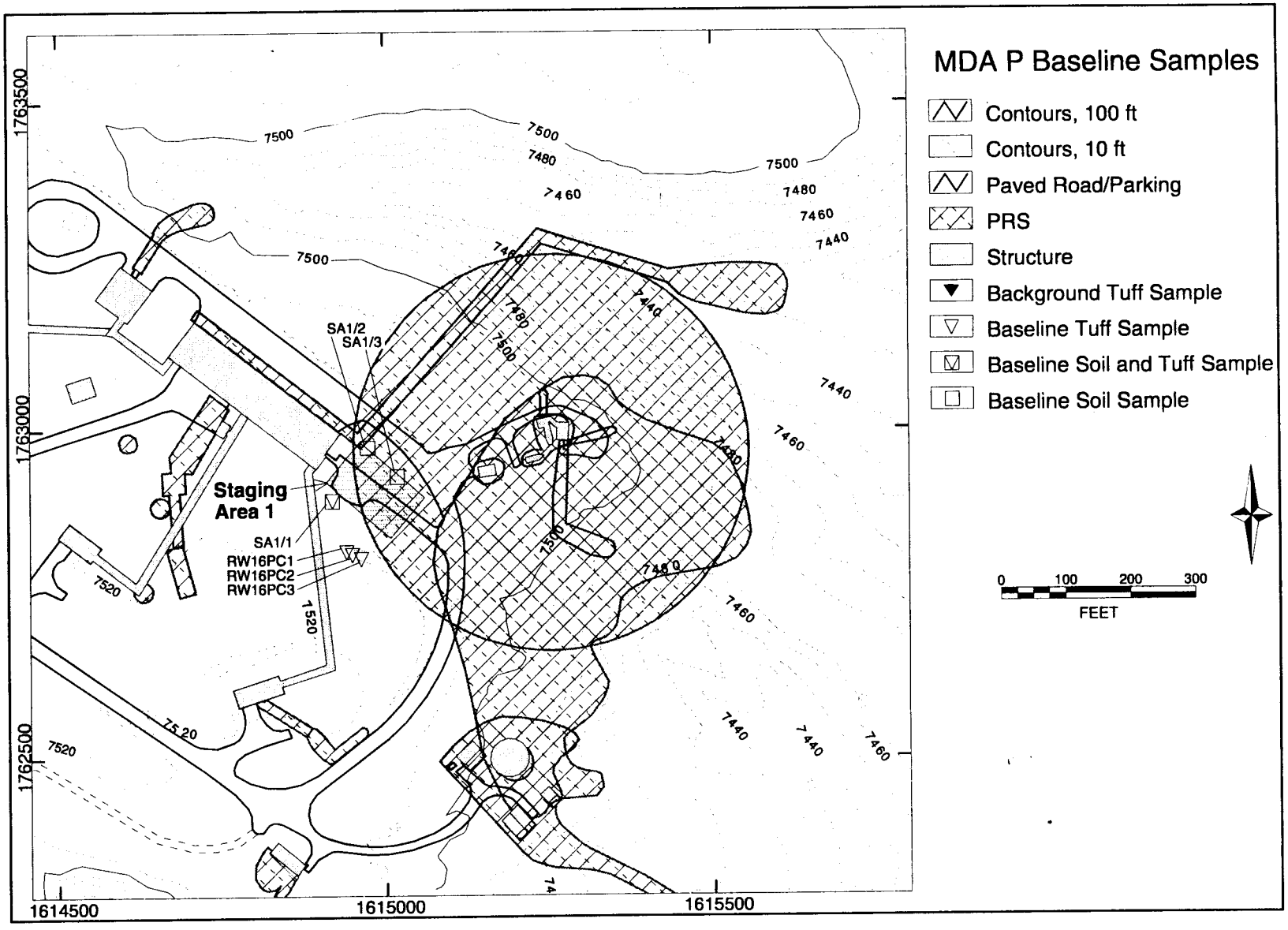

Fig. 3. Location of baseline samples and Staging Area 1 at MDA-P. See Fig. 1 for general location of area.

Table 2. General description and location for all baseline samples and background samples of tuff near MDA-P. Number of sample locations = "n".

Sample Type	Local Area	General Description	Sample Locations	n
baseline	Within Segregation Area	Exposed tuff upstream from run-on control trench	RW16PA3-9	7
baseline	Within Segregation Area	Soil and tuff beneath soil upstream from run-on control trench	GB/1, SUS/1, SLS/1, NUS/, NLS/1	5
baseline	Within or just outside Segregation Area	Exposed tuff downstream along run-on control trench	RW16PA1,2,10,11	4
baseline	Within Decontamination Pad	Fill and tuff beneath fill	DCN1,2,3	3
baseline	Within Staging Area 1	Fill and tuff beneath fill	RW16PC1,2 and SA1/1-3	3
baseline	Just outside Staging Area 1	Exposed tuff	RW16PC3	1
background	North side of Cañon de Valle, across from MDA-P	Exposed tuff	DEB5/95/1-13	1 3
background	South side of Cañon de Valle, west from MDA-P	Tuff exposed by roadcut	DEB6/95/1-7	7
background	North side of Cañon de Valle, nearly 2000 ft NE from MDA-P	Exposed tuff	DEB5/95/14-16	3

Precise elevations and locations digitized directly from field maps, measured using tape and Brunton compass or obtained by surveying, are provided in Appendix A for all baseline samples and for background tuff samples. Relative elevations within each local sample area described in Table 2 were measured using a Jacob Staff and level and have an estimated 2 sigma uncertainty of 0.5 ft. Absolute elevations, from large-scale maps produced by FIMAD, have a 2 sigma uncertainty of 2.5 ft, determined by comparing 15 surveyed values with superseded values obtained as described above. Two sigma uncertainties in horizontal position differ for each sample set from about 5 to 50 ft, depending on the scale of the field map used, and are provided in meters in Appendix A. Samples for baseline study that were not surveyed generally have a 2 sigma uncertainty for a horizontal position of 20 ft, determined by comparing 15 surveyed values with superseded values. Surveyed values are assumed to have a 2 sigma uncertainty for a horizontal position of 3 ft. Locations for background samples DEB6/95/1 through 7 were measured using a Jacob Staff, level, and Brunton compass from a nearby surveyed well location, and so are considered to be surveyed locations, although the 2 sigma uncertainty in horizontal position is assumed to be larger than for locations that are determined entirely by survey.

3.0. SAMPLE PREPARATION AND ANALYTICAL METHODS

Soil samples were passed through a 2.0-mm sieve to remove pebbles and organic fragments greater than 2 mm in diameter. Soil samples were air-dried for at least 24 hours. All samples were split using a standard mechanical soil/sediment splitter into representative fractions for trace element chemistry. All equipment used in sample preparation was cleaned between samples.

All weathered material was removed in the field from the samples of tuff, resulting in uniform pieces with long dimensions up to 10 cm. Field and subsequent binocular microscope descriptions for these samples, and for the 23 locations sampled earlier in 1995 for background study of tuff, are found in Appendices B and C. All samples of tuff for baseline study were prepared for chemical and mineralogical analysis by pulverizing them within an alumina ceramic shatterbox, but those for background study were prepared by pulverizing within a tungsten carbide shatterbox.

Concentrations of trace elements were analyzed using two sample digestion methods:

(1) Total element concentrations extracted from the complete digestion of soil material using concentrated hydrofluoric acid (HF). This method was applied only for soil samples.

(2) Partial element concentrations extracted from the partial digestion of soil and bedrock using concentrated nitric acid (HNO_3) at pH 1 (EPA Method 3050A; EPA, 1986).

The HNO_3 digestion method (also referred to as HNO_3-leachable) is used for estimating the bioavailabilty of elements, information required for performing risk analyses, by approximating the partial dissolution of soil particles and particle coatings, including clay minerals, ferric (oxy)hydroxides, and calcium carbonate, that might occur in a low-pH environment inside the human gastrointestinal system (LANL unpubl.; EPA, 1986). Unless analyses are erroneous or differences are within analytical uncertainties, element concentrations from partial digestion techniques must be less than the total element concentrations obtained using HF extraction or X-ray fluorescence.

Trace element chemistry was determined using EPA-SW846 analytical methods (Table 3), which are described in detail in EPA (1986), Gautier and Gladney (1986), and Gladney et al. (1980, 1981). Concentrations were measured for 28 leachable elements: Ag, Al, As, Ba, Be, Ca, Cd, Cl^-, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, SO_4^{2-}, Ta, Th, Tl, U, V, and Zn. Except for Cl^-, Hg, SO_4^{2-}, total concentrations were also measured for these same elements. Radioactive isotopes were not analyzed in this investigation, although gross alpha and beta activities were measured for all bedrock samples. Quality control samples, including duplicates and spiked samples, were analyzed at frequencies specified by the EPA (1986).

Table 3. Summary of analytical techniques used for chemical characterization of elements in area near MDA-P. Techniques are IC = ion chromatography; ES = inductively coupled plasma emission spectroscopy; EV = electrothermal vapor atomic absorption spectroscopy; MS = inductively coupled plasma mass spectrometry; CV = cold vapor atomic absorption spectroscopy; GF = graphite furnace absorption spectroscopy. Detection limits are in ppm; multiple values for the same technique indicate different limits for different datasets. No values are provided for all analyses that are above detection limits. Datasets are 1 = baseline soil; 2 = baseline bedrock; 3 = background soil; 4 = background bedrock.

El	Tech	Det	Sets	El	Tech	Det	Sets
Ag	MS	0.1	1	Mg	ES		all
Ag	ES	0.1, 0.4	2, 3, 4	Mn	ES		all
Al	ES		all	Na	ES		all
As	ES		1, 2	Ni	ES		all
As	EV		3	Pb	MS		1, 3, 4
As	GF		4	Pb	ES		2
Ba	ES		all	Sb	MS	0.1	1, 3, 4
Be	ES		all	Sb	ES	3.3	2
Ca	ES		all	Se	GF	0.2	4
Cd	MS	0.1	1, 3	Se	ES	0.2	1, 2, 3
Cd	ES	0.1, 0.2	2, 4	SO_4	IC		1, 2, 4
Cl	IC		1, 2, 4	Ta	MS	0.1	1, 3
Co	ES	0.6	all	Tl	MS	0.1	1, 3, 4
Cr	ES		all	Tl	ES	0.2	2
Cu	ES		all	Th	MS		all
Fe	ES		all	U	MS		all
Hg	CV	0.02	1, 2	V	ES		all
K	ES		all	Zn	ES		all

Sample digestion and analyses were performed by Rust-Geotech, Grand Junction Projects Office Analytical Laboratory, Grand Junction, Colorado. Complete documentation of analytical results from Rust-Geotech is reported under request number LANL 1859 and Project numbers 6LA414623 and 6LA414624 for soils, and request number LANL 1794 and Project number 6LA414541 for bedrock. Analytical results are reported in Appendices D, E, and F.

Two samples collected for baseline study were analyzed for total element contents by X-ray fluorescence (Appendix G) and for bulk mineralogy by X-ray diffraction (Appendix H), following methods described in Broxton et al. (1996). Samples of individual pumices collected at site DEB6/95/8 during background sampling were not chemically analyzed but are described in appendices in case they might be useful for future work.

Comparisons between analytical datasets relevant to this study suggest analytical errors for elements in some datasets. Elements with clear or probable analytical errors include As, Cd, Tl, Na, K, and gross alpha. These problems are discussed below, where such problems must be addressed to define the nature of chemical trends within bedrock samples.

4.0. DESCRIPTION OF SOILS NEAR MDA-P AND A STATISTICAL APPROACH FOR ANALYSIS OF RESULTS

4.1. Soil and Colluvium Stratigraphy

Soils within the Segregation Area are generally undisturbed, shallow (<50 cm), and consist of simple A to R horizon soil profiles. Both A horizons (Table 1) and underlying bedrock were sampled at each site. The bedrock samples are described in the section below. Total sampled soil A horizon thickness ranges from 15 to 37 cm. A horizons are surface and near-surface soil layers that are strongly influenced by the accumulation of organic matter and by biologic activity (e.g., plant roots). A horizons near MDA-P generally have sandy-loam textures with clay-sized material (< 2 micrometers) ranging from 5.4% to 20.5% by weight (McDonald et al., 1996). The A horizons of soils on north-facing slopes are covered by an O horizon that ranges in thickness from 2 to 4 cm. O horizons on south-facing slopes range in thickness from 0 to 3 cm. O horizons are layers that largely consist of solid organic matter composed of forest litter for the most part. O horizons were not sampled as part of this baseline investigation.

R horizons are common in soils formed on slopes along drainages cut into the Bandelier Tuff. R horizons near MDA-P consist of weakly weathered and highly fractured Units 3 to 5 of the Tshirege Member of the Bandelier Tuff. R horizons near MDA-P differ from the local bedrock in that R horizons are usually more fractured than the underlying Tshirege Member, may show signs of incipient weathering, and contain abundant soil matrix along fractures. Although this horizon was sampled in the bottom of all baseline soil pits, all weathered material was removed from bedrock during sample collection so that samples from the bottom of baseline soil pits represent bedrock and not R horizon.

The soil cover within the Decontamination Pad and Staging Area has been disrupted by site modifications. The soil cover mainly consists of a mixture of undifferentiated fill, probably derived from local soils, and rubble derived from Units 4 and 5 of the Tshirege Member.

4.2. Statistical Analysis of Soil Horizons

The mean, standard deviation, maximum, and minimum values for each analyte were determined for each of three baseline areas. Separate values are calculated for each baseline area as a result of variations in the composition of the soil (i.e., disrupted or nondisrupted) and proximity to the MDA-P burning ground and landfill site. The Decontamination Pad and Segregation Area are in close proximity to MDA-P, but the Staging Area is several hundred meters away.

Upper tolerance limit (UTL) values for inorganic analytes are not calculated for these samples for two reasons. First, better background screening layers (BSL) exist based on soil background studies conducted at MDA-P (McDonald et al., 1996) and Laboratory wide (Longmire et al., 1997). Second, initial analysis of analyte data indicates that contamination of several of the soils had probably occurred (discussed more below); therefore, calculating UTL values for these soil samples would be inaccurate and potentially misleading. Analyte results from baseline soils are instead compared to existing background screening values for soils. Background screening values are calculated for each analyte for individual soil horizons (i.e., A, B, C, R) and for combined soil horizons (all soil background data) by using either UTLs or the maximum reported values for infrequently detected analytes or sparsely sampled soil horizons. Separate background values have been calculated for the acid leachable results and the total sample results of each inorganic chemical.

4.3. Background Screening Value Data Sets Used for Soils

Background screening level data sets were selected based on established guidelines for the application of LANL background data (Ryti, et al., 1996). Baseline soil acid-leachable results from the Segregation area are compared with background screening values calculated for (1) site-specific MDA-P soil A horizons and (2) Laboratory-wide combined soil horizons. Baseline soil acid leachable results from the Staging Area and Decontamination Pad are compared with background screening values calculated for (1) site-specific MDA-P combined soil horizons and (2) Laboratory-wide combined soil horizons.

Total sample results from the Segregation Area are compared with background screening values calculated for (1) site-specific MDA-P soil A horizons and (2) MDA-P combined soil horizons. Total sample results from the Staging Area and Decontamination Pad are compared with background screening values calculated for (1) site-specific MDA-P combined soil horizons and (2) MDA-P combined soil horizons. Background screening values have not been calculated for Laboratory-wide combined soils horizons.

5.0. RESULTS AND DISCUSSION FOR SOILS

Tables 4 through 9 contain results for leachable (HNO_3 sample digestion) and total soil (HF digestion) inorganic analytes measured in each MDA-P baseline soil sample collected from the Decontamination Pad, and Segregation and Staging Areas, as well as a statistical summary of these analyses. Tables 10 and 11 summarize means, standard deviations, minima, and maxima for both acid-leachable and total analytes for each of the three baseline areas and provide a summary of background screening levels.

5.1. Distribution of Ba, Cu, Hg, and Zn in Soils

Soil concentrations of HNO_3-leachable Ba, Cu, Hg, and Zn are important because the MDA-P wastepile contains debris that has concentrations of these metals that are significantly above background

Table 4. Summary of acid-leachable results for the Segregation Area.

Sample ID	0816-95-0024	0816-95-0025	0816-95-0026	0816-95-0027	0816-95-0028	0816-95-0029	0816-95-0030	0816-95-0031	0816-95-0032	Mean	St Dev	Max	Min
Site #	SUS-1-A	SLS-1-A1	SLS-1-A2	NLS-1-A1	NLS-1-A2	GB-1-A1	GB-1-A2	NUS-1-A1	NUS-1-A2				
Aluminum	10700	9520	6470	6010	5930	5990	7010	6520	4070	6913	2007	10700	4070
Antimony	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Arsenic	3.7	4.1	2.7	2.8	2.3	2.8	3.1	3.8	2.9	3.1	0.6	4.1	2.3
Barium	**480**	**1680**	70	**1020**	56	**656**	90	**1650**	**229**	**659**	652	1680	56
Beryllium	0.88	0.64	0.79	0.4	0.64	0.47	0.8	0.45	0.47	0.6	0.2	0.9	0.4
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Calcium	1910	2950	1340	2210	1560	1260	1950	2120	2120	1936	515	2950	1260
Chloride	22.7	47.4	22.5	9.2	15.1	15.9	11.8	16.8	23.2	20.5	11.2	47.4	9.2
Chromium	6.2	7.6	4.5	5.8	5	5.2	5.1	4.6	2.8	5.2	1.3	7.6	2.8
Cobalt	2.5	2.6	1.8	1.7	1.7	2	2.2	1.8	1.3	2.0	0.4	2.6	1.3
Copper	5.2	6.9	3.2	6.1	3.5	6.1	4.6	8.7	4.4	5.4	1.7	8.7	3.2
Iron	11800	13100	9800	10700	10500	10600	10600	10300	8460	10651	1275	13100	8460
Lead	8.8	15	5	9.9	4.4	10.6	8	16.8	4	9.2	4.5	16.8	4.0
Manganese	184	303	106	293	196	251	287	280	104	223	79	303	104
Magnesium	1400	1610	1060	1350	1170	1180	1230	1130	731	1207	244	1610	731
Mercury	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	0.02		0.03	<0.02
Nickel	5.2	5.8	3	3.7	4.1	4.3	5.3	3.6	2.8	4.2	1.0	5.8	2.8
Potassium	1680	1900	1220	1250	1050	1310	1320	1470	1070	1363	279	1900	1050
Selenium	1.1	**1.7**	1.1	1.6	1.6	1.3	1.1	1.4	1.2	1.3	0.2	1.7	1.1
Silver	0.21	0.71	<0.1	0.34	0.1	0.31	0.16	0.61	0.26	0.3	0.2	0.7	0.1
Sodium	543	475	563	431	536	495	465	478	657	516	68	657	431
Sulfate	52.1	82.3	26.5	82.4	18.2	46.9	7.2	99.4	25.6	49.0	32.7	99.4	7.2
Tantalum	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Thallium	0.24	0.2	0.16	0.15	0.14	0.18	0.23	0.14	<0.1	0.2		0.2	0.1
Thorium	5.8	4.7	4.3	4.1	4.2	3.5	4.5	4.2	3.6	4.3	0.7	5.8	3.5
Uranium	1.1	2.6	0.53	1.2	0.44	1	0.47	1.7	0.48	1.1	0.7	2.6	0.4
Vanadium	12.2	13.3	9.3	10.2	9.1	9.8	9.7	9	5.6	9.8	2.2	13.3	5.6
Zinc	35.1	52.1	31.8	44.6	37.5	43.4	35	44.8	30.9	39.5	7.1	52.1	30.9

Notes: Mean value exceeds background screening level (BSL) calculated for MDA-P soil A horizons shown by underline.
Mean value exceeds BSL calculated for LANL-wide soil horizons (A,B,C,R) shown in **bold**.

Table 5. Summary of acid-leachable results for the Decontamination Pad.

Sample ID	0816-95-0039	0816-95-0040	0816-95-0041	Mean	St Dev	Max	Min
Site #	DCN-1	DCN-2	DCN-3				
Aluminum	5510	5890	<0.1	5700	269	5890	5510
Antimony	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Arsenic	3.2	3.5	3.3	3.3	0.2	3.5	3.2
Barium	270	**515**	**1270**	**685**	521	1270	270
Beryllium	0.46	0.54	0.61	0.5	0.1	0.6	0.5
Cadmium	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Calcium	1080	1200	2210	1497	621	2210	1080
Chloride	20.2	15.6	15.4	17.1	2.7	20.2	15.4
Chromium	4.1	4.7	4.9	4.6	0.4	4.9	4.1
Cobalt	2	1.7	1.4	1.7	0.3	2.0	1.4
Copper	6.9	10.7	7.2	8.3	2.1	10.7	6.9
Iron	9680	9650	10000	9777	194	10000	9650
Lead	15.1	18.8	18.9	17.6	2.2	18.9	15.1
Manganese	197	185	182	188	8	197	182
Magnesium	806	847	1180	944	205	1180	806
Mercury	<0.02	<0.02	0.02	0.02	0.00	0.02	<0.02
Nickel	2.9	3.6	3.2	3.2	0.4	3.6	2.9
Potassium	1230	1300	1790	1440	305	1790	1230
Selenium	0.94	1.3	1.1	1.1	0.2	1.3	0.9
Silver	0.34	8.8	2.6	3.9	4.4	8.8	0.3
Sodium	**690**	**576**	**649**	**638**	58	690	576
Sulfate	37	49.5	99	61.8	32.8	99.0	37.0
Tantalum	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Thallium	0.45	0.57	0.37	0.46	0.1	0.6	0.4
Thorium	4.1	4.3	4.1	4.2	0.1	4.3	4.1
Uranium	0.58	0.72	0.96	0.8	0.2	1.0	0.6
Vanadium	9.2	9.4	8.8	9.1	0.3	9.4	8.8
Zinc	40.4	44	39.9	41.4	2.2	44.0	39.9

Notes: Mean value exceeds background screening level (BSL) calculated for MDA-P soil A horizons shown by underline.
Mean value exceeds BSL calculated for LANL-wide soil horizons (A,B,C,R) shown in **bold**.

levels (Technical Area 16, Material Disposal Area P Closure Plan, Revision 0, February, 1995). The distribution energy of each of these important elements in the soil environment is discussed below.

Concentration of HNO_3-leachable Ba in most of the soil layers sampled within the Segregation Area and Decontamination Pad have concentrations that are two to five times greater than Ba concentrations in background MDA-P soil A horizons and LANL-wide combined soil horizons (Table 11). Concentrations of total Ba are also above site-specific MDA-P screening background levels for most of the samples collected from the Segregation Area and Decontamination Pad (Table 10). Concentrations of acid-leachable and total Ba are within the background range for samples collected from the Staging Area (Table 11).

Concentrations of leachable Ba are highest in surface samples represented by the uppermost soil A horizons. Concentrations of leachable Ba in surface samples range from 270 to 1680 mg/kg and 56 to 229 mg/kg for subsurface soils layers. Concentrations of total Ba in surface samples range from 611 to

Table 6. Summary of acid-leachable results for Staging Area 1.

Sample ID	0816-95-0033	0816-95-0034	0816-95-0035	0816-95-0036	0816-95-0037	0816-95-0038	Mean	St Dev	Max	Min
Site #	SA1/1-0.15	SA1/1-0.70	SA2/1-0.15	SA2/1-1.12	SA3/1-0.15	SA3/1-0.62				
Aluminum	10200	16100	14100	23200	8650	8810	13510	5615	23200	8650
Antimony	0.1	0.1	0.1	0.1	0.1	0.1	<0.1		<0.1	<0.1
Arsenic	2.4	1.9	2.3	1.4	1.6	2.2	2.0	0.4	2.4	1.4
Barium	103	224	126	154	69	97	129	55	224	69
Beryllium	0.68	1	0.8	1.2	0.56	0.6	0.8	0.2	1.2	0.6
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Calcium	1780	2480	2480	2940	1660	1380	2120	601	2940	1380
Chloride	10.3	9.3	14.2	20.4	14.6	11	13.3	4.1	20.4	9.3
Chromium	7.3	7.5	8.7	10.7	5	7	7.7	1.9	10.7	5.0
Cobalt	4.6	3.4	4.6	3.4	3.2	3.5	3.8	0.6	4.6	3.2
Copper	5.5	7.8	9.1	7.7	4.9	4.6	6.6	1.8	9.1	4.6
Iron	10900	12900	12400	17300	8590	8320	11735	3317	17300	8320
Lead	13.3	9.9	15.4	11.4	11.9	11.8	12.3	1.9	15.4	9.9
Manganese	332	300	286	287	213	293	285	39	332	213
Magnesium	1450	2140	1790	2460	1080	1400	1720	513	2460	1080
Mercury	<0.02	0.03	0.03	<0.02	<0.02	<0.02	0.02	0.01	0.03	<0.02
Nickel	6.1	7.7	7	7.7	4.1	4.4	6.2	1.6	7.7	4.1
Potassium	1530	2250	2150	2560	1580	1940	2002	400	2560	1530
Selenium	1.3	1.1	1.4	**2.0**	1.1	1.1	1.3	0.4	2.0	1.1
Silver	<0.1	0.12	0.12	0.17	<0.1	<0.1	0.1	0.0	0.2	0.1
Sodium	270	620	476	762	377	363	478	183	762	270
Sulfate	6	102	23.4	83.3	9.3	8.7	38.8	42.6	102.0	6.0
Tantalum	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Thallium	0.22	0.27	0.23	0.38	0.25	0.24	0.3	0.1	0.4	0.2
Thorium	5.8	6.5	5.8	9.1	5	6.4	6.4	1.4	9.1	5.0
Uranium	0.97	0.59	0.78	1	0.93	0.98	0.9	0.2	1.0	0.6
Vanadium	16.9	12.1	17.1	14.4	10.9	18.9	15.1	3.1	18.9	10.9
Zinc	23.1	30	33	35.5	18.1	16.9	26.1	7.9	35.5	16.9

Notes: Mean value exceeds background screening level (BSL) calculated for MDA-P soil A horizons shown by underline.
Mean value exceeds BSL calculated for LANL-wide soil horizons (A,B,C,R) shown in **bold**.

Table 7. Summary of whole-soil (HF digestion) results for the Segregation Area.

Sample ID	0816-95-0024	0816-95-0025	0816-95-0026	0816-95-0027	0816-95-0028	0816-95-0029	0816-95-0030	0816-95-0031	0816-95-0032	Mean	St Dev	Max	Min
Site #	SUS-1-A	SLS-1-A1	SLS-1-A2	NLS-1-A1	NLS-1-A2	GB-1-A1	GB-1-A2	NUS-1-A1	NUS-1-A2				
Aluminum	47900	42400	38700	43200	43200	43400	49500	43500	33600	42822	4659	49500	33600
Antimony	0.55	0.83	0.41	0.63	0.43	0.52	0.48	**0.91**	0.54	0.6	0.2	0.9	0.4
Arsenic	4.7	3.5	1.9	2	0.85	0.41	1.8	1.9	0.75	2.0	1.4	4.7	0.4
Barium	**764**	**2040**	431	**1320**	**430**	**1040**	447	**1860**	489	**980**	632	2040	430
Beryllium	1.7	1.5	1.7	1.3	1.5	1.3	1.8	1.4	1.4	1.5	0.2	1.8	1.3
Cadmium	0.16	0.22	0.1	0.18	0.13	0.2	0.12	0.31	0.18	0.2	0.1	0.3	0.1
Calcium	3520	4290	3080	4240	3720	3970	4190	3610	3200	3758	447	4290	3080
Chromium	11.7	12.1	7.9	11.1	8.1	9.1	9.8	9.5	4.2	9.3	2.4	12.1	4.2
Cobalt	5.7	6.3	5.2	6.2	5.6	6.2	6.6	5.5	3.6	5.7	0.9	6.6	3.6
Copper	11.9	10.3	7.3	8.3	6.1	8.8	6.6	11	6.8	8.6	2.1	11.9	6.1
Iron	16200	18300	14600	17400	16000	17400	18800	16800	11800	16367	2125	18800	11800
Lead	20.2	26	17.4	22.5	17.6	21.9	21.1	28.7	16.6	21.3	4.0	28.7	16.6
Manganese	320	462	279	480	381	474	508	461	261	403	95	508	261
Magnesium	1860	2210	1570	1990	1710	1940	1880	1710	1030	1767	333	2210	1030
Nickel	8.7	9.4	4.6	5.8	5.4	4.7	7.1	6.8	4.5	6.3	1.8	9.4	4.5
Potassium	31700	30700	34100	32400	34100	33100	33100	31800	33500	32722	1161	34100	30700
Selenium	1.9	2	1.5	1.7	1.6	**1.9**	2	1.8	1.1	1.7	0.3	2.0	1.1
Silver	0.5	0.78	0.29	0.48	0.36	0.46	0.34	**0.88**	0.45	0.5	0.2	0.9	0.3
Sodium	23600	23800	27800	26500	28700	29700	27000	25200	27800	26678	2116	29700	23600
Sulfate	2.4	2.4	2.1	2.3	2.4	2.1	2.5	2.4	2.3	2.3	0.1	2.5	2.1
Thallium	0.6	0.51	0.38	0.27	0.31	0.51	0.72	0.34	0.27	0.4	0.2	0.7	0.3
Thorium	7.3	6.4	5	6.1	5.7	5.3	6.4	5.2	4.5	5.8	0.9	7.3	4.5
Uranium	2	3	1.3	1.7	1	1.5	1.3	2.5	1	1.7	0.7	3.0	1.0
Vanadium	21.9	23	17	19.9	15.7	19.2	20.7	19.2	9.2	18.4	4.1	23.0	9.2
Zinc	60.1	73.8	58.7	74.1	65.4	75.2	67.4	73	51.1	66.5	8.4	75.2	51.1

Notes: Mean value exceeds background screening level (BSL) calculated for MDA-P soil A horizons shown by underline.
Mean value exceeds BSL calculated for LANL-wide soil horizons (A,B,C,R) shown in **bold**.

Table 8. Summary of whole-soil (HF digestion) results for the Decontamination Pad.

Sample ID	0816-95-0039	0816-95-0040	0816-95-0041	Mean	St Dev	Max	Min
Site #	DCN-1	DCN-2	DCN-3				
Aluminum	54100	56300	47300	52567	4692	56300	47300
Antimony	0.47	0.74	0.8	0.7	0.2	0.8	0.5
Arsenic	1.3	1.6	1.5	1.5	0.2	1.6	1.3
Barium	611	839	1570	1007	501	1570	611
Beryllium	1.6	1.5	1.6	1.6	0.1	1.6	1.5
Cadmium	0.23	0.22	0.2	0.2	0.0	0.2	0.2
Calcium	3780	3940	3780	3833	92	3940	3780
Chromium	8.9	11.5	11.4	10.6	1.5	11.5	8.9
Cobalt	5	6.5	5.5	5.7	0.8	6.5	5.0
Copper	9.5	14.9	11.4	11.9	2.7	14.9	9.5
Iron	16200	19600	18000	17933	1701	19600	16200
Lead	27.2	29.1	33.3	29.9	3.1	33.3	27.2
Manganese	383	421	374	393	25	421	374
Magnesium	1630	1870	1890	1797	145	1890	1630
Nickel	5.8	6.6	6.5	6.3	0.4	6.6	5.8
Potassium	34000	33500	34400	33967	451	34400	33500
Selenium	1.4	1.8	1.2	1.5	0.3	1.8	1.2
Silver	0.59	0.75	2.4	1.2	1.0	2.4	0.6
Sodium	27400	26400	25000	26267	1206	27400	25000
Sulfate	2.3	2.4	2.6	2.4	0.2	2.6	2.3
Thallium	2.1	2	1.3	1.8	0.4	2.1	1.3
Thorium	7.4	7.5	6.8	7.2	0.4	7.5	6.8
Uranium	1.8	1.7	2.1	1.9	0.2	2.1	1.7
Vanadium	17.4	22.1	20.2	19.9	2.4	22.1	17.4
Zinc	67.6	81.4	74.3	74.4	6.9	81.4	67.6

Notes: Mean value exceeds background screening level (BSL) calculated for MDA-P soil A horizons shown by underline.

2040 mg/kg and 431 to 489 mg/kg for subsurface soils layers. By comparison, background screening levels for acid-leachable Ba range from 211 (MDA-P A horizons) to 315 (LANL-combined) mg/kg and total Ba 501 (MDA-P A horizons) to 454 (MDA-P combined) mg/kg (Tables 10 and 11). Because there is no reason for Ba to be pedologically concentrated within the uppermost soil horizon relative to underlying horizons, these data suggest that surface soil horizons have been contaminated by anthropogenic Ba. Significantly elevated levels of Ba in surface samples (but below UTLs) were also found on south-facing slopes north of MDA-P (McDonald et al., 1996). Widespread concentration of Ba relative to natural soil conditions indicates localized contamination of Ba that probably is due to wind-blown emissions of Ba generated from the TA-16 burning ground. These results indicate that Ba is widely dispersed across areas marginal to MDA-P. As a result, a low level of Ba contamination above background levels exists in soils and sediments downwind of the MDA-P waste pile and in areas not currently slated for clean-up. In addition, dust released during clean-up activities around MDA-P (e.g., emission of fine-grained particles during the removal of the waste pile) may also result in a significant down-wind transport of Ba onto nearby soils and tuff bedrock surfaces.

Concentrations of acid-leachable Cu and Zn are generally similar among all soil samples from all three baseline areas. Concentrations for Cu range from 3.2 to 10.7 mg/kg and are below soil background concentrations (Tables 4 to 6). Concentrations for Zn range from 16.9 to 75.2 mg/kg and are below soil background screening levels. Concentrations of total Cu and Zn are also below MDA-P site-specific soil background screening levels (Tables 7 to 9).

Table 9. Summary of whole-soil (HF digestion) results for Staging Area 1.

Sample ID	0816-95-0033	0816-95-0034	0816-95-0035	0816-95-0036	0816-95-0037	0816-95-0038	Mean	St Dev	Max	Min
Site #	SA1/1-0.15	SA1/1-0.70	SA2/1-0.15	SA2/1-1.12	SA3/1-0.15	SA3/1-0.62				
Aluminum	39300	48600	54600	36600	40500	43200	54100	6679	54600	36600
Antimony	0.74	0.57	0.63	0.5	0.55	0.64	0.47		<0.1	<0.1
Arsenic	2.1	1.5	1.7	0.41	0.51	1.8	1.3	0.7	2.1	0.4
Barium	508	484	508	393	492	586	611	62	586	393
Beryllium	1.7	2.3	1.9	2.2	1.6	1.5	1.6	0.3	2.3	1.5
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Calcium	3000	2970	4480	2010	3030	3630	3780	820	4480	2010
Chromium	19.6	16.6	18.4	22.7	14.4	19.8	8.9	2.9	22.7	14.4
Cobalt	10.2	7.5	9.9	8.1	7.9	10.3	5.0	1.3	10.3	7.5
Copper	10.9	11.2	12	10.8	9.5	10.7	9.5	0.8	12.0	9.5
Iron	16700	20600	19500	21800	14900	12800	16200	3502	21800	12800
Lead	20.7	19.2	24.6	18.1	19.9	19.1	27.2	2.3	24.6	18.1
Manganese	394	407	435	295	317	368	383	54	435	295
Magnesium	2590	3280	3070	3330	2030	2460	1630	517	3330	2030
Nickel	9.2	11.9	9.8	11.4	8.8	7.7	5.8	1.6	11.9	7.7
Potassium	25100	30400	26900	23700	27400	23500	34000	2620	30400	23500
Selenium	1.3	1.5	1.9	2.0	1.6	1.1	1.4	0.3	2.0	1.1
Silver	0.49	0.57	0.49	0.54	0.46	0.48	0.6	0.0	0.6	0.5
Sodium	17600	20400	18600	17300	22000	16800	27400	2026	22000	16800
Sulfate	1.9	2.6	2.1	2.3	1.8	1.9	2.3	0.3	2.6	1.8
Thallium	0.5	0.58	0.66	0.72	0.61	0.48	2.1	0.1	0.7	0.5
Thorium	7.6	8.6	10	6	7.2	9.2	7.4	1.5	10.0	6.0
Uranium	2.6	2.4	2.5	2.4	2.5	2.7	1.8	0.1	2.7	2.4
Vanadium	39.4	31.9	37.2	39.5	27.8	40.4	17.4	5.1	40.4	27.8
Zinc	46.2	68.5	57.5	66.1	48.4	33.3	67.6	13.3	68.5	33.3

Notes: Mean value exceeds background screening level (BSL) calculated for MDA-P soil A horizons shown by underline.

Table 10. Summary of whole-soil (HF digestion) results for baseline and MDAP background soil samples.

	MDAP Baseline						Soil Background					
	Segregation Area		Decontamination Area		Staging Area		MDA-P: Soil Horizon A			MDA-P: All Soil Horizons		
ANALYTE	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	BSL	Mean	St Dev	BSL
Aluminum	42822	4659	52567	4692	43800	6679	66400	6270	81100	68500	9760	88400
Antimony	0.59	0.17	0.67	0.18	0.61	0.08	0.45	0.065	0.624	0.478	0.134	0.751
Arsenic	2.0	1.4	1.5	0.2	1.3	0.7	NA	NA	NA	8.3	5.2	NC
Barium	*980*	632	1007	501	495.2	61.9	501	72	671	454	96	650
Beryllium	1.5	0.2	1.6	0.1	1.9	0.3	1.7	0.2	2.2	1.9	0.5	2.9
Cadmium	0.18	0.06	0.22	0.02	0.11	<0.1	0.19	0.03	0.27	0.18	0.04	0.25
Calcium	3758	447	3833	92	3187	820	5699	852	7700	5280	1150	7620
Chromium	9.3	2.4	10.6	1.5	18.6	2.9	13.1	2.82	19.8	13.9	6.14	26.5
Cobalt	5.7	0.9	5.7	0.8	9.0	1.3	7.38	1.24	10.3	7.39	1.96	11.4
Copper	8.6	2.1	11.9	2.7	10.9	0.8	7	1.52	10.6	7.33	3.03	13.5
Iron	16367	2125	17933	1701	17717	3502	17600	1815	22000	18800	4730	28400
Lead	21.3	4.0	29.9	3.1	20.3	2.3	22.3	2.7	28.6	22	3.36	28.9
Mercury	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA	0.05	0.01	0.1
Magnesium	1767	333	1797	145	2793	517	2510	468	3607	2720	1270	5310
Manganese	403	95	393	25	369	54	473	71	640	443	91	629
Nickel	6.3	1.8	6.3	0.4	9.8	1.6	7.0	1.3	10.1	7.8	3.1	14.1
Potassium	32722	1161	33967	451	26167	2620	28906	5776	42480	27700	7350	42800
Selenium	1.7	0.3	1.5	0.3	1.6	0.3	0.2	0.4	1.8	0.2	0.2	1.8
Silver	0.50	0.20	1.25	1.00	0.51	0.04	0.24	0.09	<0.4	0.22	0.06	0.52
Sodium	26678	2116	26267	1206	18783	2026	23300	2270	28700	23200	4040	31500
Tantalum	2.3	0.1	2.4	0.2	2.1	0.3	NA	NA	NA	2.9	0.8	NC
Thallium	0.4	0.2	1.8	0.4	0.6	0.1	0.66	0.206	1.14	0.698	0.289	1.29
Thorium	5.8	0.9	7.2	0.4	8.1	1.5	9.14	1.09	11.7	9.76	1.75	13.3
Uranium	1.7	0.7	1.9	0.2	2.5	0.1	2.19	0.877	4.25	2.03	0.686	3.43
Vanadium	18.4	4.1	19.9	2.4	36.0	5.1	25.0	5.1	37.0	27.2	11.4	50.6
Zinc	66.5	8.4	74.4	6.9	53.3	13.3	61.1	6.47	76.3	61.2	8.2	77.9

Notes: BSL = Background screening level. Calculated from UTL values. See Ryti et al. (1996) for more information.
Mean value exceeds BSL calculated for MDA-P soil A horizons shown by underline.
Mean value exceeds BSL calculated for combined MDA-P soil horizons (A, B,C,R) shown in *italics*.
NA = Not analyzed in the LANL-wide soil background study.
NC = Not calculated.

Table 11. Summary of acid-leachable (HNO_3) results for baseline, MDA-P background, and LANL-wide soil samples.

	MDAP Baseline						Soil Background								
	Segregation Area		Decontam. Area		Staging Area		MDA-P Soil Horizon A			MDA-P: All Soil Horizons			LANL Wide: All Soil Horizons		
ANALYTE	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	BSL	Mean	St Dev	BSL	Mean	St Dev	BSL
Aluminum	6913	2007	6297	1051	13510	5615	7370	1470	11900	8600	4660	25700	11680	8810	38700
Antimony	0.1	0.0	0.1	0.0	0.	0.0	0.066	0.03	0.13	0.066	0.034	0.17	0.066	0.034	
Arsenic	3.1	0.6	3.3	0.2	2.0	0.4	NA	NA	NA	NA	NA	NA	3.95	1.92	7.82
Barium	*659*	652	685	521	128.9	54.6	117	598.6	283	89.4	50.9	211	142.7	74.1	315
Beryllium	0.6	0.2	0.5	0.1	0.8	0.2	0.617	0.13	0.84	0.833	0.474	1.83	0.911	0.447	1.95
Cadmium	<0.10	0.0	<0.10	0.0	<0.10	0.0	0.05	0.0	<0.1	0.05	0	<0.1	0.364	0.465	2.7
Calcium	1936	515	1497	621	2120.0	601.1	2520	765	5657	2291	1200	6759	2644	1771	6120
Chloride	20.5	11.2	17.1	2.7	13.3	4.1	NA	NA	NA	NA	NA	NA	28.1	42.6	75.9
Chromium	5.2	1.3	4.6	0.4	7.7	1.9	4.89	0.997	8.2	5.6	2.29	15.3	9.04	4.36	19.3
Cobalt	2.0	0.4	1.7	0.3	3.8	0.6	2.65	0.761	5.39	3	1.3	7.81	7.41	5.28	19.2
Copper	5.4	1.7	8.3	2.1	6.6	1.8	4.27	1.07	19.3	4.66	2.04	15.5	6.06	2.59	15.5
Iron	10651	1275	9777	194	11735	3317.2	8980	1480	12700	10200	3010	16500	12149	4256	21300
Lead	9.2	4.5	17.6	2.2	12.3	1.9	8.96	2.53	14.9	8.57	3.28	5.3	12.66	5.25	23.3
Magnesium	1207	244	944	205	1720.0	512.6	1330	209	1974	1480	670	4185	2160	1150	4610
Manganese	223	79	188	8	285.2	39.2	278	78.1	490	273	109	526	340.5	166.4	714
Nickel	4.2	1.0	3.2	0.4	6.2	1.6	4.12	0.828	6.07	4.73	1.91	8.64	7.07	4.01	15.2
Potassium	1363	279	1440	305	2001.7	399.9	1240	223	1818	1250	444	2233	1748	786	3410
Selenium	*1.3*	0.2	1.1	0.2	1.3	0.4	0.243	0.21	0.77	0.202	0.175	0.77	0.477	0.417	1.7
Silver	0.3	0.2	3.9	4.4	0.1	0.0	0.214	0.057	<0.47	0.206	0.036	<0.47	NA	NA	NA
Sodium	*516*	68	*638*	58	478.0	183.0	86.9	26.7	207	98	42.6	295	304	292	915
Sulfate	49.0	32.7	61.8	32.8	38.8	42.6	NA	NA	NA	NA	NA	NA	62.5	125.7	316.6
Tantalum	0.1	0.0	0.1	0.0	0.1	0.0	NA	NA	NA	NA	NA	NA	0.18	0.13	<0.9
Thallium	0.15	0.06	0.46	0.10	0.27	0.06	0.157	0.076	0.39	0.19	0.128	0.452	0.276	0.186	1
Thorium	4.3	0.7	4.2	0.1	6.4	1.4	4.33	0.854	6.24	5.19	1.75	8.76	8.59	2.98	14.6
Uranium	1.1	0.7	0.8	0.2	0.9	0.2	0.845	0.486	1.333	0.785	0.457	1.72	0.985	0.436	1.87
Vanadium	9.8	2.2	9.1	0.3	15.1	3.1	10.1	2.19	15.7	11.7	4.51	22.1	21.3	8.92	41.9
Zinc	39.5	7.1	41.4	2.2	26.1	7.9	29.5	7.22	47.9	31.9	9.65	52.3	31.5	9	50.8

Notes: BSL = Background screening level. Calculated from UTL values. See Ryti et al. (1996) for more information.
Mean value exceeds BSL calculated for MDA-P soil A horizons shown by underline. This applies only to soil samples from the Segregation area.
Mean value exceeds BSL calculated for combined MDA-P soil horizons (A, B,C,R) shown in *italics*. This applied only to soil samples from the Decontamination Pad and Staging Area 1.
Mean value exceeds BSL calculated for all LANL-wide soil horizons (A,B,C,R) shown in **bold**.
NA = Not analyzed in the LANL wide soil background study.
NC = Not calculated.

Concentrations of acid-leachable mercury are low in all soil samples from all three baseline areas and are similar to LANL background concentrations (Tables 4 to 6). Laboratory-wide investigations of soil background concentrations of Hg indicate that Hg naturally occurs at very low levels (less than 0.1 ppm) in soils across the Pajarito Plateau (Longmire, et al, 1997).

5.2. Distribution of Other Constituents in Soils

Other metals, including Ag, Be, Cr, Cd, Fe, Pb, and U are also of some concern because these metals may be associated with materials deposited at MDA-P. Acid-leachable concentrations of Ag are slightly above site-specific MDA-P background screening levels for two soil layers sampled at the Segregation Area (0816-95-0025, A1 horizon; 0816-95-0031; A1 horizon; Table 4). The acid-leachable concentration of Be in a single surface A horizon sampled from the Segregation Area (0816-95-0024, A horizon) is slightly above site-specific MDA-P background screening levels for A horizons. Acid-leachable concentrations of Fe are slightly above site-specific MDA-P background screening levels for soil layers sampled at the Segregation Area (0816-95-0025, A1 horizon) and one sample within Staging Area 1 (0816-95-0036, fill). Concentrations of acid-leachable Fe are below LANL-combined background screening levels. Acid-leachable concentrations of Pb are slightly above site-specific MDA-P background levels for soil layers sampled at the Segregation Area (0816-95-0025, A1) and one sample within Staging Area 1 (0816-95-0035, fill). Concentrations of acid-leachable Pb in these samples are below LANL-combined background levels. Uranium concentrations exceed acid-leachable Laboratory-wide screening levels in only one soil sample (0816-95-0025, A1). Uranium concentrations are below HF digestible (total) Laboratory-wide background screening levels for all soil samples. Elevated levels of Ag, Be, Fe, Pb, and U in some samples within the Segregation Area and Decontamination Pad suggest localized contamination from MDA-P activities. Alternatively, these elevated levels might represent natural background as "statistical artifacts." But both the Segregation Area and Decontamination Pad are downwind from the TA-16 burning pit, so airborne contamination from that source is likely. Acid-leachable concentrations of Cr, Cd, Fe, and Pb within baseline areas are below Laboratory-wide mean acid-leachable background levels.

Total concentrations of Ag are above site-specific MDA-P background levels for two soil layers sampled at the Segregation Area (0816-95-0025, A1; 0816-95-0031; A1; Table 7), for all three soil layers sampled at the Decontamination Pad, and for two soil layers sampled at Staging Area 1 (0816-95-0034, fill; 0816-95-0036, fill; Tables 8 and 9). Total concentrations of Pb are above site-specific MDA-P background levels for two soil layers sampled at the Decontamination Pad (0816-95-0040, 0816-95-0041). Total concentrations of Be, Cr, Cd, Fe, and U within baseline areas are below Laboratory-wide mean acid-leachable background levels.

Nitrates are also of some concern because this compound is associated with materials deposited at MDA-P. Nitrates were not analyzed as part of the soil background data, nor was NO_3^- analyzed as part of the Laboratory-wide background data. Nitrates are generally low in soil environments that are not under active cultivation. Previous sampling of soils and sediments at MDA-P indicates that concentrations of nitrates are low (Technical Area 16, Material Disposal Area P Closure Plan, Revision 0, February, 1995). Additional analysis for nitrate will be required to determine if elevated levels of nitrate are present within the area surrounding MDA-P.

5.3. Other Elements above Local and LANL Soil Background Screening Levels

Several other elements were measured at concentrations above background screening levels. Concentrations of acid-leachable selenium occurred above MDA-P site-specific background screening levels for nearly all samples at all three baseline areas and above LANL combined soil background screening values for two samples (0816-95-0025, 0816-95-0036; Tables 4 to 6). Total Se concentrations for several samples are also above MDA-P site-specific background concentrations (Tables 7 and 8). Concentrations of acid-leachable Na are above MDA-P site-specific background screening levels for nearly all samples in all three baseline areas, and above LANL combined background screening for several samples. Acid-leachable Na concentration in the tuff is about twice its concentration in soil background levels. Elevated levels of Na at all three baseline areas suggest that local influence from Units 4 and 5 of the Bandelier Tuff may be one potential source of elevated levels of these elements. More likely, the elevated levels of Na are the result of analytical errors, as discussed in detail below. Concentrations of acid-leachable Th occur above MDA-P site-specific background screening values for one soil layer at the Decontamination Pad (0816-95-0040). Concentrations of total Th also occur above MDA-P site-specific background screening values for two soil layers at the Decontamination Pad (0816-95-0040, 0816-95-0039).

6.0. DESCRIPTION OF BEDROCK NEAR MDA-P AND GRAPHICAL APPROACH FOR ANALYSIS OF RESULTS

Just as soils are best described as a series of horizontal layers, so is bedrock best described as a sequence of stratigraphic layers. The Tshirege Member of the Bandelier Tuff is the sole bedrock unit at MDA-P and throughout much of the Laboratory. Previous studies of the lower part of the Tshirege Member, summarized by Broxton et al. (1996), have shown that Units 1 through 3 are relatively homogeneous, and therefore amenable to simple statistical analysis. But our results for the upper part of the Tshirege Member show that the uppermost part of Units 3, 4, and 5 are not homogeneous, due to very strong magmatic zonation. In addition, we have found that natural processes produce abnormally high concentrations of many elements that might be misinterpreted as contamination. Therefore, we rely on a thorough consideration of potential natural processes and plots of concentrations versus stratigraphic level as much as on our statistical analyses to assess the occurrence of contamination in baseline bedrock samples at MDA-P.

6.1. Geologic Factors and Their Potential Chemical Effects on Background and Baseline Chemistry of Bedrock at MDA-P

Geologic factors and their potential chemical effects are summarized below in Table 12. Four geologic factors typically described for rock samples that might exert an influence on the chemistry of bedrock samples are the stratigraphic unit, sample type, lithology, and alteration, which are provided for each baseline and background sample in Appendix C. The influence of stratigraphic unit within the Tshirege Member has been demonstrated in previous work, but these other potentially important geologic factors have not been investigated. Alteration essentially describes bulk mineralogy of a sample, and markedly different bulk mineralogies might respond very differently to chemical leaching procedures. In particular, vitric samples, which consist primarily of glass, might behave differently than devitrified samples, which consist primarily of feldspar and cristobalite or quartz. Bulk mineralogy is best determined by X-ray diffraction, or less accurately from binocular examination by an experienced volcanologist (Appendix B). Samples of bedrock buried beneath soil are subject to different weathering conditions than those exposed at the surface. Tuff samples with poorly nonwelded or partially

Table 12. Description of sample sets available for evaluation of effects of rock characteristics on bedrock chemistry. These sample sets are not independent. Number of sample locations = "n." Symbols are those provided in Appendix C.

Characteristic	n	Symbol	Description
Stratigraphic unit	7	Qbt5	Unit 5 of Tshirege Member
Stratigraphic unit	30	Qbt4	Unit 4 of Tshirege Member
Stratigraphic unit	9	Qbt3	Unit 3 of Tshirege Member
Sample type	24	O	Exposed bedrock
Sample type	11	C,T	Bedrock buried beneath soil or fill
Lithology	33	NWT,PWT,WBE	Poorly welded tuff
Lithology	2	MWT,DWT	Strongly welded tuff
Alteration	7	GL	Entirely to partly vitric tuff
Alteration	28	all except GL	Devitrified tuff
Typical weathering	6		DEB6/95/1-4,6,7
Extreme weathering	1		DEB6/95/5
Hydrologically transmissive zone	3		DEB5/95/11-13
Downstream from waste pile	4		RW16PA1,2,10,11

welded lithologies are typically very porous and so conduct fluids by porous flow, very differently than the nonporous strongly (moderately or densely) welded lithologies, which conduct by fracture flow. Except for lithology, sample sets are sufficiently robust to evaluate chemical effects of each geologic factor.

To evaluate the chemical effects of stratigraphic unit, 7 samples assigned to Unit 5 of the Tshirege Member, 30 samples assigned to Unit 4, and 9 assigned to Unit 3 can be compared. Unit 5 is here informally defined as the "caprock" above the prominent base surge near the top of Unit 4 of Broxton and Reneau (1995). Unit 5 is exactly equivalent to Unit F of Rogers (1995). For sample type, 24 of the 35 samples assigned to Unit 4 from exposed tuff can be compared to 11 from tuff buried beneath shallow soil. To evaluate the effects of alteration, 7 of the 35 samples, all but one assigned to Unit 5, are entirely to partly vitric, whereas the remaining 28 are devitrified. Only 2 of the 35 samples assigned to Units 4 and 5 are strongly welded, so a meaningful comparison of chemistry versus poorly welded lithology is not possible for this dataset. The datasets available to evaluate chemical effects of each of the above geologic factors are listed in Table 12. Additional geologic factors listed in Table 12 are described below.

The potential chemical effects of weathering within the uppermost part of bedrock tuff were explored with the collection of samples DEB6/95/1 to 4 and 5 to 7. Each of these two sequences were sampled a short distance downwards from the tuff-soil interface. In both cases, ovoid spherules approximately 10 mm in diameter (see descriptions in Appendix B) decrease markedly away from the tuff-soil interface, and so clearly demonstrate changes in tuff resulting from weathering. DEB6/95/5, sampled from a block of tuff entirely surrounded by soil, is banded by weathering, and so represents the most extremely weathered sample within the two sequences.

Hydrologically transmissive zones are associated with thin bedded tuffs, and provide an environment within bedrock tuff conducive to strong chemical and mineralogical modification (Broxton et al., in review) and extreme concentration of mobile elements, possibly a result of evaporation (Rogers and Gallaher, 1995; Rogers et al., 1996). These bedded tuffs are highly channelized pyroclastic surges at the base of depositional subunits within the Tshirege Member (Broxton et al., in review). Such a hydrologically transmissive zone and associated base surge were sampled for the background study as DEB5/95/11 to 13.

6.2. Graphical Representation of Background and Baseline Chemical Data for Bedrock at MDA-P

Stratigraphic effects on the chemistry of samples of the Tshirege Member are well known (Broxton et al., in review) and must be considered for any interpretation of results. Although background and baseline samples are scattered in local sets up to 1.1 km apart, the estimated elevation for the contact between Units 3 and 4 ranges between 7411 and 7421 ft throughout the entire area, and the contact between Units 4 and 5 ranges between 7490 and 7497 ft (Appendix C), both with a two sigma uncertainty of 20 ft. Thus, both stratigraphic contacts are perfectly flat within this uncertainty, and stratigraphic level can be represented simply by the sample elevation. Ordering the chemical analyses of background and baseline samples by their elevation (Appendix F) thus provides a list in stratigraphic order. Thus, plots of elevation versus chemical data provide an accurate view not only to compare Units 3, 4, and 5, but to assess chemical trends within each unit of the Tshirege Member. Figure 4 schematically represents the important features of bedrock near MDA-P.

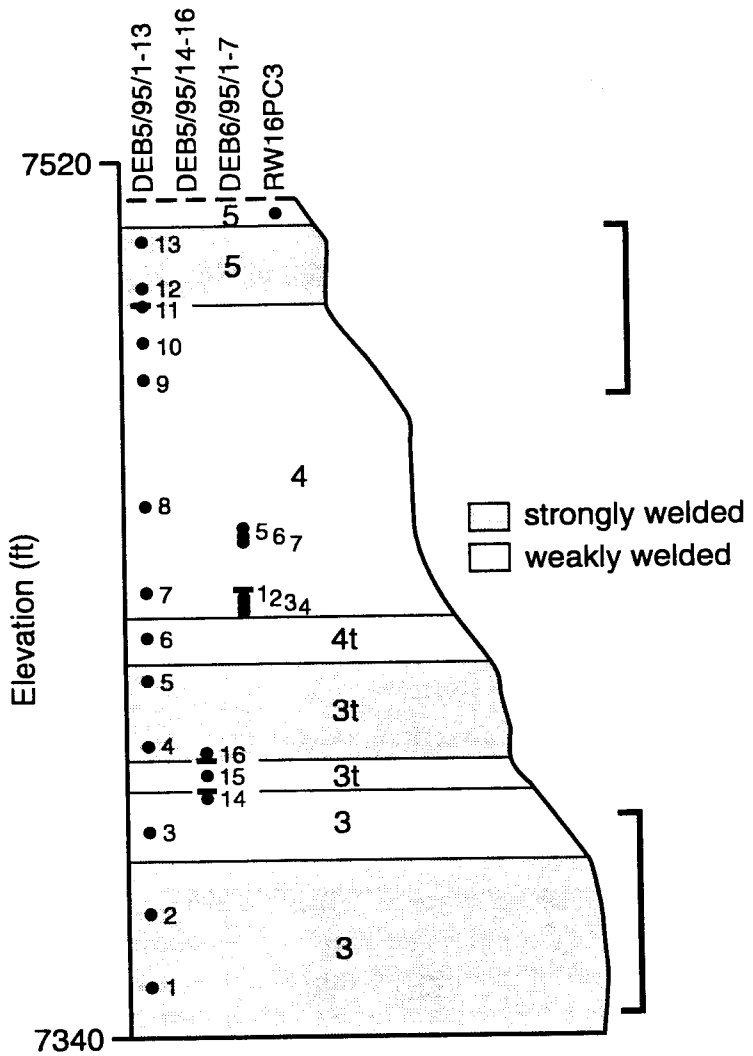

Fig. 4. Schematic diagram showing important features of bedrock at MDA-P. Thickened lines represent base surge layers recognized at MDA-P. Units of the Tshirege Member are 3 to 5, with transitional units 3t and 4t defined and described later in the report. Brackets to right represent continuous exposures within the section of background bedrock sampled as DEB/5/95/1-13. Background bedrock samples DEB5/95/14-16, DEB6/95/1-4, and DEB6/95/5-7 each represent isolated, continuous exposures. Baseline samples from the Segregation Area and Decontamination Pad fall within the lower half of Unit 4, except for RW16PA1 and 10, within Unit 4t, and RW16PA11, within Unit 3t. Baseline samples from Staging Area 1 are all within uppermost Unit 5.

Although the consistency of structural data probably precludes significant variations in the character of the rock column near MDA-P, base surge layers here are observed, as typical, to be discontinuous (see field description for samples DEB5/95/14 to 16 in Appendix C). As discussed above, base surge layers can be associated with a very different hydrologic character than that observed within massive ash flow layers. Thus, any conclusions based on the stratigraphic equivalence of samples at the same elevation near MDA-P can be applied only to massive ash flow layers. Base surge layers probably account for <1% of the bedrock volume near MDA-P and therefore do not significantly affect general patterns of chemistry versus stratigraphic level near MDA-P.

Each element with most values above detection limits defines a general pattern with respect to stratigraphic position (elevation), with exceptions for a few elements caused by analytical inconsistencies between background and baseline chemical data sets for bedrock (Table 13). Plots of elevation versus chemical data are provided for elements with most values above detection limits that represent most patterns described in Table 13 (Fig. 5). Additionally, for many elements, a few analyses, termed excursions, all positive or relatively high values (Table 14), do not conform to these patterns, for reasons inferred in the discussion below.

7.0. GENERAL PATTERNS IN BACKGROUND AND BASELINE CHEMISTRY FOR BEDROCK AT MDA-P

7.1. Statistical Summary of EPA SW846 Chemical Analyses for Background and Baseline Samples near MDA-P

Basic statistics for background and baseline bedrock samples from MDA-P are provided in Table 15. Table 15 provides useful central measures, but chemical values are strongly influenced by geologic factors, analytical biases, or contamination, as described below, which complicate the use of simple statistical measures to define differences between bedrock datasets. Chemical differences are significant between baseline samples of Units 4 and 5 for 10 elements, and between baseline and background samples of Unit 4 for 8 elements (Table 16). But in only two cases are baseline values significantly higher than background values for Unit 4, quite opposite the result expected from such a comparison, considering the likelihood that baseline samples are contaminated.

Table 13. Summary of patterns related to stratigraphic level in background and baseline chemical data for bedrock samples from MDA-P. Elements listed in order of decreasingly good fit to pattern. Patterns are not well defined for elements with asterisk because most analyses are below detection limits.

Pattern	Elements
Large analytical bias between background and baseline chemical data; background analyses spurious from contaminant introduced by pulverizing in tungsten carbide shatterbox.	Co
Large analytical bias between background and baseline chemical data; pattern indeterminate for Cd.	Alpha, As, Cd*, Tl*
Small, analytical bias between background and baseline chemical data; pattern recognizable.	Beta, Na, K
Continuous increase with stratigraphic level.	Al, S, Be
Increase with stratigraphic level is discontinuous between Units 3 and 4.	Ba, Ni, Mg, K, Na, Hg*, Se*
Discontinuous increase between Units 3 and 4 to highest values at base of Unit 4, decreasing upward in Unit 4.	V, Cr, Ca, Cu, Fe, Tl*
Continuous decrease with stratigraphic level.	Zn, As, Mn
Decrease with stratigraphic level is discontinuous between Units 3 and 4.	Th, U, Alpha, Beta
Decrease with stratigraphic level but values increase upward in Unit 4.	Pb, Cl

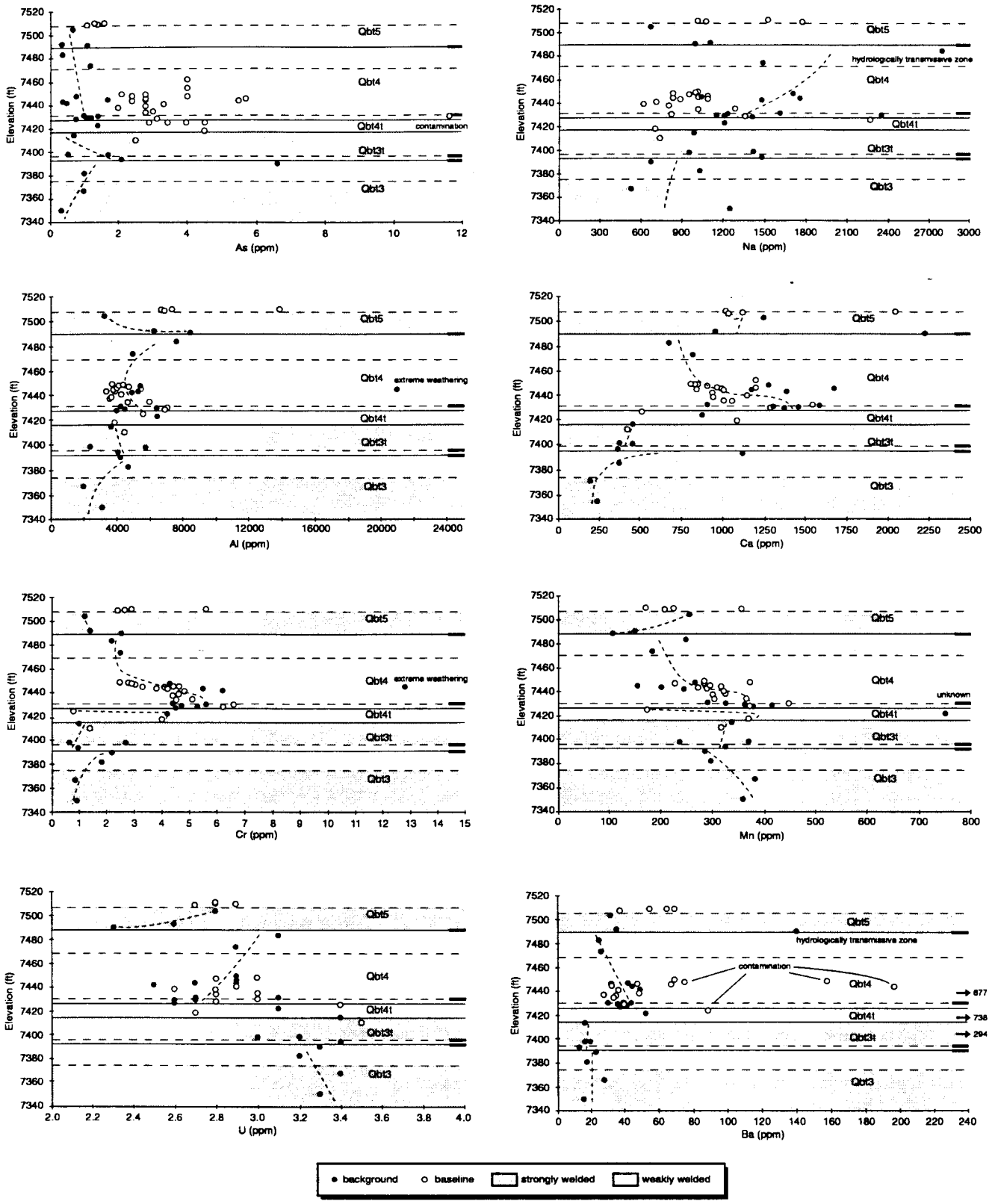

Fig. 5. Plot of representative nitric acid-leachable elements versus elevation (stratigraphic level) for background and baseline samples of bedrock from MDA-P. Solid horizontal lines show boundaries between stratigraphic units, and broken horizontal lines show boundaries for alteration or lithology. Interpretation of trends, shown as dashed lines through the data, is highly influenced by trends recognized from whole-rock analyses by XRF and from detailed petrographic analyses, as discussed in text below. Types of trends versus elevation are described for all nitric acid-leachable elements in Table 13.

Table 14. Summary of positive analytical excursions from patterns related to stratigraphic level in background and baseline chemical data for bedrock samples from MDA-P. Number of excursions = "n." Asterisk indicates that excursion does not exceed UTL for appropriate stratigraphic unit (Broxton et al., 1996); UTLs are not available for Cl, Fe, and SO_4 in Unit 4. Causes are discussed in text below.

Element	n	Cause	Sample numbers
Al	1	Extreme weathering	DEB6/95/5
As	1	Contamination	RW16PA2
Ba	1	Hydrologically transmissive zone	DEB5/95/11
Ba	9	Contamination	RW16PA1,6-11; DCN1,3-R
Be	1	Contamination	RW16PA2*
Cl	2	Hydrologically transmissive zone	DEB5/95/11,12
Cl	3	Concentration due to extreme mobility	DEB5/95/7,9; DCN1-R
Cr	1	Extreme weathering	DEB6/95/5
Fe	1	Extreme weathering	DEB6/95/5
K	1	Hydrologically transmissive zone	DEB5/95/10
Mg	1	Hydrologically transmissive zone	DEB5/95/11*
Mg	1	Extreme weathering	DEB6/95/5*
Mn	1	Unknown	DEB5/95/5
Na	1	Hydrologically transmissive zone	DEB5/95/10*
Pb	2	Contamination	RW16PA2; DCN2-R
SO4	3	Hydrologically transmissive zone	DEB5/95/11-13
SO4	2	Concentration due to extreme mobility	DEB5/95/7; RW16PA8
V	1	Extreme weathering	DEB6/95/5
Zn	1	Contamination	RW16PA2

Conversely, the lack of a significant difference between background and baseline for Ba disguises very clear contamination of baseline Ba values from operations at MDA-P that has been well documented by previous work (McLin, 1989; Rivera-Dirks and Conrad, 1995). In this case, a population attributed to contamination in the discussion below is similar in size to that reflecting natural bedrock Ba. Statistical analysis of all Ba values as a single population results in a large standard deviation for Ba in baseline Unit 4 (Table 15), which in turn fails to account for contamination in the statistical comparison of Table 16. One approach to overcome the problem of multiple populations is to employ more robust statistical analyses, as suggested for Ba in Table 16. Alternatively, we instead apply graphical representations of the chemical data to evaluate the role of geologic factors, analytical biases, or contamination in the cause of differences between baseline and background data sets. Once causes for differences are established, then proper statistical analyses can be performed.

7.2. General Patterns Related to Analytical Bias in Bedrock and Soil

Background samples of bedrock were prepared for chemical analysis by pulverizing in a tungsten carbide shatterbox, which introduces levels of contamination for Co (Thompson and Bankston, 1970) that overwhelms levels present in silicic rocks. Analysis has confirmed about 10% Co in the specific shatterbox used to pulverize the background samples. Baseline samples of bedrock were pulverized in an alumina-ceramic shatterbox, which contaminates only Al among the elements analyzed in baseline samples (Thompson and Bankston, 1970). Such contamination in Al is not evident as a leachable element because the Al apparently is insoluble in the leachate, nor is it evident as the total element (Broxton et al., in review) because the contaminant is overwhelmed by Al from the rock.

For five elements (Table 13), correspondence between background and baseline analyses of bedrock is poor, and it is generally clear that the disagreement must be an analytical discrepancy. For gross alpha

Table 15. Summary of basic statistics for background and baseline samples from MDA-P. For those sets with less than half of analytical values below detection limits, values below these limits have been converted to half the detection limit for computation of statistical values. Asterisk indicates that values are strongly affected by contamination or by analytical errors, as described in text.

Symbol	Data Group	Number	Minimum	Median	Maximum	Mean	St Dev
Al	Qbt3-background	8	1910	3830	5720	3694	1240
Al	Qbt4-background	12	4000	5060	20900	6555	4639
Al	Qbt4-baseline	18	3330	4180	7030	4573	1120
Al	Qbt5-background	7	3220	6840	13800	7477	3207
Sb	Qbt3-background	8	<0.1	<0.1	<0.1	<0.10	
Sb	Qbt4-background	12	<0.1	<0.1	<0.1	<0.10	
Sb	Qbt4-baseline	18	<3.3	<3.3	<3.3	<3.30	
Sb	Qbt5-background	7	<0.1	<3.3	<3.3	<1.01	
As	Qbt3-background	8	0.33	0.99	6.6	1.75	2.05
As	Qbt4-background	12	0.37	1.045	1.7	0.98	0.43
As*	Qbt4-baseline	18	2	2.85	11.6	3.69	2.23
As	Qbt5-background	3	0.35	0.7	1.1	0.72	0.38
As*	Qbt5-baseline	4	1.1	1.35	1.6	1.35	0.21
Ba	Qbt3-background	8	13.4	17.3	27.4	18.7	4.5
Ba	Qbt4-background	12	24.4	39.15	51.6	38.2	8.5
Ba*	Qbt4-baseline	18	27.6	47.75	738	135.3	213.3
Ba	Qbt5-background	7	31.6	54.4	139	61.3	37.2
Be	Qbt3-background	8	0.31	0.435	0.77	0.51	0.18
Be	Qbt4-background	12	0.33	0.62	1.1	0.61	0.22
Be	Qbt4-baseline	18	0.32	0.45	1.5	0.55	0.28
Be	Qbt5-background	7	0.22	0.64	1.2	0.65	0.31
Ca	Qbt3-background	8	199	376	1120	448	287
Ca	Qbt4-background	12	678	1295	1680	1214	321
Ca	Qbt4-baseline	18	513	983.5	1550	999	220
Ca	Qbt5-background	7	967	1120	2230	1382	528
Cd*	Qbt3-background	8	0.26	0.5	0.76	0.50	0.18
Cd*	Qbt4-background	12	0.46	0.895	1.5	0.88	0.28
Cd	Qbt4-baseline	18	<0.1	<0.1	<0.1	<0.10	
Cd*	Qbt5-background	3	0.1	0.57	0.7	0.46	0.32
Cd	Qbt5-baseline	4	<0.1	<0.1	<0.1	<0.1	
Cl^-	Qbt3-background	8	8.6	16.95	34.8	20.6	9.2
Cl^-	Qbt4-background	12	4.2	6.15	78.7	17.2	24.3
Cl^-	Qbt4-baseline	18	3.3	7.3	49.9	11.5	11.4
Cl^-	Qbt5-background	7	2.3	5.3	465	84.8	171.4
Cr	Qbt3-background	8	0.62	0.95	2.7	1.37	0.76
Cr	Qbt4-background	12	2.2	4.6	12.8	5.18	2.67
Cr	Qbt4-baseline	18	0.79	4.15	6.6	4.00	1.35
Cr	Qbt5-background	7	1.2	2.5	5.6	2.67	1.44

Table 15 (continued).

Symbol	Data Group	Number	Minimum	Median	Maximum	Mean	St Dev
Co*	Qbt3-background	8	24.1	41.25	66.8	45.4	16.4
Co*	Qbt4-background	12	8.2	24	75.8	32.4	21.1
Co	Qbt4-baseline	18	<0.6	1.15	2	1.2	0.4
Co*	Qbt5-background	3	16.1	18.3	34	22.8	9.8
Co	Qbt5-baseline	4	<0.6	0.695	1.1	0.7	0.33
Cu	Qbt3-background	8	0.7	1.45	2.1	1.37	0.51
Cu	Qbt4-background	12	2.4	3.25	6.2	3.58	1.17
Cu	Qbt4-baseline	18	1.4	2.45	6.4	2.67	1.13
Cu	Qbt5-background	7	2.1	3.6	5	3.53	1.11
Fe	Qbt3-background	8	7170	8755	10400	8874	1039
Fe	Qbt4-background	12	6350	12150	19500	11950	3208
Fe	Qbt4-baseline	18	8330	10750	15300	11110	1820
Fe	Qbt5-background	7	5250	9000	12100	9139	2277
Pb	Qbt3-background	8	3.1	4.65	9	4.93	1.92
Pb	Qbt4-background	12	2.1	4.65	9.5	5.20	2.45
Pb*	Qbt4-baseline	18	2.9	5.25	513	34.48	119.47
Pb	Qbt5-background	7	1.8	2.9	6	3.43	1.39
Mg	Qbt3-background	8	149	263.5	707	358	217
Mg	Qbt4-background	12	726	1020	2720	1151	520
Mg	Qbt4-baseline	18	220	818.5	1880	827	332
Mg	Qbt5-background	7	532	822	2820	1186	877
Mn	Qbt3-background	8	237	331.5	382	324	49
Mn	Qbt4-background	12	155	278.5	752	319	158
Mn	Qbt4-baseline	18	174	303	448	312	61
Mn	Qbt5-background	7	107	209	357	211	81
Hg	Qbt3-background	0					
Hg	Qbt4-background	0					
Hg	Qbt4-baseline	18	<0.02	0.03	0.06	0.03	0.01
Hg	Qbt5-background	4	<0.02	0.04	0.06	0.04	0.02
Ni	Qbt3-background	8	0.83	2.1	2.6	1.95	0.71
Ni	Qbt4-background	12	2.9	4.45	8.4	4.73	1.47
Ni	Qbt4-baseline	18	2	3.5	6.5	3.63	0.94
Ni	Qbt5-background	7	3.1	7.3	10.5	6.84	2.26
K	Qbt3-background	8	560	1540	1860	1415	402
K	Qbt4-background	12	1670	2325	4720	2453	884
K	Qbt4-baseline	18	1090	1445	3430	1614	526
K	Qbt5-background	7	1280	1730	2230	1810	309
Se	Qbt3-background	8	<0.2	<0.2	<0.2	<0.20	
Se	Qbt4-background	12	<0.2	<0.2	0.21	<0.20	
Se	Qbt4-baseline	18	<0.2	0.32	0.59	0.33	0.15
Se	Qbt5-background	3	<0.2	<0.2	0.21	<0.20	
Se	Qbt5-baseline	4	<0.2	0.4	0.43	0.33	0.16

Table 15 (continued).

Symbol	Data Group	Number	Minimum	Median	Maximum	Mean	Std Dev
Ag	Qbt3-background	8	<0.4	<0.4	<0.4	<0.40	
Ag	Qbt4-background	12	<0.4	<0.4	0.4	<0.23	
Ag	Qbt4-baseline	18	<0.1	<0.1	<0.1	<0.10	
Ag	Qbt5-background	7	<0.1	<0.1	<0.4	<0.34	
Na	Qbt3-background	8	531	1010	1480	1041	335
Na	Qbt4-background	12	1040	1445	2790	1507	464
Na*	Qbt4-baseline	18	620	977	2270	1018	367
Na*	Qbt5-background	7	676	1080	1780	1171	367
SO_4^{2-}	Qbt3-background	8	1.5	2.35	27	5.7	8.7
SO_4^{2-}	Qbt4-background	12	1.6	4.3	93.9	12.6	25.8
SO_4^{2-}	Qbt4-baseline	18	3	7.9	71	11.9	15.5
SO_4^{2-}	Qbt5-background	7	4.7	20.2	1430	352.9	535.0
Tl	Qbt3-background	8	<0.1	<0.1	<0.1	<0.10	
Tl	Qbt4-background	12	<0.1	0.14	0.49	0.17	0.13
Tl*	Qbt4-baseline	18	<0.1	0.42	0.86	0.43	0.16
Tl	Qbt5-background	3	<0.1	<0.1	<0.1	<0.10	
Tl*	Qbt5-baseline	4	0.1	0.305	0.36	0.27	0.12
Th	Qbt3-background	8	12	13.25	14.2	13.1	0.7
Th	Qbt4-background	12	9.9	10.9	13.1	11.3	1.0
Th	Qbt4-baseline	18	10.3	11.4	13.4	11.4	0.7
Th	Qbt5-background	7	9.2	11.9	14	12.0	1.5
U	Qbt3-background	8	3	3.3	3.4	3.28	0.14
U	Qbt4-background	12	2.5	2.8	3.1	2.82	0.21
U	Qbt4-baseline	18	2.6	2.9	3.4	2.89	0.16
U	Qbt5-background	7	2.3	2.8	2.9	2.70	0.20
V	Qbt3-background	8	2.5	3.95	7.1	4.54	1.60
V	Qbt4-background	12	4.4	10	21.2	10.44	4.37
V	Qbt4-baseline	18	2.9	7.3	12.5	7.58	2.46
V	Qbt5-background	7	2.9	5.7	9.3	5.54	2.16
Zn	Qbt3-background	8	39.6	48.6	60.4	48.7	6.9
Zn	Qbt4-background	12	24.7	51.05	59.1	47.7	9.5
Zn	Qbt4-baseline	18	37.7	49.15	356	65.9	72.6
Zn	Qbt5-background	7	20.1	28.4	65.6	33.0	14.9
Alpha	Qbt3-background	8	21	25	30	24.8	3.0
Alpha	Qbt4-background	12	11	19.5	30	18.8	5.2
Alpha*	Qbt4-baseline	18	5	10.5	15	10.4	2.6
Alpha	Qbt5-background	3	21	22	26	23.0	2.6
Alpha*	Qbt5-baseline	4	9	11.5	13	11.3	1.7
Beta	Qbt3-background	8	35	37.5	40	37.5	1.6
Beta	Qbt4-background	12	33	35	39	35.6	2.0
Beta	Qbt4-baseline	18	33	38	46	38.4	2.9
Beta	Qbt5-background	7	34	39	41	38.1	2.7

Table 16. Significance of statistical differences between stratigraphic and geographic groups of background and baseline bedrock samples from MDA-P

	MDA P Baseline	MDA P Background	Background	Background vs Baseline Comparison		
Symbol	Number >DL	Number >DL	Qbt4 vs Qbt5	Qbt4	UTL Groups	Comments
As	19	27	ns	base>bkg		52 of 105 <DL for Qbt123
Ba	19	27	ns	ns	Qbt123 Qbt4	Elevated values impact the upper tail, try quantile test
Pb	19	27	ns	ns	Qbt123 Qbt4	Shift in median is not large, but 513 mg/kg measured in baseline Qbt4
Zn	19	27	Qbt4>Qbt5	ns	Qbt1g23 Qbt1v Qbt4	No statistical shift, but 356 mg/kg measured in baseline Qbt4
Al	19	27	ns	bkg>base	Qbt1g23 Qbt1v Qbt4	
Cu	19	27	ns	bkg>base		49 of 106 <DL for Qbt123
Ni	19	27	Qbt5>Qbt4	bkg>base		97 of 106 <DL for Qbt123
K	19	27	Qbt4>Qbt5	bkg>base	Qbt1g2 Qbt1v Qbt3 Qbt4	
Na	19	27	ns	bkg>base	Qbt1 Qbt23 Qbt4	
V	19	27	Qbt4>Qbt5	bkg>base	Qbt1g Qbt1v23 Qbt4	
Be	19	27	ns	ns	Qbt123 Qbt4	
Ca	19	27	ns	ns	Qbt1 Qbt23 Qbt4	
Cl	19	27	ns	ns	Qbt1 Qbt2 Qbt3 Qbt4	
Cr	19	27	Qbt4>Qbt5	ns		38 of 106 <DL for Qbt123
Fe	19	27	Qbt4>Qbt5	ns	Qbt1g Qbt1v23 Qbt4	
Mg	19	27	ns	bkg>base	Qbt1g2 Qbt1v3	
Mn	19	27	ns	ns	Qbt1g Qbt1v2 Qbt3 Qbt4	
SO4	19	27	Qbt5>Qbt4	ns	Qbt123 Qbt4	
Th	19	27	ns	ns	Qbt1g Qbt1v Qbt2 Qbt3 Qbt4	
U	19	27	ns	ns	Qbt1g Qbt1v Qbt2 Qbt3 Qbt4	
Sb ^						
Cd ^		22				
Co *	18	26				
Hg +	16	3				
Se ^	15	6				
Ag ^		2				
Tl ^	18	11				
Alpha	19	27	ns	bkg>base		gross alpha is not a COC
Beta	19	27	Qbt5>Qbt4	base>bkg		gross beta is not a COC

Meta analysis Summary

Qbt4>Qbt5	5
ns	14
Qbt5>Qbt4	3
total elements	22

8	bkg>base
12	ns
2	base>bkg
22	total elements

* Known bias introduced into cobalt background chemical analysis, no statistical comparisons performed.
^ Freqency of nondetects in either background or baseline greater than 50%, statistical comparisons not performed.
\+ Insufficient number of samples in background for statistical comparisons.
ns = no statistically sigificant difference between subgroups.
DL = detection limit.

and Cd, background and baseline analyses of bedrock used the same method. For Cd, HNO_3-leachable baseline analyses by inductively coupled plasma emission spectroscopy (ICPES), uniformly <0.1 ppm (Appendix F), are lower than total element values typical for silicic rocks of 0.1 to 0.2 ppm (Wedepohl, 1978), whereas background analyses are higher, averaging 0.5 to 0.9 ppm for Units 3 to 5 (see discussion below). It is conceivable that the higher Cd values for the background samples reflect contamination from pulverizing in a tungsten carbide shatterbox. Thompson and Bankston (1970) provide no data for Cd to evaluate this possibility, but they do demonstrate extremely low levels of contamination by Zn, a strongly associated element. Thus, it is unlikely that Cd was introduced during sample preparation. Both background and baseline soil samples from MDA-P, analyzed for Cd by the superior method of inductively coupled plasma mass spectrometry (ICPMS), like baseline bedrock analyses, show HNO_3-leachable Cd contents (Table 11) uniformly <0.1 ppm (Appendix D). The much higher LANL-wide average value for Cd of 0.4 ppm in all soil horizons shown in Table 11 was obtained by ICPES (Table 2 in McDonald et al., 1996). Such a discrepancy is most likely due to erroneously high Cd by ICPES. But this conclusion is consistent with analyses for bedrock only if baseline Cd was actually analyzed by ICPMS, rather than by ICPES as reported in request number LANL 1794. Such may be the case because the detection limit of 0.1 ppm reported for baseline Cd (Appendix F) matches that for soils (Appendices D, E), which were analyzed by ICPMS, but is lower than that reported for background bedrock (0.2 ppm), analyzed by ICPES (Broxton et al., 1996).

For background samples, As was analyzed by superior methods (graphite furnace absorption spectroscopy for bedrock and electrothermal vapor atomic absorption spectroscopy for soil), whereas for baseline samples, As was analyzed by ICPES (Table 3). Neutron activation analysis (NAA) for As in nine samples of Unit 4 bedrock average 1.00 ppm (David E. Broxton, personal communication), similar to an average of 0.98 ppm for background analyses (Broxton et al., 1996). Baseline analyses average nearly four times higher, as described later in the report. Because As should be almost entirely in leachable form, and because NAA is a superior analytical method for As, background analyses are probably correct and baseline analyses are erroneously high. The possibility that all baseline samples are contaminated with As is highly unlikely because most baseline samples show no evidence of contamination, as discussed below. For As in soils, HNO_3-leachable values average more than twice those for total element values, providing very direct evidence for the poor quality of As analyses by ICPES.

Analyses for Tl in both background and baseline soil samples and in background bedrock samples were by the superior method of ICPMS, as opposed to ICPES for baseline samples of bedrock. The baseline samples of bedrock exhibit much higher values for Tl than the other three datasets so these Tl values are undoubtedly erroneously high.

For several additional elements, analyses were performed by the same method but values are statistically different between datasets without any apparent natural or anthropogenic cause. These differences certainly reflect small analytical biases between datasets for gross beta, Na, and K in bedrock (Table 13), and a large, statistically significant analytical bias between datasets for Na in soil (Table 11). Baseline analyses for Na in bedrock (Appendix F) were flagged with a relatively low-quality level, but Na analyses for background analyses (Broxton et al., 1996) were not, indicating that the background analyses for Na are superior.

7.3. General Patterns Related to Stratigraphic Level of Bedrock at MDA-P

The variety of patterns in background and baseline chemistry for the leachable portions of elements at MDA-P (Table 13) closely resemble the general patterns for total element present or phenocryst miner-

alogy at MDA-P (Appendix I; Broxton et al., 1996), and at other areas where the Tshirege Member has been analyzed (Broxton et al., in review). Chemical trends that are obscured by the relatively poor analytical quality of EPA-SW846 analytical methods are clearly recognizable from XRF analyses, which have 2 sigma accuracies as good as 1% of the value (see Appendix G and Broxton et al., 1996 for estimated accuracies of each analysis). Petrographic trends are revealing because phenocryst abundances may differ within a zoned tuff by orders of magnitude, such as apatite abundances within Units 3 to 5 of the Tshirege Member. Taken together, the remarkable covariation of total element present by XRF analyses and phenocryst mineralogy defines an unusual pattern of reverse primary (magmatic) zonation within Unit 4 of the Tshirege Member.

The patterns that demonstrate reverse zonation within the Tshirege Member are illustrated for two element/phenocryst pairs in Fig. 6. Apatite represents compatible minerals such as mafic minerals and P_2O_5 represents compatible elements such as transition elements. Such phenocryst minerals and elements generally concentrate in upper parts of zoned tuffs such as the Tshirege Member, reflecting their concentration in the lower parts of magma chambers. Quartz represents incompatible minerals such as sphene (not present in Tshirege Member) and SiO_2 represents incompatible elements such as U and Th that concentrate in residual glass. Such phenocryst minerals and elements generally concentrate in lower parts of zoned tuffs such as the Tshirege Member, reflecting their concentration in the upper parts of magma chambers. Previous work (Broxton et al., 1996; Smith and Bailey, 1966) has demonstrated a general pattern of normal zonation within the Tshirege Member, which is observed in Fig. 6 as a general upward increase in compatible minerals and elements, together with a general upward decrease in incompatible minerals and elements. But a large upward decrease in apatite and P_2O_5, together with a slight upward increase in quartz and SiO_2, define a reverse zonation within Unit 4 that has been previously unrecognized. This reverse zonation results in a three-fold systematic variation within Unit 4 for P_2O_5 and several other elements, such as CaO, Sr, and Fe_2O_3 (see Broxton et al., 1996). The associated variation in phenocryst content is nearly two orders of magnitude for apatite.

Subunits that are transitional in chemistry and petrography between Units 3 and 4 are also defined from the XRF analyses, detailed petrography, and field characteristics. These subunits are Unit 3t, which is chemically indistinguishable from Unit 3, but contains a much lower content of quartz phenocrysts, and Unit 4t, which is petrographically indistinguishable from Unit 4, but chemically intermediate between Units 3 and 4 (Fig. 6).

It is remarkable that patterns for leachable portions follow magmatic patterns defined from total element concentrations, considering the large differences in leachable fraction for each element. For example, transition metal elements such as Fe and Zn occur in 50% to 100% leachable form, primarily within magnetite, mafic minerals (mostly pyroxene), and their alteration products. But Al and Ca also show patterns similar to magmatic patterns even though only about 7% of the Al and 25% of the Ca occurs in leachable form. The similarities between leachable and total element concentrations are demonstrated for representative elements in Fig. 7.

7.4. General Patterns Related to Alteration of Bedrock at MDA-P

Plots of elevation versus HNO_3-leachable chemical data (Fig. 5) show that vitric samples of bedrock, which are the eight samples in these plots with the highest elevations (except for the fifth highest) conform to the same patterns as devitrified samples. This conclusion is tentative because it is based on few samples and somewhat obscured by excursions for many elements in samples DEB5/95/11-13,

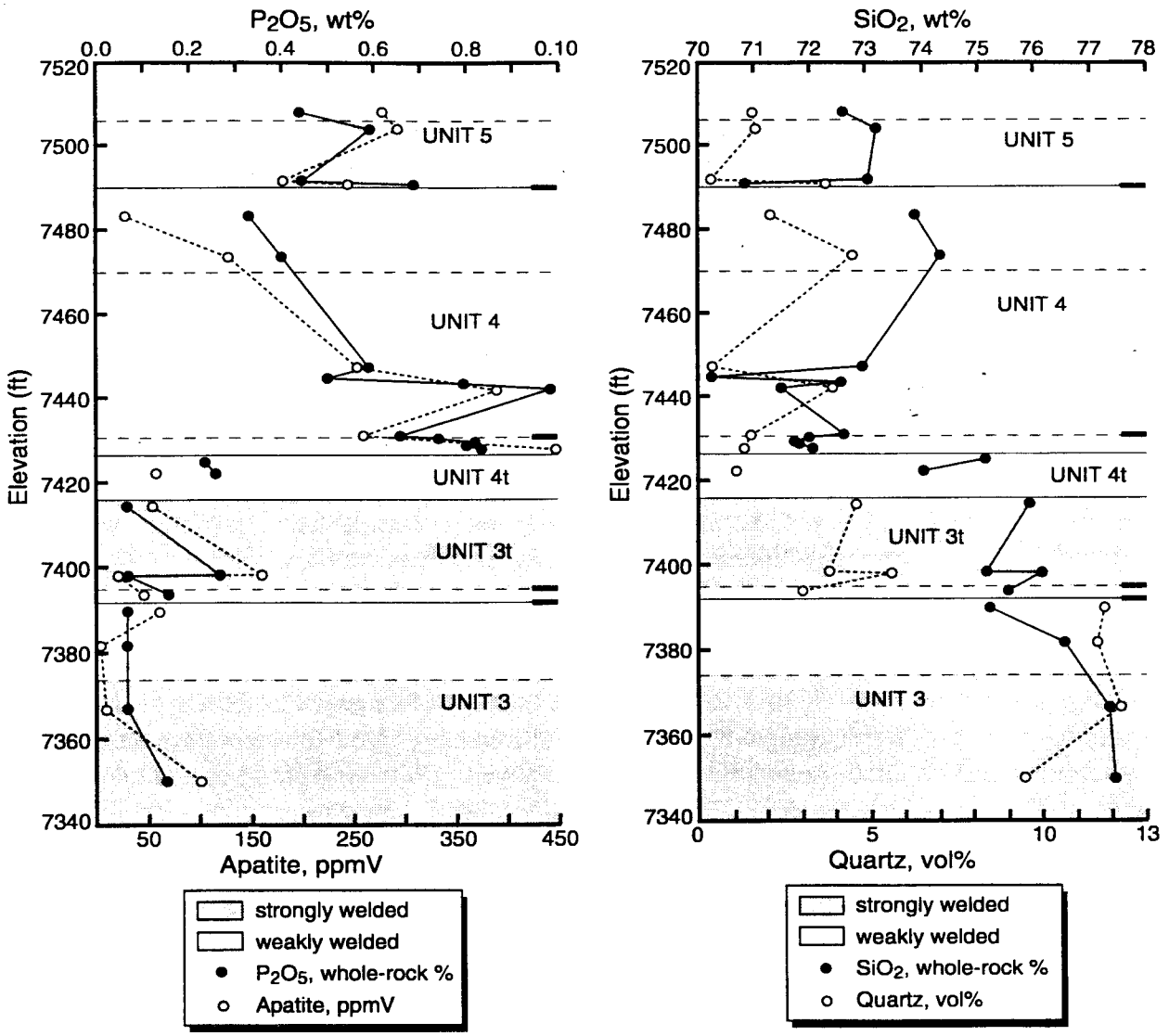

Fig. 6. The left plot represents compatible minerals and elements versus elevation (stratigraphic level), and the right plot represents incompatible minerals and elements versus stratigraphic level in the Tshirege Member at MDA-P. Units 3t and 4t are defined from this work as described in text. Solid horizontal lines show boundaries between stratigraphic units, and broken horizontal lines show boundaries for alteration or lithology.

which are attributed to a hydrologically transmissive zone, rather than to their vitric alteration, as discussed below. The tentative finding that vitric and devitrified samples of the Tshirege Member have similar leachate chemistry is surprising considering their large difference in bulk mineralogy and whole rock chemistry for some elements, particularly for Cl^-. Although whole-rock Cl^- is not available for background samples, vitric rocks typically contain five times higher Cl^- contents than devitrified rocks (Noble et al., 1967); yet the leachable Cl^- contents of vitric Units 4 and 5 are generally lower than those of devitrified Unit 4, following the general pattern of upward depletion within the Tshirege Member (Table 13). Apparently, the large amount of Cl^- that resides in glass within vitric rocks is unavailable to leaching.

7.5. General Patterns Related to Burial of Bedrock by Soil at MDA-P

Plots of elevation versus HNO_3-leachable chemical data also demonstrate no general differences between exposed tuff of Units 4 and 5 versus five samples of tuff buried beneath shallow soil (Table 2).

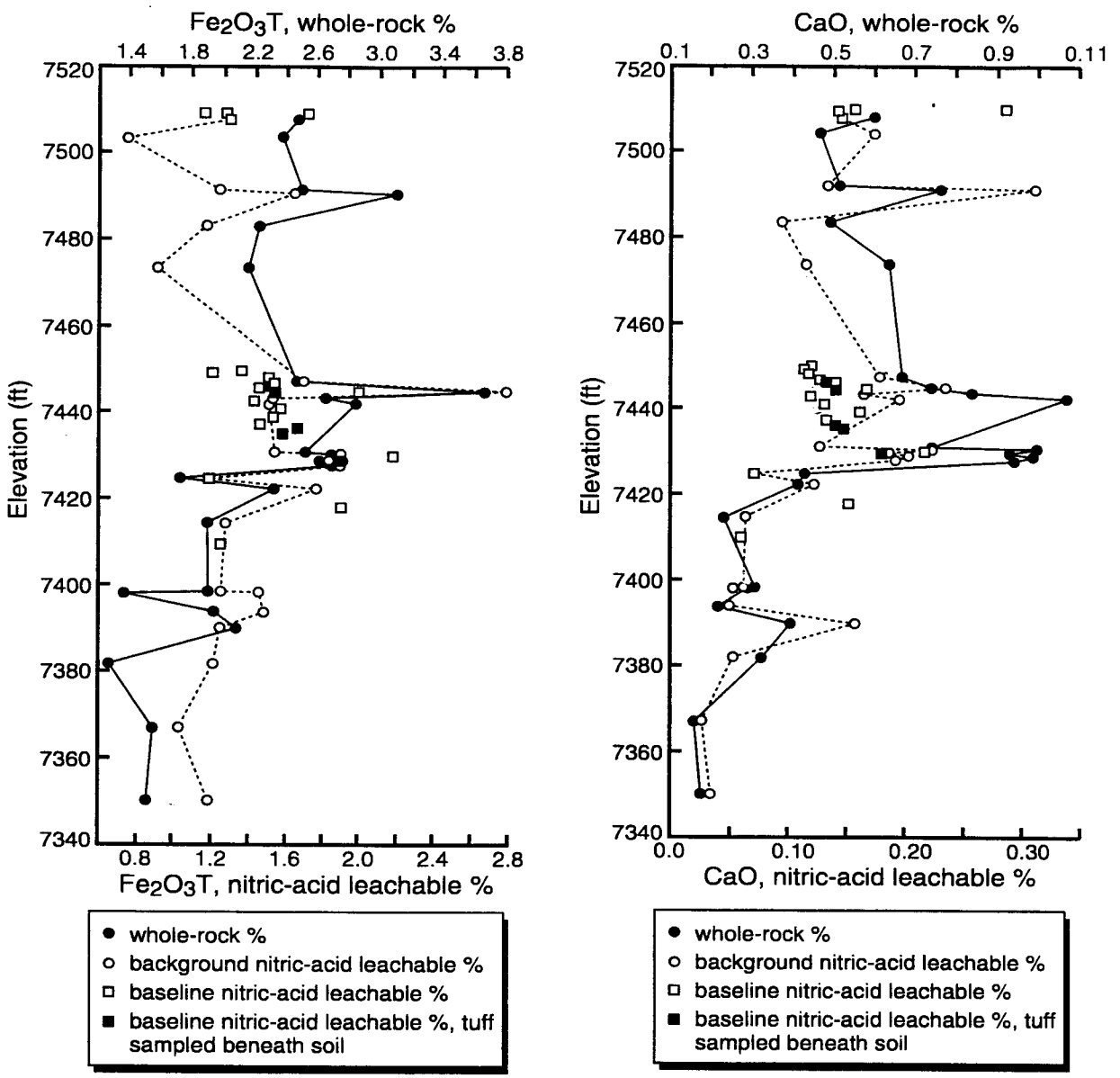

Fig. 7. The correspondence between HNO_3-leachable values from EPA-SW846 analytical methods and total element values from XRF. The left plot shows correspondence for typical transition element, which occurs mostly in leachable form, and the right plot shows correspondence for an element that occurs mostly in unleachable form.

For example, all five samples of tuff buried beneath shallow soil show Ca and Fe contents very close to those for exposed tuff. Therefore, burial of tuff beneath soil appears not to generally affect the chemistry of Units 3, 4, or 5 of the Tshirege Member.

8.0. DISCUSSION OF EXCURSIONS FROM TYPICAL PATTERNS IN BACKGROUND AND BASELINE CHEMICAL DATA FOR BEDROCK AT MDA-P

The previous sections have discussed factors that generally affect the natural chemistry of bedrock. The following sections discuss additional, less widespread factors that result in excursions from typical chemical values. Excursions in background and baseline chemical data for MDA-P are attributed to four causes in Table 14: Extreme weathering, association with a hydrologically transmissive zone, concentration due to extreme mobility and contamination.

8.1. Excursions in Bedrock Related to Alteration and Weathering at MDA-P

Two sets of samples were collected to evaluate a common weathering effect, recognizable by the formation of spherules in samples collected from MDA-P (Table 12). No sample from either set showed any deviation from the general pattern observed for Unit 4 of the Tshirege Member, indicating that such effects occur within an effectively closed chemical system on the 10-cm scale of sampling at MDA-P. But one extremely weathered sample, DEB6/95/5, sampled as an alteration-banded block surrounded by soil (Table 12), provided excursions for five elements (Table 14); all five elements showed similar excursions for total element present (Broxton et al., 1996).

8.2. Excursions in Bedrock Related to Association with a Hydrologically Transmissive Zone and Concentration due to Extreme Mobility at MDA-P

Cations mobile in aqueous solution, Na, K, and Mg, each show a single positive excursion from the typical general pattern versus stratigraphic level, but all cases are confined to samples DEB5/95/11-13 (Table 14). The value for each element, each just below its UTL, is the highest value for each element in Appendix IV of Broxton et al. (1996). Samples DEB5/95/11-13 comprise a lithologic sequence, including and above a base surge that generally forms hydrologically transmissive zones throughout the Tshirege Member that can easily concentrate elements from solutions passing through preferentially (Rogers and Gallaher, 1995; Broxton et al., in review; Rogers et al., 1996). This zone at MDA-P is also an enormous sink for Cl^- and SO_4^{2-}, which travel as anions. Apparently, these anions are so extremely mobile in the weathering environment that they can also be concentrated, but to a lesser degree, in less optimum environments, as indicated by the listing of several excursions in Table 14. The excursions attributed to extreme mobility are those >49.9 ppm for Cl^- and those ≥71 ppm for SO_4^{2-} in Appendix F and Appendix IV of Broxton et al. (1996).

Alternatively, most of the excursions attributed to a hydrologically transmissive zone might instead be the result of vitric alteration. However, two observations argue against this interpretation: (1) DEB5/95/10, immediately below the base surge, is vitric as are all four samples from Staging Area 1, but none of these samples show a single excursion, and (2) DEB5/95/13, a devitrified densely welded tuff that lies within the hydrologically transmissive zone shows an extreme excursion for SO_4^{2-}.

8.3. Excursions in Bedrock Related to Contamination at MDA-P

Large excursions from the general patterns of chemistry versus stratigraphic level occur for Pb and Zn in sample RW16PA2, and small excursions occur for As and Be in this same sample (Table 14). These excursions exceed UTLs for Unit 4 (Broxton et al, 1996), except for Be, which therefore cannot be confidently defined as an excursion. These elements are not highly mobile within the weathering environment, so their abnormal values in this sample are attributed instead to contamination from operations at the TA-16 burning ground. Table 2 in Rivera-Dirks and Conrad (1995) reports concentrations for the same suite of elements within a soil sample (PRS16-010B14) that are two orders of magnitude higher in Pb and As than any of the other 27 soil samples reported; Zn was not analyzed. This sample also has the highest levels for Ag, Cd, Cr, and Se shown in their Table 2. Samples RW16PA2 and PRS010B14 suggest the presence of an uncommon contaminant with a distinctive chemical signature of Pb, Zn, As, and Cd, and much lesser Be and Se. It is also possible that these two samples might reflect natural enhancements resulting from absorption by iron oxides and hydroxides, as demonstrated for As and Be in soils of the Pajarito Plateau (Figures 17 and 18 in Longmire et al., 1996). Indeed,

sample RW16PA2 (the baseline value plotted in Fig. 7 at 7430 ft elevation) is enriched in Fe (Fe is not reported for sample PRS16-010B14). But sample RW16PA2 is also enriched in other compatible elements (e.g., Ca as seen in Fig. 7), so that the elevated Fe may simply reflect magmatic zonation. Although the small degree of enrichment in As and particularly Be might reflect natural enhancement resulting from absorption by iron oxides and hydroxides, the Pb value for sample RW16PA2 exceeds the highest background value for soils (Table 7 in Longmire, et al., 1996) by nearly an order of magnitude and certainly reflects contamination.

Baseline bedrock samples show evidence of widespread Ba contamination at MDA-P, similar to that found for soils and discussed earlier within this report (Fig. 5). Although sample RW16PA2 does not exhibit an excursion for Ba, all three other samples collected along the Run-on Control Trench (Table 2) show large to small excursions, and six other samples collected from the Segregation Area and Decontamination Pad near the waste pile show large excursions. Except for samples DCN1-R and DCN3-R, collected from the Decontamination Pad very near to the waste pile and covered by very shallow fill (Table 2), samples of tuff that are protectively buried beneath soil exhibit Ba values that closely follow the general patterns of chemistry versus stratigraphic level. Contamination from Ba has been clearly defined in previous work at MDA-P for soils and sediment (McLin, 1989; Rivera-Dirks and Conrad, 1995; McDonald et al., 1996). This work indicates that Ba contaminates bedrock exposed near the TA-16 burning ground as well.

8.4. Summary of General Patterns in Background and Baseline Chemical Data for Bedrock at MDA-P and Excursions from These Patterns

Consistent and realistic values indicate a generally good quality for most analyses of the leachable portions of 27 elements and for two measurements of gross radioactivity. However, an inconsistency between background and baseline analyses identifies major analytical problems for four elements (gross alpha, As, Tl, and Cd), and minor analytical problems for 3 others (gross beta, Na, and K). Excluding those elements with major analytical problems and several elements with most values below detection limits, all elements analyzed generally follow patterns of chemistry versus stratigraphic level that reflect primary (magmatic) zonation of the Tshirege Member, which is well defined at MDA-P from total element analyses by XRF and detailed petrographic analyses. Magmatic chemical or petrographic trends are mimicked even though the fraction of element leached varies from near 100% for many transition metal elements to <10% for Al.

Within the set of 46 background and baseline samples are several subsets of samples that allow an assessment of factors other than stratigraphic level that might affect the chemical data (Table 14). These factors include the effect of burial by soil, weathering within uppermost bedrock, and rock alteration (vitric versus devitrified tuff). In all cases, these factors appear to have a negligible effect on the general patterns of chemistry versus stratigraphic level, and only extreme weathering is recognizable as a cause of excursions from the general patterns. Excursions are very important, because they can be the result of contamination from cultural sources, but this work demonstrates that many have natural causes.

Many of the 34 excursions from the general patterns of chemistry versus stratigraphic level identified within the 1311 background and baseline analyses are attributed to contamination from operations at the TA-16 burning ground (Table 14). The majority of excursions attributed to contamination are for a single element, Ba, which is expected to be the most prominent contaminant. The contamination of Ba

depends upon the nature and location of the sample; samples downstream from the waste pile are most strongly contaminated, but those protected by soil are slightly contaminated only at locations extremely close to the waste pile.

Most of the other excursions are attributed to two natural causes: association with a hydrologically transmissive zone and extreme weathering (Table 14). Hydrologically transmissive zones apparently can foster enrichment for many elements that may be extreme for highly mobile species such as Cl^- and SO_4^{2-}. These environments are recognized by applying an understanding of the processes of hydrology and weathering to thorough geologic observations made at each local sampling area and at each sample site, such as the observations provided in Appendix B.

9.0. RELATIONSHIPS BETWEEN SOIL AND BEDROCK AT MDA-P

The geochemical development of soils is a very complex process that depends on the relative amounts of windblown and waterborne material that are added to bedrock, plus the degree to which this mixture has been weathered. Considering the complexities, underlying bedrock provides the simplest available reference to gauge the geochemical development of soils. Closely matching compositions of bedrock and soil suggest the addition of relatively small amounts of added windblown and waterborne material, as well as minimal weathering. In addition, a comparison of the HNO_3-leachable fraction of each element provides an assessment of the similarity in mineralogy between soil and bedrock.

Leachable element values are grossly similar between soil and bedrock at MDA-P. Mean values for the A2 horizon of background soils compare within a factor of 2 with those of bedrock buried beneath the Segregation Area for 75% of elements available for comparison (Fig. 8). Of the five elements outside this range, Na and Tl are untrustworthy because of analytical problems, and Ba is strongly affected by contamination even within the A2 horizon, as discussed below. The HNO_3-leachable fraction for each element is also generally similar between bedrock and soil; both have very low fractions of leachable alkali elements and relatively high fractions of transition elements (Fig. 9).

Soils sampled elsewhere on the Pajarito Plateau (generally well east of MDA-P, from stratigraphically lower Units 1 to 3) show greater chemical discrepancies with bedrock than at MDA-P. All elements enriched in soil versus bedrock at MDA-P (Fig. 8) are more enriched in soils elsewhere on the plateau (compare chemical values of all soil horizons for MDA-P versus those LANL-wide in Table 11). These same elements are more depleted in bedrock elsewhere on the plateau, from a comparison of values for Unit 4, representing MDA-P, versus those for Unit 3 (Broxton et al., 1996), representing bedrock elsewhere. This general trend of eastward elemental enrichment with decreasing elevation for soils and eastward elemental depletion with increasingly lower stratigraphic level for bedrock is illustrated for Ni in Fig. 10. Thus soil at MDA-P is more closely related to bedrock at MDA-P than elsewhere on the Pajarito Plateau, and a chemical comparison between soil and bedrock is less complicated by the processes of soil development for MDA-P than elsewhere on the Pajarito Plateau.

Despite the significant chemical control by unknown pedologic processes, comparisons between the chemistry of individual soil horizons and underlying bedrock clearly reveal contamination from anthropogenic activities at MDA-P. Figure 11 compares leachable element values for soils directly with those from underlying bedrock, and Fig. 12 shows the leachable fraction of each element for these same soils. The correspondence between elemental concentrations elevated within the upper part of the soil A horizon (Fig. 11) and those with elevated leachable fractions (Fig. 12) is striking, and

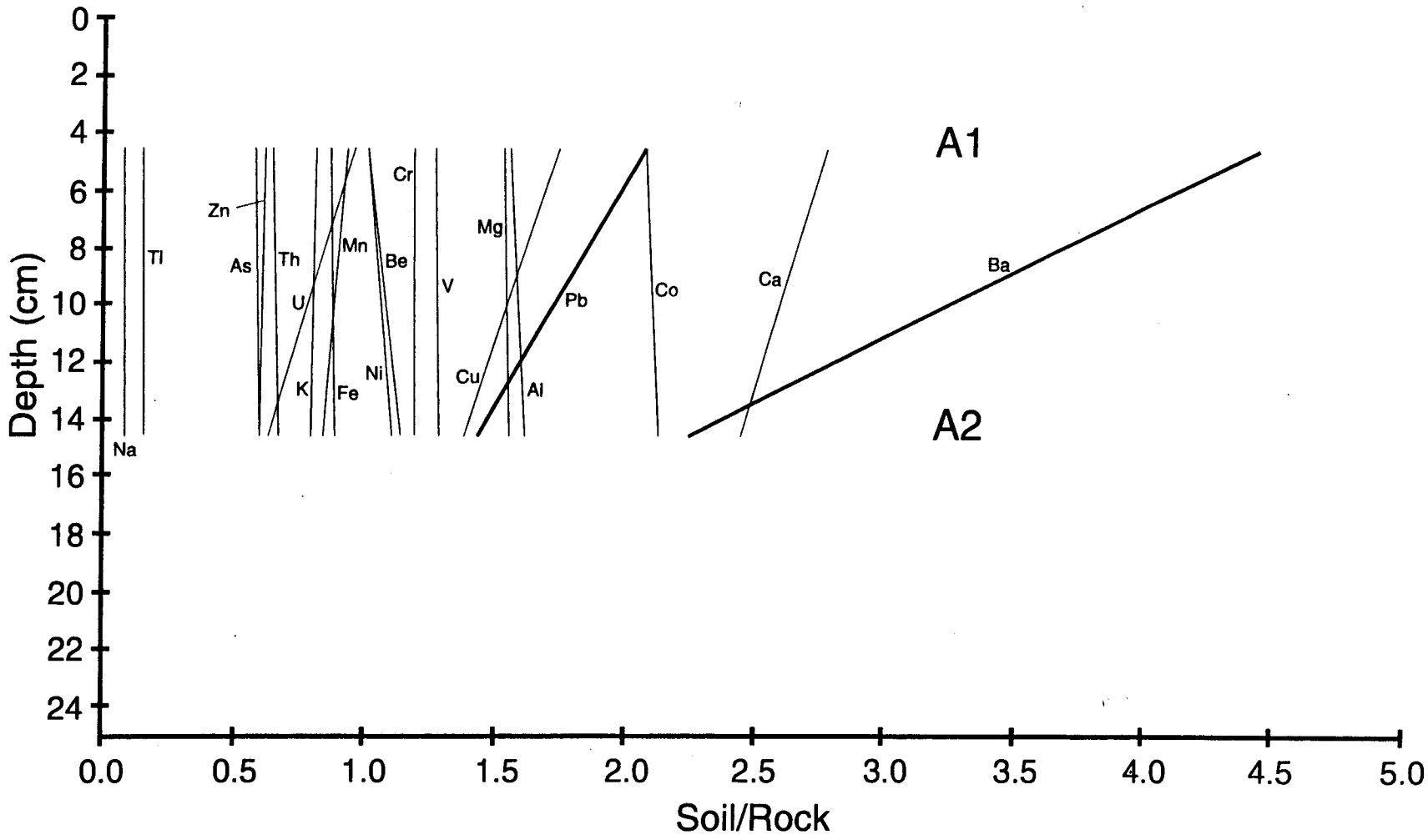

Fig. 8. Ratio of mean for HNO_3-leachable elements in A horizon of background soils from MDA-P to mean for HNO_3-leachable elements in baseline bedrock sampled beneath soil at the Segregation Area. Data for Th and U are for total element. Plotted depths are means for A1 and A2 horizons. Standard errors of these mean ratios are typically 5% to 15% of the mean ratio. Differences significant at 95% confidence are shown as bold line segments.

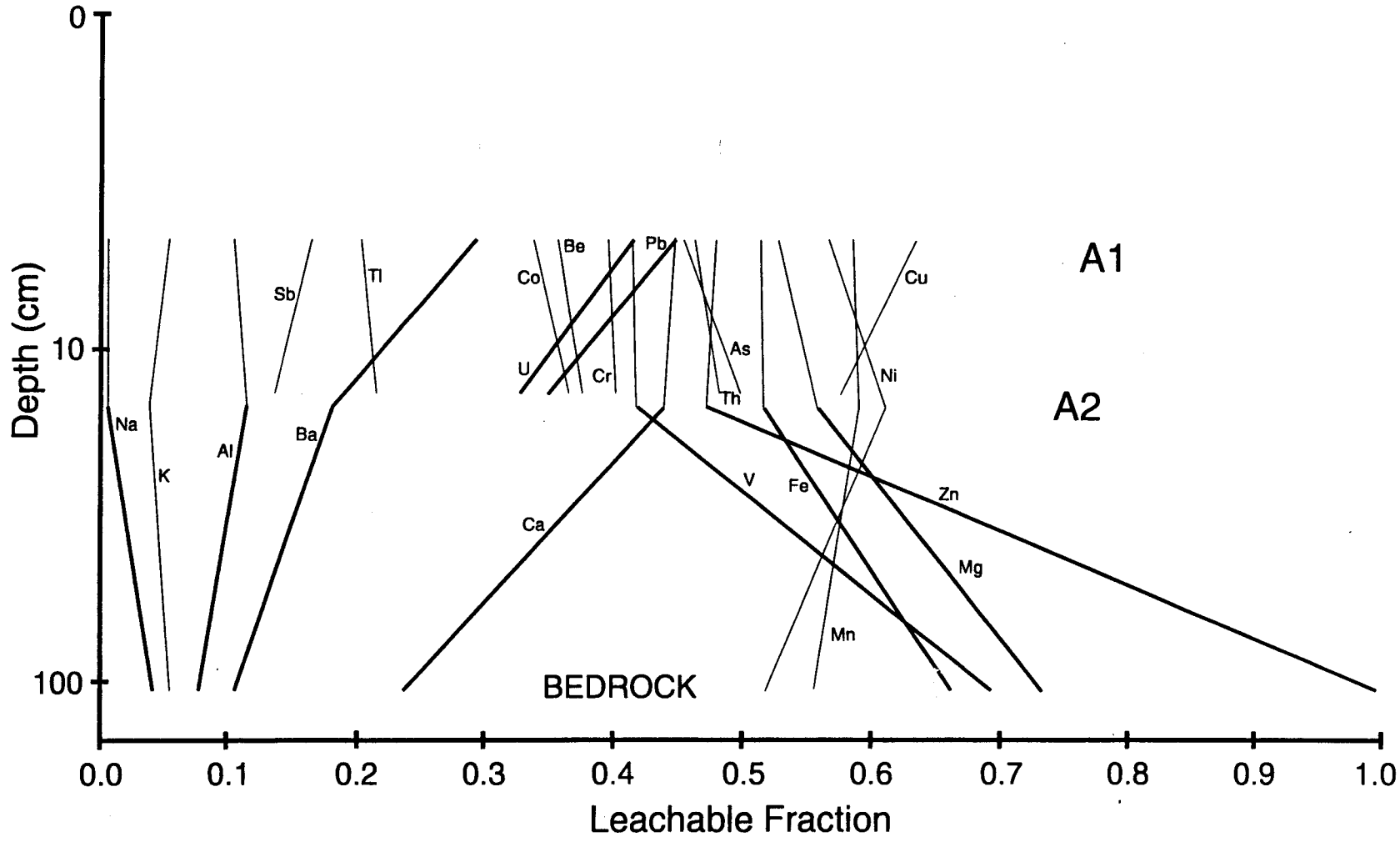

Fig. 9. Mean leachable fraction for elements in background soil samples and all bedrock samples from MDA-P. Total element values were obtained via HF digestion for soil samples and via XRF for bedrock samples. Plotted depths are means for A1 and A2 horizons and for baseline bedrock sampled beneath soil at the Segregation Area. Differences significant at 95% confidence are shown as bold line segments.

demonstrates with statistical significance that Ba, Pb, Ag, SO_4^{2-} are concentrated in soluble form near the surface. We attribute the concentration of these elements to anthropogenic contamination because there is no pedologic reason for these species to concentrate within the uppermost soil horizon relative to underlying horizons. Figures 8 and 9 demonstrate with statistical significance that Ba and Pb are concentrated in soluble form near the surface at much greater distances from the sources of anthropogenic contamination than the baseline samples; such widespread contamination does not occur for Ag, and data are unavailable to evaluate SO_4^{2-}. Figures 8, 9, 11, and 12 also define consistent widespread enrichment of U, Cu, and Ca in soluble form near the surface, probably because of contamination, although differences are not statistically significant in all cases. Concentrations of U that are above LANL-wide background have been recognized in places across the Laboratory (Longmire et al., 1997). These elevated concentrations of U appear to have resulted from aerosolic dispersal from firing sites. Elevated levels of U near MDA-P may also reflect possible contributions from firing sites located at TA-67 (Pajarito Mesa), TA-9, or TA-15.

A single element, Be, appears to vary appreciably within the soil A horizon as a result of pedologic processes. Downward decreasing concentrations and fractions of leachable Be consistently occur within both baseline and background samples. Such chemical trends are very rare and obviously cannot reflect contamination.

10.0. CONCLUSIONS FROM BASELINE STUDY OF MDA-P

The chemical analyses reported herein, when combined with field observations and detailed petrographic analyses also shown here, and the results of background studies (Broxton et al., 1966; McDonald et al., 1996), lead us to conclude that wind-borne contamination is widespread from the TA-16 burning ground. Near this contaminating source at the Segregation Area and Decontamination Pad, both amounts and relative fractions of HNO_3-leachable Ba are highly enriched in both soil and bedrock. Near source, amounts and relative fractions of HNO_3-leachable Pb and Ag are also enriched in soil. Farther from the source, background soil samples show the same enrichment patterns for Ba and Pb, indicating widespread wind-borne contamination for these elements. Although enrichments in soils are not statistically significant for all comparisons of U, Cu, and Ca, these elements consistently show the same enrichment patterns as Ba and Pb, so they too are probably widespread contaminants in soils.

Both HNO_3-leachable and total element contents, as well as the abundances of primary (phenocryst) minerals within the upper part of the Tshirege Member vary strongly within Unit 4 in a systematic pattern that reflects a primary (magmatic) reverse zonation. This zonation results in chemical variations for some elements within Unit 4 within a factor of three and variations for some phenocryst abundances that exceed two orders of magnitude. Because of this effect, accurate chemical comparisons are possible only when the stratigraphic level within Unit 4 is accurately known. In cases where Unit 4 is sampled uniformly, large standard deviations will result from simple statistical analyses of data from Unit 4. In cases where restricted parts of Unit 4 are preferentially sampled, significant chemical differences between datasets may be calculated if the parts sampled are at different stratigraphic levels, as is the case for the comparison between baseline and background bedrock for Unit 4 at MDA-P. The problem of distinguishing chemical excursions from this extreme chemical variation within Unit 4 is addressed by examining plots of data versus stratigraphic level. Within the entire area sampled for baseline and background study of MDA-P, perfectly horizontal attitudes for units of the Tshirege Member are a fortunate consequence of geologic structure, allowing the equation of stratigraphic level to sample elevation. From plots of data versus sample elevation, recognizable chemical

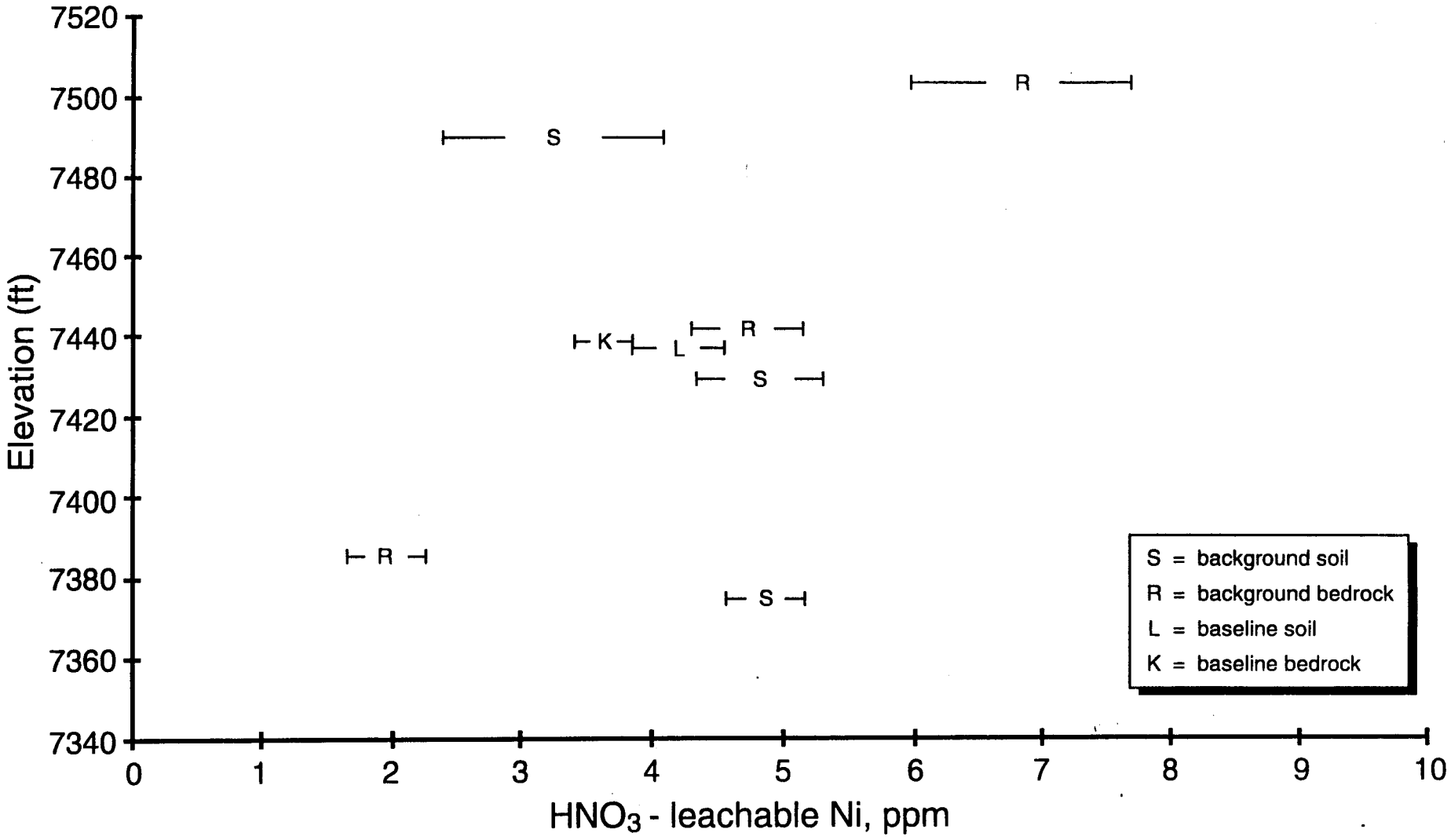

Fig. 10. Mean HNO_3-leachable Ni by unit of Tshirege Member. Error bars represent standard error of the mean. Data for bedrock includes transitional units with parent unit. Data for baseline soil exclude fill (all data from Staging Area 1 and Decontamination Pad). Soil samples with elevations 7415 to 7489 ft (Table 1 in McDonald et al., 1996) are assigned to Unit 4. Plotted elevations are means by unit. Differences are significant at 95% confidence between soil and bedrock of Units 3 and 5, and between baseline bedrock of Unit 4 and both background bedrock and soil of Unit 4.

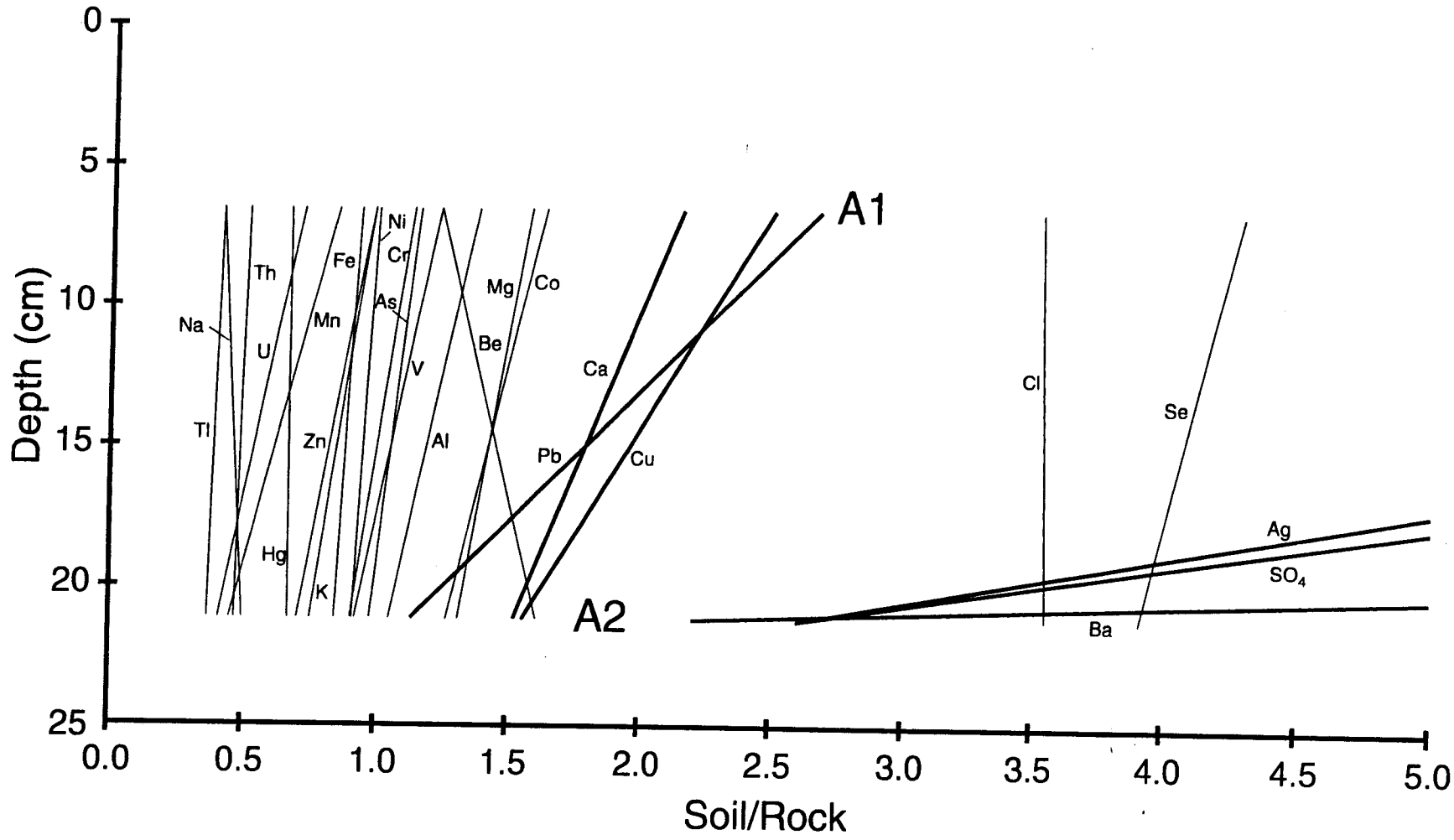

Fig. 11. Ratio of mean for HNO_3-leachable elements in A horizon of baseline soils to mean for HNO_3-leachable elements in baseline bedrock from MDA-P. Samples include only soils and bedrock where bedrock was sampled beneath soil at the Segregation Area. Data for Th and U are for total element. Plotted depths are means for A1 and A2 horizons. Standard errors of these mean ratios are typically 5% to 15% of the mean ratio. Differences significant at 95% confidence are shown as bold line segments.

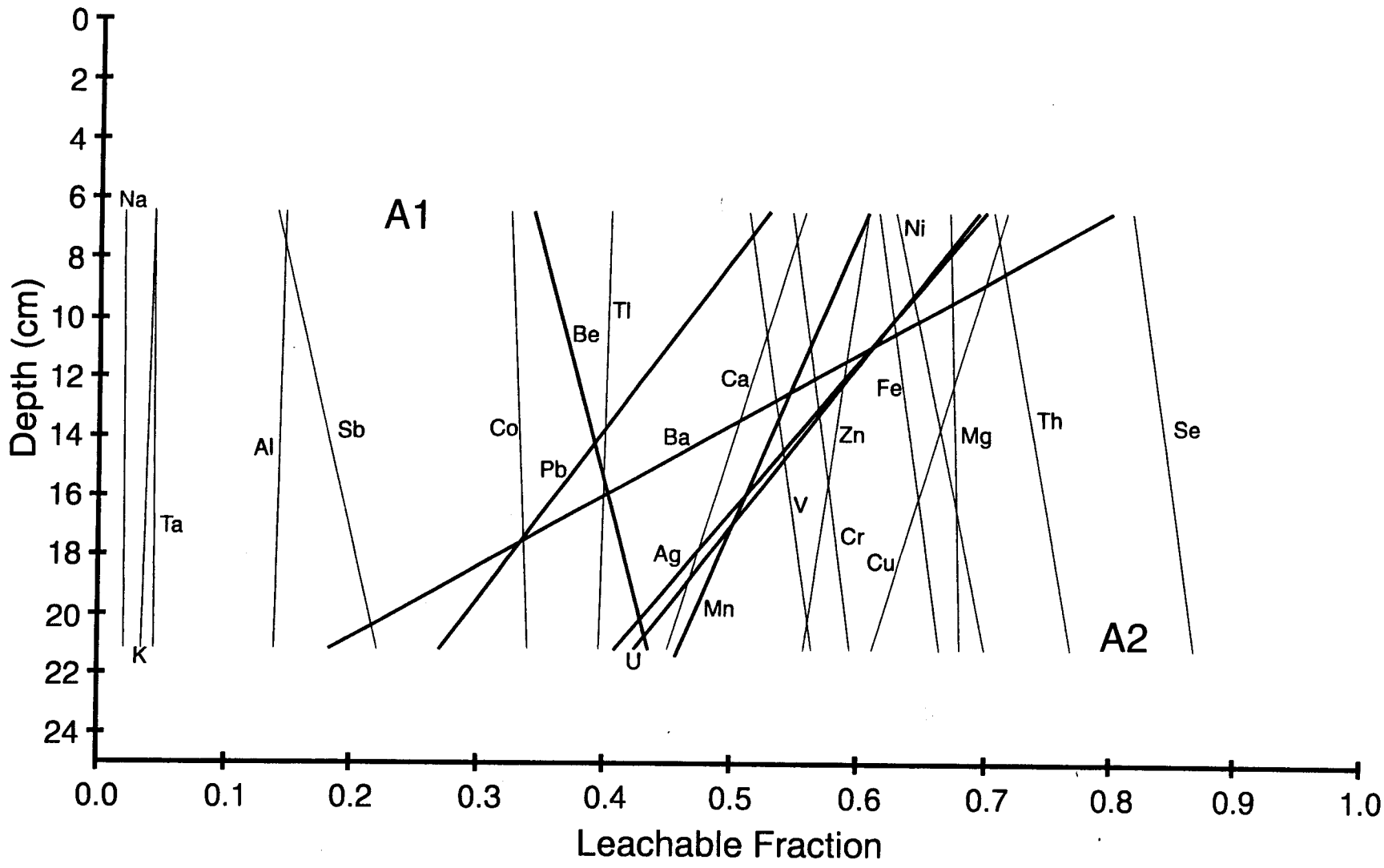

Fig. 12. Mean leachable fraction for elements in baseline soil samples from the Segregation Area at MDA-P. Total element values were obtained via HF digestion. Plotted depths are means for A1 and A2 horizons. Values for As, >>1 due to analytical errors, are not shown. Differences significant at 95% confidence are shown as bold line segments.

excursions are attributed to analytical errors, hydrologically transmissive zones and extreme chemical mobility, extreme weathering, and contamination from anthropogenic activities at MDA-P.

Individual baseline samples of both soil and bedrock provide a few large, positive excursions from mean values. For bedrock, most such excursions are attributed to natural causes, but most samples of bedrock at the Segregation Area not protected by soil display large excursions attributed to contamination from Ba. Pb and Zn show large excursions, and As and possibly Be show small excursions in a single sample that is attributed to contamination. These excursions are corroborated by a analysis of a soil sample reported by Rivera-Dirks and Conrad (1995). Unfortunately, baseline analyses are probably erroneous for As, Na, and K, and for baseline analyses of bedrock for Cd and Tl. Except for Na and K, all such values appear to be erroneously high, and they thus represent upper limits for these analytes.

ACKNOWLEDGMENTS

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Appendix A. Locations for samples collected for background and baseline study of bedrock from MDA-P. Northings and Eastings are New Mexico State Plane, NAD83. All samples were collected within the Frijoles 7.5-minute topographic quadrangle; map units are those of Rogers (1995). Samples collected for background study are in the "DEB" series; all other samples were collected for baseline study. See Appendix J for explanation of symbols.

Sample Number	North (ft)	East (ft)	Elev (ft)	Source	Map Unit
DCN1	1764279	1616033	7449.3	D6	Qf
DCN2	1764295	1616042	7447.8	D6	Qf
DCN3	1764309	1616054	7445.9	D6	Qf
DEB5/95/1	1764605	1615611	7350.0	D15	QbtD
DEB5/95/10	1764865	1615529	7483.5	D15	QbtF
DEB5/95/11	1764856	1615502	7491.0	D15	QbtF
DEB5/95/12	1764853	1615491	7491.9	D15	QbtF
DEB5/95/13	1764873	1615480	7504.2	D15	QbtF
DEB5/95/14	1765631	1617039	7390.0	D15	QbtE
DEB5/95/15	1765631	1617039	7393.9	D15	QbtE
DEB5/95/16	1765631	1617039	7398.4	D15	QbtE
DEB5/95/2	1764634	1615604	7366.7	D15	QbtD
DEB5/95/3	1764701	1615666	7381.8	D15	QbtD
DEB5/95/4	1764726	1615658	7398.2	D15	QbtD
DEB5/95/5	1764760	1615645	7414.6	D15	QbtD
DEB5/95/6	1764783	1615632	7422.5	D15	QbtE
DEB5/95/7	1764771	1615571	7431.0	D15	QbtE
DEB5/95/8	1764834	1615593	7447.4	D15	QbtE
DEB5/95/9	1764845	1615537	7473.7	D15	QbtE
DEB6/95/1	1764337	1615485	7430.4	M2	QbtE
DEB6/95/2	1764337	1615485	7429.5	M2	QbtE
DEB6/95/3	1764337	1615485	7428.9	M2	QbtE
DEB6/95/4	1764337	1615485	7428.0	M2	QbtE
DEB6/95/5	1764302	1615585	7444.9	M2	QbtE
DEB6/95/6	1764302	1615585	7443.6	M2	QbtE
DEB6/95/7	1764302	1615585	7442.2	M2	QbtE
DEB6/95/8	1763916	1615646	7477.0	M1	Qf
GB/1	1764359	1616259	7429.7	M1	QbtE
NLS/1	1764327	1616255	7436.1	M1	QbtE
NUS/1	1764275	1616255	7445.5	M1	Qf
RW16PA1	1764383	1616160	7425.0	D6	QbtE
RW16PA10	1764430	1616120	7418.1	D6	QbtE
RW16PA11	1764519	1616042	7409.9	H6	QbtE
RW16PA2	1764371	1616144	7430.3	D6	QbtE
RW16PA3	1764353	1616307	7437.4	M1	QbtE
RW16PA4	1764356	1616328	7440.5	M1	QbtE
RW16PA5	1764340	1616326	7438.8	M1	QbtE
RW16PA6	1764380	1616339	7445.6	M1	QbtE
RW16PA7	1764217	1616289	7448.0	M1	Qf
RW16PA8	1764240	1616226	7448.9	M1	Qf
RW16PA9	1764266	1616168	7443.4	M1	QbtE
RW16PC1	1762815	1614941	7509.3	M1	Qvec
RW16PC2	1762810	1614950	7509.5	M1	Qvec
RW16PC3	1762804	1614964	7508.7	M1	Qvec
SA1/1	1762893	1614920	7512.2	D6	Qvec
SA1/2	1762974	1614974	7512.0	D6	QbtF
SA1/3	1762929	1615019	7510.0	D6	QbtF
SLS/1	1764382	1616282	7435.7	M1	QbtE
SUS/1	1764398	1616306	7444.4	M1	QbtE

Appendix B. Field (F) and binocular microscope (B) descriptions (denoted in column *D*) for samples of bedrock collected for background and baseline study of bedrock from MDA-P. Samples collected for background study are in the "DEB" series; all other samples were collected for baseline study.

Sample Number	*D*	Worker	Date	Description
DCN1-R	F	RGW	1-DEC-95	Sample was taken 0.2 m below surface from the bottom of shallow soil pit DCN1 dug by Eric McDonald earlier in the day within Decontamination Area of MDA-P, 1.2 m N49E from its southwest corner. Tuff in this pit is mottled and weathered; I avoided bleached rock, sampling rock with uniform character. The surface of DCN1 was measured 6.1 m above RW16PA2 in the nearby Segregation Area, and the lowest exposure of typical Unit 4 of Tshirege Member measured 2.95 m above RW16PA2. This typical Unit 4, exposed just north of the Decontamination Area on the south side of the Run-on Control Trench, is light-colored devitrified nonwelded tuff with relatively large brown pumices, similar to GB/1 and stratigraphically higher samples from the Segregation Area.
DCN1-R	B	RGW	8-DEC-95	Sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 10 mm. Common felsics include feldspar to 5 mm and quartz to 2.5 mm. Scarce to common mafics are mostly green clinopyroxene to 1 mm, some partly altered, and black vitreous mafic, probably orthopyroxene. Single 1-mm diameter, orange, fine-grained clastic sedimentary lithic was observed.
DCN2-R	F	RGW	1-DEC-95	Sample was taken 0.25 m below the surface from the bottom of a shallow soil pit DCN2 dug by Eric McDonald earlier in the day within Decontamination Area of MDA-P, 7.0 m N32E from its southwest corner. Tuff in this pit is more solid and less weathered than bedrock in DCN1. The surface of DCN2 was measured 5.75 m above RW16PA2.
DCN2-R	B	RGW	8-DEC-95	Sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 17 mm. Common felsics, dominated by feldspar, include quartz to 2 mm. Scarce to common mafics are mostly unaltered green clinopyroxene and mostly altered black orthopyroxene; a single grain of biotite was observed. Single 1.5-mm diameter lithic was observed.
DCN3-R	F	RGW	1-DEC-95	Sample was taken 0.2 m below surface from rubbly tuff at the bottom of a shallow soil pit DCN3 dug by Eric McDonald earlier in the day within Decontamination Area of MDA-P, 12.4 m N36E from its southwest corner. I sampled large blocks of tuff, generally 70 by 60 by 50 mm. The eastern boundary of this pit coincides with the eastern boundary of the Decontamination Area. The surface of DCN3 was measured 5.45 m above RW16PA2.
DCN3-R	B	RGW	8-DEC-95	Sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 11 mm and is mottled moderate orange pink with scattered alteration spots. Common felsics include quartz to 3 mm. Scarce to common mafics are mostly green clinopyroxene to 1.5 mm, some partly altered, and lesser black, partly altered orthopyroxene. Rare lithics occur to 2 mm.
DEB5/95/1	F	DEB	10-MAY-95	Sample is pinkish brown, fairly dense partially to moderately welded ignimbrite with 10% light gray to medium gray vapor-phase pumice to 10 mm with 3:1 to 5:1 flattening, and contains 15% to 20% phenocrysts, many larger than 2 mm, primarily quartz and chatoyant sanidine. Mafics are altered to hematite pseudomorphs. Lithics are rare; a few up to 50 mm in diameter are Tschicoma lavas with 15% phenocrysts. Sample taken at base of vertical cliff-forming tuff having well-developed fractures with dihedral faces, 0.3 m above stream level.
DEB5/95/1	B	RGW	24-MAY-95	Sample is light brownish gray devitrified moderately welded tuff with scarce very light gray to light gray pumice to 10 mm. Common to abundant felsics include chatoyant sanidine and very conspicuous quartz. Common mafics are entirely altered to orange-brown hematite. No lithics were observed.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
DEB5/95/10	F	DEB	10-MAY-95	Sample is indurated, vitric medium gray to tan gray nonwelded ignimbrite with 10% to 20% orange vitric pumices that commonly contain large clots of felsic minerals to 5 mm. The matrix contains 10% to 15% phenocrysts. Lithics are 1% to 3% and include Tschicoma dacites and light gray aphanitic rhyolite lavas. Below 40 m above stream level, tuff is devitrified and vapor-phase altered; above, it is dominantly vitric. Four individual pumices (labeled as DEB5/95/10-A through D) were also collected from a very pumice-rich (30% to 40%) zone that includes a 0.5- to 1.0-m thick zone of transition from devitrified to vitric and the lower part of the vitric zone beneath the whole-rock sample. Sample was taken 1/3 to 1/2 way up from the base of the fourth cliff-forming tuff, 41.0 m above stream level. The tuff appears to become gradually partially welded above the sample point, and the top of a thin zone of devitrification between 42.55 and 42.85 m above stream level defines an upper contact with a distinctive zone described for sample DEB5/95/11.
DEB5/95/10	B	RGW	24-MAY-95	Sample is pinkish gray vitric partially welded tuff with common grayish orange pumice to 27 mm, some streaked to dominated by dark brownish gray fused tube walls. Common felsics include quartz. Scarce green clinopyroxene is present. Scarce lithics to 5 mm are mostly pale red to medium gray crystal-poor rhyolite, but include dark intermediate to basaltic lavas. Pumices have phenocryst assemblage similar to matrix. One tiny black vitreous equant mineral, possibly chevkinite, was found in a pumice.
DEB5/95/11	F	DEB	10-MAY-95	Sample is orange tan vitric (?) nonwelded ash flow tuff that may represent a crystal-rich, 0.25-m-thick surge bed. Sample was taken near the middle of the fourth cliff-forming tuff, 43.1 m above stream level. A sharp contact at 43.1 m above stream level separates tuff sampled as DEB5/95/12.
DEB5/95/11	B	RGW	18-MAY-95	Sample is pale yellowish brown vitric, moderately well sorted, partially welded tuff with very abundant pale yellowish brown pumice to 10 mm, generally streaked with dark, fused glass of tube walls. Common felsics include quartz. Scarce mafics are emerald green to dark green clinopyroxene. One small lithic was observed.
DEB5/95/12	F	DEB	10-MAY-95	Sample is hard, mottled pale pink to gray partly vitric, partly devitrified densely welded ignimbrite with 20% to 30% orange to gray pumices flattened 5:1 to 10:1. Tuff is flaggy in basal zone from 43.1 to 43.6 m above stream level, but grades upward into massive tuff. Phenocrysts are 10% to 15% and include large glomerocrysts in clots. Lithics are rare. Sample was taken near middle of fourth cliff-forming unit, 43.25 m above stream level.
DEB5/95/12	B	RGW	24-MAY-95	Sample is pale yellowish brown vitric moderately welded tuff with common grayish orange to pale yellowish brown pumice to 18 mm, the latter with dark fused tube walls, and some small black microvesicular intermediate to basaltic pumice to 2 mm. Scarce to common felsics include conspicuous quartz, highly subordinate to feldspar, which includes several very strongly resorbed grains to 6 mm. Scarce to common dark green clinopyroxene. No lithics were observed.
DEB5/95/13	F	DEB	10-MAY-95	Sample is reddish pink, brilliantly colored, densely welded hematitic ignimbrite with brick red pumices whose structures have been destroyed, with flattening ratios between 5:1 and 10:1. It contains 10% to 15% generally small phenocrysts that include gray clots of felsic glomerocrysts to 5 mm. Feldspars are dominant over quartz. Lithics are rare. Sample was obtained from the top of fourth cliff-forming unit, 47.0 m above stream level, and at the top of the mesa rim. The color and other characteristics of this sample grades continuously into those of sample DEB5/95/12 below.
DEB5/95/13	B	RGW	24-MAY-95	Pale red devitrified, densely welded tuff was found, with scarce to common grayish red pumice to 14/0.5 mm, many pumices with gray axiolitic (?) borders and white granophyric (?) interiors. Common felsics include chatoyant sanidine, strongly resorbed feldspar to 6 mm, and quartz, probably ~10% of total felsics. Common mafics are entirely altered to yellow-orange and black hematite. No lithics were observed.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
DEB5/95/14	F	DEB	18-MAY-95	Sample is pinkish white, partially welded ignimbrite with 15% to 20% varicolored (medium gray, greenish gray, and reddish brown) pumices generally 5 to 10 mm. It is crystal rich, with 20% to 25% large phenocrysts, many >1 mm. Sample was taken 0.3 m below a prominent parting that grades westward in a few m into the lower of two surges with positive relief.
DEB5/95/14	B	RGW	18-MAY-95	Sample is pale red vapor-phase partially welded tuff with scarce pumice, including pale red pumice to 6/1 mm, and lesser light gray pumice. Common felsics include chatoyant sanidine and conspicuous quartz. Common mafics are mostly altered to orange hematite, with some dark green relict cores of clinopyroxene. Rare, tiny lithics were found.
DEB5/95/15	F	DEB	18-MAY-95	Light tan to slight pinkish tan partially to moderately welded ignimbrite was found, with 5% medium gray pumices <20 mm. Phenocrysts are 10% to 15% and generally small (<1 mm). Sample was taken 0.15 m below the top of the 0.55 m thick ignimbrite between the two surge beds.
DEB5/95/15	B	RGW	18-MAY-95	Sample is very pale red, vapor-phase partially welded tuff with common medium gray to brownish gray pumice to 20 mm. It is crudely sorted, with fine-grained, pumice-poor lenses to 40-mm diameter. Scarce to common felsics include conspicuous quartz. Common mafics are mostly altered to orange hematite, with some black relict cores of clinopyroxene. No lithics were observed.
DEB5/95/16	F	DEB	18-MAY-95	Black densely welded ignimbrite was found, with pink streaks and abundant pumices with flattening ratios between 10:1 and 5:1. The ignimbrite is crystal-rich, with very large phenocrysts to >3 mm. It was sampled 0.8 m above a prominent parting that grades westward in a few m into the upper of two surges with positive relief. The ignimbrite is densely welded for 2.5 m above this parting, with welding decreasing rapidly thereafter to the top of the unit, 8.5 m above the parting.
DEB5/95/16	B	RGW	18-MAY-95	Sample is brownish gray to medium dark gray devitrified moderately welded tuff. Pumice was not observed; the degree of welding is from shard deformation. Common to abundant felsics include conspicuous quartz, and several feldspars to 6 mm. Common mafics are mostly altered to orange hematite, with some green to dark green relict cores of clinopyroxene. No lithics were observed.
DEB5/95/2	F	DEB	10-MAY-95	Sample is dense, mottled pinkish-tan moderately welded ignimbrite with whitish-gray to gray pumices that have a sugary texture. Pumices are indistinct, but appear to be relatively sparse (<10%). The matrix appears to be darker than that of DEB5/95/1, but the sample is also damp. Phenocryst assemblage and contents are similar to DEB5/95/1. Lithics are rare. Sample was obtained at top of the lower cliff-forming unit, 5.4 m above stream level.
DEB5/95/2	B	RGW	18-MAY-95	Sample is light gray devitrified moderately welded tuff with rare dark gray pumice, and common to abundant felsics that include very conspicuous quartz and chatoyant sanidine. Scarce mafics are entirely altered to orange hematite. Rare dark lithics to 6 mm are present.
DEB5/95/3	F	RGW	10-MAY-95	Very punky light pinkish orange tuff was sampled, contrasting with dense samples DEB5/95/1 and 2 below, with pervasive but very light orange-brown hematitic staining. Very pervasive vapor-phase alteration obscures primary texture. No pumice was observed; probably non or partially welded, judging from poor induration. A single, 3-mm-diameter brownish red vesicular pyroclast, probably a pumice, is entirely undeformed. Felsic phenocrysts to 3 mm, somewhat obscured by vapor-phase alteration, are 10% to 20%. Orange-brown hematitic masses after pyroxene or olivine are 0.1%. Lithics, generally 5-mm diameter, up to 120-mm diameter, are scarce, but more abundant than in samples below, and weather out conspicuously as subangular medium gray lava with 10% feldspar laths, certainly of the Tschicoma Formation. The sample was collected east from DEB5/95/2 along an old road, about 3 m above the base of an 8-m high cliff that overlooks the road, and 10.0 m above stream level.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
DEB5/95/3	B	RGW	24-MAY-95	Sample is grayish pink, vapor-phase nonwelded tuff with scarce to common medium light gray pumice generally to 3 mm, rarely to 7 mm. The sample contains common felsics, including very conspicuous quartz, and small mafics, completely altered to orange-brown hematite. No lithics were observed.
DEB5/95/4	F	DEB	10-MAY-95	Sample is medium pinkish tan, moderately welded ignimbrite with <10% medium to dark gray pumice <10 mm in diameter. Pumices are much more conspicuous and better define foliation than in DEB5/95/3 and have sugary cores that are due to vapor-phase crystallization. Shards and pumices have 3:1 to 5:1 flattening ratios. Phenocrysts are 10% to 15% (?), and the assemblage is the same as in DEB5/95/1 to 3. Lithics are rare and consist of Tschicoma dacites. Sample was collected from the second cliff-forming tuff, 15.0 m above stream level.
DEB5/95/4	B	RGW	18-MAY-95	Sample is pale red, vapor-phase moderately welded tuff with scarce to common light gray to medium light gray pumice to 16 mm. Common felsics include very conspicuous quartz and chatoyant sanidine. Scarce mafics are almost entirely altered to orange hematite, with one light green relict core of clinopyroxene observed. One tiny orange argillic lithic of basalt was observed.
DEB5/95/5	F	DEB	10-MAY-95	Sample is medium gray densely welded tuff with a slight purplish cast, distinctive in color without the pinkish color of samples DEB5/95/1 to 4 below. It contains less than 10% dark gray pumice with 5:1 to 10:1 flattening ratios. Felsic phenocrysts, mostly <1 mm, but a few 2 to 3 mm, are 10% to 15%, including very abundant quartz as in samples below. Lithics are rare. Sample was collected 1 m below top of the second cliff-forming tuff, 20.0 m above stream level.
DEB5/95/5	B	RGW	24-MAY-95	Sample is medium light gray devitrified moderately welded tuff with scarce medium gray pumice, rarely to 15/2 mm. It contains common to abundant felsics, including very conspicuous quartz, and mafics, almost entirely altered to orange-brown hematite, but a few with relicts of green clinopyroxene. No lithics were observed.
DEB5/95/6	F	DEB	10-MAY-95	Sample is light-colored nonwelded ignimbrite in soft but indurated outcrops, with 10% mottled light and dark gray sugary, vapor-phase pumice. Phenocrysts are notably smaller (<<1 mm) and less abundant (5% to 10%) than in samples DEB5/95/1 to 5 below. This unit resembles Unit 4 at Pajarito Mesa. Although no surge beds are observed here, the interval below to sample DEB5/95/5 is covered. Lithics are rare in this sample but are locally abundant nearby. Sample was collected from the lowest exposure in a third cliff-forming tuff, 22.4 m above stream level, and offset from sample DEB5/95/5 about 5 m to west. The base of Unit 4 is estimated as 22.0 m above stream level.
DEB5/95/6	B	RGW	24-MAY-95	Sample is very pale red vapor-phase nonwelded tuff with scarce to common pale reddish gray pumice to 10 mm. It contains scarce to common felsics, including very conspicuous quartz, and green clinopyroxene, partly to entirely altered to orange-brown hematite. No lithics were observed.
DEB5/95/7	F	DEB	10-MAY-95	Sample is indurated, light gray nonwelded ignimbrite with a slight pink cast. It contains 10% medium brown pumice with a slight reddish cast, typically 5 to 10 mm in diameter, generally equant, but some slightly elongate. Phenocrysts, typically <1 mm, are 5% to 10%. Dark gray lithics up to 50 mm with conspicuous felsic phenocrysts are from the Tschicoma Formation. Sample was collected from the middle of the third cliff-forming tuff, 25.0 m above stream level and offset from sample DEB5/95/6 about 30 m to west.
DEB5/95/7	B	RGW	24-MAY-95	Sample is pinkish gray vapor-phase nonwelded tuff with common pale reddish gray pumice to 10 mm. Scarce to common felsics include very conspicuous quartz. Scarce to rare tiny black lithics and dark green, partly altered clinopyroxene were found.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
DEB5/95/8	F	DEB	10-MAY-95	Sample is well-indurated, light yellowish-tan, nonwelded ignimbrite with a slight pinkish cast. It contains 10% reddish brown pumices, generally <5 mm, occasionally to 10 to 20 mm. Phenocrysts are 5% to 10%, and are similar to those in sample DEB5/95/7. Lithics are rare. Sample was collected from the top of the third cliff-forming tuff, 30.0 m above stream level, and just above the break in slope and on the lower part of the broad, sloping bench that separates the third and fourth cliff-forming units. The bench above this sample is largely covered by talus, obscuring the contact with the fourth cliff-forming unit.
DEB5/95/8	B	RGW	18-MAY-95	Sample is pale grayish orange pink vapor-phase nonwelded tuff with common pale brown pumice to 13 mm. Common felsics include conspicuous quartz, and common mafics include emerald green, unaltered clinopyroxene and black, unaltered olivine and orange hematite after olivine. No lithics were observed.
DEB5/95/9	F	DEB	10-MAY-95	Mottled light gray to white nonwelded ignimbrite was observed. The tuff is pock-marked due to selective weathering of pumices. Crude horizontal partings suggest that the fourth cliff-forming unit consists of multiple ash-flows 1 to 3 m thick. Relatively pumice rich, with 20% varicolored (white, orange, brownish, to gray) pumice to 20 to 30 mm, which has delicate vesicle structures generally well preserved. Phenocrysts are 5% to 10%, but larger (2 to 3 mm) than those in samples from the third cliff-forming tuff below. Lithics are relatively abundant (2% to 3%), and are medium to dark gray Tschicoma Formation. Sampled from base of the fourth cliff-forming tuff, 38.0 m above stream level, and offset to west following nose of the hill, towards south face.
DEB5/95/9	B	RGW	18-MAY-95	Sample is pinkish gray, mostly devitrified, partially welded tuff with common very pale red to very light brown pumice to 12 mm, one with an interior of dark brown vitric fused tube walls, and rare dark reddish brown pumice to 5 mm. Scarce to common felsics include very conspicuous quartz. Scarce to rare green clinopyroxene prisms were observed. Scarce to rare lithics of white, crystal-poor rhyolite lava to 22 mm are coated with Mn-dendrites.
DEB6/95/1	F	DEB	02-JUN-95	Very friable, punky brown to yellow brown weathered tuff is exposed, permeated by abundant roots. Relict structures of tuff are well preserved. Sample was collected from road cut 0.1 m below surge bed that probably marks the base of Unit 4.
DEB6/95/1	B	RGW	05- JUN-95	Sample is very friable moderate yellowish brown hematitic devitrified nonwelded tuff with scattered grayish yellow ovoid reduction spots to 20 mm. Felsics and lithics are generally tiny and coated with matrix, so that it is difficult to estimate their abundances. Some black, resinous, wiry grains <1 mm that spot the sample are possibly manganese oxides.
DEB6/95/2	F	DEB	02-JUN-95	Similar to sample DEB6/95/1, but with better induration, this sample was taken from road cut 0.35 m below surge bed that probably marks the base of Unit 4.
DEB6/95/2	B	RGW	05- JUN-95	Sample is moderate yellowish brown hematitic devitrified nonwelded tuff with scattered grayish yellow ovoid reduction spots to 7 mm, some with dusky yellow porcelaneous centers. Felsics and lithics are generally tiny and coated with matrix, so that it is difficult to estimate their abundances, but several feldspar phenocrysts were observed.
DEB6/95/3	F	DEB	02-JUN-95	This sample is similar to sample DEB6/95/2, but with better induration, which increases continuously from sample DEB6/95/1 through DEB6/95/4. Pumices show the greatest color change, becoming increasingly yellow orange upsection. Sample collected from road cut 0.55 m below surge bed that probably marks the base of Unit 4.
DEB6/95/3	B	RGW	05- JUN-95	Sample is moderate yellowish brown hematitic devitrified nonwelded tuff with scarce to rare dark yellowish brown pumice to 4 mm. Scattered grayish yellow ovoid reduction spots to 10 mm were observed. Felsics and lithics are generally tiny (<1 mm) so that it is difficult to estimate their abundances, but several feldspar phenocrysts were observed.
DEB6/95/4	F	DEB	02-JUN-95	This sample is similar to sample DEB6/95/3, but has the best induration among 4 samples collected beneath surge at this location. It was sampled from road cut 0.82 m below surge bed that probably marks the base of Unit 4 and is 2.7 m below well head of P14.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
DEB6/95/4	B	RGW	05- JUN-95	Sample is pale yellowish brown hematitic devitrified nonwelded tuff with scarce dark yellowish brown pumice to 10 mm. Scattered grayish yellow ovoid reduction spots to 4 mm were observed. Felsics, nearly unrecognizable except for a few quartz to 1 mm, are probably scarce to common. Scarce to common tiny (<1-mm) lithics are present.
DEB6/95/5	F	DEB	02-JUN-95	We sampled a weathered tuff block floating in finer grained sandy matrix, at the base of a 0.5-m thick rubble zone between bedrock and soil. The sample is 2.4 m above well head of P14 and above surge that probably marks the base of Unit 4.
DEB6/95/5	B	RGW	05- JUN-95	Sample is mostly moderate yellowish brown hematitic devitrified nonwelded tuff with 15/5-mm lenses of pale grayish orange pink nonhematitic tuff. Lenses of hematitic tuff become increasingly narrower and elongate towards top of sample, where rock was not sampled but is entirely nonhematitic. Common felsics to 2 mm include conspicuous quartz. Scarce to common lithics to 2.5 mm were observed.
DEB6/95/6	F	DEB	02-JUN-95	Light tan nonwelded tuff crops out with 5% to 10% small (<10 mm) light brown pumices. It was sampled 2.0 m above well head of P14, from highly fractured bedrock just below rubble zone, and above surge that probably marks the base of Unit 4. Fractures, which show evidence of alteration, were avoided for this sample, which shows little apparent weathering.
DEB6/95/6	B	RGW	05- JUN-95	Sample is very pale brown devitrified nonwelded tuff with scarce to common moderate yellowish brown pumice to 10 mm, and common felsics to 3.5 mm that include very conspicuous quartz. Scarce lithics to 3 mm are present.
DEB6/95/7	F	DEB	02-JUN-95	This sample is similar to DEB6/95/6, very pumice- and crystal-poor, massive, well indurated, and apparently unaltered. It was sampled 1.6 m above well head of P14, from less fractured bedrock 0.5 m below rubble zone and above surge that probably marks the base of Unit 4.
DEB6/95/7	B	RGW	05- JUN-95	Sample is pale grayish orange pink devitrified nonwelded tuff with scarce to common yellowish brown pumice to 13 mm. Generally very small felsics, to 2 mm, appear to be scarce to common, and include conspicuous quartz. Several small black mafics indicate that they are scarce to rare. Scarce to common lithics, generally dark gray, to 3 mm were observed.
DEB6/95/8	F	DEB	02-JUN-95	Thirty-one vitric pumices (DEB6/95/8-A through -Z, -AA through AE) were sampled from a 9.5-m thick white to light gray vitric tuff. They were sampled from a 4-m-thick interval 6.0 m below a surge bed and are equivalent to DEB5/95/11, which was sampled on the north side of Cañon de Valle. The vitric zone extends to 0.5 m below the surge bed beneath mesa-capping tuff sampled on the north side of Cañon de Valle as DEB5/95/13 and grades abruptly downward into reddish brown devitrified tuff. Thus, the vitric zone within Unit 4 is much thicker here, south of Cañon de Valle, than north of the canyon. Samples were collected from bedrock in road cut just WSW of building 16-295 at MDA-P, south of paved road. Above the sample point, the surge bed is displaced 0.35 m down to the southwest along a NW-trending fault.
DEB6/95/8-AA	B	RGW	05-JUN-95	Sample is a 60 by 50 by 35 mm pumice clast of very pale reddish gray vitric fine tube pumice. Scarce to common felsics include several probable but no definite quartz and several feldspar to 2.5 mm. Single green clinopyroxene prism was observed. Host is described for sample DEB6/95/8-Z.
DEB6/95/8-D	B	RGW	05-JUN-95	Sample is a 150 by 100 by 55 mm pumice clast of moderate yellowish brown vitric long tube pumice with common felsics (~12%) that include conspicuous quartz. Scarce to rare mafics include dark green clinopyroxene and black vitreous olivine. Host is described for sample DEB6/95/8-Z.
DEB6/95/8-H	B	RGW	05-JUN-95	Sample is a 110 by 65 by 45 mm pumice clast of grayish orange vitric long tube pumice, with scarce to common felsics (~7%). Several probable but no definite quartz phenocrysts were observed in hand sample. One probable quartz was examined in immersion oil, n = 1.55, confirming its identity. The quartz content appears to be much higher than for sample DEB6/95/8-Z. Scarce to rare mafics include dark green granular clinopyroxene, and black vitreous olivine. Host is described for sample DEB6/95/8-Z.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
DEB6/95/8-Z	B	RGW	05-JUN-95	Sample is a 150 by 100 by 50 mm pumice clast of moderate yellowish brown vitric long tube pumice with minor white vapor-phase (?) crystals in some vugs. Scarce to common felsics (~7%) are dominated by feldspar, which ranges to 7 mm and is very strongly resorbed. No definite quartz was observed, but see description for sample DEB6/95/8-H. Scarce to rare mafics include a prism and a granular aggregate of dark green clinopyroxene and black olivine. Host is pinkish gray devitrified nonwelded tuff.
GB/1-R	F	RGW	20-NOV-95	Bedrock from lower part of soil pit GB/1 excavated by Eric McDonald today along axis of W-trending drainage through middle of Segregation Area. Surface of pit is 1.9 m above RW16PA1, in center of gully. Broken bedrock reached 0.4 m below the surface is dry, moderately friable, poorly welded devitrified tuff, light brown with conspicuous dark brown pumice to 13 mm. Scattered yellow brown ovoid weathering spherules to 7 mm were avoided as much as possible during sampling. A brown band is due to weathering discolors the uppermost 10 mm of tuff, but bedrock was sampled about 0.1 m below the bedrock surface.
GB/1-R	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink, devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 7 mm. Common felsics with quartz are evident but strongly dominated by feldspar. Scarce mafics include green partly altered clinopyroxene and black equant mafic, either hornblende or orthopyroxene, and orange-brown hematitic pseudomorphs, probably after orthopyroxene. Rare lithics to 1.5 mm. Rare weathering spherules have tiny black secondary minerals coating voids to 4-mm diameter with fine white minerals deposited on the black minerals, and concentric zones of bleached rock to 7-mm diameter.
NLS/1-R	F	RGW	20-NOV-95	Bedrock from lower part of soil pit NLS/1 excavated by Eric McDonald today along north-facing slope of W-trending drainage through middle of the Segregation Area. Surface of pit is to S05W and 2.0 m above surface at GB/1. Pit exposes broken bedrock 0.1 to 0.35 m below the surface, and solid bedrock below to 0.45 m below surface. Sample 0.45 m below surface is dry, easily to moderately friable, poorly welded devitrified tuff, light brown with conspicuous dark brown pumice to 15 mm. Scattered yellow brown weathering ovoids were avoided as much as possible during sampling.
NLS/1-R	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with common pale yellowish brown pumice to 14 mm. Common felsics to 2.5 mm include conspicuous quartz. Scarce to rare mafics include partly altered green clinopyroxene and black orthopyroxene, mostly altered to brown hematitic pseudomorphs. Rare lithics to 2 mm are present.
NUS/1-R	F	RGW	20-NOV-95	Bedrock from lower part of soil pit NUS/1 excavated by Eric McDonald today along north-facing slope of W-trending drainage through middle of Segregation Area. Surface of pit is due south, 2.95 m above surface at NLS/1. Pit exposes moderately fractured bedrock 0.1-0.4 m below the surface. Sample 0.4 m below surface is dry, moderately to easily friable, poorly welded devitrified tuff, light brown with conspicuous dark brown pumice to 39 mm. Highly scattered yellow weathering ovoids to 5 mm were avoided as much as possible during sampling. Sample RW16PA8 measured 0.7 m above surface at NUS/1.
NUS/1-R	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 10 mm. Common felsics include conspicuous quartz to 3 mm. Scarce to rare mafics include unaltered green clinopyroxene and brown hematitic pseudomorphs, probably mostly after orthopyroxene. Single large (1.0 mm) mostly altered black pyroxene is probably orthopyroxene. Scarce to rare lithics to 2 mm are present.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
RW16PA1	F	RGW	20-NOV-95	Moderately friable devitrified tuff was dug out from axis of Run-on Control Trench for MDA-P, 11 m down-axis from bottom of asphalt covering that extends upditch another 20 m or so. The rock is uniformly brown, and quite moist. Sample was from interior of coherent block 20 cm on a side that was dug out and is apparently free from yellowish ovoid alteration centers 6 to 10 mm in diameter. This location and those of all other samples that I collected today were marked on a large-scale map from MDA-P sampling plan. Measured using Jacob Staff and level, this sample is 1.0 m above the lowest point in the Segregation Area.
RW16PA1	B	RGW	29-NOV-95	Sample is grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common very pale brown pumice to 8 mm. Common felsics to 2 mm are generally small (<1 mm), and dominated by feldspar; only a single definite quartz phenocryst observed. No lithics or mafics are observed; mafics appear to be entirely altered to brown hematitic pseudomorphs. Sample may be from top of Unit 3 of base of Unit 4 of Tshirege Member.
RW16PA10	F	RGW	1-DEC-95	Dark, poorly welded, moderately friable tuff was sampled from the highest exposure in gully, 2.1 m below and 18.95 m N40W from RW16PA1, just outside Segregation Area. Although exposures are good between RW16PA10 and 11, they are not continuous, and so this sample, like RW16PA1 and 2, might reside within uppermost Unit 3 or lowermost Unit 4.
RW16PA10	B	RGW	8-DEC-95	Sample is mottled, mostly very pale red and lesser grayish pink devitrified and vapor-phase nonwelded tuff with scarce to common pale grayish red pumice to 11 mm. Common felsics include feldspar to 2.5 mm and quartz to 2 mm, with only a few quartz grains observed. Scarce mafics are mostly green, partly altered clinopyroxene to 1.5 mm. Two black vitreous, partly altered mafics observed are probably orthopyroxene. A single 3-mm diameter lithic is observed.
RW16PA11	F	RGW	1-DEC-95	Sampled from dark, poorly welded, somewhat friable tuff from top of cliff that is continuously exposed down to stream level in Cañon de Valle, Unit 3 of Tshirege Member. Moderately welded tuff is exposed in gully just downstream, 0.1 m below sample site. From this site, it is 37.3 m S64E and 2.5 m up to RW16PA10 upstream in the same gully. Note added later: this location does not plot in gully, so the direction must be in error. This sample was obtained just outside the Segregation Area to characterize definite Unit 3 of Tshirege Member as close as possible to the Segregation Area. Use of chemical data from RW16PA10 and 11 might resolve whether samples RW16PA1 and 2 reside within uppermost Unit 3 or lowermost Unit 4. All other samples from the Segregation, Decontamination, and Staging 1 Areas of MDA-P definitely reside within Unit 4 of Tshirege Member.
RW16PA11	B	RGW	8-DEC-95	Sample is very pale red devitrified and vapor-phase moderately welded tuff with common medium light gray pumice to 13/2.5 mm. Common felsics include sanidine, some chatoyant, and very conspicuous quartz, both to 3 mm. Scarce to common mafics are mostly altered to orange hematitic pseudomorphs, but several relicts of black vitreous mafic, probably orthopyroxene, and single light green clinopyroxene relict were observed. No lithics were observed.
RW16PA2	F	RGW	20-NOV-95	This sample was collected directly up Run-on Control Trench S60W from RW16PA1, at 1.6-m higher elevation. It is moderately friable tuff, about 20 cm above axis of trench on south side, about 10 cm from the end of the asphalt cover, and just inside the boundary of the Segregation Area, as verified by sighting along line of boundary stakes. Tuff is dry in appearance, in contrast to appearance of RW16PA1 and of adjacent tuff in axis of trench. Bedrock is massive nonwelded tuff continuously exposed within axis of trench down to sample RW16PA1; then everywhere in the Segregation Area below is covered by at least 20 cm of soil. See also field notes for sample DCN3-R.
RW16PA2	B	RGW	29-NOV-95	Sample is very pale orange devitrified and vapor-phase nonwelded tuff with scarce to common pale yellowish brown pumice to 8 mm. Common felsics to 2 mm include conspicuous quartz; few exceed 1 mm. Scarce to rare small green clinopyroxene prisms are unaltered. Brown hematitic masses are probably pseudomorphs after orthopyroxene. Rare lithics are present to 3 mm. Sample may be from top of Unit 3 of base of Unit 4 of Tshirege Member.
RW16PA3	F	RGW	20-NOV-95	Sample is natural outcrop S80E from RW16PA1 on north side of natural drainage, 3.8 m above RW16PA1. This is the closest of 3 natural bedrock exposures east of RW16PA1. The sample was taken from south side of this 1.3 by 0.9 by 0.5 m outcrop, and is dry, poorly welded light brown devitrified tuff with dark brown pumice. The tuff contains occasional yellow-brown spherules, centers to 10 mm, and concentric bleached zones to 16-mm diameters, which were avoided in sampling as much as possible. Tuff is moderately friable; like RW16PA1 and 2, and breakable by hand.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
RW16PA3	B	RGW	29-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with common pale brown pumice to 13 mm. Common felsics to 2.5 mm include conspicuous quartz. Several grains of unaltered green clinopyroxene are observed, as well as brown hematitic masses, probably pseudomorphs after orthopyroxene. Scarce lithics are much more abundant than in RW16PA1 and 2, suggesting that these two samples are uppermost Unit 3 and RW16PA3 is lowermost Unit 4, because lithics are generally most abundant at the base of a unit.
RW16PA4	F	RGW	20-NOV-95	Sample is natural outcrop of light brown, dry, moderately friable, poorly welded tuff with conspicuous dark brown pumice, N82E up side gully from RW16PA3, 4.9 m above RW16PA1. Outcrop is 1.8 by 1.7 by 1.3 m; sampled from east end, about halfway up. Tuff also contains yellow-brown ovoids to 8 mm sparsely throughout rock, which were avoided in sampling as much as possible by sampling the interior of a 20-cm block.
RW16PA4	B	RGW	29-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common yellowish brown pumice to 13 mm. Common felsics to 2.5 mm include conspicuous quartz; few exceed 1 mm. Scarce green clinopyroxene occurs, some partly altered with hematitic rims, as well as brown hematitic masses, probably pseudomorphs after orthopyroxene. Scarce to rare lithics to 1.5 mm.
RW16PA5	F	RGW	20-NOV-95	Sample was taken about halfway up from the western end of a third separate outcrop, 4.0 by 1.8 by 1.1 m, a short distance S50E from RW16PA3, 4.3 m above RW16PA1. This outcrop is dry, moderately friable, poorly welded tuff, light brown with conspicuous dark brown pumice to 23 mm. The eastern end of the outcrop coincides with the eastern boundary of the Segregation Area.
RW16PA5	B	RGW	29-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common moderate yellowish brown pumice to 12 mm. Common felsics to 2 mm include conspicuous quartz; few exceed 1 mm. Scarce unaltered small green clinopyroxene; small brown hematitic masses are probably pseudomorphs after orthopyroxene. Scarce to rare lithics are found to 1.5 mm.
RW16PA6	F	RGW	20-NOV-95	I sampled from a low outcrop, 1.7 by 1.1 m area, 6.4 m above RW16PA1, 4.7 m S50W from the NE corner of the Segregation Area. The sample is dry, moderately friable poorly welded tuff, light brown with conspicuous dark brown pumice to 24 mm. It was taken beneath a 20-mm flake removed from top surface. Rare yellow brown ovoid weathering spherules to 4 mm were avoided as much as possible during sampling.
RW16PA6	B	RGW	29-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 5 mm. Common felsics to 2 mm, most to 1 mm, include conspicuous quartz, although a single 4-mm feldspar was observed. Scarce mafics include partly altered small green clinopyroxene and brown hematitic pseudomorphs, probably after orthopyroxene. Scarce (relatively abundant) lithics are present to 5 mm.
RW16PA7	F	RGW	20-NOV-95	This sample was obtained from low outcrop 7.6 m above RW16PA1, 7.0 m N31W from the SE corner stake of the Segregation Area, and about the same distance north from the paved road. It was sampled beneath a 20-mm flake removed from top surface. The sample is dry, moderately friable poorly welded tuff, light brown with very conspicuous dark brown pumice to 21 mm.
RW16PA7	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 11 mm. Common felsics to 2.5 mm include conspicuous quartz. Scarce mafics include green clinopyroxene and black orthopyroxene, both mostly altered to orange hematitic pseudomorphs. Scarce to rare lithics, generally <1 mm, include one 4.5-mm-diameter clast.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
RW16PA8	F	RGW	20-NOV-95	The sample was collected from low outcrop 0.2 m below RW16PA7 and thus 7.4 m above RW16PA1, 9 m north from the paved road, north of the bar ditch, about halfway between SE and SW corner stakes of the Segregation Area. Rare yellow brown spheroids to 7-mm inner diameter, with concentric bleached zones to 14 mm were avoided in sampling beneath 40-mm flake removed from top surface. The sample is dry, moderately to easily friable, poorly welded devitrified tuff, light brown with dark brown pumice to 24 mm.
RW16PA8	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 13 mm. Common felsics to 3 mm, most to 1 mm, include conspicuous quartz. Scarce mafics include unaltered green clinopyroxene prisms and brown hematitic pseudomorphs, probably after orthopyroxene. One tiny acicular mafic, probably hornblende, is 0.3 mm long. Scarce to rare lithics measure to 1.5 mm.
RW16PA9	F	RGW	20-NOV-95	I sampled on NE side of outlet for bar ditch, in fractured bedrock 2.0 m below RW16PA8 and thus 5.4 m above RW16PA1 as measured through the entire sequence of samples, versus 5.55 m above RW16PA1 as measured directly. The sample is dry, moderately friable, poorly welded devitrified tuff, light brown with conspicuous dark brown pumice to 14 mm.
RW16PA9	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common moderate yellowish brown pumice generally to 9 mm, with one exceptionally large 28-mm-diameter pumice. Common felsics to 2.5 mm include conspicuous quartz. Scarce mafics include green clinopyroxene, mostly unaltered but partly altered in vapor-phase pumice, and brown hematitic pseudomorphs, probably after orthopyroxene. One black pyroxene, probably orthopyroxene, is only partly altered. Rare lithics measured to 1.5 mm.
RW16PC1	F	RGW	1-DEC-95	All samples of tuff from Staging Area 1 (RW16PC series and SA1/1) are at relatively high elevation, >7510 ft, and undoubtedly within uppermost Unit 4 of Tshirege Member, above base surge sampled as DEB5/95/11, and caprock above this base surge sampled as DEB5/95/13. Bedrock is well exposed by shallow roadcuts between 100 ft southeast to 300 ft southwest of south corner of Staging Area 1. All measurements of distances and elevations for these samples were by tape and Brunton compass and/or Jacob Staff. RW16PC1 is 3.2 m normal to the boundary and within Staging Area 1, as measured from a 100-m tape laid out for 18 m from the south corner to the east corner, or 7.2 m N16E from south corner of Staging Area 1. Bedrock is 20 cm beneath soil on a 30-degree slope about 2 ft downslope from a 20-ft-tall ponderosa. The moderately moist sample was obtained 1.5 m below elevation of the south corner of Staging Area 1 from the uppermost 0.1 m of bedrock, exposed by digging over a 0.4-m width of slope to ensure that the rock was not a large boulder. It is friable, vitric, poorly welded tuff with extraordinarily large resorbed feldspar to 11 mm.
RW16PC1	B	RGW	8-DEC-95	Sample is moderate yellowish brown vitric, partially welded tuff with scarce, partly fused pumice to 7 mm, composed of very light gray unfused and moderate yellowish brown fused tube walls. One dark 2-mm blocky shard and one 4-mm banded vesicular blocky shard observed. Dark brown spots scattered throughout rock may represent secondary staining or dark pyroclasts. Common feldspar is found to 11 mm, with the largest grains strongly resorbed. One definite and several probable grains of quartz are observed. Scarce to rare green clinopyroxene and black orthopyroxene both occur in prisms to 1 mm. Scarce lithics are present to 2.5 mm.
RW16PC2	F	RGW	1-DEC-95	See field description of RW16PC1 for general description of samples from Staging Area 1. RW16PC2 lies exactly on the boundary of Staging Area 1, as measured from a 100-m tape laid out for 18 m from the south corner to the east corner, or 7.1 m N42E from and 1.55 m below south corner of Staging Area 1. Sample was collected from upper 0.1 m of coherent, moderately to slightly moist bedrock; it is here overlain by 0.2 m of fractured rock and soil and an additional 0.1 m of soil covered by pine needles on 30-degree slope into gully to northeast. The gully here is 2.35 m below south corner of Staging Area 1. Sample is orange-brown, friable, poorly welded tuff with large vitric pumices and feldspar, similar to RW16PC1.

Appendix B (continued)

Sample Number	*D*	Worker	Date	Description
RW16PC2	B	RGW	8-DEC-95	Sample is moderate yellowish brown vitric, partially welded tuff with scarce, partly fused pumice to 8 mm, composed of very light gray unfused and moderate yellowish brown fused tube walls. Dark brown spots scattered throughout rock may represent secondary staining or dark pyroclasts. Common feldspar occurs to 7 mm, with the largest grains generally strongly resorbed and in pumice, where they are held together in a very fragile condition during transportation in the eruptive cloud. One probable grain of quartz is observed. Scarce, unaltered green clinopyroxene prisms were observed to 2 mm, but no black mafics were observed. Rare lithics occur to 1.5 mm.
RW16PC3	F	RGW	1-DEC-95	See field description of RW16PC1 for general description of samples from Staging Area 1. RW16PC3 is 4.7 m normal to the boundary and outside Staging Area 1, 8.1 m northeastward along a 100-m tape laid out for 18 m from the south corner to the east corner, or 9.35 m N65E from south corner of Staging Area 1. I sampled from uppermost 5 cm of exposed bedrock that is 1.8 m below south corner of Staging Area 1 where a gully is 2.25 m below south corner. Note that here this gully is measured lower than at RW16PC2 due to its southeast slope; the higher measured value is within measurement error of 15 cm for this nearly flat drainage. The sample is dry, moderately friable (easily breakable by hand) orange brown vitric poorly welded tuff with large vitric pumices and feldspar.
RW16PC3	B	RGW	8-DEC-95	Sample is moderate yellowish brown vitric partially welded tuff with scarce moderate yellowish brown pumice to 24 mm. Common feldspar occurs to 6 mm, with the largest grains strongly resorbed. Two probable grains of quartz are observed. Scarce to common unaltered green clinopyroxene prisms occur to 2 mm, and scarce to rare lithics occur to 1.5 mm. A small piece (40 by 25 mm) was removed for a polished thin section.
SA1/1-0.84	F	RGW	1-DEC-95	See field description of RW16PC1 for general description of samples from Staging Area 1. Sample is at 0.76 to 0.84 m below surface from auger hole SA1/1. The surface of SA1/1 is 0.54 m below south corner of Staging Area 1 and 8.7 m S32E from west corner.
SA1/1-0.84	B	RGW	8-DEC-95	Sample is moderate yellowish brown vitric partially welded tuff with scarce pumice, mostly moderate yellowish brown to 13 mm. Scarce to common feldspar occurs to 5 mm, with the largest grains strongly resorbed. No quartz is observed. Scarce green clinopyroxene prisms exist to 2 mm, and much lesser black orthopyroxene to 0.5 mm, with pyroxene cleavage evident. Scarce lithics are present to 11 mm, with lithic surfaces and apparent fractures thinly coated with white secondary mineral, probably calcite. Coherent pieces were removed from this largely disaggregated sample for pulverization in preparation for chemical analysis.
SLS/1-R	F	RGW	20-NOV-95	This sample is bedrock from the lower part of soil pit SLS/1 excavated by Eric McDonald today along south-facing slope of W-trending drainage through middle of Segregation Area. Surface of pit is to N48E, 1.7 m above surface at GB/1. Pit exposes broken bedrock 0.1 m below the surface and solid bedrock 0.3 to 0.4 m below surface. The sample 0.4 m below surface is dry, moderately friable, poorly welded devitrified tuff, light brown with conspicuous dark brown pumice to 10 mm. Scattered yellow brown weathering ovoids to 5 mm were avoided as much as possible during sampling.
SLS/1-R	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with scarce to common pale brown pumice to 8 mm. Common felsics to 2 mm include conspicuous quartz. Scarce to rare mafics include unaltered green clinopyroxene and orange-brown hematitic pseudomorphs, probably after orthopyroxene. Rare lithics occur to 2.5 mm.
SUS/1-R	F	RGW	20-NOV-95	This sample is bedrock from the lower part of soil pit SUS/1 excavated by Eric McDonald today along south-facing slope of W-trending drainage through middle of Segregation Area. Surface of pit is to N62E, 2.8 m above surface at SLS/1, and measured 0.1 m below RW16PA6. Thus SUS/1 and RW16PA6 both measure 6.4 m above RW16PA1, a discrepancy of 0.1 m. The pit exposes fairly solid bedrock 0.15 m below the surface to 0.4 m. Sample 0.4 m below surface is moderately to easily friable, poorly welded devitrified tuff, light brown with conspicuous dark brown pumice generally to 14 mm, but with one giant light gray pumice with a dark brown border, with a long axis of 45 mm. The tuff in this pit is strongly altered along root-infested fractures that were avoided during sampling.
SUS/1-R	B	RGW	30-NOV-95	Except for RW16PA1 and 2, all samples collected from the Segregation Area on 20 Nov 95 are from lower part of Unit 4 of Tshirege Member and are similar in color. This sample is pale grayish orange pink devitrified and vapor-phase nonwelded tuff with common pale yellowish brown pumice to 19 mm. Common felsics include very conspicuous quartz to 3.5 mm. Scarce mafics include partly altered green clinopyroxene and dark brown hematitic pseudomorphs, probably after orthopyroxene. Rare lithics occur to 1.5 mm.

Appendix C. Hand sample data for samples collected for background and baseline study of bedrock from MDA-P. Depths and elevations are in feet. Samples collected for background study are in "DEB" series; all other samples were collected for baseline study. See Appendix J for explanation of symbols.

Sample Number	Strat Unit	Sample Type	Lith	Altn	mAlt	Status LHPCXM	Samples Available	Upper Depth (ft)	Lower Depth (ft)
DCN1-R	Qbt4	T	NWT	VP		DC0L00	132.2,F20.3,N	0.66	0.82
DCN2-R	Qbt4	T	NWT	VP		DC0L00	152.2,F27.5,N	0.82	0.98
DCN3-R	Qbt4	T	NWT	VP		DC0L00	192.9,F31.2,N	0.66	0.82
DEB5/95/1	Qbt3	O	MWT	MG/AX/VP		DCAXI0	X,P		
DEB5/95/10	Qbt4	O	PWT	GL		DCAXI0	X,P		
DEB5/95/11	Qbt5	O	WBE	GL/MG	AR/OP	DCAXI0	X,P		
DEB5/95/12	Qbt5	O	MWT	MG/GL		DCAXI0	X,P		
DEB5/95/13	Qbt5	O	DWT	MG/AX	HM/VP/GL	DCAXI0	X,P		
DEB5/95/14	Qbt3	O	PWT	MG/VP	GR/GL	DCAXI0	X,P		
DEB5/95/15	Qbt3t	O	PWT	MG/VP		DCAXI0	X,P		
DEB5/95/16	Qbt3t	O	MWT	MG/AX	SR/VP/GL	DCAXI0	X,P		
DEB5/95/2	Qbt3	O	MWT	MG/AX/VP	GL	DCAXI0	X,P		
DEB5/95/3	Qbt3	O	NWT	MG/VP	GR/GL	DCAXI0	X,P		
DEB5/95/4	Qbt3t	O	MWT	MG/AX/VP		DCAXI0	X,P		
DEB5/95/5	Qbt3t	O	MWT	MG/AX/VP	GL	DCAXI0	X,P		
DEB5/95/6	Qbt4t	O	NWT	MG/VP	GR	DCAXI0	X,P		
DEB5/95/7	Qbt4	O	NWT	MG/MS	VP/GL	DCAXI0	X,P		
DEB5/95/8	Qbt4	O	NWT	MG/MS	VP	DCAXI0	X,P		
DEB5/95/9	Qbt4	O	PWT	MG/MS	VP/GL	DCAXI0	X,P		
DEB6/95/1	Qbt4	O	NWT	DV/VP		MC0XI0	X		
DEB6/95/2	Qbt4	O	NWT	DV/VP		MC0XI0	X		
DEB6/95/3	Qbt4	O	NWT	DV/VP		MC0XI0	X		
DEB6/95/4	Qbt4	O	NWT	MG/MS/VP	GL	MCAXI0	X,P		
DEB6/95/5	Qbt4	O	NWT	DV	AR	MC0XI0	X		
DEB6/95/6	Qbt4	O	NWT	DV		MC0XI0	X		

Sample Number	Elev Top of Unit (ft)	Unit Above	Elev Base of Unit (ft)	Unit Below	Wet/Dry Color	Comp #1	Hue #1	Lightness #1	Chroma #1
DCN1-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
DCN2-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
DCN3-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
DEB5/95/1	7390.0	Qbt3t	7350.0	unc	D	MD	5YR	6	1
DEB5/95/10	7490.6	Qbt5	7426.8	Qbt4t	D	MV	5YR	8	1
DEB5/95/11	7504.2	unc	7490.6	Qbt4	D	MV	10YR	6	3
DEB5/95/12	7504.2	unc	7490.6	Qbt4	D	MV	10YR	6	3
DEB5/95/13	7504.2	unc	7490.6	Qbt4	D	MD	5YR	6	2
DEB5/95/14	7391.0	Qbt3t	7330.0	unc	D	MD	10YR	7	2
DEB5/95/15	7415.9	Qbt4t	7391.0	Qbt3	D	MD	5YR	7	2
DEB5/95/16	7415.9	Qbt4t	7391.0	Qbt3	D	MD	5YR	4	1
DEB5/95/2	7390.0	Qbt3t	7350.0	unc	D	MD	N	7	
DEB5/95/3	7390.0	Qbt3t	7350.0	unc	D	MD	5YR	8	2
DEB5/95/4	7421.2	Qbt4t	7390.0	Qbt3	D	MD	10YR	6	2
DEB5/95/5	7421.2	Qbt4t	7390.0	Qbt3	D	MD	N	6	
DEB5/95/6	7426.8	Qbt4	7421.2	Qbt3t	D	MD	5YR	7	2
DEB5/95/7	7490.6	Qbt5	7426.8	Qbt4t	D	MD	5YR	8	1
DEB5/95/8	7490.6	Qbt5	7426.8	Qbt4t	D	MD	5YR	8	2
DEB5/95/9	7490.6	Qbt5	7426.8	Qbt4t	D	MD	5YR	8	1
DEB6/95/1	7490.0	Qbt5	7421.3	Qbt4t	D	MD	10YR	5	4
DEB6/95/2	7490.0	Qbt5	7421.3	Qbt4t	D	MD	10YR	5	4
DEB6/95/3	7490.0	Qbt5	7421.3	Qbt4t	D	MD	10YR	5	4
DEB6/95/4	7490.0	Qbt5	7421.3	Qbt4t	D	MD	10YR	6	2
DEB6/95/5	7490.0	Qbt5	7421.3	Qbt4t	D	MD	10YR	5	4
DEB6/95/6	7490.0	Qbt5	7421.3	Qbt4t	D	MD	5YR	6	2

Appendix C (continued)

Sample Number	Comp #2	Hue #2	Lightness #2	Chroma #2	Comp #3	Hue #3	Lightness #3	Chroma #3	Comp #4	Hue #4
DCN1-R	PU	5YR	5	2						
DCN2-R	PU	5YR	5	2						
DCN3-R	MD	5YR	8	4	PU	5YR	5	2		
DEB5/95/1	PU	N	8		PU	N	7			
DEB5/95/10	PU	10YR	7	4	PU	5YR	3	1	LI	5YR
DEB5/95/11	PU	10YR	6	2						
DEB5/95/12	PU	10YR	6	2						
DEB5/95/13	PU	5YR	4	2						
DEB5/95/14	PU	10YR	6	2	PU	N	7			
DEB5/95/15	PU	N	5		PU	5YR	4	1		
DEB5/95/16	MD	N	4							
DEB5/95/2	PU	N	3							
DEB5/95/3	PU	N	6							
DEB5/95/4	PU	N	7		PU	N	6			
DEB5/95/5	PU	N	5							
DEB5/95/6	PU	5YR	6	1						
DEB5/95/7	PU	5YR	6	1						
DEB5/95/8	PU	5YR	5	2						
DEB5/95/9	PU	10YR	7	2	PU	10YR	7	4	PU	10YR
DEB6/95/1	AN	5YR	8	4						
DEB6/95/2	AN	5YR	8	4	AN	5Y	6	4		
DEB6/95/3	PU	10YR	4	2	AN	5Y	8	4		
DEB6/95/4	PU	10YR	4	2	AN	5Y	8	4		
DEB6/95/5	MD	5YR	8	2						
DEB6/95/6	PU	10YR	5	4						

Sample Number	Lightness #4	Chroma #4	Comp #5	Hue #5	Lightness #5	Chroma #5	Sampler	Collect Date	Reference
DCN1-R							RGW	01-DEC-95	
DCN2-R							RGW	01-DEC-95	
DCN3-R							RGW	01-DEC-95	
DEB5/95/1							RGW/FAC	10-MAY-95	
DEB5/95/10	6	2	LI	N	5		RGW/FAC	10-MAY-95	
DEB5/95/11							RGW/FAC	10-MAY-95	
DEB5/95/12							RGW/FAC	10-MAY-95	
DEB5/95/13							RGW/FAC	10-MAY-95	
DEB5/95/14							RGW/FAC	10-MAY-95	
DEB5/95/15							RGW/FAC	10-MAY-95	
DEB5/95/16							RGW/FAC	10-MAY-95	
DEB5/95/2							RGW/FAC	10-MAY-95	
DEB5/95/3							DEB/FAC	10-MAY-95	
DEB5/95/4							RGW/FAC	10-MAY-95	
DEB5/95/5							RGW/FAC	10-MAY-95	
DEB5/95/6							RGW/FAC	10-MAY-95	
DEB5/95/7							RGW/FAC	10-MAY-95	
DEB5/95/8							RGW/FAC	10-MAY-95	
DEB5/95/9	3	4					RGW/FAC	10-MAY-95	
DEB6/95/1							RGW	05-JUN-95	Rog,1995(E)
DEB6/95/2							RGW	05-JUN-95	Rog,1995(E)
DEB6/95/3							RGW	05-JUN-95	Rog,1995(E)
DEB6/95/4							RGW	05-JUN-95	Rog,1995(E)
DEB6/95/5							RGW	05-JUN-95	Rog,1995(E)
DEB6/95/6							RGW	05-JUN-95	Rog,1995(E)

Appendix C (continued)

Sample Number	Strat Unit	Sample Type	Lith	Altn	mAlt	Status LHPCXM	Samples Available	Upper Depth (ft)	Lower Depth (ft)
DEB6/95/7	Qbt4	O	NWT	MG/MS	GL	MCAXI0	X,P		
DEB6/95/8-AA	Qbt4	OP	NWT	DV		MC0000			
DEB6/95/8-D	Qbt4	OP	NWT	DV		MC0000			
DEB6/95/8-H	Qbt4	OP	NWT	DV		MC0000			
DEB6/95/8-Z	Qbt4	OP	NWT	DV		MC0000			
GB/1-R	Qbt4	T	NWT	VP		MC0L00	111.9,F47.9,N	1.31	1.64
NLS/1-R	Qbt4	T	NWT	VP		MC0L00	167.6,F47.1,N	1.15	1.48
NUS/1-R	Qbt4	T	NWT	VP		MC0L00	139.8,F33.5,N	0.49	1.31
RW16PA1	Qbt4t	O	NWT	DV	VP	DC0XI0	158.3,F21.7,A.8,X,N		
RW16PA10	Qbt4t	O	NWT	VP		DC0L00	291.7,F33,N		
RW16PA11	Qbt3t	O	MWT	VP		HC0L00	223.2,F31.3,N		
RW16PA2	Qbt4	O	NWT	VP		MC0L00	123.4,F37.3,N		
RW16PA3	Qbt4	O	NWT	VP		MC0L00	164.4,F28.6,N		
RW16PA4	Qbt4	O	NWT	VP		MC0L00	162.1,F34.2,N		
RW16PA5	Qbt4	O	NWT	VP		MC0L00	159.3,F42.6,N		
RW16PA6	Qbt4	O	NWT	VP		MC0L00	135.F29.7,N		
RW16PA7	Qbt4	O	NWT	VP		MC0L00	89.7,F43.5,N		
RW16PA8	Qbt4	O	NWT	VP		MC0L00	109,F31.4,N		
RW16PA9	Qbt4	O	NWT	VP		MC0L00	110.8,F29.2,N		
RW16PC1	Qbt5	T	PWT	GL		MC0L00	160,F29.5,N	0.66	0.98
RW16PC2	Qbt5	T	PWT	GL		MC0L00	159.7,F29.7,N	0.66	0.98
RW16PC3	Qbt5	O	PWT	GL	VP	DCAXI0	191.6,F19.8,A.7,X,P,N		
SA1/1-0.84	Qbt5	C	PWT	GL		DC0L00	435,F28.4,N	2.49	2.76
SLS/1-R	Qbt4	T	NWT	VP		MC0L00	91.3,F46.1,N	1.31	1.31
SUS/1-R	Qbt4	T	NWT	VP		MC0L00	134.4,F22.6,N	0.49	1.31

Sample Number	Elev Top of Unit (ft)	Unit Above	Elev Base of Unit (ft)	Unit Below	Wet/Dry Color	Comp #1	Hue #1	Lightness #1	Chroma #1
DEB6/95/7	7490.0	Qbt5	7421.3	Qbt4t	D	MD	5YR	8	2
DEB6/95/8-AA	7496.7	Qbt5	7422.7	Qbt4t	D	PU	5R	7	1
DEB6/95/8-D	7496.7	Qbt5	7422.7	Qbt4t	D	PU	10YR	5	4
DEB6/95/8-H	7496.7	Qbt5	7422.7	Qbt4t	D	PU	10YR	7	4
DEB6/95/8-Z	7496.7	Qbt5	7422.7	Qbt4t	D	MD	5YR	8	1
GB/1-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
NLS/1-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
NUS/1-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PA1	7427.6	Qbt4	7410.6	Qbt3t	D	MD	5YR	7	2
RW16PA10	7427.6	Qbt4	7410.6	Qbt3t	D	MD	5R	7	2
RW16PA11	7410.6	Qbt4t	7390.6	Qbt3	D	MD	5R	7	2
RW16PA2	7490.0	Qbt5	7427.6	Qbt4t	D	MD	10YR	8	3
RW16PA3	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PA4	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PA5	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PA6	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PA7	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PA8	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PA9	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
RW16PC1		unc	7500.0	Qbt4	D	MV	10YR	5	5
RW16PC2		unc	7500.0	Qbt4	D	MV	10YR	5	5
RW16PC3		unc	7500.0	Qbt4	D	MV	10YR	5	5
SA1/1-0.84		unc	7498.0	Qbt4	D	MV	10YR	5	5
SLS/1-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2
SUS/1-R	7490.0	Qbt5	7427.6	Qbt4t	D	MD	5YR	8	2

Appendix C (continued)

Sample Number	Comp #2	Hue #2	Lightness #2	Chroma #2	Comp #3	Hue #3	Lightness #3	Chroma #3	Comp #4	Hue #4
DEB6/95/7	PU	10YR	5	2						
DEB6/95/8-AA										
DEB6/95/8-D										
DEB6/95/8-H										
DEB6/95/8-Z	PU	10YR	5	5						
GB/1-R	PU	5YR	5	2						
NLS/1-R	PU	10YR	6	2	PU	10YR	6	3		
NUS/1-R	PU	5YR	5	2						
RW16PA1	PU	5YR	6	2						
RW16PA10	MD	5YR	8	2	PU	5YR	5	2		
RW16PA11	PU	N	6							
RW16PA2	PU	10YR	6	2						
RW16PA3	PU	5YR	5	2						
RW16PA4	PU	10YR	6	4						
RW16PA5	PU	10YR	5	4						
RW16PA6	PU	5YR	5	2						
RW16PA7	PU	5YR	5	2						
RW16PA8	PU	5YR	5	2						
RW16PA9	PU	10YR	5	3						
RW16PC1	PU	N	8		PU	10YR	5	5		
RW16PC2	PU	N	8		PU	10YR	5	4		
RW16PC3	PU	10YR	5	4						
SA1/1-0.84	PU	10YR	5	4						
SLS/1-R	PU	5YR	5	2						
SUS/1-R	PU	10YR	6	3						

Sample Number	Lightness #4	Chroma #4	Comp #5	Hue #5	Lightness #5	Chroma #5	Sampler	Collect Date	Reference
DEB6/95/7							RGW	05-JUN-95	Rog,1995(E)
DEB6/95/8-AA							DEB/RGW	05-JUN-95	
DEB6/95/8-D							DEB/RGW	05-JUN-95	
DEB6/95/8-H							DEB/RGW	05-JUN-95	
DEB6/95/8-Z							DEB/RGW	05-JUN-95	
GB/1-R							RGW	20-NOV-95	
NLS/1-R							RGW	20-NOV-95	
NUS/1-R							RGW	20-NOV-95	
RW16PA1							RGW	20-NOV-95	
RW16PA10							RGW	01-DEC-95	
RW16PA11							RGW	01-DEC-95	
RW16PA2							RGW	20-NOV-95	
RW16PA3							RGW	20-NOV-95	
RW16PA4							RGW	20-NOV-95	
RW16PA5							RGW	20-NOV-95	
RW16PA6							RGW	20-NOV-95	
RW16PA7							RGW	20-NOV-95	
RW16PA8							RGW	20-NOV-95	
RW16PA9							RGW	20-NOV-95	
RW16PC1							RGW	01-DEC-95	Rog1995(E)
RW16PC2							RGW	01-DEC-95	Rog1995(E)
RW16PC3							RGW	01-DEC-95	Rog1995(E)
SA1/1-0.84							RGW	01-DEC-95	Rog1995(E)
SLS/1-R							RGW	20-NOV-95	
SUS/1-R							RGW	20-NOV-95	

Appendix D. Analyses for samples collected for baseline study of soil (and fill) from MDA-P. Analyses follow EPA-SW846 methods for total element concentrations extracted from the complete digestion of soil material using concentrated hydrofluoric acid (HF). Data are parts per million (ppm). See Appendix J for explanation of symbols.

SAMPLE ID	FS#	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K
24	2309	0.50B	47900	4.70	764	1.7	3520	0.16	5.7	11.7	11.9	16200	31700
25	2310	0.78B	42400	3.50	2040	1.5	4290	0.22	6.3	12.1	10.3	18300	30700
26	2311	0.29B	38700	1.90	431	1.7	3080	0.10	5.2	7.9	7.3	14600	34100
27	2312	0.48B	43200	2.00	1320	1.3	4240	0.18	6.2	11.1	8.3	17400	32400
28	2313	0.36B	43200	0.85	430	1.5	3720	0.13	5.6	8.1	6.1	16000	34100
29	2314	0.46B	43400	0.41	1040	1.3	3970	0.20	6.2	9.1	8.8	17400	33100
30	2315	0.34B	49500	1.80	447	1.8	4190	0.12	6.6	9.8	6.6	18800	33100
31	2316	0.88B	43500	1.90	1860	1.4	3610	0.31	5.5	9.5	11.0	16800	31800
32	2317	0.45B	33600	0.75	489	1.4	3200	0.18	3.6	4.2	6.8	11800	33500
33	2318	0.49B	39300	2.10	508	1.7	3000	<0.10	10.2	19.6	10.9	16700	25100
34	2319	0.57B	48600	1.50	484	2.3	2970	<0.10	7.5	16.6	11.2	20600	30400
35	2320	0.49B	54600	1.70	508	1.9	4480	0.11	9.9	18.4	12.0	19500	26900
36	2321	0.54B	36600	0.41	393	2.2	2010	<0.10	8.1	22.7	10.8	21800	23700
37	2322	0.46B	40500	0.51	492	1.6	3030	<0.10	7.9	14.4	9.5	14900	27400
38	2323	0.48B	43200	1.80	586	1.5	3630	<0.10	10.3	19.8	10.7	12800	23500
39	2324	0.59B	54100	1.30	611	1.6	3780	0.23	5.0	8.9	9.5	16200	34000
40	2325	0.75B	56300	1.60	839	1.5	3940	0.22	6.5	11.5	14.9	19600	33500
41	2326	2.40B	47300	1.50	1570	1.6	3780	0.20	5.5	11.4	11.4	18000	34400

SAMPLE ID	Mg	Mn	Na	Ni	Pb	Sb	Se	Ta	Th	Tl	U	V	Zn
24	1860	320	23600	8.7	20.2	0.55	1.9	2.4	7.3	0.60	2.0	21.9	60.1
25	2210	462	23800	9.4	26	0.83	2.0	2.4	6.4	0.51	3.0	23	73.8
26	1570	279	27800	4.6	17.4	0.41	1.5	2.1	5	0.38	1.3	17	58.7
27	1990	480	26500	5.8	22.5	0.63	1.7	2.3	6.1	0.27	1.7	19.9	74.1
28	1710	381	28700	5.4	17.6	0.43	1.6	2.4	5.7	0.31	1.0	15.7	65.4
29	1940	474	29700	4.7	21.9	0.52	1.9	2.1	5.3	0.51	1.5	19.2	75.2
30	1880	508	27000	7.1	21.1	0.48	2.0	2.5	6.4	0.72	1.3	20.7	67.4
31	1710	461	25200	6.8	28.7	0.91	1.8	2.4	5.2	0.34	2.5	19.2	73.0
32	1030	261	27800	4.5	16.6	0.54	1.1	2.3	4.5	0.27	1.0	9.2	51.1
33	2590	394	17600	9.2	20.7	0.74	1.3	1.9	7.6	0.50	2.6	39.4	46.2
34	3280	407	20400	11.9	19.2	0.57	1.5	2.6	8.6	0.58	2.4	31.9	68.5
35	3070	435	18600	9.8	24.6	0.63	1.9	2.1	10.0	0.66	2.5	37.2	57.5
36	3330	295	17300	11.4	18.1	0.50	2.0	2.3	6.0	0.72	2.4	39.5	66.1
37	2030	317	22000	8.8	19.9	0.55	1.6	1.8	7.2	0.61	2.5	27.8	48.4
38	2460	368	16800	7.7	19.1	0.64	1.1	1.9	9.2	0.48	2.7	40.4	33.3
39	1630	383	27400	5.8	27.2	0.47	1.4	2.3	7.4	2.10	1.8	17.4	67.6
40	1870	421	26400	6.6	29.1	0.74	1.8	2.4	7.5	2.00	1.7	22.1	81.4
41	1890	374	25000	6.5	33.3	0.8	1.2	2.6	6.8	1.30	2.1	20.2	74.3

Appendix E. Analyses for samples collected for baseline study of soil (and fill) from MDA-P. Analyses follow EPA-SW846 methods for nitric acid leachable portion of elements. Data are parts per million (ppm). See Appendix J for explanation of symbols.

SAMPLE ID	FS#	Ag	Al	As	Ba	Be	Ca	Cd	Cl^-	Co	Cr	Cu	Fe	Hg	K
24	2309	0.21B	10700	3.7	480	0.88	1910	<0.1	22.7*	2.5	6.2	5.2	11800	<0.02	1680
25	2310	0.71B	9520	4.1	1680	0.64	2950	<0.1	47.4*	2.6	7.6	6.9	13100	0.02B	1900
26	2311	<0.10	6470	2.7	70	0.79	1340	<0.1	22.5*	1.8	4.5	3.2	9800	<0.02	1220
27	2312	0.34B	6010	2.8	1020	0.40	2210	<0.1	9.2*	1.7	5.8	6.1	10700	<0.02	1250
28	2313	0.10B	5930	2.3	56.1	0.64	1560	<0.1	15.1*	1.7	5.0	3.5	10500	<0.02	1050
29	2314	0.31B	5990	2.8	656	0.47	1260	<0.1	15.9*	2.0	5.2	6.1	10600	<0.02	1310
30	2315	0.16B	7010	3.1	90.2	0.80	1950	<0.1	11.8*	2.2	5.1	4.6	10600	<0.02	1320
31	2316	0.61B	6520	3.8	1650	0.45	2120	<0.1	16.8*	1.8	4.6	8.7	10300	0.03B	1470
32	2317	0.26B	4070	2.9	229	0.47	2120	<0.1	23.2*	1.3	2.8	4.4	8460	<0.02	1070
33	2318	<0.10	10200	2.4	103	0.68	1780	<0.1	10.3*	4.6	7.3	5.5	10900	<0.02	1530
34	2319	0.12	16100	1.9	224	1.00	2480	<0.1	9.3*	3.4	7.5	7.8	12900	0.03B	2250
35	2320	0.12	14100	2.3	126	0.80	2480	<0.1	14.2*	4.6	8.7	9.1	12400	0.03B	2150
36	2321	0.17	23200	1.4	154	1.20	2940	<0.1	20.4*	3.4	10.7	7.7	17300	<0.02	2560
37	2322	<0.10	8650	1.6	69.4	0.56	1660	<0.1	14.6*	3.2	5.0	4.9	8590	<0.02	1580
38	2323	<0.10	8810	2.2	97.2	0.60	1380	<0.1	11.0*	3.5	7.0	4.6	8320	<0.02	1940
39	2324	0.34B	5510	3.2	270	0.46	1080	<0.1	20.2*	2.0	4.1	6.9	9680	<0.02	1230
40	2325	8.80B	5890	3.5	515	0.54	1200	<0.1	15.6*	1.7	4.7	10.7	9650	<0.02	1300
41	2326	2.60B	7490	3.3	1270	0.61	2210	<0.1	15.4*	1.4	4.9	7.2	10000	0.02B	1790

SAMPLE ID	Mg	Mn	Na	Ni	Pb	Sb	Se	SO_4^{2-}	Ta	Th	Tl	U	V	Zn
24	1400	184N	543	5.2	8.8	<0.1N	1.10	52.1	<0.1N	5.8E	0.24	1.10	12.2	35.1
25	1610	303N	475	5.8	15.0	<0.1N	1.70	82.3	<0.1N	4.7E	0.20	2.6	13.3	52.1
26	1060	106N	563	3.0	5.0	<0.1N	1.10	26.5	<0.1N	4.3E	0.16B	0.53	9.3	31.8
27	1350	293N	431	3.7	9.9	<0.1N	1.60	82.4	<0.1N	4.1E	0.15B	1.20	10.2	44.6
28	1170	196N	536	4.1	4.4	<0.1N	1.60	18.2	<0.1N	4.2E	0.14B	0.44	9.1	37.5
29	1180	251N	495	4.3	10.6	<0.1N	1.30	46.9	<0.1N	3.5E	0.18B	1.00	9.8	43.4
30	1230	287N	465	5.3	8.0	<0.1N	1.10	7.2	<0.1N	4.5E	0.23	0.47	9.7	35.0
31	1130	280N	478	3.6	16.8	<0.1N	1.40	99.4	<0.1N	4.2E	0.14B	1.70	9.0	44.8
32	731	104N	657	2.8	4.0	<0.1N	1.20	25.6	<0.1N	3.6E	0.10	0.48	5.6	30.9
33	1450	332N	270	6.1	13.3	<0.1N	1.30	6.0	<0.1N	5.8E	0.22	0.97	16.9	23.1
34	2140	300N	620	7.7	9.9	<0.1N	1.10	102.0	<0.1N	6.5E	0.27	0.59	12.1	30.0
35	1790	286N	476	7.0	15.4	<0.1N	1.40	23.4	<0.1N	5.8E	0.23	0.78	17.1	33.0
36	2460	287N	762	7.7	11.4	<0.1N	2.00	83.3	<0.1N	9.1E	0.38	1.00	14.4	35.5
37	1080	213N	377	4.1	11.9	<0.1N	1.10	9.3	<0.1N	5.0E	0.25	0.93	10.9	18.1
38	1400	293N	363	4.4	11.8	<0.1N	1.10	8.7	<0.1N	6.4E	0.24	0.98	18.9	16.9
39	806	197N	690	2.9	15.1	<0.1N	0.94B	37.0	<0.1N	4.1E	0.45	0.58	9.2	40.4
40	847	185N	576	3.6	18.8	<0.1N	1.30	49.5	<0.1N	4.3E	0.57	0.72	9.4	44.0
41	1180	182N	649	3.2	18.9	<0.1N	1.10	99.0	<0.1N	4.1E	0.37	0.96	8.8	39.9

Appendix F. Analyses for samples collected for baseline study of bedrock from MDA-P. Analyses follow EPA-SW846 methods for nitric acid leachable portion of elements except Th and U, which are whole-rock analyses. Data are parts per million (ppm), followed by analytical qualifiers or uncertainty in 2 sigma. Samples collected for background study are reported in Broxton et al. (1996). See Appendix J for explanation of symbols.

Sample Number	Strat Unit	Sample Type	Lith	Altn	mAlt	Customer ID	Elev (ft)	Be	Na	Mg	Al
SA1/1-0.84	Qbt5	C	PWT	GL		0816-96-0016/01	7509.6	0.82	1020E	1550	13800
RW16PC2	Qbt5	T	PWT	GL		0816-96-0005/01	7509.5	0.67	1530E	600	7280
RW16PC1	Qbt5	T	PWT	GL		0816-96-0004/01	7509.3	0.60	1080E	822	6650
RW16PC3	Qbt5	O	PWT	GL		0816-96-0006/01	7508.7	0.40	1780E	660	6840
RW16PA8	Qbt4	O	NWT	VP		0816-96-0022/01	7448.9	0.43	1010	514	3690
DCN1-R	Qbt4	T	NWT	VP		0816-96-0007/01	7448.5	0.39	1000E	640	4330
RW16PA7	Qbt4	O	NWT	VP		0816-96-0021/01	7448.0	0.33	838	753	4120
DCN2-R	Qbt4	T	NWT	VP		0816-96-0008/01	7446.9	0.36	954E	870	4670
RW16PA6	Qbt4	O	NWT	VP		0816-96-0020/01	7445.6	0.32	1090	877	3960
DCN3-R	Qbt4	T	NWT	VP		0816-96-0009/01	7445.2	0.78	1020E	862	5360
NUS/1-R	Qbt4	T	NWT	VP		0816-96-0010/01	7444.6	0.32	844E	684	3770
SUS/1-R	Qbt4	T	NWT	VP		0816-96-0011/01	7443.5	0.45	1080E	724	3840
RW16PA9	Qbt4	O	NWT	VP		0816-96-0023/01	7443.4	0.37	884	897	3330
RW16PA4	Qbt4	O	NWT	VP		0816-96-0018/01	7440.5	0.64	713E	992	4240
RW16PA5	Qbt4	O	NWT	VP		0816-96-0019/01	7438.8	0.76	620E	994	3670
RW16PA3	Qbt4	O	NWT	VP		0816-96-0017/01	7437.4	0.66	804E	793	3540
NLS/1-R	Qbt4	T	NWT	VP		0816-96-0014/01	7434.8	0.58	1290E	844	5940
SLS/1-R	Qbt4	T	NWT	VP		0816-96-0013/01	7434.4	0.46	1020E	747	4610
RW16PA2	Qbt4	O	NWT	VP		0816-96-0012/01	7430.3	1.50	825E	1880	7030
GB/1-R	Qbt4	T	NWT	VP		0816-96-0015/01	7428.2	0.45	1360E	1070	6870
RW16PA1	Qbt4t	O	NWT	VP		0816-96-0001/01	7425.0	0.38	2270E	220	5490
RW16PA10	Qbt4t	O	NWT	VP		0816-96-0002/01	7418.1	0.74	707E	518	3850
RW16PA11	Qbt3t	O	MWT	VP		0816-96-0003/01	7409.9	0.39	743E	171	4470

Sample Number	SO_4^{2-}	Cl^-	K	Ca	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se
SA1/1-0.84	20.2*	2.3	2230	2050	9.3	5.6	172	12100	1.10	7.6	5.0	33.1	1.6	<0.20
RW16PC2	8.9*	5.3	1920	1020	5.9	2.9	226	9000	<0.60	7.3	4.6	28.9	1.3	0.39B
RW16PC1	4.7*	3.4	1700	1120	5.5	2.7	357	8150	0.65B	10.5	3.6	28.4	1.4	0.41B
RW16PC3	6.5*	4.1	2090	1040	5.7	2.4	209	9130	0.74B	5.3	2.9	28.4	1.1	0.43B
RW16PA8	71*	15.3	1380	812	4.3	2.5	285	8420	0.94B	2.6	1.9	40.3	2.1	0.32B
DCN1-R	5.4*	49.9	1300	836	6.2	2.8	372	10600	0.88B	3.6	2.5	49.3	2.8	0.49B
RW16PA7	12.2*	17.4	1340	853	5.0	2.9	285	9540	0.87B	3.1	1.7	55.9	2.4	0.34B
DCN2-R	4.2*	25.2	1320	910	6.2	3.0	228	10800	1.00	3.1	1.8	48.2	4.0	0.28B
RW16PA6	10.0*	7.1	1620	968	7.4	4.4	287	10300	1.10	4.0	2.3	49.0	2.8	0.51B
DCN3-R	13.4*	19.7	1500	1200	7.3	3.3	295	14000	1.20	3.3	6.4	49.3	5.7	0.44B
NUS/1-R	5.2*	7.5	1160	999	6.5	4.1	317	10600	0.86B	3.4	2.3	40.3	2.8	0.31B
SUS/1-R	3.6*	11.7	1450	1010	7.7	3.8	273	10800	1.00B	3.8	2.3	43.5	5.5	0.32B
RW16PA9	15.4*	6.9	1380	846	6.9	4.2	290	9990	1.30	3.2	2.7	52.8	2.4	0.39B
RW16PA4	10.8*	8.6	1860	940	8.8	4.8	322	11000	1.20	3.1	3.6	37.7	3.3	<0.20
RW16PA5	4.4*	3.3	1440	1150	7.2	4.6	325	10700	1.20	4.0	2.5	46.4	2.8	<0.20
RW16PA3	3.0*	7.5	1530	946	7.3	4.4	301	10300	1.10	3.8	2.7	48.8	2.0	<0.20
NLS/1-R	7.5*	4.3	1810	1010	9.3	5.1	366	11700	1.20	4.1	2.4	52.0	3.0	0.40B
SLS/1-R	9.8*	4.4	1410	1060	9.1	4.5	305	11100	1.50	3.8	2.8	47.3	2.8	0.28B
RW16PA2	4.1*	3.7	1980	1550	12.4	6.6	448	15300	2.00	6.5	4.0	356.0	11.6	0.59B
GB/1-R	4.4*	3.3	2060	1290	12.5	6.2	373	13200	1.90	4.7	2.8	57.5	3.1	0.32B
RW16PA1	8.3*	4.9	3430	513	2.9	0.79B	174	8330	<0.60	2.0	1.4	56.7	2.9	<0.20
RW16PA10	21.1*	7	1090	1090	9.4	4.0	370	13300	1.20	3.3	1.9	55.4	4.5	0.46B
RW16PA11	6.9*	5.2	883	425	3.8	1.4	317	8760	0.88B	2.1	3.8	41.0	2.5	0.58B

Appendix F (continued)

Sample Number	Ag	Cd	Sb	Ba	Hg	Tl	Pb	Th	U	Alpha PCI/g	Beta PIC/g
SA1/1-0.84	<0.1	<0.1	<3.3N	68.2	0.05	0.36	6.0	14.0	2.8	13 ± 14	40 ± 10
RW16PC2	<0.1B	<0.1	<3.3N	54.4	0.03B	<0.20	3.5	13.0	2.9	9 ± 12	41 ± 10
RW16PC1	<0.1B	<0.1	<3.3N	64.1	0.06	0.27	4.4	11.8	2.8	12 ± 14	39 ± 10
RW16PC3	<0.1B	<0.1	<3.3N	36.9	<0.02	0.34	2.9	11.9	2.7	11 ± 12	38 ± 10
RW16PA8	<0.1B	<0.1	<3.3N	157.0	0.03B	0.56	5.4	11.7	2.9	12 ± 12	41 ± 10
DCN1-R	<0.1B	<0.1	<3.3N	74.5	0.05	0.86	10.6	11.4	2.9	12 ± 14	38 ± 10
RW16PA7	<0.1B	<0.1	<3.3N	68.5	0.05	<0.20	8.7	11.6	3.0	10 ± 12	38 ± 10
DCN2-R	<0.1B	<0.1	<3.3N	47.1	0.03B	0.47	15.7	11.4	2.8	14 ± 14	40 ± 10
RW16PA6	<0.1B	<0.1	<3.3N	66.7	0.04B	0.47	3.4	11.6	2.9	12 ± 14	40 ± 10
DCN3-R	<0.1B	<0.1	<3.3N	196.0	0.06	0.51	9.8	12.1	2.9	10 ± 12	41 ± 10
NUS/1-R	<0.1B	<0.1	<3.3N	31.7	0.05	0.30	5.6	11.5	2.9	9 ± 12	37 ± 10
SUS/1-R	<0.1B	<0.1	<3.3N	32.5	0.04	0.38	5.1	11.4	2.9	8 ± 12	33 ± 10
RW16PA9	<0.1B	<0.1	<3.3N	677.0	0.02B	0.38	3.7	11.3	2.9	11 ± 12	38 ± 10
RW16PA4	<0.1	<0.1	<3.3N	36.1	0.03B	0.49	6.2	11.1	2.9	10 ± 12	40 ± 10
RW16PA5	<0.1	<0.1	<3.3N	48.4	0.03B	0.33	2.9	10.7	2.6	12 ± 12	37 ± 10
RW16PA3	<0.1	<0.1	<3.3N	27.6	0.03B	0.22	4.8	10.9	2.8	6 ± 12	35 ± 10
NLS/1-R	<0.1	<0.1	<3.3N	34.2	0.03B	0.36	4.2	11.6	3.0	8 ± 12	36 ± 10
SLS/1-R	<0.1	<0.1	<3.3N	33.1	0.03B	0.48	4.1	11.5	2.8	11 ± 12	36 ± 10
RW16PA2	<0.1	<0.1	<3.3N	39.2	0.04B	0.39	513.0	10.3	3.0	13 ± 14	37 ± 10
GB/1-R	<0.1	<0.1	<3.3N	39.4	0.03B	0.45	4.8	11.2	2.8	5 ± 12	41 ± 10
RW16PA1	<0.1	<0.1	<3.3N	88.1	<0.02	0.35	9.1	13.4	3.4	15 ± 14	46 ± 10
RW16PA10	<0.1	<0.1	<3.3N	738.0	<0.02	0.59	3.6	10.5	2.7	10 ± 12	38 ± 10
RW16PA11	<0.1	<0.1	<3.3N	294.0	<0.02	0.44	4.2	13.8	3.5	14 ± 14	42 ± 10

Appendix G. X-ray fluorescence analyses for total element present in samples collected for baseline study of bedrock from MDA-P. Both samples were pulverized in an alumina ceramic shatterbox and analyzed at 9:1 dilution of flux to sample using a rhodium tube source. Analyses are corrected for matrix effects using XRF11 commercial software and using loss on ignition (LOI). Total includes trace elements as oxides. Uncertainties are 2 sigma. Analyses for background study are reported in Broxton et al. (1996).

Sample Number	Date	XRF File	Fusion Number	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3T %	MnO %	MgO %	Ca %	Na_2O %	K_2O %	P_2O_5 %	LOI %
RW16PA1	10-JUN-96	WAR314	5643	75.67 ± 0.92	0.19 ± 0.012	13.31 ± 0.23	1.72 ± 0.05	0.042 ± 0.01	<0.11	0.43 ± 0.11	4.14 ± 0.1	5.12 ± 0.08	0.024 ± 0.008	0.36
RW16PC3	10-JUN-96	WAR314	5644	70.38 ± 0.88	0.259 ± 0.011	14.1 ± 0.23	2.47 ± 0.06	0.068 ± 0.01	0.24 ± 0.1	0.6 ± 0.11	3.81 ± 0.1	4.83 ± 0.07	0.043 ± 0.008	2.48

Sample Number	V ppm	Cr ppm	Ni ppm	Zn ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Ba ppm	Total %
RW16PA1	<8.9	<7	29.1 ± 8.4	57.2 ± 11.3	85.8 ± 7	27.5 ± 5.8	30 ± 7.2	337.4 ± 15.2	42.3 ± 8.8	311.2 ± 47.1	101.1
RW16PC3	19.6 ± 10.9	<7	30.3 ± 8.4	58.4 ± 11.2	77.7 ± 6	65.4 ± 4.4	39 ± 7.3	354.9 ± 17.6	34.2 ± 8.8	407.8 ± 46.9	99.42

Appendix H. X-ray diffraction analyses for bulk mineralogy of samples collected for baseline study of bedrock from MDA-P. All analyses are by Steven J. Chipera, using internal standard method. Uncertainties are 2 sigma. Analyses for background study are reported in Broxton et al. (1996). See Appendix J for explanation of symbols.

Sample Number	Strat Unit	Sample Type	Lith	Altn	mAlt	Cristobalite %	Feldspar %	Glass %	Opal/ CT %	Quartz %	Smectite %	Scapolite %	Total %
RW16PA1	Qbt4	O	NWT	DV	VP	19±1	66±9	0	0	5±1	0	1±1	91±9.1
RW16PC3	Qbt5	O	PWT	GL	VP	0	31±4	64±4	1±1	2±1	1±1	1±1	100±6.0

Appendix I. Detailed petrographic analyses by R. G. Warren for polished thin sections of samples collected from MDA-P for background and baseline study of bedrock. Methods are described in Warren et al. (1989) and Warren et al. (in press). All point counts are at 400X in reflected light, aided by transmitted light; thin section areas are from calibrated steps of point count. Negative values indicate pseudomorphs. Additional analyses are published in Broxton et al. (1996). See Appendix J for explanation of symbols.

Sample Number	Strat Unit	Sample Type	Lith	Altn	mAlt	Analyst	Pet. Date	TS Area (mm^2)	TS Area Method	Points Ct. #1	Felsics Method	Felsics Total %	Qtz Rel %	K-spar Rel %	Plag Rel %	Lithics %	Voids %	Compl ID	Compl %	Comp2 ID	Comp2 %	Comp3 ID	Comp3 %
DEB5/95/1	Qbt3	O	MWT	MG/AX/VP		RGW	31-OCT-96	327	1	323	111AL11	30.67	30.28	69.65	0.06	0.92	0.62	GX	0.00				
DEB5/95/12	Qbt5	O	MWT	MG/GL		RGW	29-OCT-96	303	1	300	111111111	15.67	2.13	87.23	10.64	0.33	11.67	PC	2.67	SC	0.67	GX	0.00
DEB5/95/14	Qbt3	O	PWT	MG/VP	GR/GL	RGW	18-OCT-96	334	1	275	111A1111	29.32	30.86	68.38	0.77	3.27	20	VP	13.45	GX	0.36		
DEB5/95/16	Qbt3t	O	MWT	MG/AX	SR/VP/GL	RGW	24-OCT-96	325	1	321	1111A11	24.61	15.19	81.01	3.80	0.06	1.56	GX	0.00				
DEB6/95/7	Qbt4	O	NWT	MG/MS	GL	RGW	22-OCT-96	282	1	279	1111111	14.70	21.95	65.85	12.20	4.3	12.9	GX	0.36				

Sample Number	Mafic Method	Biot ppmV	Hbld ppmV	Opx ppmV	Cpx ppmV	Oliv ppmV	Namaf Method	Acm ppmV	Arf ppmV	Fe Oxide Method	Mt ppmV	Ilm ppmV	Access Method	Sphene ppmV	Allan ppmV	Perri ppmV	Apatit ppmV	Zirco ppmV	Omin1 ID	Omin1 ppmV	Omin2 ID	Omin2 ppmV	Comment
DEB5/95/1	AAAA	0	208	1372	43		AA	0	0	EA	1210	1	AAAAAEA	0	0	80	98	35	OY	-1929	PO	3	PE incl some GM PE.
DEB5/95/12	AAEE	1	0	3188	4804		AA	0	0	EA	3051	147	AAAAAEA	0	0	4	161	161	OY	-583	PO	39	AP partly alt. PO mostly alt.
DEB5/95/14	AAAA	5	84	553	707		AA	0	0	EA	2187	0	AAAAAA	0	0	63	46	66	OY	-2084	GZ		
DEB5/95/16	AAEE	0	10	1298	3709		AA	0	0	EA	1963	2	AAAAAEA	0	0	30	157	110	OY	-232	PO	8	PO mostly alt.
DEB6/95/7	AAEEA	7	27	2612	3879	-7	AA	0	0	EE	2356	418	AAACAA	0	0	7	322	115	PO	21			PO almost entirely alt.

Appendix J. Explanation of symbols used in appendices.

Stratigraphic Unit (Appendices C, F, H, I):
Qbt3 = Unit 3 of Tshirege Member of Bandelier Tuff (Broxton et al., in review) = QbtD of Rogers (1995)
Qbt3t = Transitional Unit 3 of Tshirege Member of Bandelier Tuff (defined in text)
Qbt4t = Transitional Unit 4 of Tshirege Member of Bandelier Tuff (defined in text)
Qbt4 = Unit 4 of Tshirege Member of Bandelier Tuff (Broxton et al., in review) = QbtE of Rogers (1995)
Qbt5 = Unit 5 of Tshirege Member of Bandelier Tuff (defined in text) = QbtF of Rogers (1995)

Sample Type (Appendices C, F, H, I):
O = outcrop; OP = single pumice from outcrop; T = soil pit and C = core from auger (upper and lower depth limits provided for each sample in Appendix C)

Lithology (Appendices C, F, H, I):
NWT = nonwelded tuff; PWT = partially welded tuff; WBE = welded bedded tuff; MWT = moderately welded tuff; DWT = densely welded tuff

Alteration and minor alteration (Appendices C, F, H, I):
DV = high-temperature primary devitrified: (MG = microgranophyric; MS = microspherulitic; GR = granophyric; SR = spherulitic; AX = axiolitic; VP = vapor phase)
GL = vitric (unaltered)
AR = argillic; HM = hematitic; OP = opaline

Components and minerals (Appendices C and I):
AN = alteration; AP = apatite; CA = chalcopyrite; CX = clinopyroxene; GL = glass; GQ = granophyric quartz; GT = garnet; GZ = groundmass zircon; HM = hematite; HN = hornblende; KF = alkali feldspar; LI = lithic; MD = devitrified matrix; MN = monazite; MT = magnetite; MV = vitric matrix; OX = orthopyroxene; OY = pyroxene or olivine; PC = colorless pumice; PE = perrierite or chevkinite; PL = plagioclase; PO = pyrrhotite; PP = pale brown pumice; PU = pumice; QZ = quartz; SB = brown shard; SC = colorless shard; SP = pale brown shard; VK = vapor-phase alkali feldspar; VP = vapor-phase mineral

Samplers and analysts (Appendices B and C):
DEB = David E. Broxton; ECK = Emily C. Kluk; FAC = Florrie A. Caporuscio; RGW = Richard G. Warren

Reference (Appendices C and F):
Defines source for top and base elevations of unit. Source is this work if reference is not provided.

Source (Appendix A). Number represents 2 sigma horizontal uncertainty in meters, character represents method:
M = surveyed or accurately measured from nearby surveyed location
D = digitized from points plotted on field map

Map unit (Appendix A):
Location plots within unit designated on map defined by Reference Map Unit

Qualifiers for nitric acid-leachable chemical analyses (Appendices D, E, F):
B = value exceeded detection limit for individual analysis but was below required detection limit.
E = serial dilution for Pb differed from the sample by more than 10%, but the original result was more than 50 times the detection limit.
N = recovery for Sb from the sample used for spike analysis was not within control limits.
W = analytical spike recovery for As or Se was outside control limits (85% to 115%) and the sample concentration was <50% of the spike concentration.
+ = Method of standard addition for As or Se.
* = Duplicate analysis is not within control limits.

Appendix J (continued)

Samples available (Appendix C):
Numerical value without character indicates stored weight (g) of hand sample
Numerical value preceded by "F" indicates stored weight (g) of pulverized sample
Numerical value preceded by "A" indicates stored weight (g) of pulverized sample with corundum added for internal-standard XRD analysis
"X" indicates storage of XRF fusion disk
"B" indicates storage of butt for thin section
"P" indicates storage of polished thin section
"N" indicates storage of original field notes

Status (Appendix C):
First character denotes source of coordinates in Appendix A:
M = surveyed or accurately measured from nearby surveyed location
D = digitized from points plotted on field map
Second character denotes status of hand sample work and stratigraphic position:
C = complete
Third character denotes status of petrographic analyses:
A = detailed analysis
Fourth character denotes status of chemical analyses:
L = HNO_3-leachable analysis
X = HNO_3-leachable and total element analysis
Fifth character denotes status of mineralogical analyses by XRD:
I = analysis by internal standard method

Petrographic methods (Appendix I):
First character defines method for first mineral or component that follows, second character defines method for second mineral, etc. For example, if "Mafic methods" is defined as "12AA," then the first mineral following, biotite, is determined by method "1" and the second mineral, hornblende, by method "2." For more detailed descriptions of petrographic methods see Warren et al. (in press):
1 = Point count
A = All areas (from summed areas for all grains, divided by area of thin section)
C = Count of grains (from total number of grains above threshold area in thin section)
E = Extrapolation (from summed areas for largest grains, divided by area of thin section)
L = Largest (crude estimate from summed areas for largest grains, divided by area of thin section)