Broxton et al., 1996
SFO 54948

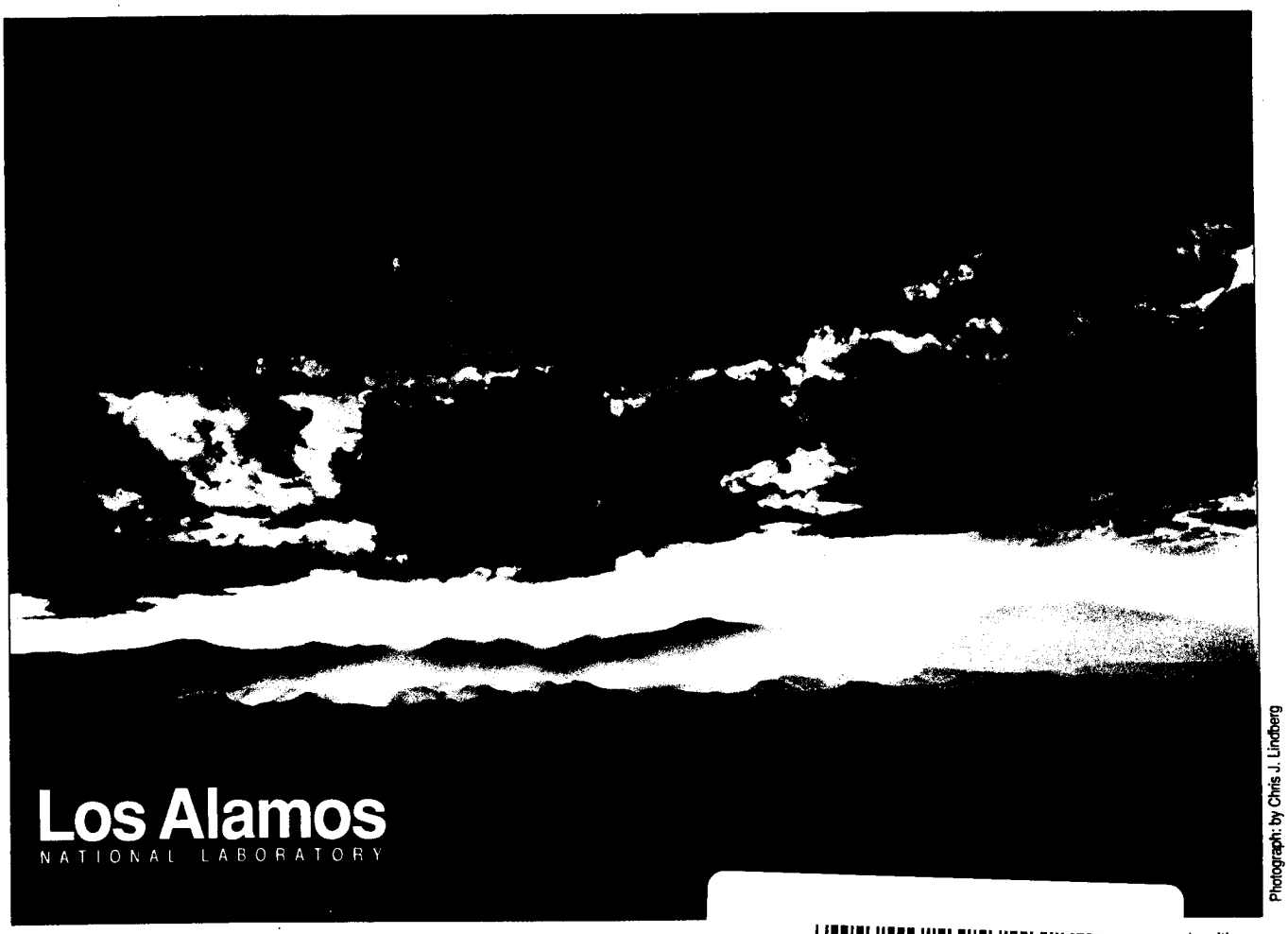
NATURAL BACKGROUND GEOCHEMISTRY OF THE BANDELIER TUFF AT MDA P, LOS ALAMOS NATIONAL LABORATORY

LA-UR-96-1151
March 20, 1996

Los Alamos Environmental Restoration Records Processing Facility
ER Record I.D.# 0054948

by

David E. Broxton, Randall T. Ryti, Deborah Carlson,
Richard G. Warren, Emily Kluk, and Steve Chipera



Photograph: by Chris J. Lindberg

This is a preprint of a paper intended for publication in a journal or proceedings. Because cha ole with the understanding that it will not be cited or reproduced without the permission of the author.

13515

NATURAL BACKGROUND GEOCHEMISTRY OF THE BANDELIER TUFF AT MDA P, LOS ALAMOS NATIONAL LABORATORY

LA-UR-96-1151
March 20, 1996

by

David E. Broxton, Randall T. Ryti, Deborah Carlson,
Richard G. Warren, Emily Kluk, and Steve Chipera

NATURAL BACKGROUND GEOCHEMISTRY OF THE BANDELIER TUFF AT MDA P, LOS ALAMOS NATIONAL LABORATORY

by

David E. Broxton[1], Randall T. Ryti[2], Deborah Carlson[2],
Richard G. Warren[1], Emily Kluk[1], and Steve Chipera[1]

ABSTRACT

Background elemental concentrations were determined for inorganic constituents of the Bandelier Tuff in support of the closure plan for Material Disposal Area P at Technical Area 16. A total of 23 bulk-rock samples was collected from outcrops of Bandelier Tuff in areas of Canon de Valle adjacent to MDA P. Total elemental concentrations were determined by X-ray fluorescence to determine the stratigraphic identity and chemical variability of rock units at the site.

Samples were also analyzed by EPA SW846 methods for their leachable (nitric acid digestion) or total concentrations of inorganic analytes. Leachable aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, silver, sodium, vanadium, and zinc were analyzed by inductively-coupled plasma-atomic emission. Antimony, lead, thallium, thorium, and uranium were analyzed inductively-coupled plasma-mass spectometry for their leachable concentrations, except for uranium and thorium, which were determined for their total concentrations. Leachable arsenic and selenium were analyzed using graphite furnace atomic absorption spectrometry. Chloride and sulfate were determined by ion chromatography. Gross alpha and beta activities were determined by gas proportional counting.

The bedrock units at MDA P consist of Qbt 3 and Qbt 4 of the Bandelier Tuff. The Wilcoxon rank sum test indicated that the MDA P Qbt 4 data can be combined with the Laboratory-wide background data for Qbt 4, and the UTLs are presented for the combined data sets. The Wilcoxon rank sum test also clearly indicates that these Qbt 4 chemical data are significantly different from those of the other Tshirege Member units. Wilcoxon rank sum test comparisons between the MDA P Qbt 3 data and those of the Laboratory-wide background data for Qbt 3 indicate that there are significant chemical differences for most elements between these data sets. Thus, UTLs are calculated separately for MDA P for Qbt 3.

The spatial coverage and population size of background chemistry samples are considered adequate for defining background screening values for units Qbt 3 and Qbt 4 at MDA P.

1. Geology/Geochemistry Group
2. Neptune and Company, Inc.

INTRODUCTION

This report presents background geochemical information for bedrock units (Bandelier Tuff) in support of the closure plan for Material Disposal Area P (MDA P) at Technical Area 16 (TA 16), Los Alamos National Laboratory (Technical Area 16, Material Area P Closure Plan, Revision 0, February, 1995). These background investigations conform with guidelines set forth in Task IV of the Laboratory's Hazardous and Solid Waste and Amendments (HSWA) permit to "...describe the extent of contamination (qualitative/quantitative) in relation to the background levels indicative for the area". The background data will be used to define performance criteria for clean closure of MDA P and supplement earlier investigations which define the regional background data for the Bandelier Tuff (Broxton et al., 1996a).

Two types of analytical data for inorganic constituents are presented in this report. Leachable elemental concentrations are provided to determine the bioavailabilty of elements for risk assessment calculations. Leachable elemental concentrations were determined by first leaching the loosely bound inorganic constituents of the rocks in a deionized water or nitric acid solution at a pH~1, and then analyzing the leachate. The leachable elemental concentrations are the primary focus of this report because soils and rocks for Environmental Restoration (ER) Project investigations also are analyzed for their leachable elemental concentrations.

Total elemental concentrations by X-ray fluorescene (XRF) also are discussed in this report and refer to the total concentration of an inorganic element in a rock, including the insoluble forms of the elements tightly bound in mineral structures as well as nitric acid leachable (bioavailable) forms. Total elemental concentrations provide important information about: (1) the identity and natural geochemical variability of the rock units at MDA P, (2) the leachability behavior of inorganic constituents in different geologic settings, (3) discrimination of contaminated vs. uncontaminated media, and (4) geochemical processes controlling contaminant transport.

METHODS

A total of 23 bulk-rock samples was collected from rock units at MDA P. All of the samples were collected from outcrops in areas unaffected by disposal operations. Sample locations are shown in Fig. 1.

Field work was performed using the procedure Characterization of Lithologic Variations within the Rock Outcrops of a Volcanic Field (LANL-ER-SOP-03.07). Samples were collected in vertical stratigraphic sections at a nominal vertical spacing of 5 m or at major changes in lithology. Metal tags mark sample sites in the field. Vertical control was maintained by Jacob staff and Abney level in the field, and locations were estimated from maps. Vertical stratigraphic positions were measured above base levels, and elevations were estimated from maps. Site observations generally included descriptions of rock type, unit thickness, type and degree of alteration, welding and compaction, phenocryst assemblage and abundance, color of fresh and weathered surfaces, pumice size and abundance, and weathering characteristics. Bedding characteristics, fractures and their filling materials, and lithic assemblage, size, and abundance were also noted.

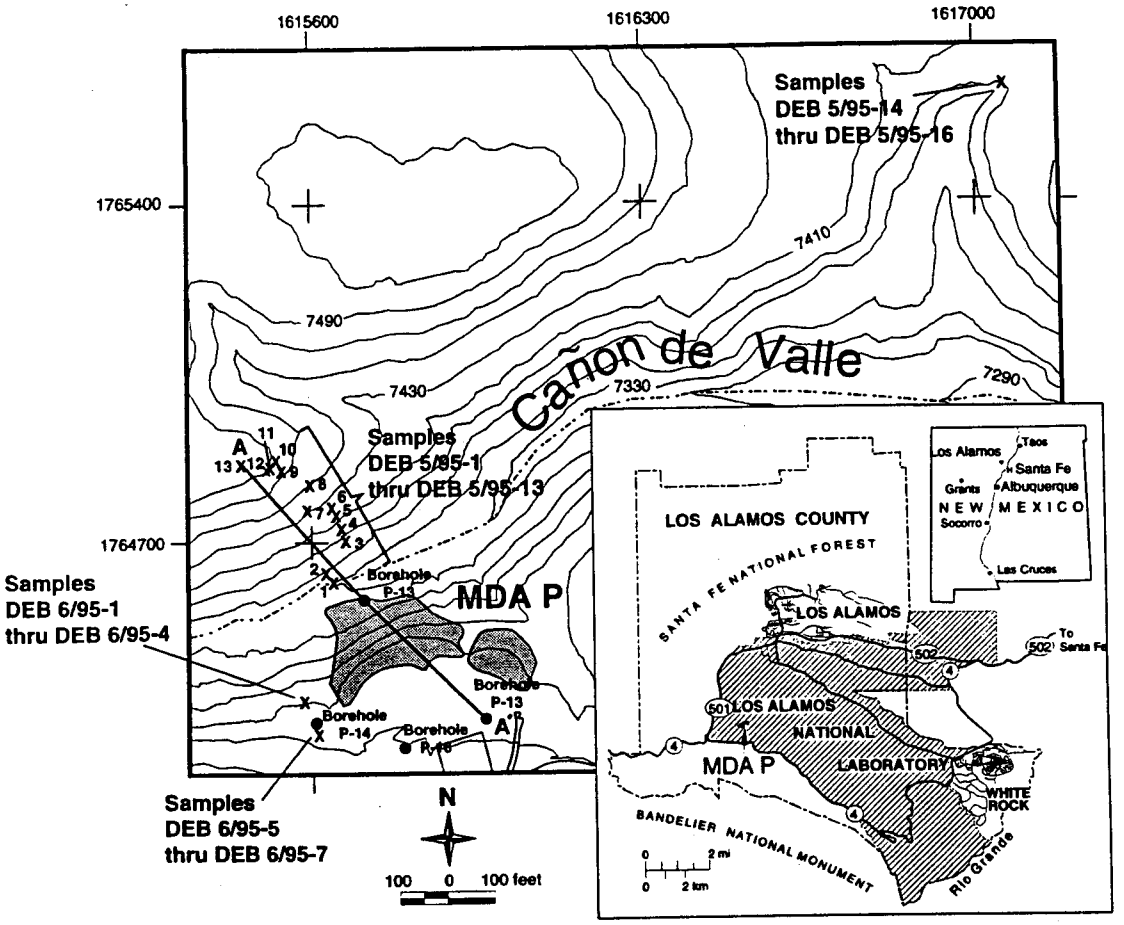


Fig. 1. Map showing location of MDA P on the south rim of Canon de Valle. Background samples for the Bandelier Tuff were collected at locations indicated by Xs. Cross section A-A' is shown in Fig. 2. Selected boreholes (solid circles) are shown for reference.

Total elemental concentrations were determined by XRF to determine the stratigraphic identity and chemical variability of rock units in the vicinity of MDA P (Appendix I). Total elemental concentrations were made using an automated Rigaku wavelength-dispersive XRF spectrometer located in the Geology/Geochemistry Group (EES-1) at LANL. Details about XRF analytical conditions are summarized in Broxton et al. (1995b, 1995c). Loss on ignition (LOI) was determined by measuring the difference in sample weight at room temperature and after heating at 1000°C for one hour. The mineralogy of the tuffs (Appendix II) was determined by X-ray diffraction (XRD) following procedures described by Bish and Chipera (1988; 1989). Petrographic analysis for phenocryst minerals (Appendix III), including trace minerals, were performed for 14 of the tuff samples using methods of Warren et al. (1989) and Warren et al. (1984). All point coints were made on polished thin sections at 400X.

The samples also were analyzed by EPA SW846 methods for their leachable (nitric acid digestion) or total concentrations of inorganic analytes (Appendix IV). Leachable aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, silver, sodium, vanadium, and zinc were analyzed by inductively-coupled plasma-atomic emission spectometry (ICP-AES). Antimony, lead, thallium, thorium, and uranium

were analyzed by inductively-coupled plasma-mass spectometry (ICP-MS) for their leachable concentrations, except for uranium and thorium, which were determined for their total concentrations. Leachable arsenic and selenium were analyzed using graphite furnace atomic absorption spectrometry. Chloride and sulfate were determined by ion chromatography after leaching the sample with deionized water. Whole rock (gross) alpha and beta activities were determined by gas proportional counting.

GEOLOGIC SETTING

Figure 2 shows the stratigraphic relations of the units at MDA P. Two units of the Tshirege Member of the Bandelier Tuff are exposed on the walls of Canon de Valle. The lower unit correlates with Qbt 3 of the Tshirege Member and the upper unit correlates with Qbt 4, based on total elemental chemistry (Figs. 3 and 4). The stratigraphic nomenclature for the Bandelier Tuff used in this investigation follows the usage of Broxton and Reneau (1995). Stratigraphic assignments by Purtymun (1995) for tuffs penetrated in boreholes at MDA P are shown in Figure 2 for reference.

The exposed portion of Qbt 3 in Canon de Valle is made up of two hard, pinkish-brown, partially to moderately welded, cliff-forming ignimbrites that are separated by a soft, pinkish-orange, nonwelded, slope-forming tuff. The upper cliff-forming subunit of Qbt 3, which is the bedrock unit in the lower part of MDA P (Fig. 2), grades up into a broad, gently-sloping bench developed on top of medium-gray, moderately to densely welded ignimbrite.

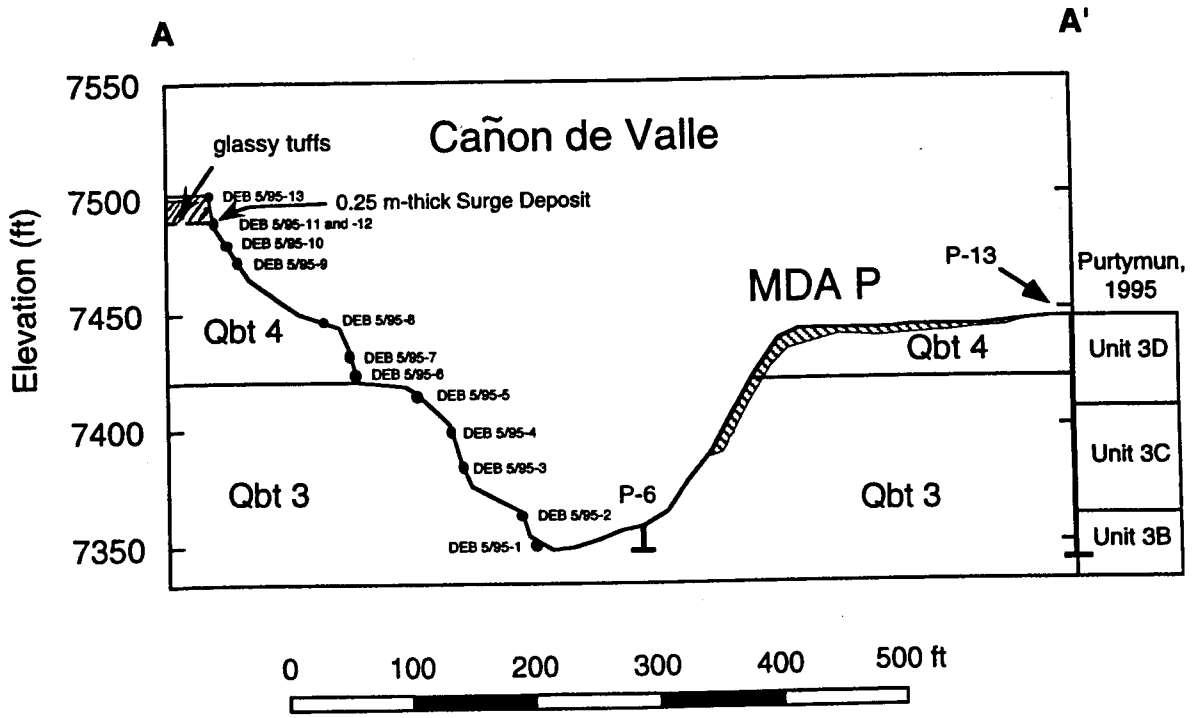


Fig. 2. Geologic cross section across Canon de Valle showing stratigraphic units at MDA P. Line of section shown in Fig. 1. Geologic units identified in boreholes P-6 and P-13 (Purtymun, 1995) shown for reference on right side of figure.

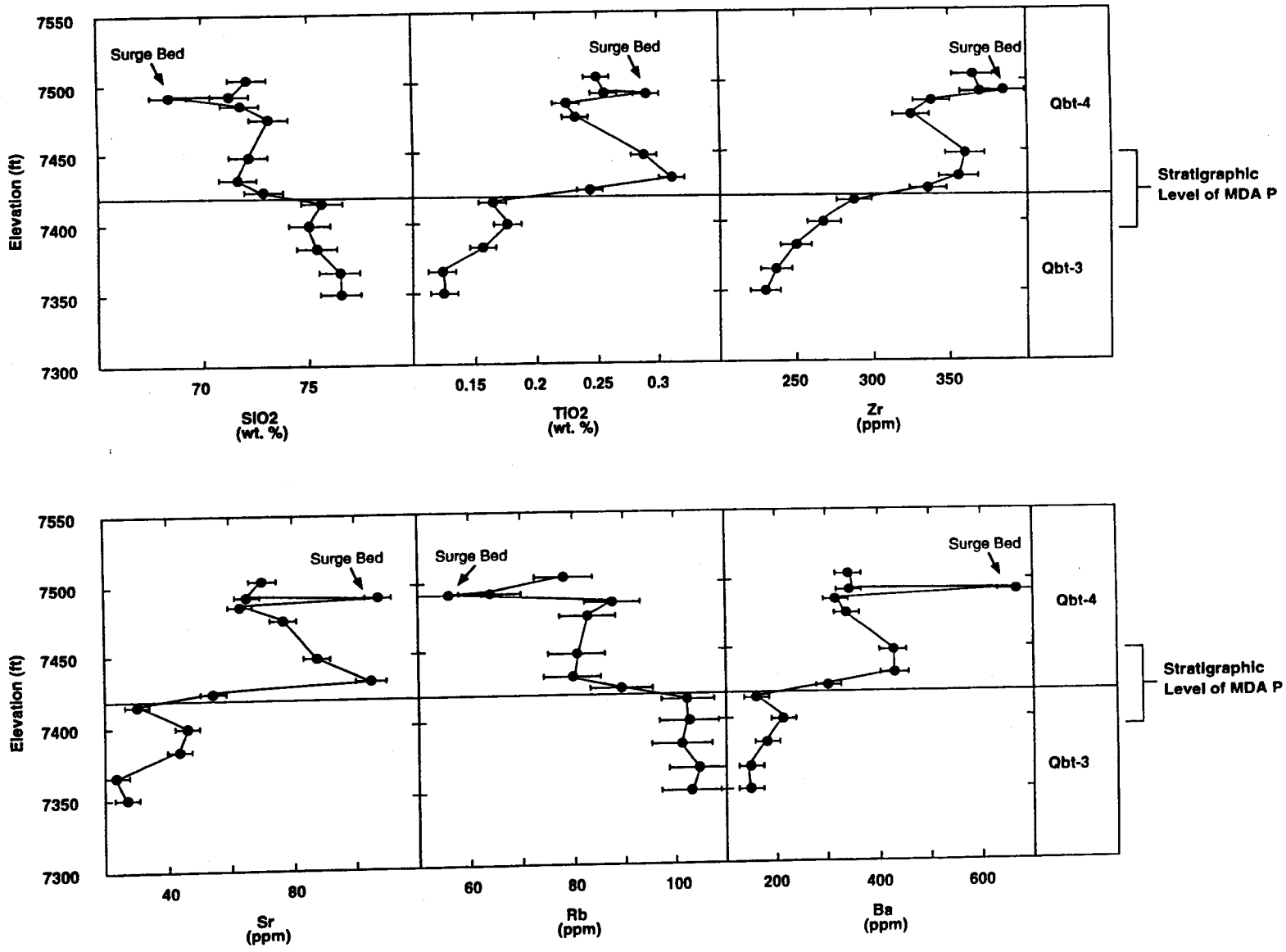


Fig. 3. Total concentrations for selected elements in the Bandelier Tuff on the north wall of Canon de Valle (Samples DEB 5/95-1 through DEB 5/95-13). The boundary between Qbt 3 and Qbt 4 is marked by a change in chemistry. Error bars are two standard deviation estimates of analytical uncertainty. Data from Appendix I.

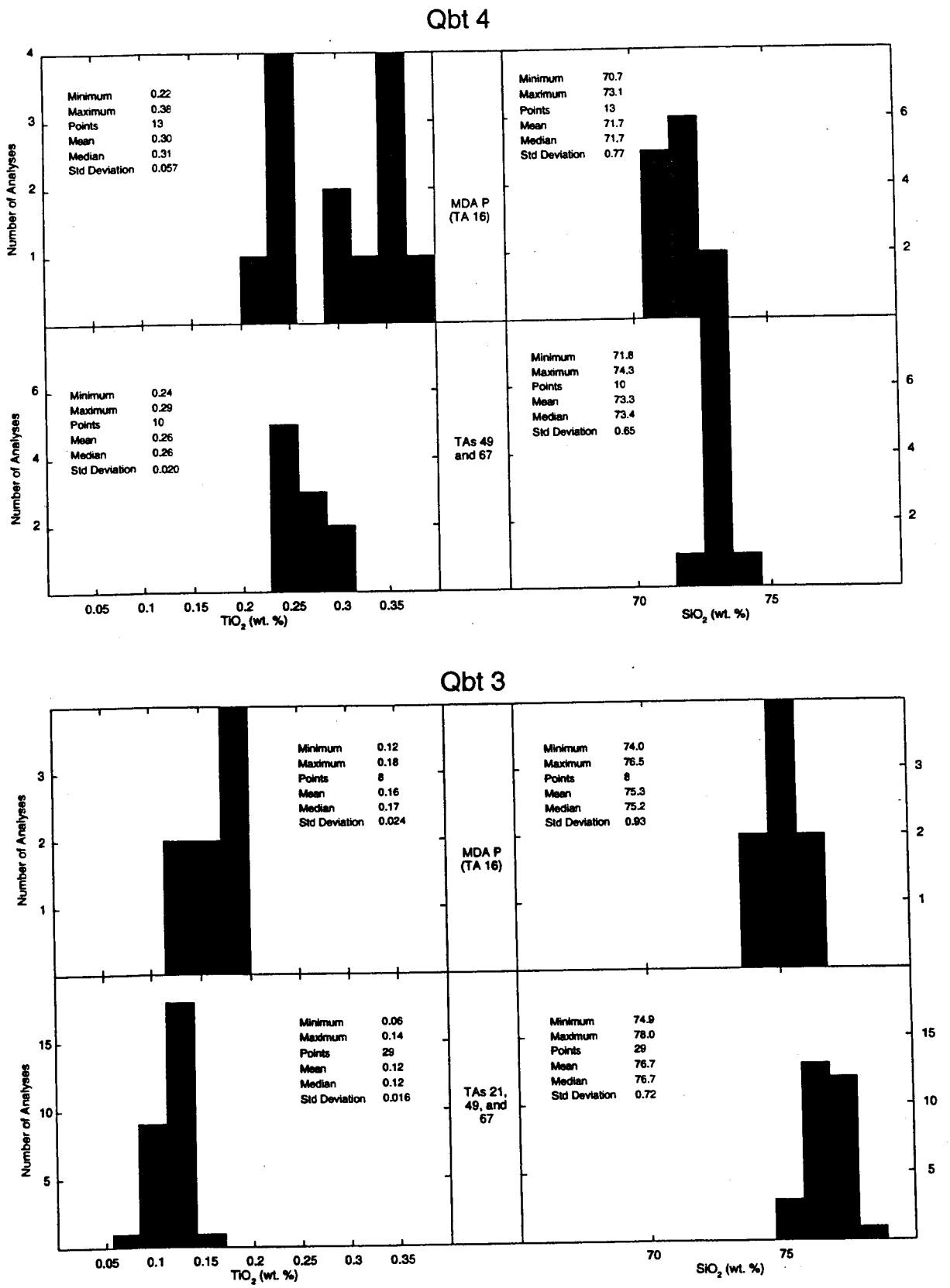
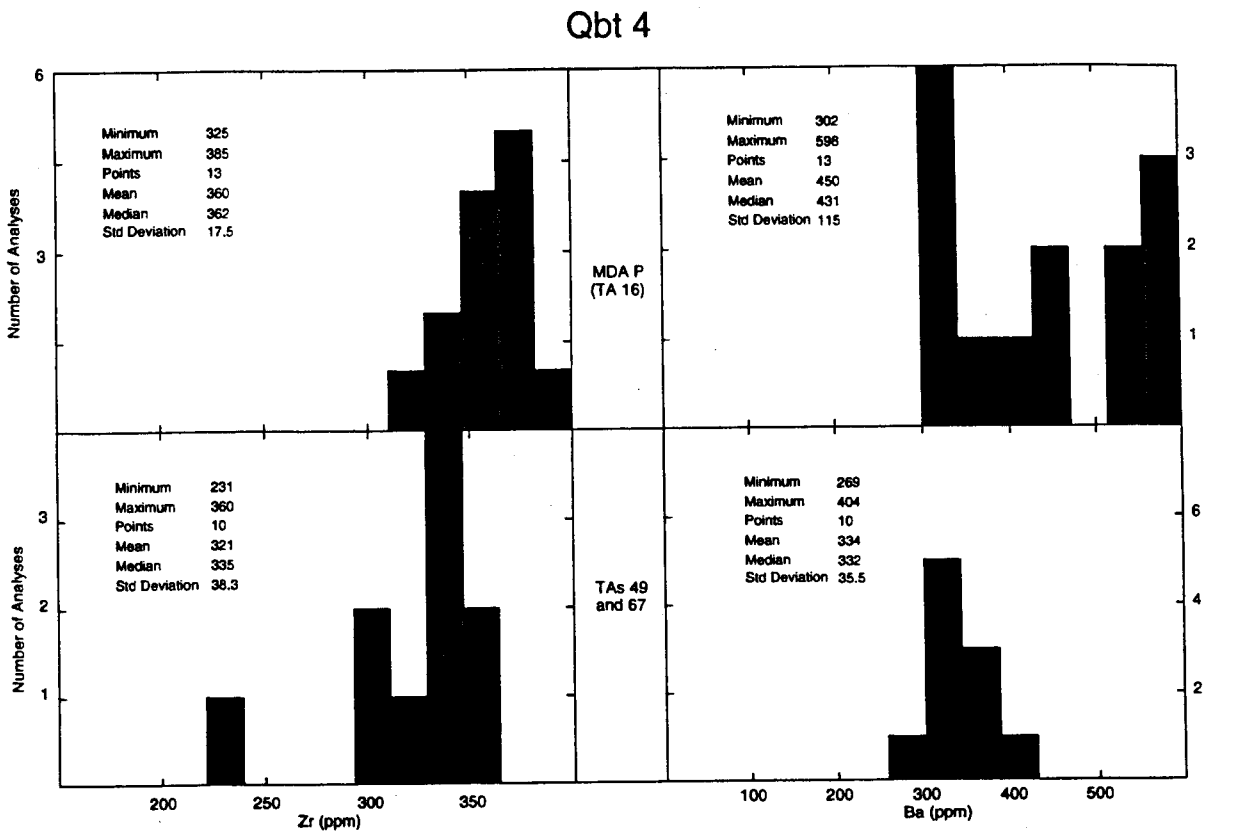


Fig. 4. Histograms comparing total elemental concentrations of Qbt 3 and Qbt 4 at MDA P (Appendix I) with elemental concentrations from the Laboratory-wide data set (Broxton et al., 1996a).


Qbt 4
Minimum 325
Maximum 385
Points 13
Mean 360
Median 362
Std Deviation 17.5
MDA P
(TA 16)
Minimum 302
Maximum 598
Points 13
Mean 450
Median 431
Std Deviation 115
Minimum 231
Maximum 360
Points 10
Mean 321
Median 335
Std Deviation 38.3
TAs 49
and 67
Minimum 269
Maximum 404
Points 10
Mean 334
Median 332
Std Deviation 35.5
Number of Analyses
Zr (ppm)
Ba (ppm)

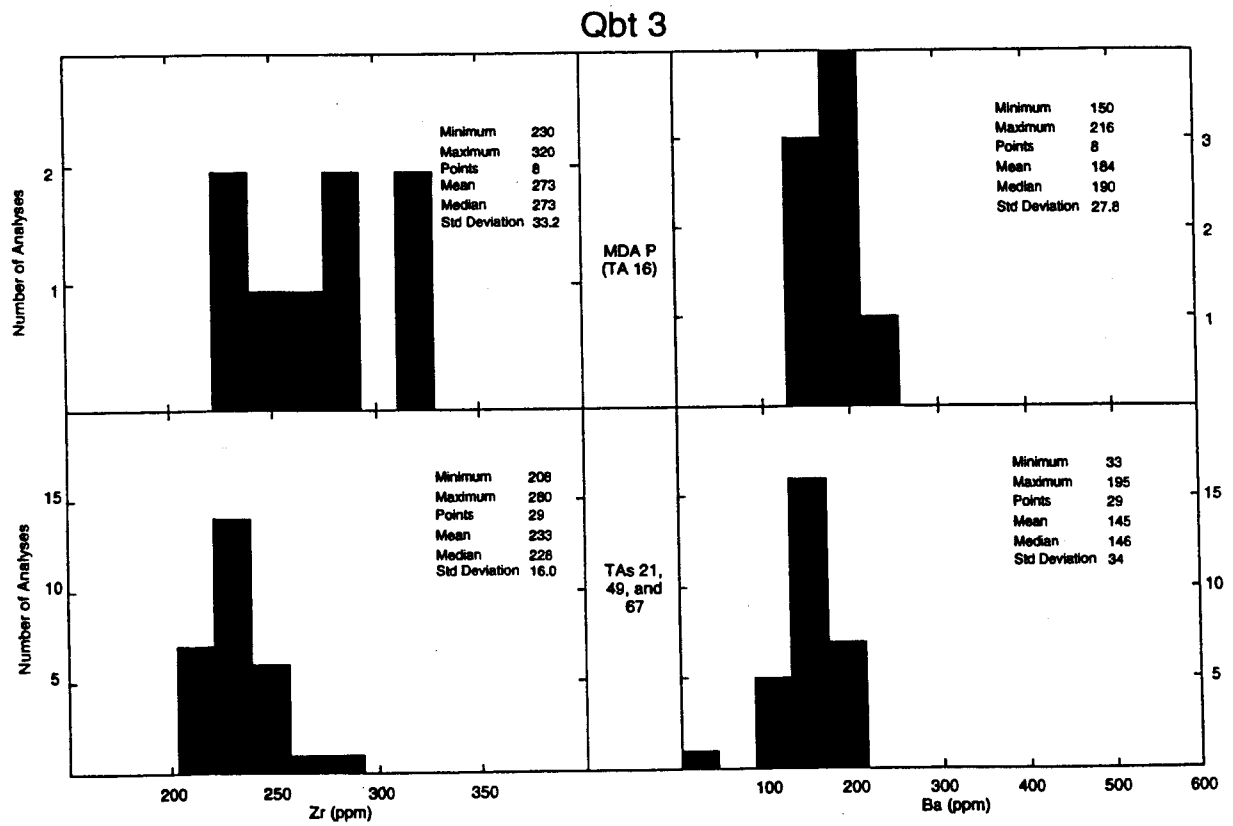

Qbt 3
Minimum 230
Maximum 320
Points 8
Mean 273
Median 273
Std Deviation 33.2
MDA P
(TA 16)
Minimum 150
Maximum 216
Points 8
Mean 184
Median 190
Std Deviation 27.8
Minimum 208
Maximum 280
Points 29
Mean 233
Median 228
Std Deviation 16.0
TAs 21,
49, and
67
Minimum 33
Maximum 195
Points 29
Mean 145
Median 146
Std Deviation 34
Number of Analyses
Zr (ppm)
Ba (ppm)

Fig. 4. (cont)

Qbt 4 is a lithologically complex unit consisting of, in ascending order: 1) a poorly indurated, white to light-gray, nonwelded ignimbrite; 2) an indurated light tan, nonwelded, cliff-forming tuff capped by a broad, talus-covered bench; 3) a varicolored, nonwelded, cliff-forming tuff that includes a devitrified base and a 3-m thick glassy upper part (Fig. 5); 4) a crystal-rich surge bed 0.25 m-thick, and 5) a hard, densely-welded tuff that forms the caprock of the mesa. The uppermost unit in Qbt 4 has a thin (0.5 m) flaggy vitric base which grades up into a massive, hematitic stained, devitrified upper part. The upper part of MDA P was developed in the lower two subunits of Qbt 4 (Fig. 2); the upper units of Qbt 4, including the vitric tuffs, were removed by erosion before the material disposal area was sited.

There are differences in total elemental concentrations between Qbt 3 and Qbt 4 at MDA P (Appendix I) and the same units exposed at other parts of the Laboratory (Broxton et al., 1996a). For instance, Qbt 3 at MDA P includes some tuffs that are intermediate in composition to Qbt 3 and Qbt 4 tuffs at TA 21, TA 49, and TA 67 (Fig. 4). Similarly, Qbt 4 tuffs at MDA P are slightly less-evolved (lower SiO_2 and greater TiO_2, Zr, and Ba) compared to Qbt 4 tuffs at TA 49 and TA 67 (Fig. 4). These differences in total elemental concentrations probably are due to the proximity of MDA P to the Valles caldera, which is the source area for the Bandelier Tuff. Because of its proximal location, a great thickness of ignimbrites was deposited at MDA P, including many smaller ignimbrites that were not deposited as far east as TA 21, TA 49, and TA 67. Thus, Qbt 3 and Qbt 4 at MDA P have wide compositional ranges because they include tuffs not deposited at more distal parts of the Pajarito Plateau. As discussed below, there also are differences between the acid-leachable compositions at MDA P and Laboratory-wide background values, resulting in our use of local background data for Qbt 3.

Total and acid-leachable concentrations for many elements in the Bandelier Tuff are also strongly affected by the mineralogy of the tuffs. The mineralogy is divided into two components, which are largely independant of each other. The primary mineralogy, which makes up 10 to 30% of the tuff, consists of relatively large free-standing crystals (mostly alkali feldspar and quartz) which grew in the magma chamber before eruption. The matrix mineralogy includes all other material that was co-erupted with the phenocrysts, and it consists of highly-fragmented chilled magma in the form of volcanic glass and includes small amounts of crystalline material that occur as exotic lithics. Following emplacement, most of the volcanic glass in tuffs at MDA P was replaced by crystalline phases (minerals) during slow cooling of the tuff.

The bulk mineralogy (combined primary and matrix mineralogy) of the tuffs at MDA P was determined by x-ray diffraction (Appendix II). The mineralogy of Qbt 3 is relatively simple, consisting of alkali feldspar + tridymite + quartz + cristobalite (Fig. 5). Smectite is present as a trace mineral (<1%). Qbt 4 contains a similar mineral assemblage to that of Qbt 3, but it is more complex because it contains a glassy zone in the upper part of the unit (Fig. 5). The glassy zone in Qbt 4 is marked by relatively high glass contents (up to 50%) and abrupt decreases in all crystalline components (Fig. 5). Glassy zones in Qbt 4 have not been described in previous geologic studies, although another outcrop of this horizon occurs along State Road 4 about 2 km south of MDA P.

The four samples of glassy tuff sampled in the upper Qbt 4 have distinctive patterns of elemental enrichment or depletion compared to the crystalline tuffs that occur above and below them. However, the patterns of enrichment or depletion are not uniform except for a few elements such as lead which is consistently depleted and sulfate which is consistently en-

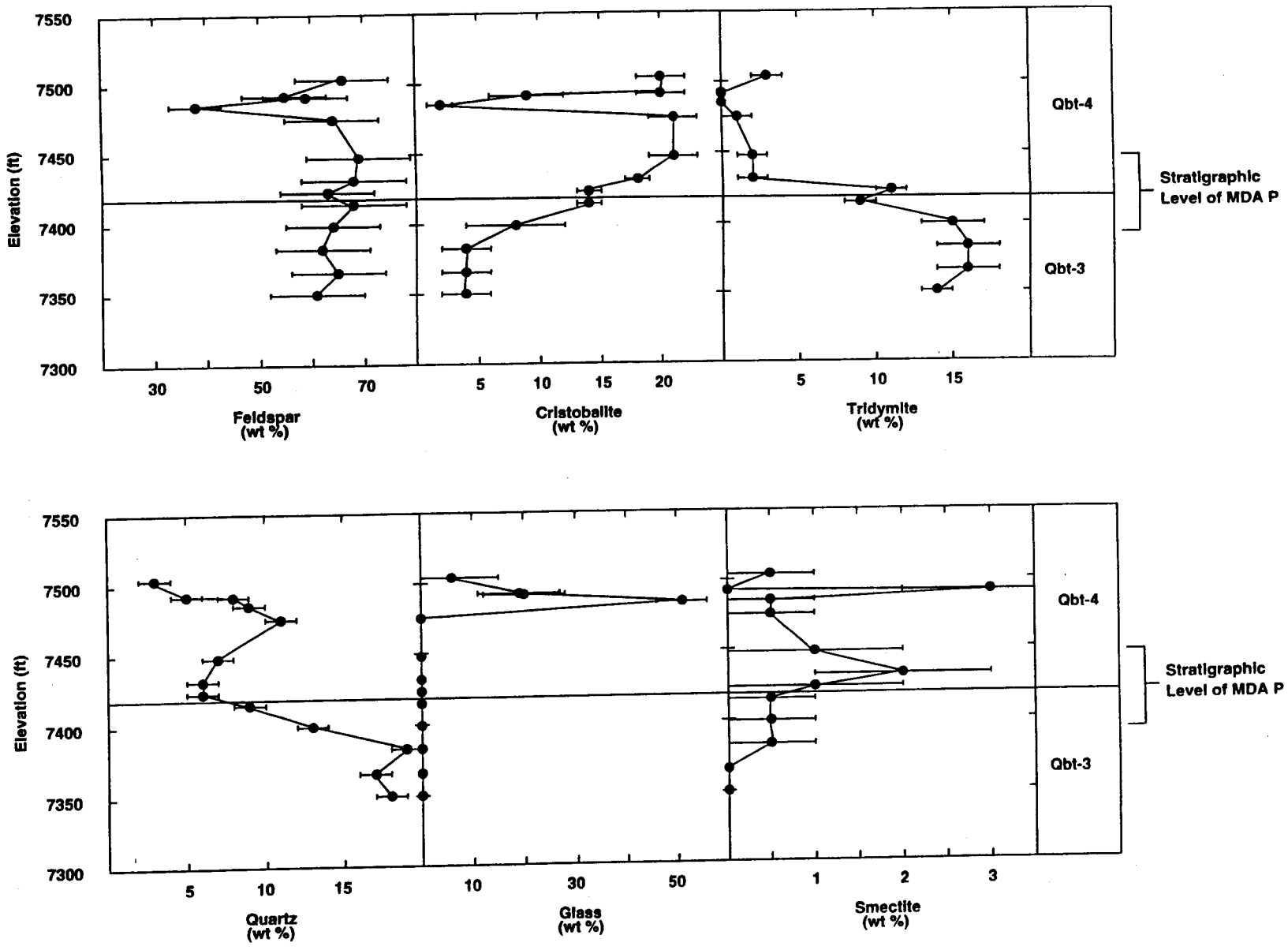


Fig. 5. Mineralogy of the Bandelier Tuff on the north wall of Canon de Valle (Samples DEB 5/95-1 through DEB 5/95-13). Error bars are two standard deviation estimates of analytical uncertainty. Data from Appendix II.

riched. These heterogeneities in the compositions of the tuffs as a function of mineralogy are not critical for determining backgrounds at MDA P itself because the glassy tuffs occur above the level of the material disposal area. However, the effects of mineralogy on background chemistry will need to be addressed for staging areas for materials removed from MDA P, which are sited in the vitric tuffs of Qbt 4. Separate backgrounds are being determined for these staging areas, and they will be reported separately.

In general, the bulk mineralogy of Qbt 4 is characterized by less tridymite and quartz and by more cristobalite than Qbt 3 (Appendix II). The pattern of tridymite and cristobalite distributions in Qbt 3 and Qbt 4 is similar to that found at the proposed Mixed Waste Disposal Facility at TA-67 (Broxton et al., 1996b) and at TA-49 (Stimac et al., 1996). These mineralogic relationships suggest that Qbt 3 has undergone more vapor-phase crystallization than Qbt 4. The decrease in quartz in Qbt 4 primarily reflects the change in magma chemistry that took place with the eruption of Qbt 4 (Figs. 3 and 4), with the Qbt 4 magmas crystallizing less phenocrystic quartz.

Petrographic analyses for phenocryst minerals for the Tshirege Member at MDA P are summarized in Appendix III. Phenocrysts, particularly trace minerals, strongly affect rock chemistry because they are highly concentrated in many elements, particularly trace elements (Hurley and Fairbairn, 1957; Watson and Harrison, 1984). An example of correlation between phenocryst mineralogy and rock chemistry is seen in Figure 6, which compares the P_2O_5 content of Tshirege Member at MDA P with the content of apatite, a phosphate, in these same samples. A similar correlation for Ca and Sr with plagioclase, which strongly concentrates

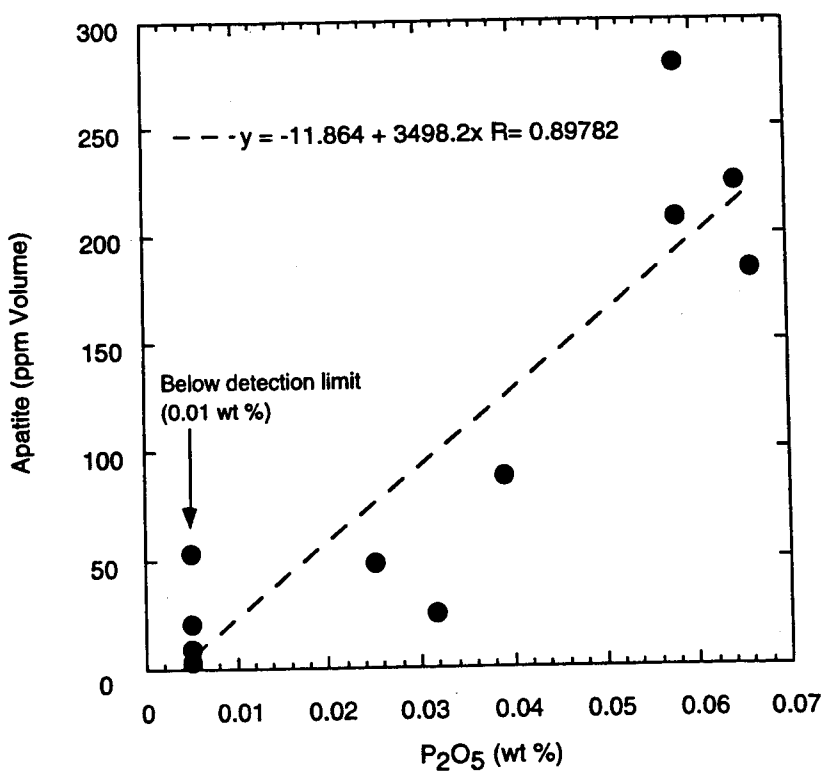


Fig. 6. Comparison of total concentration P2O5 determined by XRF with apatite abundances from detailed petrographic analysis. Petrographic data have been recalculated to void- and lithic-free abundances using data in Appendix III.

these elements (compare Appendixes I and III). Other elements reported in Appendix I generally correspond well to abundances for those phenocrysts reported in Appendix III that are expected to concentrate the particular element.

STATISTICAL APPROACH

Statistical Analysis of Bandelier Tuff

The background chemical data are used to support the Resource Conservation and Recovery Act (RCRA) closure of MDA P (Technical Area 16, Material Area P Closure Plan, Revision 0, February, 1995). As a part of the RCRA closure process, data are compared to natural background concentrations of inorganic analytes. Statistical comparisons will include comparing post-closure data to geologically appropriate background screening values (or hot measurement comparison). The background screening value for inorganic analytes is the upper tolerance limit (UTL) calculated as the upper 95% confidence limit of the 95th percentile. In addition to the background screening comparison, other statistical tests may be used to determine if there are any residual elevated concentrations. The other tests include distribution shift tests discussed in the ER Project policy paper on background comparisions (Environmental Restoration Project Assessments Council 1995, 1218).

The statistical analysis of the background data consists of the following steps:

a) determine if the MDA P Qbt 4 chemical data can be combined with Laboratory-wide Qbt 4 chemical data (Broxton et al., 1996a) to produce a single set of new LANL Qbt 4 background data.

b) determine if the MDA P Qbt 3 chemical data can be combined with Laboratory-wide Qbt 3 chemical data (Broxton et al., 1996a) to produce a single set of new LANL Qbt 4 background data.

c) determine if there are significant chemical differences between Qbt 4 and other units of the Tshirege Member.

d) estimate the type of data distribution for each inorganic analyte so that UTLs can be calculated.

e) calculate background screening values for each analyte by stratigraphic unit using either UTLs where satisfactory statistics are available or the maximum reported values for infrequently detected analytes or sparsely sampled stratigraphic units.

Initial Data Analysis Steps

Some of the inorganic results in the combined background rock data set are reported as less than the detection level (<DL). To facilitate statistical analysis of the data, all values reported as <DL were replaced by one-half of the detection limit. This replacement approach is recommended in the EPA risk assessment guidance (EPA 1992, 1166). Concentrations below detection limits commonly occurred for antimony, selenium, silver, and thallium. These analytes are excluded from further statistical analyses.

Comparison of Units Qbt 3 and Qbt 4 of the Tshirege

Box plots for all inorganic chemical data are presented in Figure 7. These box plots compare background elemental concentrations for units Qbt 3 and Qbt 4 at MDA P as well as MDA P background chemical data to Laboratory-wide background chemical data for these units (Broxton et al., 1996a). Actual values (as filled circles) are shown for each stratigraphic unit. The ends of the box represent the "inter-quartile" range of the data distribution. The inter-quartile range is specified by the 25th percentile and 75th percentile of the data distribution. The horizontal line within the box plot is the median (50th percentile) of the data distribution. Thus, the box indicates concentration values for the central half of the data, and concentration shifts can be readily assessed by comparing the boxes. If the majority of the data is represented by a single concentration value (usually the detection limit), the box is reduced to a single line.

Existing Laboratory-wide background data for units Qbt 3 and Qbt 4 and the MDA P data for units Qbt 3 and Qbt 4 were statistically compared by the Wilcoxon rank sum test. The Wilcoxon rank sum test is one of the "distribution shift" methods discussed in the LANL ER Project Policy Paper on background comparisons (Environmental Restoration Project Assessments Council, 1995, 1218). The Wilcoxon rank sum test was also used to determine if unit Qbt 4 is chemically different from other units of the Tshirege Member. Statistical distributions that best model the data were used to calculate the UTLs.

Calculation of Background Screening Values

UTLs were calculated for all inorganic analytes where enough values were detected to allow estimation of the statistical distribution. Chloride, iron, and sulfate have unusual distributions, which do not allow use of a simple statistical distribution model. Therefore, we propose use of the maximum detected value as a background screening value for iron and sulfate as well as for the rarely detected elements (antimony, selenium, silver, and thallium).

For elements that are normally distributed without any data transformation and elements that are normally distributed after a square root transformation (1), we calculated parametric tolerance limits by using the following equation:

$$\text{UTL} = \text{mean} + \text{standard deviation} * k_{0.95,0.95} \quad (1)$$

The k-factor depends on the number of background samples; complete tables of k-factors are published in the RCRA ground water statistical analysis document (EPA 1989, 1141) and Gilbert (1987, 0312). Readers are referred to the LANL ER Project policy paper on background comparisons for example k-factors.

The UTLs for log normally distributed elements were estimated by a simulation process. These simulations were run in the S-plus statistical programming environment. The S-plus code is presented in Appendix V. These simulations were run for 10,000 trials, which were sufficient to estimate the log normal UTLs from two to three significant digits.

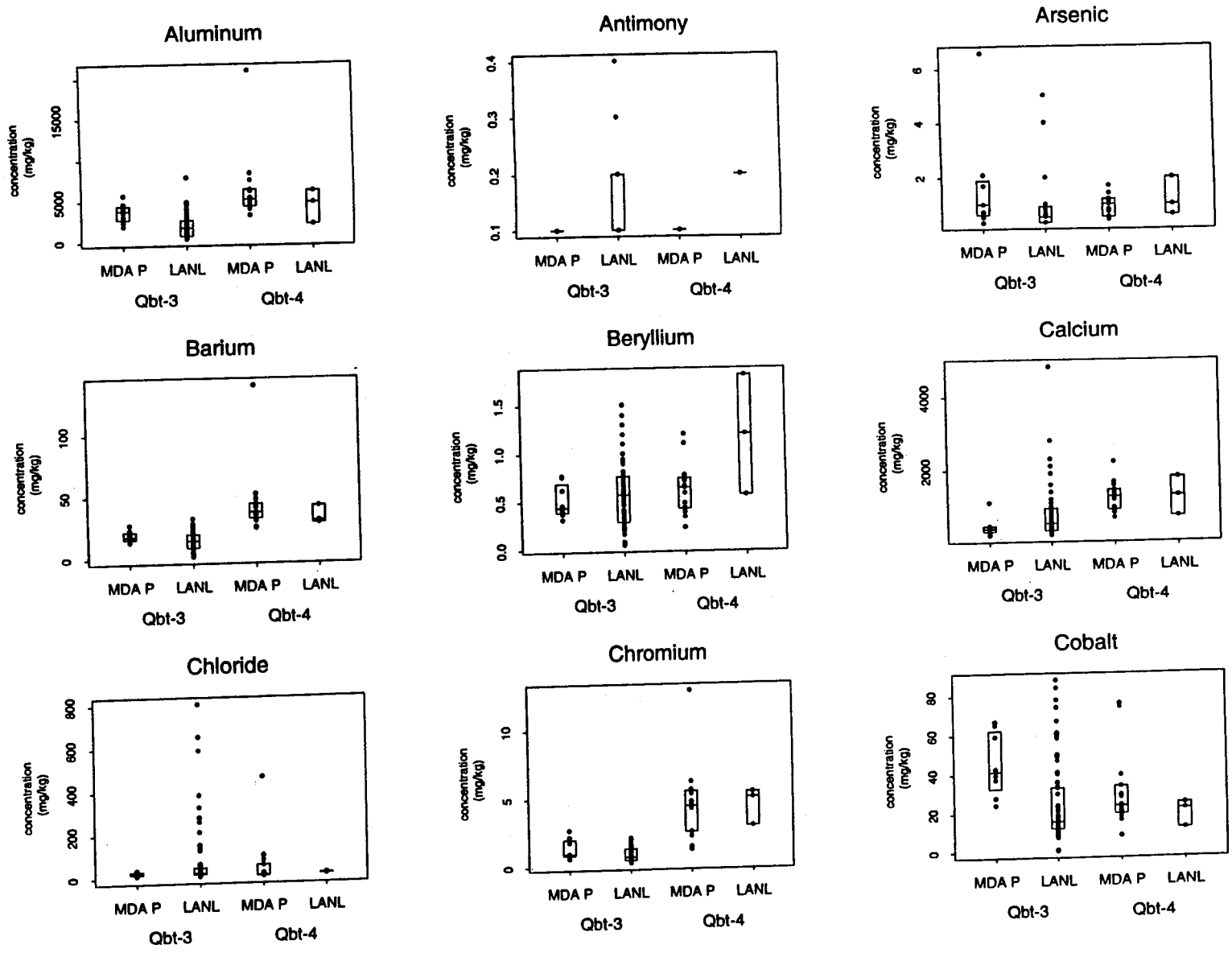


Fig. 7. Box plots of Qbt 3 and Qbt 4 chemical data from MDA P sampling and Laboratory-wide background sampling. Except for total uranium and thorium data, all analyses are leachable elemental concentrations as discussed in the text.

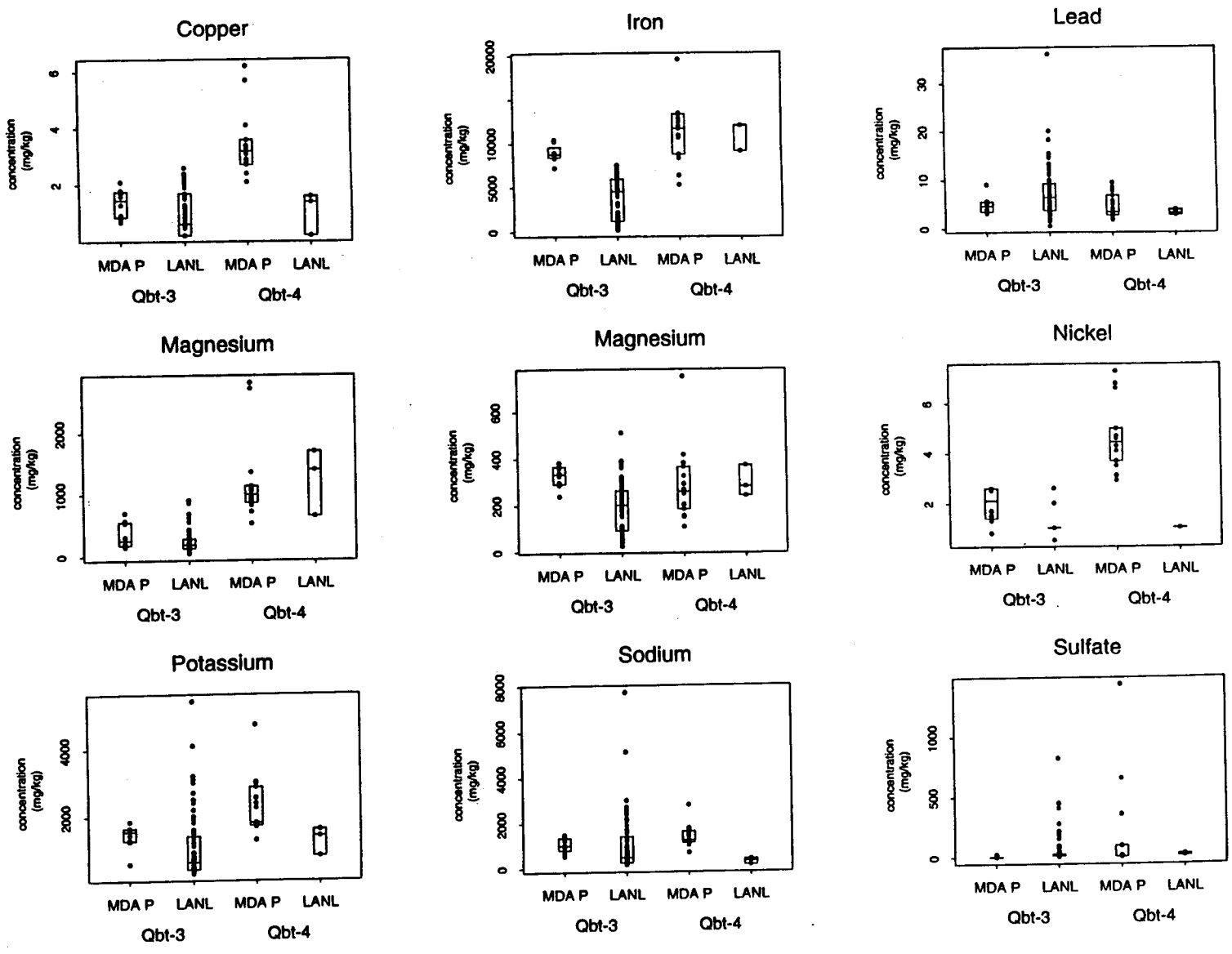

Copper
Iron
Lead
Magnesium
Magnesium
Nickel
Potassium
Sodium
Sulfate
concentration (mg/kg)
MDA P
LANL
Qbt-3
Qbt-4

Fig. 7. (cont)

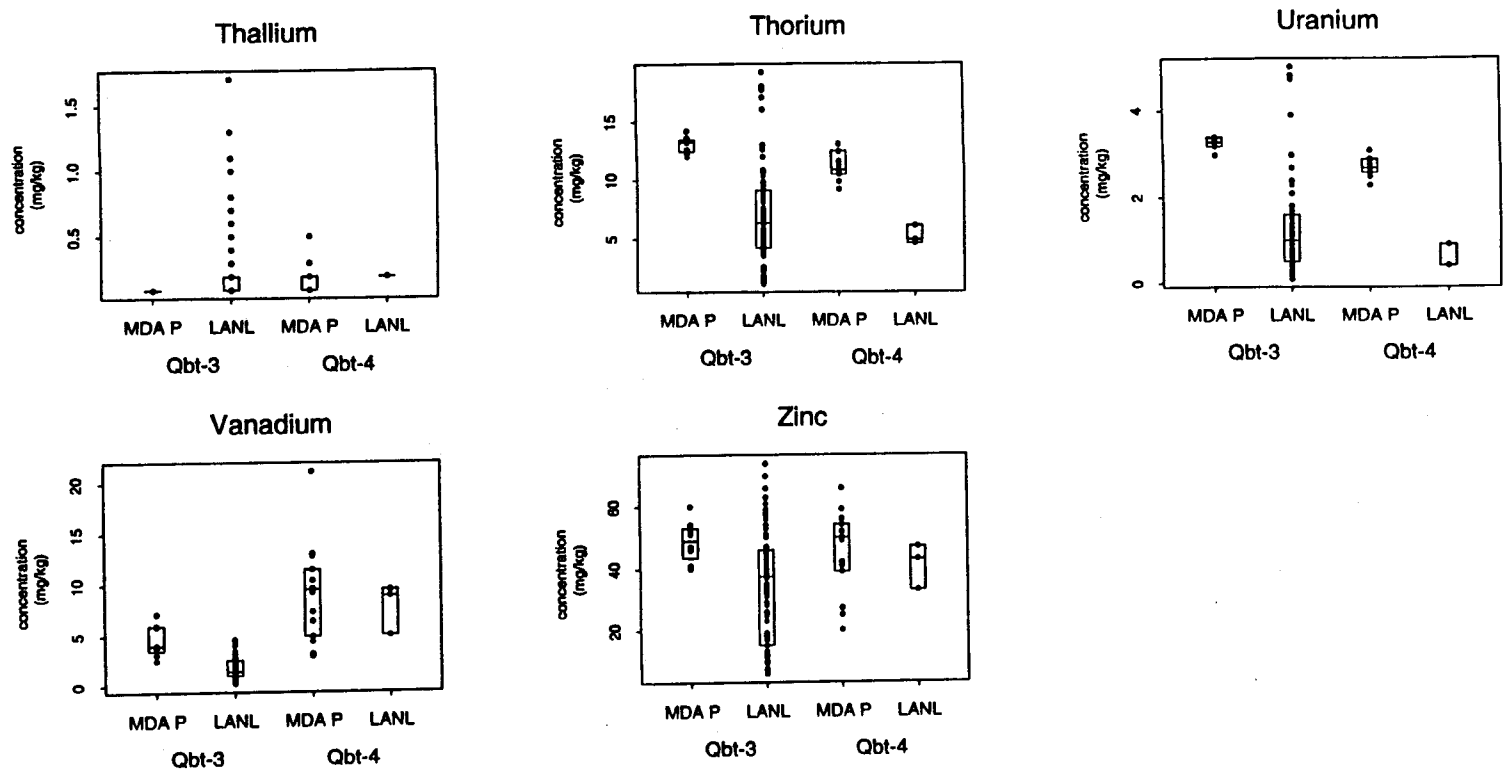

Thallium
concentration (mg/kg)
0.5
1.0
1.5
MDA P
LANL
MDA P
LANL
Qbt-3
Qbt-4
Thorium
concentration (mg/kg)
5
10
15
MDA P
LANL
MDA P
LANL
Qbt-3
Qbt-4
Uranium
concentration (mg/kg)
0
2
4
MDA P
LANL
MDA P
LANL
Qbt-3
Qbt-4
Vanadium
concentration (mg/kg)
0
5
10
15
20
MDA P
LANL
MDA P
LANL
Qbt-3
Qbt-4
Zinc
concentration (mg/kg)
20
40
60
MDA P
LANL
MDA P
LANL
Qbt-3
Qbt-4

Fig. 7. (cont)

The raw calculated UTL results were screened to ensure that the estimated UTLs were not artificially inflated due to a small sample size or by the presence of a single high concentration value, or outlier.

RESULTS AND DISCUSSION

Table I summarizes the detection limits, number of samples above and below detection limits, and the minimum, maximum, and mean value of samples above detection limits for all leachable inorganic analytes for MDA P and for Laboratory-wide Qbt 3 chemical data. Table II presents a summary of the same statistics for the combined Qbt 4 chemical data. The box plot summaries of all analytes are presented in Figure 7.

The Wilcoxon rank sum test indicated that the MDA P Qbt 4 chemical data can be combined with the Laboratory-wide background chemical data for Qbt 4. The advantage of combining these data is that a more robust estimate of the UTL will be calculated. The Wilcoxon rank sum test also clearly indicated that these Qbt 4 data are significantly different from the other Tshirege rock units. Most of the Wilcoxon rank sum test comparisons between the MDA P Qbt 3 chemical data and the Laboratory-wide background data for Qbt 3 indicated that there are significant chemical differences between these data sets. Thus, UTLs were calculated separately for MDA P based on the subset of site specific Qbt 3 chemical data. The results of all Wilcoxon rank sum tests are summarized in Table III.

Table IV summarizes the distribution properties of the Bandelier Tuff inorganic analytes. Distributions were either normally distributed or were transformed to normality with either a log- or square root transformation.

The calculated UTLs (or sample maximum) for inorganic constituents are presented in Tables I and II. There was one outlier for barium that had an unacceptable effect on the estimated UTL, and this outlier was trimmed before calculating the Qbt 4 barium UTL. A summary of these new background screening calculated for MDA P are presented with the Laboratory-wide background screening values in Table V. Qbt 4 is typically enriched in most major and trace elements relative to other Bandelier Tuff units. The local background data for Qbt 3 falls within the transitional zone in concentration values between the Laboratory-wide background data for Qbt 3 and Qbt 4.

Artificially high concentrations of cobalt were introduced into the samples analyzed by ICPES during sample preparation. Cobalt contamination was added to the samples during powdering the samples in a tungsten-carbide shatter box. Because acid leachable cobalt concentrations by ICPES are suspected of being in error, background screening levels for cobalt in the Bandelier Tuff (Table V) are based on the Laboratory-wide background data. The Laboratory-wide background data are based on maximum total cobalt concentrations determined by instrumental neutron activation analysis of samples powdered in a ceramic shatter box.

High concentrations of many elements analyzed by EPA SW846 methods are associated sample DEB5/95-11 which was collected from a surge deposit located in the upper part of Qbt-4 (Fig. 2). Though generally thin (<0.3 m), surge beds are not unusual at MDA P, and it should be expected that uncontaminated samples from similar lithologies may provide EPA SW846 analyses that approach or exceed background screening values for many elements. The unusual

TABLE I.
SUMMARY OF RESULTS FOR MDA P BEDROCK BACKGROUND SAMPLES FROM QBT 3.

Analyte (mg/kg)	MDA P									LANL								
	NON-DETECTS			DETECTS						NON-DETECTS			DETECTS					
	count	min	max	count	min	max	mean	st. dev.	UTL	count	min	max	count	min	max	mean	st. dev.	UTL
Aluminum	0			8	1910	5720	3690	1240	7650	0			27	400	3000	1160	729	3700
Antimony	8	0.1	0.1				0.05	0	NC	23	0.2	0.3	4	0.2	0.4	0.2	0.1	NC
Arsenic	0			8	0.33	6.6	1.7	2.0	9.81	6	0.5	0.5	21	0.5	5	1.1	1.1	NC
Barium	0			8	13.4	27.4	18.7	4.5	33.2	0			27	1.7	26	12.8	6.8	28.0
Beryllium	0			8	0.31	0.77	0.51	0.18	1.21	3	0.14	0.14	24	0.15	0.91	0.43	0.25	1.53
Cadmium	0			8	0.26	0.76	0.49	0.19	1.08									
Calcium	0			8	199	1120	448	286	1370	0			27	200	2100	605	498	1520
Chloride	0			8	8.6	34.8	20.6	9.2	NC	0			27	11	279	25.2	51.0	64.8
Chromium	0			8	0.62	2.7	1.4	0.76	3.80	10	0.5	2	17	0.6	2.1	1.1	0.60	NC
Cobalt	0			8	24.1	66.8	45.4	16.4	NC	0			27	9	34	15.5	5.5	NC
Copper	0			8	0.7	2.1	1.4	0.51	3.00	21	0.5	1.3	6	0.92	2	0.58	0.60	NC
Iron	0			8	7170	10400	8870	1040	NC	0			27	190	7500	3940	2820	9040
Lead	0			8	3.1	9	4.9	1.9	12.1	0			27	1.6	9.1	4.2	2.0	16.2
Magnesium	0			8	149	707	358	217	NC	0			27	42	550	218	131	628
Manganese	0			8	237	382	324	48.8	480	0			27	22	310	155	87.0	426
Nickel	0			8	0.83	2.6	2.0	0.72	NC	26	2	2	1	2	2	1.1	0.36	NC
Potassium	0			8	560	1860	1420	402	2970	0			27	250	800	420	132	735
Selenium	8	0.2	0.22	0			0.1	0.004	NC									
Silver	8	0.4	0.4	0			0.2	0	NC	26	1	1	1	1.9	1.9	0.6	0.3	NC
Sodium	0			8	531	1480	1040	335	2110	0			27	150	7700	538	1430	1940
Sulfate	0			8	1.5	27	5.7	8.7	NC	0			27	3.8	277	24.4	51.4	815
Thallium	8	0.1	0.1	0					NC	24	0.2	0.3	3	1	1.7	0.3	0.4	NC
Thorium-total	0			8	12	14.2	13.1	0.7	15.4	0			27	1.9	10.4	5.1	1.7	9.29
Uranium-total	0			8	3	3.4	3.3	0.1	3.72	0			27	0.2	5	0.9	0.9	4.37
Vanadium	0			8	2.5	7.1	4.5	1.6	9.65	5	0.5	0.5	22	0.89	1	2.0	1.3	4.01
Zinc	0			8	39.6	60.4	48.7	6.9	70.3	0			27	5.5	45	25.2	13.2	55.5

**Note: Means, standard deviations (st. dev.), and UTLs were calculated using 1/2 of the detection limits, where applicable.*
NC = UTL was not calculated, the maximum will be used a background screening value.
Total = Samples were analyzed for total elemental concentrations for these analytes.
LANL = Laboratory-wide background data (Broxton et al., 1996a).
Cobalt data are affected by contamination introduced by grinding of samples in a tungsten-carbide shatterbox. The background screening value for MDA P (1.39 mg/kg) is based on the Laboratory site-wide background screening value. This screening value was based on the maximum total cobalt concentration determined by instrumental neutron activation analyses.

TABLE II.
SUMMARY OF RESULTS FOR MDA P BEDROCK BACKGROUND SAMPLES FROM QBT 4.

Analyte	NON-DETECTS			DETECTS					
(mg/kg)	count	min	max	count	min	max	mean	st. dev.	UTL
Aluminum				18	2100	20900	6090	3990	15700
Antimony	18	0.1	0.3				0.1	0.04	NC
Arsenic				18	0.35	2	1.0	0.46	2.18
Barium (1)				18	24.4	139	42.4	25.3	56.6
Beryllium				18	0.22	1.8	0.72	0.39	1.82
Cadmium	1	0.2	0.2	14	0.46	1.5	0.80	0.32	1.63
Calcium				18	678	2230	1270	403	2770
Chloride				18	4.2	465	45.7	108	NC
Chromium				18	1.2	12.8	4.5	2.6	10.9
Cobalt				18	8.2	75.8	28.7	18.3	NC
Copper	1	0.5	0.5	17	1.4	6.2	3.0	1.4	6.43
Iron				18	5250	19500	11200	3140	NC
Lead				18	1.8	9.5	4.4	2.3	11.0
Magnesium				18	532	2820	1210	631	2950
Manganese				18	107	752	291	143	656
Nickel	3	2	2	14	2.9	7.3	4.0	1.9	8.72
Potassium				18	800	4720	2110	890	4540
Selenium	15	0.2	0.22	0			0.1	0.002	NC
Silver	18	0.4	1	0			0.3	0.1	NC
Sodium				18	130	2790	1210	615	3290
Sulfate				18	1.6	1430	146	361	NC
Thallium	10	0.1	0.3	8	0.11	0.49	0.2	0.1	NC
Thorium-total				18	4.6	13.1	10.3	2.6	16.5
Uranium-total				18	0.4	3.1	2.4	0.9	4.55
Vanadium				18	2.9	21.2	9.0	4.4	20.2
Zinc				18	20.1	65.6	44.8	12.4	75.4

**Note: Means, standard deviations (st. dev.), and UTLs were calculated using 1/2 of the detection limits, where applicable.*
NC = UTL was not calculated, the maximum will be used a background screening value.
(1) = One outlier was removed before calculating the mean, standard deviation and UTL.
Total = Samples were analyzed for total elemental concentrations for these analytes.
Cobalt data are affected by contamination introduced by grinding of samples in a tungsten-carbide shatterbox. The background screening value for MDA P (3.14 mg/kg) is based on the Laboratory site-wide background screening value. This screening value was based on the maximum total cobalt concentration determined by instrumental neutron activation analyses.

chemistry of surge deposits is due to their unique phenocryst mineralogy and lithology relative to the other tuffs (ignimbrites) collected for background chemical analysis. High values for leachable Ca, Ba, and Al (Appendix IV) and for whole-rock Ba and Sr (Fig. 3), and for whole-rock Al and Ca (Appendix I), reflect the high content of plagioclase phenocrysts in the surge deposit (DEB5/95-11 in Appendix III). The plagioclase is associated with a high content of felsic phenocrysts (Appendix III), which is characteristic of surge beds (Fisher, 1979). On the other hand, although high values for leachable Zn, Fe, and Mg (Appendix IV) parallel high values for whole-rock (Appendix I), no phenocrysts such as pyroxene, magnetite, or ilmenite that concentrate these elements occur in unusually high abundances (Appendix III). These elements were probably concentrated in the surge bed by secondary (alteration) processes,

TABLE III.
SUMMARY OF WILCOXON RANK SUM TEST RESULTS

Analyte	Qbt 3 MDA P vs LANL	Qbt 4 MDA P vs LANL	Qbt 4 vs other Tshirege units
Aluminum	MDA P > LANL	No significant difference	Qbt 4 > other units
Antimony	No detects	No detects	Insufficient detects
Arsenic	No significant difference	No significant difference	Qbt 4 > other units
Barium	No significant difference	No significant difference	Qbt 4 > other units
Beryllium	No significant difference	No significant difference	No difference
Cadmium	No LANL data	No LANL data	No LANL data
Calcium	No significant difference	No significant difference	Qbt 4 > other units
Chloride	MDA P > LANL	MDA P > LANL	other units > Qbt 4
Chromium	No significant difference	No significant difference	Qbt 4 > other units
Cobalt	MDA P will use LANL data	MDA P will use LANL data	MDA P will use LANL data
Copper	MDA P > LANL	MDA P > LANL	Qbt 4 > other units
Gross Alpha	No LANL data	No LANL data	No LANL data
Gross Beta	No LANL data	No LANL data	No LANL data
Iron	MDA P > LANL	No significant difference	Qbt 4 > other units
Lead	No significant difference	No significant difference	other units > Qbt 4
Magnesium	No significant difference	No significant difference	Qbt 4 > other units
Manganese	MDA P > LANL	No significant difference	Qbt 4 > other units
Nickel	Insufficient detects	MDA P > LANL	Qbt 4 > other units
Potassium	MDA P > LANL	MDA P > LANL	Qbt 4 > other units
Radium	No MDA P data	No MDA P data	No significant difference
Selenium	No LANL data	No LANL data	No LANL data
Silver	No detects	No detects	Too few detects
Sodium	MDA P > LANL	MDA P > LANL	Qbt 4 > other units
Sulfate	LANL > MDA P	MDA P > LANL	other units > Qbt 4
Tantalum	No MDA P data	No MDA P data	Qbt 4 > other units
Thallium	Insufficient detects	No significant difference	Insufficient detects
Thorium-total	MDA P > LANL	MDA P > LANL	Qbt 4 > other units
Uranium-total	MDA P > LANL	MDA P > LANL	Qbt 4 > other units
Vanadium	MDA P > LANL	No significant difference	Qbt 4 > other units
Zinc	MDA P > LANL	No significant difference	Qbt 4 > other units

Total = Samples were for total elemental concentrations for these analytes.
LANL = Laboratory-wide background data (Broxton et al., 1996a).

TABLE IV.
DISTRIBUTIONAL PROPERTIES OF THE MDA P QBT 3 AND THE COMBINED LABORATORY-WIDE AND MDA P QBT 4 DATA.

Analyte	Statistical Distribution
Aluminum	For data group Qbt 3, the data appear to originate from a normal distribution. The data for Qbt 4 appear to originate from a square root normal distribution.
Antimony	The data for both groups contain no detects, no distribution was estimated.
Arsenic	The data for Qbt 3 indicate a lognormal distribution. The data for Qbt 4 appear to originate from a normal distribution.
Barium	The data for both groups appears to originate from a normal distribution.
Beryllium	The data for both groups appears to originate from a square root normal distribution.
Cadmium	The data for both groups appears to originate from a log normal distribution.
Calcium	The data for both groups appears to originate from a log normal distribution.
Chloride	The data for both groups indicate a mixture distribution.
Chromium	The data for both groups appear to originate from a normal distribution.
Cobalt	The data for cobalt is affected by contamination introduced by use of a tungsten-carbide shatter box. Site-wide data will be used instead.
Copper	The data for both groups appear to originate from a normal distribution.
Iron	The data for both groups indicate a mixture distribution.
Lead	The data for both groups appears to originate from a square root normal distribution.
Magnesium	The data for Qbt 3 indicate a mixture distribution, while the data for Qbt 4 appear to originate from a square root normal distribution.
Manganese	The data for both groups appears to originate from a normal distribution.
Nickel	The data for Qbt 3 indicate a mixture distribution. The data for Qbt 4 appear to originate from a normal distribution.
Potassium	The data for Qbt 3 indicate a normal distribution, while the data for Qbt 4 indicate a square root normal distribution.
Radium	The samples for Qbt 3 were not analyzed for radium; the data for Qbt 4 contain 2 detects. Therefore, no distribution was estimated for either group.
Selenium	Only one detect among both groups, no distribution was estimated.
Silver	The data for both groups contain no detects, no distribution was estimated.
Sodium	The data for both groups appears to originate from a square root normal distribution.
Sulfate	The data for both groups indicate a mixture distribution.
Tantalum	The samples for Qbt 3 were not analyzed for tantalum; the data for Qbt 4 contain 1 detect. Therefore, no distribution was estimated for either group.
Thallium	The data for Qbt 3 contain no detects; the data for Qbt 4 contain 8 detects. Therefore, no distribution was estimated for either group.
Thorium-Total	The data for both groups appears to originate from a normal distribution.
Uranium-Total	The data for both groups appears to originate from a normal distribution.
Vanadium	The data for both groups appears to originate from a normal distribution.
Zinc	The data for both groups appears to originate from a normal distribution.

Total = Samples were analyzed for total elemental concentrations for these analytes.

TABLE V.
SUMMARY OF BACKGROUND SCREENING VALUES FOR THE BANDELIER TUFF

Analyte (mg/kg)	Geologic strata						
	Qbt 4 LANL	Qbt 4 with MDA P	Qbt 3 LANL	Qbt 3 MDA P	Qbt 2 LANL	Qbt 1v LANL	Qbt 1g LANL
Aluminum	6200	15700	3700	7650	3700	8170	3700
Antimony	<0.3	<0.3	0.4	<0.1	0.3	0.3	<0.3
Arsenic	2	2.18	5	9.81	2	2	0.7
Barium	42.0	56.6	28.0	33.2	28.0	28.0	28.0
Beryllium	1.80	1.82	1.53	1.21	1.53	1.53	1.53
Cadmium	NA	1.63	NA	1.08	NA	NA	NA
Calcium	1800	2770	1520	1370	1520	4140	4140
Chloride	14.9	465	64.8	34.8	107	405	405
Chromium	5.4	10.9	2.1	3.80	1.6	1.7	0.94
Cobalt	3.14	3.14	1.39	1.39	1.34	1.78	1.27
Copper	1.6	6.43	2	3.00	2	2.6	2.4
Iron	12000	19500	9040	10400	9040	9040	3250
Lead	4	11.0	16.2	12.1	16.2	21.9	16.2
Magnesium	1700	2950	628	707	548	628	548
Manganese	370	656	426	480	533	533	273
Nickel	<2	8.72	2.6	2.6	<2	2	<2
Potassium	1600	4540	735	2970	2730	5540	2730
Silver	<1	<1	1.9	<0.4	<1	<2	<2
Selenium	NA	<0.22	NA	<0.22	NA	NA	NA
Sodium	390	3290	1940	2110	1940	4290	4290
Sulfate	26.4	1430	815	27	815	815	815
Thallium	<0.3	0.49	1.7	<0.1	1.3	1.7	0.7
Thorium-Total	15.6	16.5	16.3	15.4	25.9	30.1	37.1
Uranium-Total	2.93	4.55	4.37	3.72	7.12	7.59	10.1
Vanadium	9.50	20.2	4.01	9.65	4.01	4.01	1.67
Zinc	47.0	75.4	55.5	70.3	55.5	84.6	55.5

Total = Samples were analyzed for total elemental concentrations for these analytes.

LANL = Laboratory-wide background data (Broxton et al., 1996a).

Cobalt data are affected by contamination introduced by grinding of samples in a tungsten-carbide shatterbox. The background screening values are based on Laboratory site-wide background screening values taken from maximum total cobalt concentrations determined by instrumental neutron activation analyses.

probably in association with the relatively high clay content of DEB5/95/11 (Fig. 5). Thus, for DEB5/95-11 the combination of unusual lithology and alteration have resulted in EPA SW846 analyses for many elements that approach background screening values and far exceed the background screening value for Ba.

SUMMARY

Local background samples were collected in support of the MDA P closure plan. The bedrock units at MDA P consist of Qbt 3 and Qbt 4 of the Bandelier Tuff. UTLs calculated for these background samples will be used to make screening level background comparisons. The background screening values for Qbt 4 are based on the combined data sets for MDA P Qbt 4 chemical data and for Laboratory-wide background data. Comparisons between MDA P Qbt 3 chemical data and Laboratory-wide background data for Qbt 3 indicate that there are significant chemical differences between these data sets, and background screening values were determined separately for MDA P Qbt 3 chemical data. Other statistical tests should be used, as needed, to support comparisons to background data during implementation of the closure plan.

ACKNOWLEDGEMENTS

This work was funded by the Los Alamos National Laboratory ER Project as part of closure activities for MDA P. We thank Ken Bostick for his support. Pat Longmire provided a critical review of this document.

REFERENCES

Bish, D. L. and Chipera, S. J., 1988, Problems and solutions in quantitative analysis of complex mixtures by X-ray powder diffraction, in Advances in X-Ray Analysis (Plenum Press, New York, 1988), v. 31, p. 295-308.

Bish, D. L. and Chipera, S. J., 1989, Revised mineralogical summary of Yucca Mountain, Nevada, Los Alamos National Laboratory report LA-11497-MS.

Broxton, D.E., Ryti, R.T., Reneau, S.L., Duffy, C., and Longmire, P., 1996a, Natural background geochemistry of the Bandelier Tuff and other rock units, Los Alamos, New Mexico, Los Alamos National Laboratory Report LAUR-95-3468, in press.

Broxton, D.E., Vaniman, D., Byers, F.M., Jr., Chipera, S.J., Kluk, E.C., and Warren, R.G., 1996b, Stratigraphy, mineralogy, and chemistry of bedrock tuffs at Pajarito Mesa, Los Alamos National Laboratory, New Mexico, Los Alamos National Laboratory Report LA-13089-MS, in press, 29p

Broxton, D.E., LaDelfe, C., Chipera, S.J., and Kluk, E.C., 1996c, Stratigraphy, mineralogy, and chemistry of bedrock tuffs at Mesita del Buey, Los Alamos National Laboratory, New Mexico, Los Alamos National Laboratory report, 32p., in press.

Broxton, D.E. and Reneau, S.L., 1995, Stratigraphic nomenclature of the Bandelier Tuff for the Environmental Restoration Project at Los Alamos National Laboratory, Los Alamos National Laboratory Report LA-13010-MS, 21p.

EPA (US Environmental Protection Agency), April 1989, "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities. Interim Final Guidance," Office of Solid Waste, Waste Management Division, US Environmental Protection Agency, Washington DC. (EPA 1989, 1141)

EPA (US Environmental Protection Agency), April 1992, "Guidance for Data Useability in Risk Assessment (Part A)," Office of Emergency Remedial Response, US Environmental Protection Agency, Washington DC. (EPA 1992, 1166)

Environmental Restoration Project Assessments Council, March 28,1995, Statistical Comparisons to Background, Part I," Los Alamos National Laboratory Report LA-UR-95-1217, Los Alamos, New Mexico. (Environmental Restoration Project Assessments Council 1995, 1218)

Fisher, R. V., 1979, Models for pyroclastic surges and pyroclastic flows, Journal of Volcanology and Geothermal Research, Vol. 6, pp. 305-318.

Gilbert, R.O., 1987, Statistical Methods for Environmental Pollution Monitoring., Von Nostrand Reinhold Company Inc., New York, 320 pp.

Hurley, P. M., and Fairbairn, H. W., 1957, Abundance and distribution of uranium and thorium in zircon, sphene, apatite, epidote, and monazite in granitic rocks, Transactions, American Geophysical Union, Vol. 38, No. 6, pp. 939-944.

Purtymun, W. D., 1995, Geologic and hydrologic records of observation wells, test holes, test wells, supply wells, springs, and surface water in the Los Alamos area: Los Alamos National Laboratory Report LA-12883-MS, 339 p.

Stimac, J.A., Broxton, D.E., Kluk, E., and Chipera, S., 1996, Preliminary stratigraphy of tuffs from borehole 49-2-700-1 at Technical Area 49, Los Alamos National Laboratory, New Mexico, Los Alamos National Laboratory report, in press.

Watson, E. B., and Harrison, T. M., 1984, Accessory minerals and the geochemical evolution of crustal magmatic systems: a summary and prospectus of experimental approaches, Physics of the Earth and Planetary Interiors, Vol. 35, pp. 19-30.

APPENDIX I

TOTAL ELEMENTAL CONCENTRATIONS OF BEDROCK UNITS AT MDA P BY XRF

Sample Number	DEB5/95-1	DEB5/95-2	DEB5/95-3	DEB5/95-4	DEB5/95-5	DEB5/95-6	DEB5/95-7	DEB5/95-8
Stratigraphic Unit	Qbt 3	Qbt 3	Qbt 3	Qbt 3	Qbt 3	Qbt 4	Qbt 4	Qbt 4
XRF Fusion Number	5409	5410	5411	5412	5413	5414	5415	5416
Major Elements (wt. %)								
SiO_2	76.5 ± 1.0	76.5 ± 1.0	75.4 ± 1.0	75.0 ± 1.0	75.6 ± 1.0	72.9 ± 0.9	71.6 ± 0.9	72.2 ± 0.9
TiO_2	0.13 ± 0.01	0.12 ± 0.01	0.16 ± 0.01	0.18 ± 0.01	0.16 ± 0.01	0.24 ± 0.01	0.31 ± 0.01	0.29 ± 0.01
Al_2O_3	11.9 ± 0.2	12.0 ± 0.2	12.6 ± 0.2	12.8 ± 0.2	12.6 ± 0.2	13.3 ± 0.2	13.7 ± 0.2	13.7 ± 0.2
Fe_2O_3T	1.50 ± 0.05	1.54 ± 0.05	1.26 ± 0.05	1.36 ± 0.05	1.89 ± 0.06	2.32 ± 0.06	2.52 ± 0.06	2.46 ± 0.06
MnO	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.11 ± 0.01	0.08 ± 0.01	0.07 ± 0.01
MgO	<0.07	<0.07	0.08 ± 0.07	0.10 ± 0.07	<0.07	0.15 ± 0.07	0.27 ± 0.07	0.20 ± 0.07
CaO	0.17 ± 0.12	0.16 ± 0.12	0.32 ± 0.12	0.29 ± 0.12	0.23 ± 0.12	0.41 ± 0.11	0.74 ± 0.11	0.67 ± 0.11
Na_2O	4.03 ± 0.08	4.01 ± 0.08	4.00 ± 0.08	4.01 ± 0.08	4.22 ± 0.09	4.20 ± 0.09	4.51 ± 0.09	4.44 ± 0.09
K_2O	4.44 ± 0.05	4.47 ± 0.05	4.55 ± 0.05	4.56 ± 0.05	4.71 ± 0.05	4.66 ± 0.05	4.67 ± 0.05	4.71 ± 0.05
P_2O_5	0.01 ± 0.01	<0.01	<0.01	<0.01	<0.01	0.03 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
LOI	0.30	0.26	0.56	0.62	0.45	0.95	0.49	0.74
Totals	99.0	98.8	98.4	98.5	99.5	98.3	98.5	98.8
Trace Elements (ppm)								
V	8 ± 7	8 ± 7	11 ± 7	<7	<7	<8	11 ± 8	<8
Cr	<10	<10	<10	<10	<10	<10	<10	<10
Ni	12 ± 6	13 ± 6	<6	<6	<6	9 ± 6	14 ± 6	11 ± 6
Zn	32 ± 7	44 ± 8	16 ± 7	20 ± 7	52 ± 8	61 ± 8	62 ± 8	56 ± 8
Rb	103 ± 6	105 ± 6	101 ± 6	103 ± 6	102 ± 5	89 ± 6	80 ± 6	81 ± 6
Sr	27 ± 4	24 ± 4	44 ± 4	46 ± 4	30 ± 4	54 ± 4	105 ± 5	88 ± 4
Y	38 ± 4	34 ± 4	40 ± 5	32 ± 5	38 ± 6	40 ± 5	40 ± 5	36 ± 5
Zr	230 ± 10	237 ± 10	250 ± 10	268 ± 11	287 ± 11	336 ± 12	355 ± 13	360 ± 13
Nb	48 ± 6	46 ± 6	41 ± 6	42 ± 6	52 ± 6	43 ± 6	41 ± 6	46 ± 6
Ba	150 ± 25	150 ± 25	182 ± 25	213 ± 24	160 ± 25	302 ± 24	431 ± 27	428 ± 26

Elemental abundances determined by XRF; uncertainties are two standard deviation estimates of analytical precision.

APPENDIX I (CONT)

Sample Number	DEB5/95-9	DEB5/95-10	DEB5/95-11	DEB5/95-12	DEB5/95-13	DEB5/95-14	DEB5/95-15	DEB5/95-16
Stratigraphic Unit	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 3	Qbt 3	Qbt 3
XRF Fusion Number	5417	5418	5419	5420	5421	5422	5423	5424
Major Elements (wt. %)								
SiO_2	73.1 ± 0.9	71.8 ± 0.9	68.4 ± 0.9	71.3 ± 0.9	72.1 ± 0.9	74.3 ± 1.0	74.7 ± 1.0	74.0 ± 0.9
TiO_2	0.23 ± 0.01	0.22 ± 0.01	0.29 ± 0.01	0.26 ± 0.01	0.25 ± 0.01	0.17 ± 0.01	0.18 ± 0.01	0.18 ± 0.01
Al_2O_3	13.1 ± 0.2	13.5 ± 0.2	14.4 ± 0.2	13.9 ± 0.2	13.7 ± 0.2	12.8 ± 0.2	12.7 ± 0.2	12.8 ± 0.2
Fe_2O_3T	2.15 ± 0.06	2.22 ± 0.06	3.10 ± 0.06	2.49 ± 0.06	2.37 ± 0.06	2.07 ± 0.06	1.92 ± 0.06	1.89 ± 0.06
MnO	0.06 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
MgO	0.21 ± 0.07	0.18 ± 0.07	0.78 ± 0.06	0.22 ± 0.07	0.12 ± 0.07	0.13 ± 0.07	<0.07	<0.07
CaO	0.64 ± 0.11	0.49 ± 0.11	0.76 ± 0.11	0.51 ± 0.11	0.46 ± 0.11	0.39 ± 0.11	0.22 ± 0.12	0.31 ± 0.12
Na_2O	4.14 ± 0.08	3.82 ± 0.08	4.35 ± 0.09	4.23 ± 0.09	4.50 ± 0.09	4.21 ± 0.09	4.20 ± 0.09	4.43 ± 0.09
K_2O	4.55 ± 0.05	4.75 ± 0.05	4.20 ± 0.05	4.51 ± 0.05	4.80 ± 0.05	4.54 ± 0.05	4.79 ± 0.05	4.75 ± 0.05
P_2O_5	0.04 ± 0.01	0.03 ± 0.01	0.07 ± 0.01	0.04 ± 0.01	0.06 ± 0.01	<0.01	0.02 ± 0.01	0.03 ± 0.01
LOI	0.62	2.09	2.63	1.47	0.85	0.70	0.44	0.32
Totals	98.3	97.0	96.3	97.4	98.4	98.7	98.8	98.4
Trace Elements (ppm)								
V	<8	9 ± 7	20 ± 8	11 ± 8	<8	<7	<7	<7
Cr	<10	<10	<10	<10	<10	<10	<10	<10
Ni	<6	<6	23 ± 6	19 ± 6	9 ± 6	9 ± 6	9 ± 6	<6
Zn	49 ± 8	59 ± 8	63 ± 9	49 ± 8	39 ± 8	56 ± 8	62 ± 8	60 ± 9
Rb	83 ± 6	88 ± 5	56 ± 6	64 ± 6	78 ± 6	97 ± 6	104 ± 6	90 ± 5
Sr	77 ± 4	63 ± 4	107 ± 4	65 ± 4	70 ± 4	45 ± 4	28 ± 4	35 ± 4
Y	64 ± 6	45 ± 6	100 ± 8	54 ± 6	37 ± 5	37 ± 5	39 ± 6	27 ± 4
Zr	325 ± 12	338 ± 12	370 ± 13	385 ± 13	365 ± 13	277 ± 11	320 ± 12	312 ± 12
Nb	41 ± 6	41 ± 6	29 ± 6	40 ± 6	43 ± 6	43 ± 6	47 ± 6	44 ± 6
Ba	338 ± 25	317 ± 24	668 ± 35	343 ± 25	341 ± 25	205 ± 24	199 ± 24	216 ± 24

APPENDIX I (CONT)

Sample Number	DEB6/95-1	DEB6/95-2	DEB6/95-3	DEB6/95-4	DEB6/95-5	DEB6/95-6	DEB6/95-7
Stratigraphic Unit	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 4
XRF Fusion Number	5476	5477	5478	5479	5480	5481	5482
Major Elements (wt. %)							
SiO_2	70.7 ± 0.9	70.9 ± 0.9	70.9 ± 0.9	71.7 ± 0.9	67.8 ± 0.9	71.8 ± 0.9	70.9 ± 0.9
TiO_2	0.35 ± 0.01	0.36 ± 0.01	0.36 ± 0.01	0.35 ± 0.01	0.36 ± 0.01	0.34 ± 0.01	0.38 ± 0.01
Al_2O_3	14.1 ± 0.2	14.3 ± 0.2	14.3 ± 0.2	14.2 ± 0.2	15.4 ± 0.2	13.7 ± 0.2	14.2 ± 0.2
Fe_2O_3T	2.69 ± 0.06	2.72 ± 0.06	2.60 ± 0.06	2.69 ± 0.06	3.64 ± 0.06	2.64 ± 0.06	2.84 ± 0.06
MnO	0.07 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.05 ± 0.01	0.07 ± 0.01	0.09 ± 0.01
MgO	0.27 ± 0.07	0.25 ± 0.07	0.27 ± 0.07	0.23 ± 0.07	0.60 ± 0.06	0.33 ± 0.07	0.45 ± 0.07
CaO	1.00 ± 0.11	0.93 ± 0.11	0.99 ± 0.11	0.94 ± 0.11	0.74 ± 0.11	0.83 ± 0.11	1.07 ± 0.11
Na_2O	4.57 ± 0.09	4.73 ± 0.09	4.74 ± 0.09	4.67 ± 0.09	3.79 ± 0.08	4.48 ± 0.09	4.60 ± 0.09
K_2O	4.21 ± 0.05	4.42 ± 0.05	4.33 ± 0.05	4.44 ± 0.05	4.02 ± 0.05	4.53 ± 0.05	4.39 ± 0.05
P_2O_5	0.07 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.05 ± 0.01	0.08 ± 0.01	0.10 ± 0.01
LOI	1.18	0.53	0.54	0.48	3.02	0.57	0.50
Totals	98.0	98.7	98.6	99.3	96.5	98.9	99.0
Trace Elements (ppm)							
V	11 ± 9	20 ± 9	15 ± 9	14 ± 9	32 ± 9	16 ± 9	16 ± 9
Cr	<10	<10	<10	<10	21 ± 10	<10	<10
Ni	15 ± 6	15 ± 6	<6	<6	8 ± 6	<6	<6
Zn	58 ± 8	59 ± 8	47 ± 8	60 ± 9	67 ± 9	61 ± 9	71 ± 9
Rb	72 ± 6	75 ± 6	73 ± 6	73 ± 6	88 ± 6	76 ± 6	78 ± 6
Sr	134 ± 5	127 ± 5	136 ± 5	127 ± 5	103 ± 4	114 ± 5	144 ± 5
Y	32 ± 5	31 ± 5	35 ± 5	34 ± 5	35 ± 5	32 ± 5	36 ± 5
Zr	362 ± 13	376 ± 13	360 ± 13	379 ± 13	353 ± 13	366 ± 13	369 ± 13
Nb	40 ± 6	42 ± 6	34 ± 5	37 ± 6	41 ± 6	40 ± 6	39 ± 6
Ba	586 ± 32	598 ± 32	552 ± 31	553 ± 31	430 ± 26	464 ± 28	598 ± 32

APPENDIX II

MINERALOGY OF BEDROCK UNITS AT MDA P BY XRD

Sample Number		Smectite	Tridymite	Cristobalite	Quartz	Feldspar	Glass	Hematite	Mica	Total
DEB 5/95-1	Qbt-3	---	14 ± 1	4 ± 2	18 ± 1	61 ± 9	---	---	---	97 ± 9
DEB 5/95-2	Qbt-3	---	16 ± 2	4 ± 2	17 ± 1	65 ± 9	---	---	---	102 ± 9
DEB 5/95-3	Qbt-3	Trc	16 ± 2	4 ± 2	19 ± 1	62 ± 9	---	---	---	101 ± 9
DEB 5/95-4	Qbt-3	Trc	15 ± 2	8 ± 4	13 ± 1	64 ± 9	---	---	Trc	100 ± 10
DEB 5/95-5	Qbt-3	Trc	9 ± 1	14 ± 1	9 ± 1	68 ± 10	---	---	---	100 ± 10
DEB 5/95-6	Qbt-4	1 ± 1	11 ± 1	14 ± 1	6 ± 1	63 ± 9	---	---	---	95 ± 9
DEB 5/95-7	Qbt-4	2 ± 1	2 ± 1	18 ± 1	6 ± 1	68 ± 10	---	Trc	---	96 ± 10
DEB 5/95-8	Qbt-4	1 ± 1	2 ± 1	21 ± 2	7 ± 1	69 ± 10	---	Trc	Trc	100 ± 10
DEB 5/95-9	Qbt-4	Trc	1 ± 1	21 ± 2	11 ± 1	64 ± 9	---	1 ± 1	---	98 ± 9
DEB 5/95-10	Qbt-4	Trc	---	2 ± 1	9 ± 1	38 ± 5	51 ± 5	Trc	---	100 ± 5
DEB 5/95-11	Qbt-4	3 ± 1	---	9 ± 3	8 ± 1	59 ± 8	20 ± 8	1 ± 1	---	100 ± 9
DEB 5/95-12	Qbt-4	---	---	20 ± 2	5 ± 1	55 ± 8	19 ± 8	1 ± 1	---	100 ± 8
DEB 5/95-13	Qbt-4	Trc	3 ± 1	20 ± 2	3 ± 1	66 ± 9	6 ± 9	2 ± 1	---	100 ± 9
DEB 5/95-14	Qbt-3	---	14 ± 1	7 ± 3	11 ± 1	64 ± 9	---	Trc	---	96 ± 10
DEB 5/95-15	Qbt-3	1 ± 1	10 ± 1	15 ± 2	6 ± 1	69 ± 10	---	---	---	101 ± 10
DEB 5/95-16	Qbt-3	Trc	3 ± 1	22 ± 2	8 ± 1	62 ± 9	---	Trc	---	95 ± 9
DEB 6/95-1	Qbt-4	---	6 ± 1	12 ± 1	7 ± 1	70 ± 10	---	Trc	---	95 ± 10
DEB 6/95-2	Qbt-4	1 ± 1	7 ± 1	13 ± 1	7 ± 1	68 ± 10	---	1 ± 1	---	97 ± 10
DEB 6/95-3	Qbt-4	1 ± 1	5 ± 1	13 ± 1	7 ± 1	72 ± 10	---	Trc	---	98 ± 10
DEB 6/95-4	Qbt-4	Trc	5 ± 1	13 ± 1	7 ± 1	71 ± 10	---	Trc	---	96 ± 10
DEB 6/95-5	Qbt-4	6 ± 2	---	19 ± 1	7 ± 1	63 ± 9	---	Trc	---	95 ± 9
DEB 6/95-6	Qbt-4	Trc	---	20 ± 2	7 ± 1	70 ± 10	---	Trc	---	97 ± 10
DEB 6/95-7	Qbt-4	2 ± 1	---	17 ± 1	8 ± 1	71 ± 10	---	1 ± 1	---	99 ± 10

Mineral abundances reported as weight percent; uncertainties are two standard deviations estimates of analytical precision ; --- indicates mineral not detected; Trc = trace abundance (<0.5 wt. %).

APPENDIX III

MODAL PETROGRAPHY OF BEDROCK UNITS AT MDA P NORMALIZED VOID- AND LITHIC-FREE

Explanation of symbols used in Petrography table:

Symbols for lithology: NWT = nonwelded ignimbrite; PWT = partially welded ignimbrite; MWT = moderately welded ignimbrite; DWT = densely welded ignimbrite; WBE = partially welded bedded tuff (ignimbrite base surge).

Symbols for alteration and minor alteration: DV= devitrified (MG = microgranophyric; GR = granophyric; AX = axiolitic; MS = microspherulitic; SR = spherulitic; VP = vapor phase); AR = argillic; OP = opaline; GL = vitric.

Symbols for thin section type and light: PS = polished section; RT = reflected and transmitted light.

Mineral analysis method (first character applies to first following mineral or component, second character to second mineral, etc.): 0 = undeterminable; 1 = from point count #1; A = from summed areas of all grains; C = from number of grains in section; E = extrapolated from summed areas of largest grains; L = estimated from summed areas of largest grains.

Symbols for minerals and components: CA = chalcopyrite; GT = garnet; GX = groundmass Fe-Ti oxides; GZ = groundmass zircon; MN = monazite; PC = colorless pumiceous glass; PO = pyrrhotite; PP = pale brown pumiceous glass; SB = brown glass shards; SP = pale brown glass shards; SC = colorless glass shards.

Qualifying symbols for minerals and components: negative sign = all pseudomorhic; no abundance provided = present but not determined.

Note: Sample RW16PC3 is 15 ft southwest of Staging Area 1 of MDA P, with approximate New Mexico State Plane coordinates N1614850 ft, E176795 ft, elevation 7512 ft.

APPENDIX III (CONT)

Sample Number	RW16PC3	DEB5/95-13	DEB5/95-11	DEB5/95-10	DEB5/95-9	DEB5/95-8	DEB5/95-7
Stratigraphic Unit	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 4	Qbt 4
Lithology	PWT	DWT	WBE	PWT	PWT	NWT	NWT
Major Alteration	GL	MG/AX	GL/MG	GL	MG/MS	MG/MS	MG/MS
Minor Alteration		HM/VP/GL	AR/OP		VP/GL	VP	VP/GL
Thin Section Area (mm^2)	289	311	288	273	262	320	299
Points Counted	290	312	289	328	259	321	300
Felsics Total (volume %)	22.14	20.88	34.72	15.55	27.53	20.19	20.46
Quartz (volume %)	1.58	1.68	3.70	2.12	4.49	0.41	1.54
Alkali Feldspar (volume %)	18.98	17.82	28.24	13.04	22.06	18.26	17.76
Plagioclase (volume %)	1.58	1.37	2.78	0.39	0.97	1.51	1.16
Biotite (volume ppm)	0	4	0	3	22	3	23
Hornblende (volume ppm)	19	56	22	58	17	80	0
Orthopryoxene (volume ppm)	2431	4750	3921	832	1734	2367	2159
Clinopyroxene (volume ppm)	1614	1899	6178	2530	5639	2749	3000
Olivine (volume ppm)	0	219	0	3	0	0	
Mafic Total (volume ppm)	4064	10320	10159	3723	7413	5356	5385
Magnetite (volume ppm)	710	5423	5090	3137	3064	2276	2401
Ilmenite (volume ppm)	198	444	210	43	6	200	393
Perrierite (volume ppm)	6	3	19	24	2E+02	16	0
Apatite (volume ppm)	279	293	245	28	128	253	260
Zircon (volume ppm)	66	2E+02	92	4E+02	2E+02	1E+02	2E+02
Pyrrotite (volume ppm)	29	4	21	36	7	69	12
Chalcopyrite (volume ppm)							
Monazite (volume ppm)	2			3			
Garnet (volume ppm)				17			
Felsics Method	1111A1111	1111111	11111111111	11111111111	1111L11	1A11111	1111111
Felsics Total %	14.48	19.87	25.95	13.41	18.92	16.54	17.67
Quartz Relative %	7.14	8.06	10.67	13.64	16.33	2.05	7.55
Alkali Feldspar Relative %	85.71	85.35	81.33	83.85	80.14	90.48	86.79
Plagioclase Relative %	7.14	6.58	8.00	2.51	3.53	7.47	5.66
Lithics %	0.12	0.32	0.35	0.91	0.39	1.87	2.67
Voids %	34.48	4.49	24.91	12.80	30.89	16.20	11.00
Comp1 ID	SC	GX	PC	SP	GX	GX	GX
Comp1 %	20.69	0.64	9.00	6.71	0.00	0.00	0.00
Comp2 ID	PC		PP	PC			
Comp2 %	8.62		1.73	6.10			
Comp3 ID	GX		SB	SC			
Comp3 %	0.00		1.38	4.27			
Comp4 ID			SC	PP			
Comp4 %			0.35	0.91			
Comp5 ID			GX	GX			
Comp5 %			0.00	0.00			
Mafic Method	AAAAA	AAEEEE	AAAAAA	AAAAAA	AAAAA	AAEEAE	AAEE0E
Biot ppmV	0	4	0	2	15	3	20
Hbld ppmV	12	54	17	50	11	65	0
Opx ppmV	1590	4522	2930	718	1192	1940	1864
Cpx ppmV	1055	1808	4617	2183	3876	2252	2590
Olv ppmV	0	-208	0	-3	0	0	
Mafic ppmV		-3228	-28	-256		-128	-175
Namaf Method	AA	AA	AA	AA	AA	AA	AA
Acm ppmV	0	0	0	0	0	0	0
Arf ppmV	0	0	0	0	0	0	0
Namaf ppmV							
Fe Oxide Method	AA	EE	EE	EE	AA	EE	EE
Mt ppmV	464	5162	3804	2706	2105	1865	2073
Ilm ppmV	129	423	157	37	4	164	339
Access Method	AAAAAAA	AAACAA	AAAAAA	AAAAAAAA	AAAAAA	AAAAAA	AAAAAA
Sphene ppmV	0	0	0	0	0	0	0
Allan ppmV	0	0	0	0	0	0	0
Perri ppmV	4	3	15	21	1E+02	13	0
Apatite ppmV	183	279	183	25	88	207	224
Zircon ppmV	43	2E+02	69	3E+02	1E+02	95	2E+02
Omin1 ID	PO	PO	PO	PO	PO	PO	PO
Omin1 ppmV	19	-4	15	31	-5	57	11
Omin2 ID	MN			GT		GZ	GZ
Omin2 ppmV	1			15			
Omin3 ID				MN			
Omin3 ppmV				2			
Comments	PO almost entirely alt.	Voids include 1.28% voids after OY. MT mostly alt. Other mafic=OY.	PO almost entirely alt. CX,OX partly alt.	PO almost entirely alt. CX,OX partly alt.		PO almost entirely alt.	Other mafic=OY. PO mostly alt.

APPENDIX III (CONT)

Sample Number	DEB5/95-6	DEB6/95/4	DEB5/95-15	DEB5/95-5	DEB5/95-4	DEB5/95-3	DEB5/95-2
Stratigraphic Unit	Qbt 4	Qbt 3	Qbt 3	Qbt 3	Qbt 3	Qbt 3	Qbt 3
Lithology	NWT	NWT	PWT	MWT	MWT	NWT	MWT
Major Alteration	MG/VP	MG/MS/VP	MG/VP	MG/AX/VP	MG/AX/VP	MG/VP	MG/AX/VP
Minor Alteration	GR	GL		GL		GR/GL	GL
Thin Section Area (mm^2)	339	284	304	311	308	262	330
Points Counted	335	285	301	312	309	263	326
Felsics Total (volume %)	16.79	22.22	21.97	23.13	23.02	31.49	31.83
Quartz (volume %)	1.07	1.33	3.00	4.56	5.57	11.59	12.22
Alkali Feldspar (volume %)	15.36	18.69	18.97	18.57	17.38	19.81	19.52
Plagioclase (volume %)	0.36	2.20	0.00	0.01	0.07	0.09	0.10
Biotite (volume ppm)	0	26	0	0	0	5	50
Hornblende (volume ppm)	0	104	144	42	296	62	137
Orthopryoxene (volume ppm)	1094	3541		788			96
Clinopyroxene (volume ppm)	2416	5302		961			
Olivine (volume ppm)							
Mafic Total (volume ppm)	5394	9299	2505	3882	1164	2455	2713
Magnetite (volume ppm)	2239	2570	2695	2617	1051	898	1130
Ilmenite (volume ppm)	240	405	0	0	40	19	4
Perrierite (volume ppm)	36	18	41	21	88	10	40
Apatite (volume ppm)	58	446	45	54	21	3	9
Zircon (volume ppm)	1E+02	1E+02	79	76	33	46	45
Pyrrotite (volume ppm)	160	12	2				3
Chalcopyrite (volume ppm)		0					
Monazite (volume ppm)							
Garnet (volume ppm)							
Felsics Method	1111111	1111111	111AL11	111A111	111A111	111A111	1111111
Felsics Total %	14.03	17.54	21.93	22.76	22.73	24.79	30.37
Quartz Relative %	6.38	6.00	13.64	19.71	24.21	36.82	38.38
Alkali Feldspar Relative %	91.49	84.10	86.36	80.26	75.47	62.90	61.31
Plagioclase Relative %	2.13	9.90	0.00	0.03	0.32	0.28	0.31
Lithics %	0.90	1.40	0.19	0.32	0.65	7.22	2.15
Voids %	15.52	19.65	0.00	1.28	0.65	14.07	2.45
Comp1 ID	GX	GX	GX	GX	GX	GX	GX
Comp1 %	0.60	0.00	0.00	0.32	0.00	0.00	0.31
Comp2 ID							
Comp2 %							
Comp3 ID							
Comp3 %							
Comp4 ID							
Comp4 %							
Comp5 ID							
Comp5 %							
Mafic Method	AAAA0A	AAEE0E	AA000A	AAAA0A	AA000A	AA000A	AAA00A
Biot ppmV	0	20	0	0	0	4	48
Hbld ppmV	0	82	144	42	293	49	130
Opx ppmV	914	2795		776			92
Cpx ppmV	2019	4185		945			
Oliv ppmV							
Mafic ppmV	-1575	-258	2357	-2057	-857	-1879	-2318
Namaf Method	AA	AA	AA	AA	AA	AA	AA
Acm ppmV	0	0	0	0	0	0	0
Arf ppmV	0	0	0	0	0	0	0
Namaf ppmV							
Fe Oxide Method	AA	EE	EA	EA	AA	AA	AA
Mt ppmV	1871	2029	2690	2575	1037	707	1078
Ilm ppmV	201	320	0	0	40	15	4
Access Method	AAAAAA	AAAAAAA	AAAAAA	AAAAA	AAAAA	AAAAA	AAAAAA
Sphene ppmV	0	0	0	0	0	0	0
Allan ppmV	0	0	0	0	0	0	0
Perri ppmV	30	14	41	21	87	8	38
Apatite ppmV	48	352	45	53	21	3	9
Zircon ppmV	95	1E+02	79	75	32	36	43
Omin1 ID	PO	PO	PO	GZ			PO
Omin1 ppmV	-134	9	2				-3
Omin2 ID	GZ	CA					
Omin2 ppmV		0					
Omin3 ID		GZ					
Omin3 ppmV							
Comments	Phenos overgrown by GQ. Coarse GX is HM that jackets most OY; distinct from MT, which have lamellae. Est 10-50% of AP altered out, and a minor amount of PE might be alt out. Other mafic=OY.	Voids also incl .35% voids after OY. PO,OX,CX mostly alt. Other mafic=OY.	10-50% of AP altered out. Other mafic=OY. Most OY pseudomorphic, mantled by HM; v rare unidentifiable relicts. HN, PO partly alt.	Other mafic=OY.	10-50% of AP altered out. Other mafic=OY.	Trace of GL in QZ. VK overgrows PL,KF str, QZ weakly.	Other mafic=OY.

APPENDIX IV

SW 846 DATA USED TO CALCULATED UTLS FOR BEDROCK UNITS AT MDA P

Analytical information and Qualifiers Related to the SW 846 Analyses

These samples were analyzed under Los Alamos Request Number 968.

Analytical Methods Key: AS-2 = graphite furnace atomic absorption spectrometry; AS-5 = inductively-coupled plasma-atomic emission spectometry; AS-6 = inductively-coupled plasma-mass spectometry; D-3 = ion chromatography; RC-3 = gas proportional counting.

The usual holding times for chloride and sulfate is 28 days; this sample set exceeded the usual holding times by 55 to 78 days.

The recovery of antimony from the sample used for spike analysis was not within control limits, as indicated by the "N" qualifier.

A "+" qualifier beside the arsenic and selenium results indicate that the result was obtained by the method of standard addition (MSA). The MSA is required for a graphite furnace analysis if the analytical spike recovery is outside of control limits (85-115%) and the sample concentration is greater than or equal to 50% of the spike concentration. The "+" qualifier further signifies that the correlation coefficient for the MSA was less than 0.995.

The "E" qualifiers for the lead results indicates that the serial dilution differed from the sample by more than 10%, and the original sample result was more than 50 times the instrument detection limit.

A "W" qualifier next to arsenic and selenium results indicates that the analytical spike recovery for the graphite furnace analysis of selenium was outside of control limits (85-115%) and the sample concentration was less than 50% of the spike concentration.

A "M" qualifier next to arsenic result indicates that the graphite furnace atomic absorption duplicate injection precision was not met.

A "B" qualifier indicates that the reported value was obtained from a reading that was less than the required detection limit but greater than or equal to the actual detection limit. A "U" qualifier indicates that the analyte was not detected.

Except as noted above, all laboratory quality contral parameters were met.

Units Methods	Customer Id:	Lab ID	Strat. Unit	Elev. (ft)	Silver MG/KG AS-5 R05	Aluminum MG/KG AS-5 R05	Gross Alpha PCI/G RC-3 R03	Arsenic MG/KG AS-2 R06
Sample #								
DEB 5/95-1	ID: 0816-95-0001 01	230985	Qbt-3	7350.0	<0.40 U	3060	21 ± 8	0.33 U+
DEB 5/95-2	ID: 0816-95-0012 01	230996	Qbt-3	7366.0	<0.40 U	1910	22 ± 8	~0.98 B+
DEB 5/95-3	ID: 0816-95-0017 01	231001	Qbt-3	7383.0	<0.40 U	4660	27 ± 9	1
DEB 5/95-4	ID: 0816-95-0018 01	231002	Qbt-3	7399.0	<0.40 U	5720	30 ± 9	1.7
DEB 5/95-5	ID: 0816-95-0019 01	231003	Qbt-3	7415.0	<0.40 U	3620	26 ± 9	~0.72 B
DEB 5/95-6	ID: 0816-95-0020 01	231004	Qbt-4	7423.0	<0.40 U	6410	30 ± 9	1.4
DEB 5/95-7	ID: 0816-95-0021 01	231005	Qbt-4	7432.0	<0.40 U	4190	19 ± 8	~0.99 B
DEB 5/95-8	ID: 0816-95-0022 01	231006	Qbt-4	7448.0	~0.40 U	5410	20 ± 8	0.77 BW
DEB 5/95-9	ID: 0816-95-0023 01	231007	Qbt-4	7475.0	<0.40 U	4920	15 ± 7	1.2 S
DEB 5/95-10	ID: 0816-95-0002 01	230986	Qbt-4	7485.0	<0.40 U	7550	21 ± 8	~0.37 B
DEB 5/95-11	ID: 0816-95-0003 01	230987	Qbt-4	7491.4	~0.40 U	8370	21 ± 8	1.1
DEB 5/95-12	ID: 0816-95-0004 01	230988	Qbt-4	7491.9	<0.40 U	6180	26 ± 9	~0.35 B
DEB 5/95-13	ID: 0816-95-0005 01	230989	Qbt-4	7504.0	<0.40 U	3220	22 ± 8	~0.70 B+
DEB 5/95-14	ID: 0816-95-0006 01	230990	Qbt-3	7390.0	<0.40 U	4180	25 ± 8	6.6
DEB 5/95-15	ID: 0816-95-0007 01	230991	Qbt-3	7393.9	<0.40 U	4040	22 ± 8	2.1
DEB 5/95-16	ID: 0816-95-0008 01	230992	Qbt-3	7398.4	<0.40 U	2360	25 ± 8	~0.53 BW
DEB 6/95-1	ID: 0816-95-0009 01	230993	Qbt-4	7430.4	<0.40 U	6370	13 ± 7	1.4
DEB 6/95-2	ID: 0816-95-0010 01	230994	Qbt-4	7429.5	<0.40 U	4460	20 ± 8	~1.1 B+
DEB 6/95-3	ID: 0816-95-0011 01	230995	Qbt-4	7428.9	<0.40 U	4380	19 ± 8	1.2
DEB 6/95-4	ID: 0816-95-0013 01	230997	Qbt-4	7428.0	<0.40 U	4000	21 ± 8	~0.74 B+
DEB 6/95-5	ID: 0816-95-0014 01	230998	Qbt-4	7444.9	<0.40 U	20900	13 ± 7	1.7 N
DEB 6/95-6	ID: 0816-95-0015 01	230999	Qbt-4	7443.6	~0.40 U	5200	23 ± 8	~0.40 B
DEB 6/95-7	ID: 0816-95-0016 01	231000	Qbt-4	7442.2	<0.40 U	4870	11 ± 7	~0.48 B

APPENDIX IV (CONT)

Units Methods	Strat. Unit	Barium MG/KG AS-5 R05	Beryllium MG/KG AS-5 R05	Gross Beta PCI/G RC-3 R03	Calcium MG/KG AS-5 R05	Cadmium MG/KG AS-5 R05	Chloride MG/KG D-3 R12	Cobalt MG/KG AS-5 R05	Chromium MG/KG AS-5 R05
Sample #									
DEB 5/95-1	Qbt-3	15.1 B	0.4 B	35 ± 4	238 B	0.54	16	66.8	0.88 B
DEB 5/95-2	Qbt-3	27.4	~0.37 B	38 ± 4	~199 B	~0.46	14.2	28	~0.83 B
DEB 5/95-3	Qbt-3	~17.7	0.62	37 ± 4	~376 B	~0.26 B	8.6	59	1.8
DEB 5/95-4	Qbt-3	~19.5 B	~0.46 B	38 ± 4	~376 B	0.6	17.9	42.8	2.7
DEB 5/95-5	Qbt-3	~16.4 B	~0.41 B	39 ± 4	~457 B	~0.38 B	30.2	39.7	~0.97 B
DEB 5/95-6	Qbt-4	51.6	0.77	38 ± 4	879	0.9	5.3	24.2	4.2
DEB 5/95-7	Qbt-4	29.8	0.66	37 ± 4	913	0.82	56.6	28.3	4.4
DEB 5/95-8	Qbt-4	41.3	0.74	35 ± 4	1280	0.89	9.6	75.8	4.3
DEB 5/95-9	Qbt-4	25.4	0.73	35 ± 4	824	0.52	78.7	74	2.5
DEB 5/95-10	Qbt-4	24.4	0.58	39 ± 4	678	~0.46 B	16.6	39.4	2.2
DEB 5/95-11	Qbt-4	139	1.2	34 ± 4	2230	0.7	465	34	2.5
DEB 5/95-12	Qbt-4	34.9	0.64	35 ± 4	967	0.57	101	16.1	1.4
DEB 5/95-13	Qbt-4	31.6	~0.22 B	40 ± 4	1250	<0.2 U	12.5	18.3	1.2
DEB 5/95-14	Qbt-3	22.8	0.77	36 ± 4	1120	~0.31 B	15.2	37.3	2.2
DEB 5/95-15	Qbt-3	~13.4 B	0.76	40 ± 4	~364 B	0.76	28	24.1	~0.93 B
DEB 5/95-16	Qbt-3	~16.9 B	~0.31 B	37 ± 4	~455 B	0.71	34.8	65.1	~0.62 B
DEB 6/95-1	Qbt-4	43.6	~0.48 B	33 ± 4	1590	1	7.6	29.5	5.6
DEB 6/95-2	Qbt-4	35.7	~0.33 B	35 ± 4	1310	1.1	4.8	19.7	4.7
DEB 6/95-3	Qbt-4	40.9 B	~0.42	33 ± 4	1460	0.97	6.3	23	5.3
DEB 6/95-4	Qbt-4	37.4	~0.38 B	37 ± 4	1380	0.96	4.6	20.9	4.5
DEB 6/95-5	Qbt-4	44.2	1.1	33 ± 4	1680	1.5	6	8.2	12.8
DEB 6/95-6	Qbt-4	35.7	~0.43 B	37 ± 4	1180	0.83	5.8	23.8	5.5
DEB 6/95-7	Qbt-4	48.4	0.71	35 ± 4	1390	0.63	4.2	21.7	6.2

APPENDIX IV (CONT)

Units Methods	Strat. Unit	Copper MG/KG AS-5 R05	Iron MG/KG AS-5 R05	Potassium MG/KG AS-5 R05	Magnesium MG/KG AS-5 R05	Manganese MG/KG AS-5 R05	Sodium MG/KG AS-5 R05	Nickel MG/KG AS-5 R05	Lead MG/KG AS-6 R05
Sample #									
DEB 5/95-1	Qbt-3	0.82 B	8260	1640	201 B	359	1250	1.7 B	3.6 E
DEB 5/95-2	Qbt-3	~0.70 B	7170	560	~149 B	382	531	~2.5 B	3.4 E
DEB 5/95-3	Qbt-3	~2.1 B	8490	1860	536	296	1030	~2.6 B	4 E
DEB 5/95-4	Qbt-3	~1.3 B	10200	1450	576	370	956	~2.6 B	5.4
DEB 5/95-5	Qbt-3	1.8 B	8960	1290	~206 B	338	989	~1.5 B	5.3
DEB 5/95-6	Qbt-4	3.1	12400	1810	908	752	1210	6.6	5.7 E
DEB 5/95-7	Qbt-4	2.8	10800	2860	1090	291	1610	5	4.2 E
DEB 5/95-8	Qbt-4	3.6	11900	2990	1060	266	1710	4.1	8.5 E
DEB 5/95-9	Qbt-4	~2.4 B	6350	2550	1070	184	1490	4.7	9.5 E
DEB 5/95-10	Qbt-4	3.4	8250	4720	726	249	2790	~2.9 B	2.1 E
DEB 5/95-11	Qbt-4	4.1	11600	1730	2820	107	1000	7.3	2.5 E
DEB 5/95-12	Qbt-4	~2.1 B	8740	1720	871	150	1110	6.8	2.9 E
DEB 5/95-13	Qbt-4	~2.4 B+	5250	1280	532	257	676	~3.1 B	1.8 E
DEB 5/95-14	Qbt-3	~1.7 B	8750	1240	707	286	674	~2.6 B	3.1 E
DEB 5/95-15	Qbt-3	~1.6 B	10400	1630	~321 B	325	1480	~0.83 B	9
DEB 5/95-16	Qbt-3	~0.93 B	8760	1650	~170 B	237	1420	~1.3 B	5.6 E
DEB 6/95-1	Qbt-4	5.7	13300	1730	945	325	1230	4.3	3.5
DEB 6/95-2	Qbt-4	3.2	12800	1700	960	364	1150	~3.7 B	3.2 E
DEB 6/95-3	Qbt-4	3.6	13400	1670	998	416	1210	4.7	3.2 E
DEB 6/95-4	Qbt-4	2.9	13300	1740	829	380	1410	~3.5 B	2.8 E
DEB 6/95-5	Qbt-4	6.2	19500	3020	2720	155	1040	8.4	7.8 E
DEB 6/95-6	Qbt-4	2.7	10800	2390	1140	202	1760	4.3	5.1 E
DEB 6/95-7	Qbt-4	3.3	10600	2260	1360	246	1480	4.6	6.8 E

APPENDIX IV (CONT)

Units Methods	Strat. Unit	Antimony MG/KG AS-6 R05	Selenium MG/KG AS-2 R06	Sulfate MG/KG D-3 R12	Thorium MG/KG AS-6 R05	Thallium MG/KG AS-6 R05	Uranium MG/KG AS-6 R05	Vanadium MG/KG AS-5 R05	Zinc MG/KG AS-5 R05
Sample #									
DEB 5/95-1	Qbt-3	<0.10 UN	<0.20UW	1.5 B	12.6	<0.10 U	3.3	~3.9 B	51.5
DEB 5/95-2	Qbt-3	<0.10 UN	<0.20 UW	~1.8 B	13.3	<0.10 U	3.4	~3.8 B	39.6
DEB 5/95-3	Qbt-3	<0.10 UN	<0.20 U	2.6	12	<0.10 U	3.2	6	46.6
DEB 5/95-4	Qbt-3	<0.10 UN	<0.20 U	1.6 B	13.3	<0.10 U	3.2	7.1	54
DEB 5/95-5	Qbt-3	<0.10 UN	<0.20 UW	2.7	13.6	<0.10 U	3.4	3.1 B	40.5
DEB 5/95-6	Qbt-4	<0.10 UN	<0.20 UW	3.9	13.1	~0.49 B	3.1	9.2	54
DEB 5/95-7	Qbt-4	<0.10 UN	~0.21 BW	93.9	12.5	~0.21B	3.1	9.5	41.8
DEB 5/95-8	Qbt-4	<0.10 UN	<0.20 U	3.2	11.3	~0.11 B	2.9	7.3	49.8
DEB 5/95-9	Qbt-4	<0.10 UN	<0.20 U	4.5	10.9	~0.27 B	2.9	~4.9 B	40.9
DEB 5/95-10	Qbt-4	<0.10 UN	<0.20 U	15.7	12.5	~0.19 B	3.1	~4.4 B	24.7
DEB 5/95-11	Qbt-4	<0.10 UN	<0.20 U	1430	9.2	<0.10 U	2.3	6.4	65.6
DEB 5/95-12	Qbt-4	<0.10 UN	~0.21 B	352	11.6	<0.10 U	2.6	~3.1 B	26.5
DEB 5/95-13	Qbt-4	<0.10 UN	<0.20 U	648	12.5	<0.10 U	2.8	~2.9 B+	20.1
DEB 5/95-14	Qbt-3	<0.10 UN	<0.20 U	27	13.2	<0.10 U	3.3	5.9	50.6
DEB 5/95-15	Qbt-3	<0.10 UN	<0.22 U+	6.4	14.2	<0.10 U	3.4	4 B	60.4
DEB 5/95-16	Qbt-3	<0.10 UN	<0.20 UW	2.1	12.3	<0.10 U	3	~2.5 B	46.3
DEB 6/95-1	Qbt-4	<0.10 UN	<0.20 UW	4.1	10.6	<0.10 U	2.7	13	48.5
DEB 6/95-2	Qbt-4	<0.10 UN	<0.20 U	5	10.9	<0.10 U	2.7	11.5	52.4
DEB 6/95-3	Qbt-4	<0.10 UN	<0.20 UW	4.9	10.5	<0.10 U	2.6	12.8	53.5
DEB 6/95-4	Qbt-4	<0.10 UN	~0.20 BW	3.3	10.5	<0.10 UN	2.6	11.5	55.6
DEB 6/95-5	Qbt-4	<0.10 UN	<0.20 UW	8.1	12.4	~0.23 B	2.9	21.2	59.1
DEB 6/95-6	Qbt-4	<0.10 UN	<0.20 UW	3.5	10.6	~0.13 B	2.7	9.6	39.2
DEB 6/95-7	Qbt-4	<0.10 UN	<0.20 UW	1.6 B	9.9	~0.15 B	2.5	10.4	52.3

APPENDIX V

S-PLUS CODE USED TO CALCULATE LOGNORMAL UTLS

File: lnorm_utl1.s

```
function(q,p,n,ave,sd,nt)
{
# lnorm_utl1.s is used as function LUTL1 in Splus
# This function is used to estimate the upper p% CI of the qth percentile
# percentile for a lognormal distribution.  Uses Gilbert's MBE (minimum unbiased estimator) of LN.
#    q = the quantile to estimate
#    p = the confidence limit of q
#    n = number of values sampled
#  ave = mean of logtranformed data
#   sd = st. dev. of logtranformed data
#   nt = number of simulation trials
#.............................................................

# Calculate the qth quantile of the normal distribution
q1_qnorm(q)

# Initialize arrays
t1_rep(-1,n)
t2_rep(-1,nt)

i_0

repeat

 { i_i+1

# Get the "n" lognormal samples
   t1_rlnorm(n,ave,sd)

# Calculate the mean and sd the hard way
   dummy_lnormUMV.s(t1)
   ave1_dummy$mu
   sd1_sqrt(dummy$s2)

# Calculate an estimate of the qth percentile
   t2[i]_exp(ave1+q1*sd1)
   if(i>=nt) break
 }

# Find the upper p*100% of the qth percentile
quantile(t2,p)


}
```

File: lnormUMV.s

```
function(x)
{
# lnormUMV.s (Splus function)
# Calls: psi.s
# Min Variance Unbiased ests of parameters of lognormal(mu,var=s2) distn
```

```
# for X~lognorm(mu,s2), Y=log(X)~normal(mu,s2)
# returns:E=mean(X), V=var(X)
#       mu=mean(Y),s2=var(Y)
# ref:Gilbert('87),Stat Methods for Env Pollution Mon, pp165-166
        n <- length(x)
        y <- log(x)
        ymu <- mean(y)
        vy <- var(y)
        psi1 <- psi.s(vy/2, n)
        psi2 <- psi.s(2 * vy, n)
        psi3 <- psi.s((vy * (n - 2))/(n - 1), n)
        E <- exp(ymu) * psi1
        V <- exp(2 * ymu) * (psi2 - psi3)
        mu <- log(E^2/(V + E^2)^0.5)
        s2 <- log(V/E^2 + 1)
        return(E, V, mu, s2)
}
```

File: psi.s

```
function(t, n)
{
# psi.s (Splus function)
# called by lnormUMV.s
# psi function in Gilbert('87) Stat. Meth. Env. Pollution. Mon, pp 165
# for Min Variance Unbiased ests of parameters of lognormal(mu,var=s2) distn
        psi <- 0
        psi[1] <- ((n - 1) * t)/n
        for(i in 1:25) {
                psi[i + 1] <- (psi[i] * (n - 1)^2 * t)/((i + 1) * n * (n + (2 *
                        i - 1)))
                if(abs((psi[i + 1] - psi[i])/psi[i]) < 1e-09)
                        break
        }
        psi <- 1 + sum(psi)
        psi
}
```