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URANIUM MILL ORE DUST CHARACTERIZATION

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November 1980

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U. S. Department of Energy
New York, New York

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ABSTRACT

Cascade impactor and general air ore dust measurements were taken in a uranium processing mill in order to characterize the airborne activity, the degree of equilibrium, the particle size distribution and the respirable fraction for the ^{238}U chain nuclides. The sampling locations were selected to limit the possibility of cross contamination by airborne dusts originating in different process areas of the mill. The reliability of the modified impactor and measurement techniques was ascertained by duplicate sampling.

The results reveal no significant deviation from secular equilibrium in both airborne and bulk ore samples for the ^{234}U and ^{230}Th nuclides. In total airborne dust measurements, the ^{226}Ra and ^{210}Pb nuclides were found to be depleted by 20 and 25%, respectively. Bulk ore samples showed depletions of 10% for the ^{226}Ra and ^{210}Pb nuclides. Impactor samples show disequilibrium of ^{226}Ra as high as $\pm 50\%$ for different size fractions. In these samples the ^{226}Ra ratio was generally found to increase as particle size decreased. Activity median aerodynamic diameters of the airborne dusts ranged from 5 to 30 μm with a median diameter of 11 μm . The maximum respirable fraction for the ore dusts, based on the proposed International Commission on Radiological Protection's (ICRP) definition of pulmonary deposition, was $< 15\%$ of the total airborne concentration. Ore dust parameters calculated for impactor duplicate samples were found to be in excellent agreement.

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INTRODUCTION

The special air concentration limit for uranium ore dust, promulgated by the Atomic Energy Commission (AEC) in 1960 and later adopted by the Nuclear Regulatory Commission (NRC), was based on two assumptions:

1. uranium decay products in the ore are in secular equilibrium with the parent ^{238}U , and
2. after inhalation ^{230}Th remains with uranium and exhibits a 120 day biological half-life instead of the 4 year half-life usually assumed for thorium.^(1, 2)

The technical validity of these assumptions has been questioned by a number of people in the ensuing years.^(3, 4) Occasional measurements of airborne ore dust have disclosed significant deviation from equilibrium among uranium decay products.⁽⁵⁾ Also, experiments at Battelle Northwest Laboratories (BNWL) have shown that ^{230}Th separates out of inhaled uranium ore dust in dogs and rats and remains longer than uranium in the lungs and pulmonary nodes.⁽⁶⁾

As a result of these uncertainties a study was undertaken to characterize uranium ore dust with respect to concentration, particle size distribution, and degree of radionuclide equilibrium in support of a reevaluation of the ore dust maximum permissible concentration (MPC).

As a preliminary step, range-finding measurements were made in a few mills prior to implementation of a full scale investigation. Samples of ore dust were collected with a 1 cfm Andersen cascade impactor* and with open-faced reference filters in three ore concentrating mills in Wyoming. Results of radionuclide analysis of the impactor samples revealed that a sampling rate greater than 1 cfm would be needed to collect the quantities of ore dust required for chemical analyses. Also, activity median diameters often exceeded the impactor first stage (D_p)0.50 value of 11 μm in the ore crushing areas of the mill and extreme disequilibrium of uranium decay products was observed in a number of samples.⁽⁷⁾

It was evident after reviewing field sampling procedures and radionuclide analysis from the preliminary study, that a cascade impactor of greater capacity than the 1 cfm Andersen sampler would be needed and the following conditions had to be met:

*The impactor used did not have the new high capacity preseparator stage now available from the manufacturer for removal of particles > 10 μm .

- very low radioactivity background in collection (impaction) media
- larger upper stage cut-off sizes compatible with median particle diameters ranging between 5 and 15 μm
- minimal loss of sample during handling of the impaction substrate after particle collection
- selection of sampling locations to preclude the possibility of cross contamination of samples (the proximity of ore crushing, leaching, and final product areas may have resulted in the erratic nuclide equilibrium ratios found in some samples in the preliminary study).

SELECTION AND MODIFICATION OF SAMPLING APPARATUS

A Sierra Model 235 slotted cascade impactor was chosen from among available high volume cascade impactors and adapted to the conditions found in the preliminary study. An important initial reason for its selection over the high volume Andersen impactor, a prospective alternate, was the smaller size of the impaction filter. The smaller size of the collection substrate for a given type of collection media minimized radioactive background and facilitated sample handling in the field. Another reason for selecting the Sierra was the close familiarity with the instrument that had been acquired in an earlier evaluation.⁽⁸⁾ Although some deficiencies in the instrument such as wall losses and particle rebound had been observed during the evaluation, the modifications required to meet the ore mill study needs were expected to minimize if not eliminate these deficiencies. These basic modifications were:

- Substitution of Whatman #41 filter paper soaked in mineral oil for the dry glass fiber impaction substrate used for the preliminary study. The mineral oil drastically reduced particle rebound and minimized particulate losses previously encountered when unloading dry impaction substrates. The Whatman #41 paper contains a minimal amount of radioactivity and presented less background interference to the low level chemical analysis methods.
- Reduction of sampling flow rate to 0.21 m^3/min from the nominal design flow rate of 1.13 m^3/min . This change increases impactor stage (D_p)0.50 values by a factor of 2.3. The experimentally determined Sierra impactor stage characteristics for a flow rate of 0.21 m^3/min are given in Table 1.⁽⁹⁾

MILL AND PROCESS DESCRIPTIONS

Mill

All samples reported in this study were taken at Kerr-McGee's uranium processing mill located in the Ambrosia Lake area near Grants, NM. The mill uses an acid leach method to extract uranium oxide (U_3O_8) concentrate, commonly called yellowcake, from uranium-bearing ores.⁽¹⁰⁾ The physical layout of this mill minimizes the possibilities of cross contamination of airborne dusts from crushing, leaching, extraction and final product areas. This was a primary consideration in selecting the mill for this second survey as cross contamination may have caused the extreme deviations in nuclide disequilibrium which were reported for some samples taken in uranium mills in a previous study.⁽⁷⁾

Physical Process

Ore from the mines is fed to the primary crusher where it is crushed into chunks less than 4" in diameter. A conveyor belt then moves the ore to a secondary crusher which reduces the ore to less than 1" diameter pieces. From the secondary crusher the ore is carried on another conveyor belt to the sample tower. In the sample tower the ore is processed through a series of sample cutters until a representative sample of the ore is obtained. This sample is used by the chemists to obtain an accurate assay of the uranium oxide content of the ore lot. From the curter the ore is conveyed to the fine ore bins which provide storage capacity for the ore and a facility for blending the ore to a proper grade for plant processing.

Ore leaving the fine ore bins is mixed with water and fed to the rod mills where in its final physical treatment it is ground to a minus 28 mesh. The ore is then in a slurry form and ready for chemical processing.

Chemical Process

From the rod mills the ore slurry is pumped to the leaching agitators where sulfuric acid and sodium chlorate are added. Aided by the sodium chlorate oxidizer, the sulfuric acid dissolves the uranium and other soluble metals. The slurry is then passed through a number of classification, leaching and counter current decantation processes removing the uranium from the rock. Since the leaching process removes metals other than uranium, it is necessary to extract the uranium from the acid water solution. This is accomplished in the solvent extraction circuit which selectively removes uranium from the acid water solution leaving the unwanted metals in solution and concentrates the uranium in the solvent. The concentrated uranium is then stripped from the solvent and flows to a precipitation circuit. Leaving the precipitation process the uranium now in a suspension rather than solution is pumped to a thickener tank where the uranium

particles are allowed to settle out.

The precipitated uranium, in the form of a slurry, is pumped through a filter circuit where the uranium is washed thoroughly to remove impurities and then fed to the dryer where the product uranium is dried by steam heat and packaged in drums for shipment.

PROCEDURES

Description of Samples

Samples collected during this investigation included the following:

1. Sierra impactor samples - used to determine nuclide activity, particle size distribution, respirable fraction, and nuclide equilibrium ratios,
2. Total air reference filters - used to determine impactor collection efficiency, nuclide activity and equilibrium ratios;
3. Mill bulk ore samples - used to compare nuclide activity and equilibrium ratios of the ore to values determined for impactor and reference filter airborne dust samples; and
4. General air samples - used to determine the nuclide activity and equilibrium ratios in areas of the mill not covered by the impactor samplers.

Impactor Preparation and Use

The Whatman #41 filter paper impaction substrate was soaked in mineral oil until saturated, removed from the oil and allowed to drip until all excess oil was removed. The oil saturated filter was then carefully placed on the orifice-impactor plates, preventing any of the mineral oil from entering the slots of the plate. After a sampling run was completed, the impactor and back-up filter were removed from the tripod sampling stand and taken to a clean work area in a nearby building. The oil-treated Whatman #41 impaction substrates and the dry back-up filter were then carefully removed and placed in individual glassine envelopes. The impactor orifice-impaction plates were cleaned by washing in a mild detergent and dried. The impactors were then reloaded as described previously. The same procedures were used for all of the impactor tests, omitting the mineral oil soaking of the Whatman #41 filter paper in one impactor for two duplicate tests in order to study the effect of rebound on particle size distribution measurements

Sampling Procedures

The samples described in this report were taken on August 23, 24, and 25, 1977. Sample durations were determined in part by mill activity. Samplers were allowed to run longer during low loading exposures to assure collection of sufficient activity for adequate radiochemical analysis. Samplers were located in areas of the mill where operators would normally be present during part of their normal work shift. The approximate location in the mill where each impactor sample was taken is shown in Figure 1. The majority of the impactor samples with a concurrent reference filter sample were taken in the primary and secondary ore crushing areas which were located in buildings separated from ore storage and chemical processing areas of the mill. Two additional concurrent impactor and reference filter samples were taken: one in the ore bin storage area, another in the sample preparation room. Five of the 18 impactor samples collected consisted of paired samples with a single concurrent total air reference filter sample. Three of the five paired impactor tests were used to study duplicate measurement correlations. Two tests were used to determine the effect, if any, of particle rebound and reentrainment on particle size distribution determinations and nuclide equilibrium ratios.

Figure 2 shows the original impactor sampling test arrangement with the impactor mounted on a standard high-volume filter holder, followed by a calibrated orifice and a variable speed high-volume sampler motor. The flow rate was controlled by manually regulating the voltage to the sampler motor to maintain a predetermined pressure drop across the calibrated orifice. The assembly was positioned in the tripod stand so that the impactor first stage orifice inlets were located five feet above the floor approximating the breathing zone of a worker. The total air reference filter samples were taken using a similar test arrangement without the impactor preceding the back-up filter. When obtaining paired impactor samples the reference filter sampler was placed between the impactor samplers.

During the first day of sampling it was evident that the ore dust particle concentrations in the primary and secondary crusher areas were high and contained very large particles. After the initial tests, the first stage of each impactor was found to have a considerable amount of ore dust deposited on the orifice plate surface. These particles had settled on the orifice plate and did not enter the first stage orifice inlets of the impactor. Other large particles fell directly through the orifice inlets and settled on the first stage impaction surface by gravitational rather than inertial forces.

In order to preclude the overloading of the first stage impaction surface, a thin 22x30 cm deflector plate was placed 20 cm above each impactor and reference filter. This deflector plate arrangement was used on impactor tests 7 through 18 and is shown positioned above the impactor sampler in Figure 3.

General air samples were taken using nominal 10 cm diameter or 20x25 cm high volume sampler heads containing Whatman #41 filter paper

Bulk ore samples used for determination of nuclide activity and equilibrium ratios were 200 g aliquots of the sample prepared by the mill chemists to obtain accurate assay of the uranium oxide content of the ore being processed. The bulk ore samples reported are representative of the ore which was processed during this study.

Analytical Procedures

In March 1977, a meeting was held at the Environmental Measurements Laboratory (EML) to determine the sampling and analytical techniques to be used for future ore dust measurements. Representatives of NRC, Pacific Northwest Laboratories (PNL), Health Services Laboratory (HSL), and EML were present. Based on HSL's analytical results from a few of the impactor samples taken in the Wyoming mills, it was agreed that greater amounts of sampled material would be required on the impactor stages in order to obtain statistically significant data. Table 2 contains the sample weights required for radiochemical and direct counting analyses of the uranium chain nuclides for measurement precisions of 1, 3 and 10%, as determined by PNL. It was decided that radiochemical analysis of the impactor samples would be required since overloading of impactor stages could occur if sample weights as large as those needed to obtain the desired measurement precision by the direct counting method were collected.

Radiochemical analysis of the individual impaction stages and back-up filter, total air reference filters, mill bulk ore samples, and general air samples for ^{238}U , ^{234}U , ^{230}Th , ^{226}Ra and ^{210}Pb nuclides were done by the Physical Science Department, Battelle Pacific Northwest Laboratories Richland, WA. The results of the radiochemical analysis are given in Appendix I.

RESULTS AND DISCUSSION

Total Airborne Activity Concentrations

Tables 3 and 4 show the ^{238}U activity concentrations determined for the impactor, reference filter, and general air samples. Mean ^{238}U activity values for various locations in the mill are shown in Table 5. Assuming nuclide equilibrium exists in the samples, $\sim 55 \alpha \text{ dpm/m}^3$ of ^{238}U would be equivalent to the occupational MPC limit for gross alpha activity ($1 \times 10^{-10} \mu\text{Ci/ml}$ or $220 \alpha \text{ dpm/m}^3$).⁽¹⁾ Highest activity levels for individual samples were found in the primary crusher, secondary crusher (lower level), and the ore barreling areas.

Three of the samples taken in these areas were equivalent to or slightly above the MPC limit.

It should be noted that due to sampling equipment failure it was necessary to operate the reference filter sampler run concurrent with all impactor #3 samples at a flow rate three times that of the impactor. This caused faster and heavier loading of the reference filter especially when dust concentrations were elevated and continual adjustment of the reference sampler blower voltage was required in order to maintain the desired flow rate. These adjustments were not made when extreme loading conditions occurred during periods that the sampler was unattended.

A specific example of this problem occurred while taking impactor and reference sample #6 in the primary crusher location. This sample was taken during the night shift when the impactor and reference sampler were unattended for a number of hours. When returning to collect the samples, it was observed that the primary crusher area where the samplers were located had been swept and cleaned during the night shift. The clean-up process had generated extremely high dust levels which caused non-uniform loading of the reference filter. The total sample volume for the reference filter for this test was estimated from flow rate measurements taken at the beginning and end of sampling. This estimate of sample volume is obviously in error since the filter loading was not linear over the sampling period, as assumed. Although the impactor flow rate remained constant over the sampling interval, examination of the impactor during sample recovery revealed heavy loading of the first and second stage impactor substrates. This was caused by the reentrainment and impactor collection of large dust particles during the clean-up operations.

Nuclide Equilibrium Measurements

Although ore from several different mining areas in the Ambrosia Lake region was being processed during the three days of sampling, chemical analyses of the impactor, total air reference, and general air samples revealed no significant variation from equilibrium in the ^{234}U and ^{230}Th ratios. The mean ratio of the nuclide daughter activity to the ^{238}U parent for the impactor stages, impactor total activity, impactor reference filters, and bulk ore samples are listed in Table 6. The mean ^{230}Th ratio for the bulk ore samples was found to be ~10% greater than the mean of the air sample ratios. The ^{226}Ra was depleted by ~20% in the air samples, while the bulk ore ^{226}Ra showed depletions of only 5%. It should be noted that the ^{230}Th and ^{226}Ra activity values for the bulk ore samples were obtained by direct counting of the ore samples using an intrinsic germanium diode. The ^{210}Pb ratios for the impactor and reference filters showed a mean depletion of 25% compared to 12% in the bulk ore samples.

The mean ^{210}Pb ratio of 0.93 for the general air samples is considerably higher than the impactor and reference filter mean values. This is attributed, in part, to one high ^{210}Pb ratio of 1.49 found for a sample taken in the ore bin

area. In impactor samples 1 through 5, ^{226}Ra ratios show a definite increase as particle size decreases. Individual nuclide ratios for all impactor, reference, general air and bulk ore samples are detailed in Appendix II.

Particle Size Measurements

Log-probability plots for the 18 impactor samples taken during this investigation are shown in Appendix III. Activity median aerodynamic diameter (AMAD) and standard geometric deviation (σ_g) were calculated, assuming a log-normal distribution for each nuclide. The majority of the distribution curves show only a slight deviation from log normality which is typically found in impactor size distribution measurements.

The larger deviations from log normality are attributed to overloading of impactor stages (e.g. impactor sample 6) or the possibility of radical changes in the airborne particle size distribution occurring during the sampling interval (e.g. impactor sample 9, when extremely wet ore was being processed during part of the sampling interval).

AMAD's for the five nuclides ranged from $\sim 5\ \mu\text{m}$ to $30\ \mu\text{m}$ depending on the location of the sample, the milling operation and the bulk ore moisture content. In most samples the ^{238}U , ^{234}U and ^{230}Th nuclides were found to exhibit nearly identical AMAD and σ_g values. A slight shift to a lower AMAD for ^{226}Ra is clearly seen in all impactor samples taken the first day of sampling. In other samples the ^{226}Ra and ^{210}Pb AMAD values were found to deviate only slightly from the ^{238}U , ^{234}U and ^{230}Th values.

Duplicate Sample Comparisons

Airborne Activity Concentrations - Using the ^{238}U activity concentration values for comparison, we find an excellent agreement for total sample activity in duplicate impactor and concurrent impactor and reference filter samples. For the five paired impactor samples, variations in total ^{238}U concentration values ranged from 1.5 to 8.2% with a mean of 4.8%. When comparing three concurrent samplers, two impactors, and the total reference filter, variations ranged from 5.1 to 15.9% with a mean of 11.7%.

A review of this data, shown in Table 3, reveals the possibility that addition of the deflection plate, not used for impactor and reference samples 1 through 6, may have prevented a greater percentage of the larger airborne particles from reaching the impactor inlets. However, the addition of the deflector plate together with the obvious difference in inlet characteristics of the impactor and reference filter was not considered to have introduced any significant bias in the determination of activity concentration values.

Nuclide Equilibrium Ratios - A detailed comparison of the individual impactor stage, final filter, and total impactor nuclide ratios for the five duplicate samples is given in Appendix IV. The range of difference for duplicate sample nuclide ratios and the range of the propagated measurement uncertainties associated with the ratio are summarized in Table 7. Except for the ^{210}Pb values, the differences of the nuclide ratios for the majority of the duplicate impactor samples are within the limits of the measurement uncertainties associated with the ratio determination. The larger variances in nuclide ratios were generally found in the lower impactor stages and the final filter where activity levels were lowest.

Particle Size Measurements - Table 8 shows a comparison of the ^{238}U AMAD and σ_g computed for the five duplicate impactor samples. The first three sets show good agreement for the AMAD and σ_g values for concurrent impactor samples. The fourth and fifth sets of samplers were run to ascertain the effect, if any, of particle rebound on impactor size distribution measurements. In these two duplicate measurements, the lower AMAD values determined for the impactors having the dry impaction substrate confirm the detrimental effect particle rebound can have on the determination of AMAD and σ_g values. This effect was also seen during an earlier study of the Sierra impactor at the nominal flow rate of $1.13 \text{ m}^3/\text{min}$.⁽⁸⁾ Even at the lower flow rate of $0.21 \text{ m}^3/\text{min}$ used for the ore dust measurements, particle rebound and displacement to lower impactor stages resulted in the underestimation of AMAD values. Table 9 lists the impactor determined AMAD and σ_g values calculated for the five nuclides considered in this investigation.

Respirable Dust Definitions

In 1959, Committee II of the International Commission on Radiological Protection (ICRP) recommended values of maximum permissible body burden of radionuclides and maximum permissible concentration of these nuclides in air and water. A respiratory tract deposition and retention model for inhaled particles was adopted by the ICRP at that time. The MPC values for internal hazards were calculated using this model.⁽¹¹⁾

The common physiological meaning of the term "respirable" is "that which is breathed in". Of the total 100% breathed in, the original ICRP model assumed 25% is exhaled, 50% is deposited in the upper respiratory passages and subsequently swallowed, and 25% is deposited in the lungs (lower respiratory passage). For "insoluble" particles, it was further assumed that one-half of the 25% lower respiratory passage deposition, 12.5%, is rapidly cleared and the remaining 12.5% undergoes "long-term retention". It was also noted that the true picture of dust deposition is complicated by the vagueness and ambiguity concerning the definition of the respiratory compartments.

The development of size-selective samplers, such as two-stage cyclones⁽¹²⁾ and elutriators,^(13, 14) brought about the terms "respirable dust", "respirable fraction" and "respirable mass". The "respirable" terms when applied to size selective instruments, usually designates the fraction of the sampled dust collected by the second stage of the sampler which is designed to meet the criteria specified for "respirable" dust measurements. Two of these are the British Medical Research Council's "Johannesburg" criterion⁽¹⁵⁾ and the AEC "Los Alamos" curve criterion adopted at the 1961 Los Alamos Conference sponsored by the Atomic Energy Commission's Office of Health and Safety.⁽¹⁶⁾ In these size-selective samplers, the second stage collection represents the assumed 25% lower respiratory deposition designated by the original ICRP model.

In 1966, an ICRP Task Group proposed new curves giving total deposition of all sizes in the respiratory tract as a function of the mass or activity median aerodynamic size.⁽¹⁷⁾ Figure 4 represents the 1966 ICRP deposition estimate for the pulmonary compartment while breathing at a moderate rate of 20 l/min. With the proposal of the new lung model which determines the deposition fractions from the aerosol mass or activity median aerodynamic diameter, the use of two stage or size-selective samplers which did not measure this parameter was considered inadequate. However, Mercer has subsequently shown that the total deposition in the pulmonary space determined by the new ICRP curve is equivalent to ~30% of the deposition represented by the second stage collection of the cyclone.⁽¹⁸⁾

Comparison of ICRP and Two-Stage Cyclone Percent Respirable Determinations

The percent respirable (e.g. pulmonary deposition) for each of the 18 impactor samples calculated from the experimentally determined activity median aerodynamic diameter of the ore dust and the ICRP Task Group pulmonary deposition curve is listed in Table 10.

In Table 10, we have also listed the percent respirable which would have been determined by a cyclone sampling the same aerosol distributions as the impactor and operating at conditions set to meet the ACGIH* "respirable dust" curve. The ACGIH percent respirable values were determined from curves previously reported by Moss and Ettinger.⁽¹⁹⁾ Their curves predict the fraction of the aerosol which would be collected by the second stage of a cyclone sampler based on the aerosol aerodynamic mass median diameter and standard geometric deviation. These calculations are based on the assumption that the sampled

*The American Conference of Governmental Industrial Hygienists (ACGIH) curve is a slight modification of the aforementioned AEC "Los Alamos" conference curve. The ACGIH criterion allows the size selective device to retain 10% of the $< 2 \mu\text{m}$ dust, while the "Los Alamos" criterion allowed 0% of the $< 2 \mu\text{m}$ dust to be retained by the size selector.

aerosol follows a log-normal particle size distribution. As shown in Table 10, by taking 30% of the percent respirable determined for the ACGIH cyclone measurement as suggested by Mercer, good agreement with the percent respirable determined from the ICRP deposition curve is found for the majority of the samples.

Originally the ICRP estimated that 0.5 of the aerosol which is deposited in the lung undergoes long-term retention. The new lung model has increased this fraction to 0.6. Therefore 18% ($.30 \times 0.6$) of the material collected on the second stage of a two-stage sampler, usually designated as the "respirable fraction", undergoes long-term retention in the lung. Accordingly, the ICRP pulmonary deposition value calculated from the AMAD of the aerosol should be multiplied by 0.6 to obtain the equivalent long-term retention. Based on these calculations the maximum long term pulmonary burden for the aerosol distributions found in this investigation was $< 8\%$ of the total airborne activity concentration, with a mean of 5% for all the impactor samples.

Solubility

The dissolution rates of two airborne ore dust samples collected simultaneously with impactor samples 12 and 15 have been reported by Kalkwarf.⁽²⁰⁾ The dissolution half-time measurements for thorium, 123 days for both samples, was approximately twice that found for uranium, 78 days and 67 days. The AMAD values calculated from impactor measurements and listed in Table 9 reveal almost identical size distribution values for the uranium and thorium nuclides in the individual samples. Based on these few measurements of airborne ore dust, it appears that dissolution rates are more dependent on chemical than physical properties of the sample.

CONCLUSIONS

The airborne particle size distribution, nuclide activity concentration, degree of equilibrium and respirable fraction were determined for uranium mill ore dusts. The use of the modified Sierra impactor allowed larger sample volumes to be collected facilitating analysis of the nuclide activity in the fractionated sample. The AMAD, σ_g and equilibrium ratio determined for ^{234}U and ^{230}Th in the airborne dust samples were found to be in good agreement. Mean values of the equilibrium ratios calculated for ^{226}Ra and ^{210}Pb were found to be slightly less in the airborne dust than in the bulk ore. However, these small differences were usually within the statistical variance of the measurement uncertainties. Respirable fractions of the ore dust samples based on the impactor determined AMAD and the ICRP pulmonary deposition curve were $< .15$ of the total airborne activity concentration.

A cursory evaluation of the respirable fraction values generated from this investigation reflects the findings of other investigators who have shown that two-stage "respirable dust" sampler data can be adapted to estimate the deep-lung deposition as defined by the proposed ICRP pulmonary deposition curve. The use of suitably calibrated two-stage cyclone samplers to obtain nuclide activity and equilibrium ratios for the respirable fraction of airborne ore dust would facilitate sample acquisition and greatly reduce analysis time and expense.

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TABLE 1

SIERRA IMPACTOR STAGE (D_p) 0.50 VALUES
AT A FLOW RATE OF 0.21 m³/min

Stage	(D_p) 0.50 (μm)
1	15.55
2	6.65
3	3.95
4	2.05
5	1.05

TABLE 2

MEASUREMENT PRECISION FOR ANALYSIS OF URANIUM CHAIN MEMBERS

	Chemical Analysis					Direct Counting			
	Radiochemical Recovery (%)	Counting Efficiency (%)	Wt. Required ^a (mg) for Precision of			Photon Energy (keV)	Counting Efficiency (%)	Wt. Required ^a (mg) for Precision of	
			(1%)	(3%)	(10%)			(3%)	(10%)
²³⁸ U	88	33	84	8.4	0.84	63 ^c	0.49	400	70
²³⁴ U	88	33	84	8.4	0.84	52	0.14	d	d
²³⁰ Th	78	33	95	9.5	0.95	68	0.055	3000	800
²²⁶ Ra	84	175	16	1.6	0.16	186	0.30	400	130
²¹⁰ Pb	44 ^b	33	170	17.0	1.7	46	0.54	200	50

^a 0.2% U₃O₈ ore, 1000 minute count, 1/3 aliquot.

^b Combination of 95% Pb recovery, 92% Po recovery, and 50% ²¹⁰Po ingrowth.

^c ²³⁴Th

^d Normal accuracy is approximately ±20%.

TABLE 3

IMPACTOR AND REFERENCE AIRBORNE ^{238}U ACTIVITY CONCENTRATIONS (α dpm/m³)

Sample No.	Location	Impactor #1	Impactor #2	Impactor #3	Reference Filter
1,2	Secondary crusher	27.5	26.0		28.5
3	Primary crusher			8.9	10.4
4,5	Secondary crusher	12.7	10.9		12.8
6	Primary crusher			57.9	27.8 ^a
7,8	Secondary crusher	20.8	20.2		26.9
9	Primary crusher			30.0	22.2 ^a
10,11	Secondary crusher	10.8	11.7		13.3
12	Secondary crusher (lower level)			28.7	30.4
13,14	Secondary crusher	29.0	24.6		31.8
15	Secondary crusher (lower level)			71.1	54.9 ^a
16	Ore bin area	3.0			4.5
17	Primary crusher (screening post)		5.2		8.7
18	Sample preparation room			2.6	2.5

^a Concentration values are suspect due to flow rate variability caused by heavy loading of reference filter.

TABLE 4
GENERAL AIR SAMPLES ^{238}U ACTIVITY CONCENTRATIONS

Sample No.	Location	^{238}U (α dpm/m ³)
1	Ore bin area	2.8
2	Ore barreling area	38.2
3	Sample preparation room (A)	19.2
4	Sample preparation room (B)	7.0
5	Ore bin area	3.0
6	Secondary crusher (cat walk)	10.8
7	Ore barreling area	23.9
8	Sample preparation room (A)	7.1
9	Sample preparation room (B)	5.3
10	Sample preparation room (A)	18.8
11	Ore barreling area	43.5

TABLE 5

MEAN ^{238}U ACTIVITY CONCENTRATIONS

Location	No. of Samples	^{238}U (α dpm/m ³)
Ore bin area	4	3.3
Ore barreling area	3	35.2
Primary crusher	6	26.2
Secondary crusher	15	20.5
Secondary crusher (lower level)	4	46.2
Secondary crusher (cat walk)	1	10.8
Sample preparation rooms	7	8.9

TABLE 6

MEAN RATIO $\pm$ STANDARD DEVIATION OF DAUGHTER ACTIVITY TO ^{238}U PARENT

Type of Sample	No. of Values	$\frac{^{234}\text{U}}{^{238}\text{U}}$	$\frac{^{230}\text{Th}}{^{238}\text{U}}$	$\frac{^{226}\text{Ra}}{^{238}\text{U}}$	$\frac{^{210}\text{Pb}}{^{238}\text{U}}$
Impactor					
Stage 1	18	0.99 $\pm$ 0.02	0.97 $\pm$ 0.06	0.76 $\pm$ 0.12	0.75 $\pm$ 0.08
Stage 2	18	1.01 $\pm$ 0.03	0.97 $\pm$ 0.06	0.82 $\pm$ 0.14	0.74 $\pm$ 0.09
Stage 3	18	0.99 $\pm$ 0.03	0.93 $\pm$ 0.08	0.84 $\pm$ 0.16	0.74 $\pm$ 0.12
Stage 4	18	1.02 $\pm$ 0.02	0.97 $\pm$ 0.08	0.85 $\pm$ 0.34	0.72 $\pm$ 0.12
Stage 5	18	1.00 $\pm$ 0.04	1.00 $\pm$ 0.07	0.89 $\pm$ 0.29	0.72 $\pm$ 0.13
Final filter	18	0.98 $\pm$ 0.04	0.89 $\pm$ 0.11	0.85 $\pm$ 0.34	0.78 $\pm$ 0.19
Impactor total	18	1.00 $\pm$ 0.02	0.96 $\pm$ 0.06	0.81 $\pm$ 0.14	0.74 $\pm$ 0.09
Reference filter	13	1.00 $\pm$ 0.02	0.96 $\pm$ 0.06	0.79 $\pm$ 0.15	0.75 $\pm$ 0.11
General air	8 ^a	1.00 $\pm$ 0.02	0.98 $\pm$ 0.04	0.84 $\pm$ 0.16	0.93 $\pm$ 0.24
Bulk ore	10	0.99 $\pm$ 0.03	1.07 $\pm$ 0.04 ^b	0.95 $\pm$ 0.11 ^b	0.88 $\pm$ 0.10

^a Yellowcake areas are omitted from calculations.^b The ^{230}Th and ^{226}Ra activities for the bulk ore samples were obtained by direct counting of bulk ore samples using an intrinsic germanium diode. All other ratios were obtained from radiochemical analysis.

TABLE 7

DUPLICATE IMPACTOR EQUILIBRIUM RATIO ANALYSIS

Impactor	$\frac{^{234}\text{U}}{^{238}\text{U}}$	$\frac{^{230}\text{Th}}{^{238}\text{U}}$	$\frac{^{226}\text{Ra}}{^{238}\text{U}}$	$\frac{^{210}\text{Pb}}{^{238}\text{U}}$
<u>Range of Difference (%)</u>				
Stage 1	0.2- 5.5	1.3-16.5	3.3-13.1	0.9-22.7
Stage 2	0.2- 4.0	0.9- 9.7	0.9-11.9	7.4-31.0
Stage 3	0.3- 5.4	0.9- 9.6	0.8-22.9	0.8-14.8
Stage 4	0.1- 4.2	1.8- 8.1	1.1-12.8	1.8-23.5
Stage 5	0.2- 5.8	0.2-13.6	2.0-22.8	3.4-43.5
Final filter	0.6-14.9	5.9-14.2	1.0-17.3	5.1-42.9
Total activity	0.6- 3.0	1.0- 8.8	0.5- 8.1	0.5-18.3
<u>Range of Propagated Measurement Uncertainties (%)</u>				
Stage 1	2.0- 4.9	3.8- 6.7	5.8- 7.6	2.8- 4.8
Stage 2	2.9- 5.3	4.4- 6.1	7.1- 9.8	2.8- 4.4
Stage 3	2.7- 5.1	4.1- 6.8	7.1-23.0	3.3- 5.9
Stage 4	3.6- 6.0	5.2- 6.8	7.3- 8.0	5.4- 6.8
Final filter	4.0- 6.4	5.1- 7.1	7.3-11.0	4.4- 7.8
Total activity	3.6- 4.9	4.9- 6.4	7.6-11.3	3.9- 6.0

TABLE 8

DUPLICATE IMPACTOR PARTICLE SIZE MEASUREMENTS^a

Sample No.	Impaction Surface (Whatman #41)	AMAD (μm)	σ_g
1	oiled	10.6	3.9
2	oiled	9.6	3.7
4	oiled	12.0	4.0
5	oiled	12.6	4.4
7	oiled	6.0	3.8
8	oiled	5.8	3.9
10	dry	6.8	3.1
11	oiled	10.7	4.0
13	dry	10.9	3.3
14	oiled	14.0	3.9

^aThe values in this table are based on ²³⁸U activity measurements. Duplicate sample analysis for ²³⁴U, ²³⁰Th, ²²⁶Ra and ²¹⁰Pb show similar agreement for AMAD and σ_g values (see Table 9).

TABLE 9

ORE DUST NUCLIDE AMAD AND σ_g VALUES DETERMINED
FROM IMPACTOR MEASUREMENTS

Test No.	Nuclide	AMAD (μm)	σ_g	Test No.	Nuclide	AMAD (μm)	σ_g
1	^{238}U	10.6	3.9	10	^{238}U	6.8	3.1
	^{234}U	10.5	3.9		^{234}U	6.8	3.0
	^{230}Th	10.1	4.0		^{230}Th	6.7	3.1
	^{226}Ra	7.2	4.0		^{226}Ra	6.0	3.0
	^{210}Pb	9.9	4.4		^{210}Pb	6.5	3.1
2	^{238}U	9.6	3.7	11	^{238}U	10.7	4.0
	^{234}U	9.7	3.6		^{234}U	10.7	4.0
	^{230}Th	10.2	3.7		^{230}Th	10.8	3.8
	^{226}Ra	7.6	3.9		^{226}Ra	9.5	3.9
	^{210}Pb	9.6	3.9		^{210}Pb	9.2	4.0
3	^{238}U	7.6	2.8	12	^{238}U	15.3	4.8
	^{234}U	7.6	2.7		^{234}U	15.5	4.8
	^{230}Th	7.7	2.7		^{230}Th	15.0	4.8
	^{226}Ra	7.1	2.9		^{226}Ra	12.2	4.3
	^{210}Pb	7.7	2.7		^{210}Pb	14.2	4.8
4	^{238}U	12.0	4.0	13	^{238}U	10.9	3.3
	^{234}U	11.3	3.9		^{234}U	11.0	3.3
	^{230}Th	11.3	3.9		^{230}Th	10.6	3.3
	^{226}Ra	9.6	3.9		^{226}Ra	11.0	3.3
	^{210}Pb	11.2	4.1		^{210}Pb	10.5	3.1
5	^{238}U	12.6	4.4	14	^{238}U	14.0	3.9
	^{234}U	12.4	4.4		^{234}U	14.3	3.9
	^{230}Th	12.7	4.3		^{230}Th	14.5	4.1
	^{226}Ra	10.5	4.2		^{226}Ra	12.3	3.6
	^{210}Pb	12.6	4.6		^{210}Pb	14.5	4.0
6	^{238}U	17.3	2.9	15	^{238}U	29.4	4.9
	^{234}U	17.4	2.9		^{234}U	29.2	4.9
	^{230}Th	17.5	2.9		^{230}Th	31.1	4.9
	^{226}Ra	16.4	2.7		^{226}Ra	26.5	5.0
	^{210}Pb	17.5	2.9		^{210}Pb	26.4	4.9
7	^{238}U	6.0	3.8	16	^{238}U	7.4	4.5
	^{234}U	6.0	3.0		^{234}U	7.9	4.5
	^{230}Th	6.1	3.7		^{230}Th	7.6	4.5
	^{226}Ra	6.7	3.6		^{226}Ra	8.5	4.4
	^{210}Po	6.5	3.9		^{210}Pb	7.2	5.3
8	^{238}U	5.8	3.9	17	^{238}U	19.4	3.6
	^{234}U	5.7	3.9		^{234}U	19.0	3.6
	^{230}Th	6.0	3.9		^{230}Th	19.8	3.5
	^{226}Ra	6.4	3.8		^{226}Ra	22.0	3.5
	^{210}Pb	6.0	3.8		^{210}Pb	21.6	3.5
9	^{238}U	9.1	2.5	18	^{238}U	5.6	3.4
	^{234}U	9.2	2.6		^{234}U	5.4	3.4
	^{230}Th	9.3	2.6		^{230}Th	6.4	3.1
	^{226}Ra	9.4	2.4		^{226}Ra	6.4	3.1
	^{210}Pb	9.7	2.5		^{210}Pb	6.6	3.3

TABLE 10

PERCENT RESPIRABLE COMPARISONS

Sample No.	^{238}U		% Respirable		
	AMAD (μm)	σ_g	ICRP	ACGIH ^a	ACGIH $\times .30$
1	10.6	3.9	8	22	7
2	9.6	3.7	9	23	7
3	7.6	2.8	10	24	7
4	12.0	4.0	8	20	6
5	12.6	4.4	7	20	6
6	17.3	2.9	6	8	2
7	6.0	3.8	12	34	10
8	5.8	3.9	12	35	11
9	9.1	2.5	9	18	5
10	6.8	3.1	11	29	9
11	10.7	4.0	8	22	7
12	15.3	4.8	7	18	5
13	10.9	3.3	8	19	6
14	14.0	3.9	7	17	5
15	29.4	4.9	4	10	3
16	7.4	4.5	11	31	9
17	19.4	3.6	6	11	3
18	5.6	3.4	12	35	11

^a American Conference of Governmental Industrial Hygienists.

Figure 1. Uranium processing mill impactor sampling locations.

Figure 2. Sierra impactor sampling test arrangement..

Figure 3. Sierra impactor sampling test arrangement with deflector plate. -28-

Figure 4 The deposition estimate for the pulmonary compartment while breathing at a moderate work rate.

APPENDIX I

URANIUM ORE DUST SAMPLE ANALYSES

TABLE I-1

IMPACTOR AND REFERENCE FILTER ANALYSES
(dpm per filter)

Sample No.			^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
1	82310	Ref	1000 $\pm$ 2.2	1000 $\pm$ 2.2	940 $\pm$ 3.2	950 $\pm$ 4.8	842 $\pm$ 1.5
2	82311	1-1	359 $\pm$ 3.0	355 $\pm$ 3.2	316 $\pm$ 2.9	237 $\pm$ 4.8	275 $\pm$ 2.5
3	82312	1-2	257 $\pm$ 1.9	273 $\pm$ 1.8	236 $\pm$ 3.2	220 $\pm$ 4.8	213 $\pm$ 2.1
4	82313	1-3	148 $\pm$ 2.0	144 $\pm$ 2.0	127 $\pm$ 3.1	151 $\pm$ 4.8	107 $\pm$ 3.0
5	82314	1-4	91.5 $\pm$ 2.6	92.1 $\pm$ 2.6	83.0 $\pm$ 3.2	105 $\pm$ 4.8	65.5 $\pm$ 3.1
6	82315	1-5	59.3 $\pm$ 1.7	58.3 $\pm$ 1.8	65.4 $\pm$ 3.9	77.3 $\pm$ 4.8	57.6 $\pm$ 3.9
7	82316	ff	51.6 $\pm$ 3.1	54.2 $\pm$ 3.2	48.1 $\pm$ 3.7	80.4 $\pm$ 4.8	60.0 $\pm$ 4.0
8	82317	Env Blank	2.42 $\pm$ 12	2.16 $\pm$ 12	1.91 $\pm$ 16	.68 $\pm$ 4.8	2.86 $\pm$ 11
9	82318	Control Filter	3.19 $\pm$ 3.5	4.40 $\pm$ 3.0	3.65 $\pm$ 3.1	3.81 $\pm$ 4.8	5.62 $\pm$ 13
10	82321	2-1	309 $\pm$ 1.6	305 $\pm$ 1.6	321 $\pm$ 2.5	216 $\pm$ 4.8	216 $\pm$ 2.2
11	82322	2-2	254 $\pm$ 2.3	261 $\pm$ 2.3	257 $\pm$ 2.3	193 $\pm$ 4.8	154 $\pm$ 2.5
12	82323	2-3	154 $\pm$ 2.5	148 $\pm$ 2.6	141 $\pm$ 3.4	134 $\pm$ 4.8	96.0 $\pm$ 4.1
13	82324	2-4	83.3 $\pm$ 2.5	83.9 $\pm$ 2.5	79.2 $\pm$ 3.8	84.1 $\pm$ 4.8	70.0 $\pm$ 4.0
14	82325	2-5	67.3 $\pm$ 2.4	66.7 $\pm$ 2.4	64.8 $\pm$ 3.7	72.0 $\pm$ 4.8	**
15	82326	ff	45.2 $\pm$ 3.2	30.9 $\pm$ 3.2	39.7 $\pm$ 4.2	59.2 $\pm$ 4.8	34.0 $\pm$ 4.8
Reagent & Procedure Blank			.31 $\pm$ 29	.33 $\pm$ 27	.48 $\pm$ 18	.28 $\pm$ 8.6	.28 $\pm$ 40
16	82330	Ref	1090 $\pm$ 2.0	1060 $\pm$ 2.0	1150 $\pm$ 2.8	1240 $\pm$ 4.8	1030 $\pm$ 1.5
17	82331	3-1	64.0 $\pm$ 2.8	62.5 $\pm$ 2.8	61.4 $\pm$ 5.6	70.2 $\pm$ 4.8	54.0 $\pm$ 3.6
18	82332	3-2	116 $\pm$ 3.8	116 $\pm$ 3.8	116 $\pm$ 2.9	129 $\pm$ 4.8	94.0 $\pm$ 2.5
19	82333	3-3	78.5 $\pm$ 1.4	77.3 $\pm$ 1.4	72.4 $\pm$ 3.4	84.1 $\pm$ 4.8	71.8 $\pm$ 2.5
20	82334	3-4	24.8 $\pm$ 4.0	25.4 $\pm$ 3.9	26.6 $\pm$ 4.6	29.8 $\pm$ 4.8	16.9 $\pm$ 5.0
21	82335	3-5	16.9 $\pm$ 3.2	15.1 $\pm$ 3.4	15.9 $\pm$ 4.7	27.1 $\pm$ 4.8	13.2 $\pm$ 5.5
22	82336	ff	13.6 $\pm$ 7.9	12.8 $\pm$ 9.5	11.6 $\pm$ 8.9	19.9 $\pm$ 4.8	11.0 $\pm$ 5.2
Reagent & Procedure Blank			<.074	.71 $\pm$ 16	.08 $\pm$ 50	.20 $\pm$ 9.4	.75 $\pm$ 20
23	84710	Ref	2350 $\pm$ 1.4	2340 $\pm$ 1.4	2400 $\pm$ 2.9	2030 $\pm$ 4.8	1740 $\pm$ 1.4
24	84711	1-1	903 $\pm$ 1.6	840 $\pm$ 1.6	854 $\pm$ 2.9	662 $\pm$ 4.8	727 $\pm$ 1.4
25	84712	1-2	707 $\pm$ 2.3	724 $\pm$ 2.2	746 $\pm$ 2.5	631 $\pm$ 4.8	633 $\pm$ 1.4
26	84713	1-3	306 $\pm$ 2.0	305 $\pm$ 2.0	316 $\pm$ 2.6	292 $\pm$ 4.8	255 $\pm$ 1.8

TABLE I-1 (Cont'd)

Sample No.			^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
27	84714	1-4	182 ± 3.5	183 ± 2.5	184 ± 2.8	193 ± 4.8	161 ± 1.2
28	84715	1-5	103 ± 2.1	101 ± 2.2	104 ± 4.2	103 ± 4.8	83.1 ± 1.7
29	84716	ff	129 ± 2.4	132 ± 2.4	136 ± 3.1	147 ± 4.8	131 ± 1.4
30	84720						
Slotted filter blank			12.6 ± 3.2	12.2 ± 3.3	2.45 ± 37	1.29 ± 5.1	1.07 ± 5.9
31	84721	2-1	823 ± 2.5	809 ± 2.5	823 ± 2.5	625 ± 4.8	624 ± 1.9
32	84722	2-2	563 ± 3.0	575 ± 3.0	544 ± 2.7	526 ± 4.8	429 ± 2.0
33	84723	2-3	268 ± 3.0	270 ± 3.0	280 ± 2.5	246 ± 12	202 ± 1.6
34	84724	2-4	134 ± 2.2	137 ± 2.2	133 ± 1.2	134 ± 4.8	97.1 ± 3.2
35	84725	2-5	96.6 ± 2.4	96.6 ± 2.4	97.3 ± 3.5	101 ± 4.8	70.4 ± 3.7
36	84726	ff	128 ± 2.1	127 ± 2.2	117 ± 2.6	128 ± 4.8	105 ± 3.0
37	84730	Ref	15000 ± 1.0	14900 ± 1.0	14900 ± 3.1	10700 ± 4.8	12600 ± 1.5
38	84731	3-1	5020 ± 1.1	5010 ± 1.1	5280 ± 3.7	4000 ± 4.8	4540 ± 1.4
39	84732	3-2	4170 ± 1.0	4140 ± 1.1	4380 ± 3.0	3480 ± 4.8	3580 ± 1.8
40	84733	3-3	862 ± 1.9	835 ± 1.9	845 ± 3.1	816 ± 20	831 ± 1.7
41	84734	3-4	385 ± 1.1	379 ± 1.1	388 ± 2.5	313 ± 4.8	330 ± 2.6
42	84735	3-5	116 ± 1.6	115 ± 1.6	127 ± 2.6	93.2 ± 4.8	98.7 ± 2.4
43	84736	ff	92.6 ± 2.3	93.6 ± 2.3	87.4 ± 3.6	63.6 ± 4.8	93.3 ± 9.0
44	82410	Ref	1660 ± 2.2	1610 ± 2.2	1650 ± 2.4	1000 ± 4.8	911 ± 1.5
45	82411	1-1	277 ± 1.9	274 ± 1.9	284 ± 2.4	177 ± 4.8	174 ± 1.6
46	82412	1-2	354 ± 1.7	350 ± 1.7	354 ± 2.6	219 ± 4.8	206 ± 1.8
47	82413	1-3	199 ± 2.4	197 ± 2.5	200 ± 1.2	132 ± 4.8	122 ± 1.9
48	82414	1-4	200 ± 3.3	193 ± 3.3	200 ± 2.6	99 ± 4.8	92.1 ± 4.6
49	82415	1-5	110 ± 2.2	110 ± 2.2	113 ± 3.2	64.7 ± 4.8	62.6 ± 3.4
50	82416	ff	144 ± 2.3	144 ± 2.3	133 ± 2.7	68.5 ± 4.8	80.2 ± 3.0
51	Whatman Control Blank		$<.84$	$<.96$	<1.2	1.28 ± 16	$.212 \pm 13$
52	82421	2-1	262 ± 2.2	260 ± 2.2	272 ± 2.4	162 ± 1.0	166 ± 1.0
53	82422	2-2	333 ± 2.0	330 ± 2.0	330 ± 2.3	196 ± 8.3	217 ± 1.3
54	82423	2-3	225 ± 1.5	226 ± 1.5	224 ± 2.7	148 ± 4.8	139 ± 2.5
55	82424	2-4	146 ± 1.7	147 ± 1.7	143 ± 3.0	66.7 ± 4.8	85.1 ± 3.7

TABLE 1-1 (Cont'd)

Sample No.			^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
56	82425	2-5	124 ± 3.3	125 ± 3.3	119 ± 3.0	58.0 ± 4.8	75.7 ± 2.5
57	82426	ff	156 ± 1.6	155 ± 1.6	145 ± 3.3	81.8 ± 4.8	91.4 ± 1.8
58	82430	Ref	3250 ± 2.0	3280 ± 2.0	3100 ± 2.8	2350 ± 4.8	2270 ± 1.0
59	82431	3-1	347 ± 2.5	367 ± 2.6	336 ± 3.4	274 ± 4.8	275 ± 1.3
60	82432	3-2	630 ± 2.2	674 ± 2.2	592 ± 2.7	529 ± 4.8	486 ± 1.1
61	82433	3-3	333 ± 2.9	341 ± 2.9	309 ± 2.7	270 ± 4.8	249 ± 1.2
62	82434	3-4	82.3 ± 2.2	83.4 ± 2.2	75.1 ± 3.8	59.3 ± 4.8	46.4 ± 2.3
63	82435	3-5	34.6 ± 2.8	36.0 ± 2.8	32.9 ± 3.8	19.3 ± 4.8	18.4 ± 6.3
64	82436	ff	38.1 ± 3.2	40.8 ± 3.2	34.5 ± 3.6	20.8 ± 4.8	24.7 ± 5.7
65	82440	Ref	874 ± 1.6	872 ± 1.6	823 ± 1.3	745 ± 4.8	747 ± 2.2
66	82441	1-1	139 ± 2.0	140 ± 2.0	129 ± 4.0	107 ± 4.8	113 ± 3.0
67	82442	1-2	252 ± 1.5	249 ± 1.5	237 ± 3.0	220 ± 4.8	215 ± 2.4
68	82443	1-3	137 ± 1.4	147 ± 1.4	130 ± 4.4	128 ± 4.8	114 ± 3.1
69	82444	1-4	87.8 ± 1.7	89.4 ± 1.7	81.2 ± 4.1	88.8 ± 4.8	76.0 ± 3.4
70	82445	1-5	46.6 ± 2.2	46.5 ± 2.2	50.2 ± 3.4	50.2 ± 4.8	40.6 ± 3.0
71	82446	ff	51.7 ± 2.0	49.0 ± 2.0	45.7 ± 3.9	52.3 ± 4.8	49.1 ± 3.3
72	82451	2-1	272 ± 1.1	276 ± 1.1	258 ± 4.8	232 ± 4.8	176 ± 2.3
73	82452	2-2	246 ± 1.3	250 ± 1.3	257 ± 4.8	236 ± 4.8	177 ± 2.1
74	82453	2-3	105 ± 1.6	108 ± 1.6	93.5 ± 4.9	101 ± 4.8	83.2 ± 3.0
75	82454	2-4	55.1 ± 1.9	56.8 ± 1.9	54.5 ± 4.8	58.2 ± 4.8	44.6 ± 3.7
76	82455	2-5	42.6 ± 2.4	42.6 ± 2.4	42.4 ± 3.7	46.8 ± 4.8	33.4 ± 4.6
77	82456	ff	51.1 ± 2.0	50.2 ± 2.0	41.8 ± 3.9	52.2 ± 4.8	45.8 ± 5.5
78	82460	Ref	6030 ± 1.0	6060 ± 1.0	5700 ± 3.1	4300 ± 4.8	3690 ± 1.5
79	82461	3-1	990 ± 1.5	997 ± 1.5	888 ± 3.5	674 ± 4.8	649 ± 2.0
80	82462	3-2	544 ± 1.1	547 ± 1.1	486 ± 3.9	433 ± 4.8	382 ± 1.5
81	82463	3-3	252 ± 1.4	246 ± 1.4	227 ± 3.5	236 ± 4.8	173 ± 2.3
82	82464	3-4	126 ± 1.6	126 ± 1.6	123 ± 3.5	120 ± 4.8	95.2 ± 3.1
83	82465	3-5	103 ± 1.7	102 ± 1.7	93.8 ± 3.6	92.2 ± 4.8	72.3 ± 3.1
84	82466	ff	117 ± 1.6	115 ± 1.6	104 ± 1.7	94.2 ± 4.8	86.4 ± 2.9
85	84910	Ref	4400 ± 1.0	4490 ± 1.0	3990 ± 2.7	3250 ± 4.8	3270 ± 1.7
86	84911	1-1	1360 ± 1.0	1340 ± 1.0	1320 ± 2.4	1080 ± 4.8	974 ± 2.0

TABLE I-1 (Cont'd)

Sample No.			^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
87	84912	1-2	1430 $\pm$ 1.5	1360 $\pm$ 1.5	1390 $\pm$ 2.5	1020 $\pm$ 4.8	1160 $\pm$ 1.5
88	84913	1-3	604 $\pm$ 1.0	579 $\pm$ 1.0	603 $\pm$ 2.6	487 $\pm$ 4.8	477 $\pm$ 1.3
89	84914	1-4	295 $\pm$ 3.5	307 $\pm$ 3.5	325 $\pm$ 2.6	245 $\pm$ 4.8	215 $\pm$ 2.2
90	84915	1-5	170 $\pm$ 1.0	168 $\pm$ 1.0	181 $\pm$ 2.6	138 $\pm$ 4.8	131 $\pm$ 2.4
91	84916	ff	147 $\pm$ 2.8	140 $\pm$ 2.9	139 $\pm$ 2.8	107 $\pm$ 4.8	102 $\pm$ 1.0
92	84921	2-1	1450 $\pm$ 1.0	1450 $\pm$ 1.0	1510 $\pm$ 2.5	1010 $\pm$ 4.8	1150 $\pm$ 1.4
93	84922	2-2	1060 $\pm$ 1.4	1030 $\pm$ 1.4	1000 $\pm$ 3.3	763 $\pm$ 4.8	775 $\pm$ 1.0
94	84923	2-3	415 $\pm$ 2.0	399 $\pm$ 2.0	425 $\pm$ 2.6	421 $\pm$ 20	325 $\pm$ 2.1
95	84924	2-4	190 $\pm$ 2.4	195 $\pm$ 2.4	193 $\pm$ 3.2	156 $\pm$ 4.8	141 $\pm$ 2.5
96	84925	2-5	149 $\pm$ 2.6	139 $\pm$ 2.7	152 $\pm$ 4.0	113 $\pm$ 4.8	111 $\pm$ 1.0
97	84926	ff	136 $\pm$ 2.0	127 $\pm$ 2.0	142 $\pm$ 2.8	92.5 $\pm$ 9.5	106 $\pm$ 2.5
98	84930	Ref	21900 $\pm$ 1.0	21900 $\pm$ 1.0	23300 $\pm$ 2.7	13500 $\pm$ 4.8	14400 $\pm$ 1.3
99	84931	3-1	6030 $\pm$ 1.4	5800 $\pm$ 1.4	6310 $\pm$ 2.8	3540 $\pm$ 4.8	3950 $\pm$ 1.5
100	84932	3-2	2110 $\pm$ 1.3	2020 $\pm$ 1.3	2100 $\pm$ 2.5	1290 $\pm$ 4.8	1400 $\pm$ 1.0
101	84933	3-3	731 $\pm$ 1.3	701 $\pm$ 1.3	669 $\pm$ 2.8	480 $\pm$ 4.8	562 $\pm$ 1.1
102	84934	3-4	316 $\pm$ 1.0	319 $\pm$ 1.0	340 $\pm$ 2.9	234 $\pm$ 4.8	251 $\pm$ 2.0
103	84935	3-5	262 $\pm$ 1.3	258 $\pm$ 1.3	261 $\pm$ 2.5	184 $\pm$ 4.8	206 $\pm$ 2.4
104	84936	ff	226 $\pm$ 1.3	218 $\pm$ 1.5	202 $\pm$ 2.2	164 $\pm$ 4.8	170 $\pm$ 2.5
Reagent & Procedure Blank			.430 $\pm$ 25	.538 $\pm$ 20	.517 $\pm$ 17	.676 $\pm$ 16	625 $\pm$ 33
105	82510	Ref	302 $\pm$ 1.5	302 $\pm$ 1.5	278 $\pm$ 2.6	269 $\pm$ 4.8	226 $\pm$ 2.8
106	82511	1-1	43.8 $\pm$ 4.3	45.4 $\pm$ 4.4	36.3 $\pm$ 4.9	36.7 $\pm$ 4.8	31.2 $\pm$ 4.7
107	82512	1-2	54.9 $\pm$ 2.1	55.2 $\pm$ 2.1	46.4 $\pm$ 3.5	45.7 $\pm$ 4.8	35.8 $\pm$ 4.2
108	82513	1-3	20.9 $\pm$ 2.7	19.4 $\pm$ 2.9	15.6 $\pm$ 4.5	12.4 $\pm$ 4.8	10.4 $\pm$ 6.5
109	82514	1-4	12.6 $\pm$ 3.4	12.5 $\pm$ 3.4	11.5 $\pm$ 4.8	10.4 $\pm$ 4.8	9.42 $\pm$ 8.7
110	82515	1-5	7.92 $\pm$ 7.4	8.46 $\pm$ 7.9	7.10 $\pm$ 5.8	6.26 $\pm$ 4.8	5.55 $\pm$ 7.4
111	82516	ff	24.1 $\pm$ 3.0	22.2 $\pm$ 3.1	18.7 $\pm$ 4.1	15.4 $\pm$ 4.8	19.5 $\pm$ 4.5
112	82520	Ref	517 $\pm$ 1.2	527 $\pm$ 1.2	495 $\pm$ 2.5	390 $\pm$ 4.8	356 $\pm$ 2.2
113	82521	2-1	181 $\pm$ 1.5	177 $\pm$ 1.5	173 $\pm$ 2.8	143 $\pm$ 4.8	138 $\pm$ 2.0
114	82522	2-2	105 $\pm$ 1.6	106 $\pm$ 1.6	102 $\pm$ 2.9	82.1 $\pm$ 4.8	71.3 $\pm$ 3.2
115	82523	2-3	34.7 $\pm$ 3.1	33.9 $\pm$ 3.1	31.3 $\pm$ 6.4	20.1 $\pm$ 4.8	23.2 $\pm$ 5.0

TABLE I-1 (Cont'd)

Sample No.			^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
116	82524	2-4	11.8 ± 3.7	12.6 ± 3.7	9.47 ± 4.6	5.95 ± 4.8	6.81 ± 8.4
117	82525	2-5	8.58 ± 2.5	8.72 ± 2.5	7.79 ± 4.8	4.41 ± 4.8	3.83 ± 9.0
118	82526	ff	6.36 ± 21	6.26 ± 21	5.01 ± 21	3.40 ± 4.8	3.21 ± 9.5
119	82530	Ref	572 ± 1.5	570 ± 1.5	477 ± 2.4	409 ± 4.8	431 ± 2.2
120	82531	3-1	34.4 ± 3.5	33.6 ± 3.6	31.4 ± 4.2	30.3 ± 4.8	28.1 ± 5.4
121	82532	3-2	48.9 ± 2.5	49.1 ± 2.5	45.8 ± 3.8	48.9 ± 4.8	36.3 ± 4.0
122	82533	3-3	43.6 ± 2.8	42.1 ± 2.9	35.6 ± 3.7	35.0 ± 4.8	26.9 ± 4.8
123	82534	3-4	22.3 ± 5.3	23.5 ± 5.3	18.3 ± 5.4	16.3 ± 4.8	15.5 ± 6.1
124	82535	3-5	19.7 ± 3.8	20.8 ± 4.0	14.2 ± 5.4	16.7 ± 4.8	11.8 ± 6.3
125	82536	ff	19.6 ± 6.0	19.8 ± 6.0	11.2 ± 4.9	10.0 ± 4.8	9.16 ± 6.6

* Samples collected by EML.

EML log number, cascade impactor stages, reference high volume filters and blanks are tabulated. Results reported $\pm$ the relative standard deviation (%) from the propagation of radiation counting measurement errors.

Appropriate blank corrections have been made to all reported results. Originally, no corrections were made for the slotted filter paper blanks on cascade impactor stages since there was more uranium in the blanks than in some exposed samples. In this report, the uranium content of the slotted filters was assumed to be the average of the ^{230}Th , ^{210}Pb , and ^{226}Ra contents, and corrections were made.

The inherent variation of the ^{226}Ra emanation counting technique for these samples was approximately $\pm 4\%$ for a single replicate.

Propagating this error with other inherent errors yielded a value of $\pm 4.8\%$ --unless limited by counting statistics as in the case of blanks.

** Sample 14-82325 2-5: The ^{210}Pb fraction was lost.

TABLE 1-2

GENERAL AIR SAMPLE ANALYSES
(dpm per filter)

Sample No.	^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
126	79.8 $\pm$ 2.6	82.6 $\pm$ 2.6	77.8 $\pm$ 3.7	75.6 $\pm$ 4.8	119 $\pm$ 2.3
127	1930 $\pm$ 1.9	1900 $\pm$ 1.9	18.7 $\pm$ 4.3	5.08 $\pm$ 13	17.5 $\pm$ 9.0
128	4070 $\pm$ 1.5	4120 $\pm$ 1.5	4060 $\pm$ 2.4	4210 $\pm$ 4.8	4000 $\pm$ 1.8
129	426 $\pm$ 1.3	433 $\pm$ 1.3	425 $\pm$ 3.2	385 $\pm$ 4.8	378 $\pm$ 1.0
130	156 $\pm$ 1.8	150 $\pm$ 1.8	154 $\pm$ 3.3	142 $\pm$ 4.8	148 $\pm$ 1.1
131	458 $\pm$ 1.5	451 $\pm$ 1.5	477 $\pm$ 2.5	281 $\pm$ 4.8	326 $\pm$ 1.9
132	1450 $\pm$ 1.7	1430 $\pm$ 1.7	33 $\pm$ 3.5	22.9 $\pm$ 4.8	57.9 $\pm$ 1.7
133	1730 $\pm$ 1.4	1690 $\pm$ 1.4	1660 $\pm$ 3.1	974 $\pm$ 4.8	1380 $\pm$ 1.1
134	296 $\pm$ 1.6	297 $\pm$ 1.6	278 $\pm$ 2.8	257 $\pm$ 4.8	241 $\pm$ 1.3
135	8960 $\pm$ 1.6	9000 $\pm$ 1.6	8200 $\pm$ 2.8	7690 $\pm$ 4.8	7140 $\pm$ 1.3
136	3230 $\pm$ 1.0	3210 $\pm$ 1.0	24.6 $\pm$ 5.0	12.2 $\pm$ 4.8	4.15 $\pm$ 11
137	63.4 $\pm$ 3.1	65.0 $\pm$ 3.1	62.5 $\pm$ 4.3	48.5 $\pm$ 4.8	48.2 $\pm$ 4.2
138	79.8 $\pm$ 1.2	77.1 $\pm$ 1.2	68.8 $\pm$ 3.7	56.1 $\pm$ 4.8	52.6 $\pm$ 3.9
Reagent and Procedure Blank	7.53 $\pm$ 16	7.53 $\pm$ 16	.23 $\pm$ 18	.28 $\pm$ 16	2.37 $\pm$ 19

These samples have been corrected for the reagent blank.

TABLE 1.3

BULK CORE SAMPLE ANALYSES
(dpm/g)

Sample No.	^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
139	1070 $\pm$ 1.1	1030 $\pm$ 1.1	1130 $\pm$ 7.9	1080 $\pm$ 3.1	976 $\pm$ 7.4
140	927 $\pm$ 1.3	948 $\pm$ 1.3	1010 $\pm$ 7.9	880 $\pm$ 3.1	798 $\pm$ 3.4
141	416 $\pm$ 1.1	400 $\pm$ 1.1	434 $\pm$ 7.9	345 $\pm$ 3.1	321 $\pm$ 1.9
142	496 $\pm$ 1.2	472 $\pm$ 1.2	514 $\pm$ 7.9	415 $\pm$ 3.1	382 $\pm$ 2.3
143	549 $\pm$ 1.5	551 $\pm$ 1.5	545 $\pm$ 7.9	445 $\pm$ 3.1	442 $\pm$ 1.6
144	1050 $\pm$ 1.5	1040 $\pm$ 1.5	1120 $\pm$ 7.9	1204 $\pm$ 3.1	983 $\pm$ 4.0
145	757 $\pm$ 1.4	746 $\pm$ 1.4	805 $\pm$ 7.9	757 $\pm$ 3.1	702 $\pm$ 1.4
146	1180 $\pm$ 1.3	1240 $\pm$ 1.2	1340 $\pm$ 7.9	1180 $\pm$ 3.1	959 $\pm$ 1.3
147	1270 $\pm$ 1.3	1290 $\pm$ 1.3	1400 $\pm$ 7.9	1110 $\pm$ 3.1	1360 $\pm$ 2.5
148	4380 $\pm$ 1.2	4280 $\pm$ 1.2	4700 $\pm$ 7.9	4356 $\pm$ 3.1	4150 $\pm$ 1.0

NOTES

The ^{230}Th and ^{226}Ra results are based upon direct counting with an intrinsic germanium diode. These were used since the normal technique yielded less precise results for these samples. The error estimates for direct counting include propagated counting errors (RMS error) and estimates of the accuracy of calibration (linear error).

Appropriate reagent blank corrections have been applied to these results.

APPENDIX II

NUCLIDE EQUILIBRIUM RATIOS

TABLE 11.1

IMPACTOR AND REFERENCE FILTER NUMERICAL RATIOS

SAMPLE #1	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	359.00± 3.0	0.989±0.043	0.880±0.037	0.660±0.037	0.766±0.030
S-2	257.00± 1.9	1.062±0.028	0.918±0.034	0.856±0.044	0.829±0.023
S-3	148.00± 2.0	0.973±0.028	0.858±0.032	1.020±0.053	0.723±0.026
S-4	91.50± 2.6	1.007±0.037	0.907±0.037	1.148±0.063	0.716±0.029
S-5	59.30± 1.7	0.983±0.024	1.103±0.047	1.304±0.066	0.971±0.041
F.F.	51.60± 3.1	1.050±0.047	0.932±0.045	1.558±0.089	1.163±0.059
TOTAL	966.40± 2.4	1.011±0.034	0.906±0.038	0.901±0.048	0.805±0.032
REF.	1000.00± 2.2	1.000±0.031	0.940±0.037	0.950±0.050	0.842±0.022

SAMPLE #2	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	309.00± 1.6	0.987±0.022	1.039±0.031	0.699±0.035	0.699±0.019
S-2	254.00± 2.3	1.028±0.033	1.012±0.033	0.760±0.040	0.606±0.021
S-3	154.00± 2.5	0.961±0.035	0.916±0.039	0.870±0.047	0.623±0.030
S-4	83.30± 2.5	1.007±0.036	0.951±0.043	1.010±0.055	0.640±0.040
S-5	67.30± 2.4	0.991±0.034	0.963±0.042	1.070±0.056	0.624±0.029
F.F.	45.20± 3.2	0.905±0.041	0.878±0.046	1.310±0.076	0.752±0.043
TOTAL	912.80± 2.5	0.981±0.035	0.989±0.042	0.831±0.045	0.670±0.030
REF.	1000.00± 2.2	1.000±0.031	0.940±0.037	0.950±0.050	0.842±0.022

SAMPLE #3	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	64.00± 2.8	0.977±0.039	0.959±0.060	1.097±0.061	0.844±0.038
S-2	116.00± 3.8	1.000±0.054	1.000±0.054	1.112±0.068	0.810±0.037
S-3	78.50± 1.4	0.985±0.019	0.922±0.034	1.071±0.054	0.915±0.026
S-4	24.80± 4.0	1.024±0.057	1.073±0.065	1.202±0.075	0.681±0.044
S-5	16.90± 3.2	0.893±0.042	0.941±0.053	1.604±0.093	0.781±0.050
F.F.	13.60± 7.9	0.941±0.116	0.853±0.102	1.463±0.135	0.809±0.076
TOTAL	313.80± 4.3	0.985±0.064	0.968±0.062	1.148±0.074	0.831±0.050
REF.	1090.00± 2.0	0.972±0.028	1.055±0.036	1.138±0.059	0.945±0.024

TABLE II-1 (Cont'd)

SAMPLE #4	U-238 (DPM)	U-234 U-238	TH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	903.00± 1.6	0.930±0.021	0.946±0.031	0.733±0.037	0.805±0.017
S-2	707.00± 2.3	1.024±0.033	1.055±0.036	0.893±0.048	0.895±0.024
S-3	306.00± 2.0	0.997±0.028	1.033±0.034	0.954±0.050	0.833±0.022
S-4	182.00± 3.5	1.005±0.043	1.011±0.045	1.060±0.063	0.885±0.033
S-5	103.00± 2.1	0.981±0.030	1.010±0.047	1.000±0.052	0.807±0.022
F.F.	129.00± 2.4	1.023±0.035	1.054±0.041	1.140±0.061	1.016±0.028
TOTAL	2330.00± 2.4	0.981±0.032	1.004±0.039	0.870±0.047	0.854±0.024
REF.	2350.00± 1.4	0.996±0.020	1.021±0.033	0.864±0.043	0.740±0.015

SAMPLE #5	U-238 (DPM)	U-234 U-238	TH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	823.00± 2.5	0.983±0.035	1.000±0.035	0.759±0.041	0.758±0.024
S-2	563.00± 3.0	1.021±0.043	0.966±0.039	0.934±0.053	0.762±0.027
S-3	268.00± 3.0	1.007±0.043	1.045±0.041	0.918±0.114	0.754±0.026
S-4	134.00± 2.2	1.022±0.032	0.993±0.025	1.000±0.053	0.725±0.028
S-5	96.60± 2.4	1.000±0.034	1.007±0.043	1.046±0.056	0.729±0.032
F.F.	128.00± 2.1	0.992±0.030	0.914±0.031	1.000±0.052	0.820±0.030
TOTAL	2012.60± 2.6	1.001±0.037	0.991±0.036	0.874±0.062	0.759±0.028
REF.	2350.00± 1.4	0.996±0.020	1.021±0.033	0.864±0.043	0.740±0.015

SAMPLE #6	U-238 (DPM)	U-234 U-238	TH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	5020.00± 1.1	0.998±0.016	1.052±0.041	0.797±0.039	0.904±0.016
S-2	4170.00± 1.0	0.993±0.015	1.050±0.033	0.835±0.041	0.859±0.018
S-3	862.00± 1.9	0.969±0.026	0.980±0.036	0.947±0.190	0.964±0.025
S-4	385.00± 1.1	0.984±0.015	1.008±0.028	0.813±0.040	0.857±0.024
S-5	116.00± 1.6	0.991±0.022	1.095±0.033	0.803±0.041	0.851±0.025
F.F.	92.60± 2.3	1.011±0.033	0.944±0.040	0.687±0.037	1.008±0.094
TOTAL	10645.60± 1.6	0.993±0.022	1.043±0.036	0.823±0.078	0.890±0.039
REF.	15000.00± 1.0	0.993±0.014	0.993±0.032	0.713±0.035	0.840±0.015

TABLE II-1 (Cont'd)

SAMPLE #7	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	277.00± 1.9	0.989±0.027	1.025±0.031	0.639±0.033	0.628±0.016
S-2	354.00± 1.7	0.989±0.024	1.000±0.031	0.619±0.032	0.582±0.014
S-3	199.00± 2.4	0.990±0.034	1.005±0.027	0.663±0.036	0.613±0.019
S-4	200.00± 3.3	0.965±0.045	1.000±0.042	0.495±0.029	0.460±0.026
S-5	110.00± 2.2	1.000±0.031	1.027±0.040	0.588±0.031	0.569±0.023
F.F.	144.00± 2.3	1.000±0.033	0.924±0.033	0.476±0.025	0.557±0.021
TOTAL	1284.00± 2.4	0.988±0.034	1.000±0.035	0.592±0.032	0.574±0.022
REF.	1660.00± 2.2	0.970±0.030	0.994±0.032	0.602±0.032	0.549±0.015

SAMPLE #8	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	262.00± 2.2	0.992±0.031	1.038±0.034	0.618±0.015	0.634±0.015
S-2	333.00± 2.0	0.991±0.028	0.991±0.030	0.589±0.050	0.652±0.016
S-3	225.00± 1.5	1.004±0.021	0.996±0.031	0.658±0.033	0.618±0.018
S-4	146.00± 1.7	1.007±0.024	0.979±0.034	0.457±0.023	0.583±0.024
S-5	124.00± 3.3	1.008±0.047	0.960±0.043	0.468±0.027	0.609±0.025
F.F.	156.00± 1.6	0.994±0.022	0.929±0.034	0.524±0.027	0.586±0.014
TOTAL	1246.00± 2.1	0.998±0.030	0.990±0.035	0.572±0.032	0.621±0.019
REF.	1660.00± 2.2	0.970±0.030	0.994±0.032	0.602±0.032	0.549±0.015

SAMPLE #9	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	347.00± 2.5	1.058±0.038	0.968±0.041	0.790±0.043	0.793±0.022
S-2	630.00± 2.2	1.070±0.033	0.940±0.033	0.840±0.044	0.771±0.019
S-3	333.00± 2.9	1.024±0.042	0.928±0.037	0.811±0.045	0.748±0.023
S-4	82.30± 2.2	1.013±0.032	0.913±0.040	0.721±0.038	0.564±0.018
S-5	34.60± 2.8	1.040±0.041	0.951±0.045	0.558±0.031	0.532±0.037
F.F.	38.10± 3.2	1.071±0.048	0.906±0.044	0.546±0.031	0.648±0.042
TOTAL	1465.00± 2.7	1.053±0.040	0.942±0.041	0.800±0.044	0.751±0.034
REF.	3250.00± 2.0	1.009±0.029	0.954±0.033	0.723±0.037	0.698±0.016

TABLE II-1 (Cont'd)

SAMPLE #10	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	139.00± 2.0	1.007±0.028	0.928±0.042	0.770±0.040	0.813±0.029
S-2	252.00± 1.5	0.988±0.021	0.940±0.032	0.873±0.044	0.853±0.024
S-3	137.00± 1.4	1.073±0.021	0.949±0.044	0.934±0.047	0.832±0.028
S-4	87.80± 1.7	1.018±0.024	0.925±0.041	1.011±0.052	0.866±0.033
S-5	46.60± 2.2	0.998±0.031	1.077±0.044	1.077±0.057	0.871±0.032
F.F.	51.70± 2.0	0.948±0.027	0.884±0.039	1.012±0.053	0.950±0.037
TOTAL	714.10± 1.8	1.010±0.026	0.943±0.040	0.905±0.046	0.851±0.031
REF.	874.00± 1.6	0.998±0.023	0.942±0.019	0.852±0.043	0.855±0.023

SAMPLE #11	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	272.00± 1.1	1.015±0.016	0.949±0.047	0.853±0.042	0.647±0.016
S-2	246.00± 1.3	1.016±0.019	1.045±0.052	0.959±0.048	0.720±0.018
S-3	105.00± 1.6	1.029±0.023	0.890±0.046	0.962±0.049	0.792±0.027
S-4	55.10± 1.9	1.031±0.028	0.989±0.051	1.056±0.055	0.809±0.034
S-5	42.60± 2.4	1.000±0.034	0.995±0.044	1.099±0.059	0.784±0.041
F.F.	51.10± 2.0	0.982±0.028	0.818±0.036	1.022±0.053	0.896±0.052
TOTAL	771.80± 1.8	1.015±0.026	0.968±0.047	0.941±0.048	0.726±0.030
REF.	874.00± 1.6	0.998±0.023	0.942±0.019	0.852±0.043	0.855±0.023

SAMPLE #12	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	990.00± 1.5	1.007±0.021	0.897±0.034	0.681±0.034	0.656±0.016
S-2	544.00± 1.1	1.006±0.016	0.893±0.036	0.796±0.039	0.702±0.013
S-3	252.00± 1.4	0.976±0.019	0.901±0.034	0.937±0.047	0.687±0.018
S-4	126.00± 1.6	1.000±0.023	0.976±0.038	0.952±0.048	0.756±0.026
S-5	103.00± 1.7	0.990±0.024	0.911±0.036	0.895±0.046	0.702±0.025
F.F.	117.00± 1.6	0.983±0.022	0.889±0.021	0.805±0.041	0.738±0.024
TOTAL	2132.00± 1.5	1.000±0.021	0.901±0.033	0.774±0.039	0.684±0.021
REF.	6030.00± 1.0	1.005±0.014	0.945±0.031	0.713±0.035	0.612±0.011

TABLE II-1 (Cont'd)

SAMPLE #13	U-238 (DPM)	U-234 U-238	TH-230 U-238	RA-226 U-238	PB-210 U-238
S-1	1360.00± 1.0	0.985±0.014	0.971±0.025	0.794±0.039	0.716±0.016
S-2	1430.00± 1.5	0.951±0.020	0.972±0.028	0.713±0.036	0.811±0.017
S-3	604.00± 1.0	0.959±0.014	0.998±0.028	0.806±0.040	0.790±0.013
S-4	295.00± 3.5	1.041±0.052	1.102±0.048	0.831±0.049	0.725±0.030
S-5	170.00± 1.0	0.988±0.014	1.065±0.030	0.812±0.040	0.771±0.020
F.F.	147.00± 2.8	0.952±0.038	0.946±0.037	0.728±0.040	0.694±0.021
TOTAL	4006.00± 2.1	0.972±0.029	0.988±0.033	0.768±0.040	0.764±0.021
REF.	4400.00± 1.0	1.020±0.014	0.907±0.026	0.739±0.036	0.743±0.015

SAMPLE #14	U-238 (DPM)	U-234 U-238	TH-230 U-238	RA-226 U-238	PB-210 U-238
S-1	1450.00± 1.0	1.000±0.014	1.041±0.028	0.697±0.034	0.793±0.014
S-2	1060.00± 1.4	0.972±0.019	0.943±0.034	0.720±0.036	0.731±0.013
S-3	415.00± 2.0	0.961±0.027	1.024±0.034	1.014±0.204	0.783±0.023
S-4	190.00± 2.4	1.026±0.035	1.016±0.041	0.821±0.044	0.742±0.026
S-5	149.00± 2.6	0.933±0.035	1.020±0.049	0.758±0.041	0.745±0.021
F.F.	136.00± 2.0	0.934±0.026	1.044±0.036	0.680±0.066	0.779±0.025
TOTAL	3400.00± 1.9	0.982±0.026	1.006±0.037	0.752±0.076	0.767±0.021
REF.	4400.00± 1.0	1.020±0.014	0.907±0.026	0.739±0.036	0.743±0.015

SAMPLE #15	U-238 (DPM)	U-234 U-238	TH-230 U-238	RA-226 U-238	PB-210 U-238
S-1	6030.00± 1.4	0.962±0.019	1.046±0.033	0.587±0.029	0.655±0.013
S-2	2110.00± 1.3	0.957±0.018	0.995±0.028	0.611±0.030	0.664±0.011
S-3	731.00± 1.3	0.959±0.018	0.915±0.028	0.657±0.033	0.769±0.013
S-4	316.00± 1.0	1.009±0.014	1.076±0.033	0.741±0.036	0.794±0.018
S-5	262.00± 1.3	0.985±0.018	0.996±0.028	0.702±0.035	0.786±0.021
F.F.	226.00± 1.3	0.965±0.019	0.894±0.023	0.726±0.036	0.752±0.021
TOTAL	9675.00± 1.3	0.963±0.018	1.021±0.030	0.609±0.030	0.676±0.015
REF.	21900.00± 1.0	1.000±0.014	1.064±0.031	0.616±0.030	0.658±0.011

TABLE 11-1 (Cont'd)

SAMPLE #16	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	43.80± 4.3	1.037±0.064	0.829±0.054	0.838±0.054	0.712±0.045
S-2	54.90± 2.1	1.005±0.030	0.845±0.034	0.832±0.044	0.652±0.031
S-3	20.90± 2.7	0.928±0.037	0.746±0.039	0.593±0.033	0.498±0.035
S-4	12.60± 3.4	0.992±0.048	0.913±0.054	0.825±0.049	0.748±0.070
S-5	7.92± 7.4	1.068±0.116	0.896±0.084	0.790±0.070	0.701±0.073
F.F.	24.10± 3.0	0.921±0.040	0.776±0.039	0.639±0.036	0.809±0.044
TOTAL	164.22± 4.2	0.994±0.060	0.826±0.052	0.773±0.049	0.681±0.051
REF.	302.00± 1.5	1.000±0.021	0.921±0.028	0.891±0.045	0.748±0.024

SAMPLE #17	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	181.00± 1.5	0.978±0.021	0.956±0.030	0.790±0.040	0.762±0.019
S-2	105.00± 1.6	1.010±0.023	0.971±0.032	0.782±0.040	0.679±0.024
S-3	34.70± 3.1	0.977±0.043	0.902±0.064	0.579±0.033	0.669±0.039
S-4	11.80± 3.7	1.068±0.056	0.803±0.047	0.504±0.031	0.577±0.053
S-5	8.58± 2.5	1.016±0.036	0.908±0.049	0.514±0.028	0.446±0.042
F.F.	6.36±21.0	0.984±0.292	0.788±0.234	0.535±0.115	0.505±0.116
TOTAL	347.44± 8.9	0.991±0.125	0.946±0.123	0.745±0.075	0.709±0.079
REF.	517.00± 1.2	1.019±0.017	0.957±0.027	0.754±0.037	0.689±0.017

SAMPLE #18	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
S-1	34.40± 3.5	0.977±0.049	0.913±0.050	0.881±0.052	0.817±0.053
S-2	48.90± 2.5	1.004±0.035	0.937±0.043	1.000±0.054	0.742±0.035
S-3	43.60± 2.8	0.966±0.039	0.817±0.038	0.803±0.045	0.617±0.034
S-4	22.30± 5.3	1.054±0.079	0.821±0.062	0.731±0.052	0.695±0.056
S-5	19.70± 3.8	1.056±0.058	0.721±0.048	0.848±0.052	0.599±0.044
F.F.	19.60± 6.0	1.010±0.086	0.571±0.044	0.510±0.039	0.467±0.042
TOTAL	188.50± 4.2	1.002±0.060	0.830±0.052	0.834±0.053	0.678±0.047
REF.	572.00± 1.5	0.997±0.021	0.834±0.024	0.715±0.036	0.753±0.020

TABLE II-2
GENERAL AIR SAMPLES

SAMPLE	U-238 (DPM)	U-234 U-238	IH-230 U-238	BA-226 U-238	PB-210 U-238
1	79.80± 2.6	1.035±0.038	0.975±0.044	0.947±0.052	1.491±0.052
2	1930.00± 1.9	0.984±0.026	0.010±0.000	0.003±0.000	0.009±0.001
3	4070.00± 1.5	1.012±0.021	0.998±0.028	1.034±0.052	0.983±0.023
4	426.00± 1.3	1.016±0.019	0.998±0.034	0.904±0.045	0.887±0.015
5	156.00± 1.8	0.962±0.024	0.987±0.037	0.910±0.047	0.949±0.020
6	458.00± 1.5	0.985±0.021	1.041±0.030	0.614±0.031	0.712±0.017
7	1450.00± 1.7	0.986±0.024	0.023±0.001	0.016±0.001	0.040±0.001
8	1730.00± 1.4	0.977±0.019	0.960±0.033	0.563±0.028	0.798±0.014
9	296.00± 1.6	1.003±0.023	0.939±0.030	0.868±0.044	0.814±0.017
10	8960.00± 1.6	1.004±0.023	0.915±0.030	0.858±0.043	0.797±0.016
11	3230.00± 1.0	0.994±0.014	0.008±0.000	0.004±0.000	0.001±0.000

Sample
No.

Location

1	Ore bin area
2	Ore barreling area
3	Sample preparation room (A)
4	Sample preparation room (B)
5	Ore bin area
6	Secondary crusher (cat walk)
7	Ore barreling area
8	Sample preparation room (A)
9	Sample preparation room (B)
10	Sample preparation room (A)
11	Ore barreling area

TABLE II 3
BULK ORE SAMPLES

SAMPLE	U-238 (DPM)	U-234 U-238	TH-230 U-238	BA-226 U-238	PB-210 U-238
1	1070.00± 1.1	0.963±0.015	1.056±0.084	1.009±0.033	0.912±0.068
2	927.00± 1.3	1.023±0.019	1.090±0.087	0.949±0.032	0.861±0.031
3	416.00± 1.1	0.962±0.015	1.043±0.083	0.829±0.027	0.772±0.017
4	496.00± 1.2	0.952±0.016	1.036±0.083	0.837±0.028	0.770±0.020
5	549.00± 1.5	1.004±0.021	0.993±0.080	0.811±0.028	0.805±0.018
6	1050.00± 1.5	0.990±0.021	1.067±0.086	1.147±0.039	0.936±0.040
7	757.00± 1.4	0.985±0.020	1.063±0.085	1.000±0.034	0.927±0.018
8	1180.00± 1.3	1.051±0.019	1.136±0.091	1.000±0.034	0.813±0.015
9	1270.00± 1.3	1.016±0.019	1.102±0.088	0.874±0.029	1.071±0.030
10	4380.00± 1.2	0.977±0.017	1.073±0.086	0.995±0.033	0.947±0.015

APPENDIX 111

IMPACTOR SIZE DISTRIBUTION PLOTS

Impactor Sample 1; Secondary Crusher

Impactor Sample 2; Secondary Crusher

Impactor Sample 3; Primary Crusher

PARTICLE DIAMETER (MICROMETERS)

Impactor Sample 4; Secondary Crusher

Impactor Sample in Secondary Crusher

Impactor Sample 8; Secondary Crusher

Impactor Sample 9; Primary Crusher

Impactor Sample 10; Secondary Crusher

PARTICLE DIAMETER (MICROMETERS)

Impactor Sample 12; Secondary Crusher (Lower Level)

PARTICLE DIAMETER (MICROMETERS)

Impactor Sample 14; Secondary Crusher

Impactor Sample 16; Ore Bin Area

Impactor Sample 18; Sample Preparation Room B

APPENDIX IV

DUPLICATE SAMPLE EQUILIBRIUM RATIO COMPARISONS

TABLE IV-1

IMPACTOR # 1	U-238	U-234	IH-230	BA-226	PB-210
SAMPLE #1	(DPM)	U-238	U-238	U-238	U-238
S-1	359.00± 3.0	0.989±0.043	0.880±0.037	0.660±0.037	0.766±0.030
S-2	257.00± 1.9	1.062±0.028	0.918±0.034	0.856±0.044	0.829±0.023
S-3	148.00± 2.0	0.973±0.028	0.858±0.032	1.020±0.053	0.723±0.026
S-4	91.50± 2.6	1.007±0.037	0.907±0.037	1.148±0.063	0.716±0.029
S-5	59.30± 1.7	0.983±0.024	1.103±0.047	1.304±0.066	0.971±0.041
F.F.	51.60± 3.1	1.050±0.047	0.932±0.045	1.558±0.089	1.163±0.059
TOTAL	966.40± 2.4	1.011±0.034	0.906±0.038	0.901±0.048	0.805±0.032

IMPACTOR # 2	U-238	U-234	IH-230	BA-226	PB-210
SAMPLE #2	(DPM)	U-238	U-238	U-238	U-238
S-1	309.00± 1.6	0.987±0.022	1.039±0.031	0.699±0.035	0.699±0.019
S-2	254.00± 2.3	1.028±0.033	1.012±0.033	0.760±0.040	0.606±0.021
S-3	154.00± 2.5	0.961±0.035	0.916±0.039	0.870±0.047	0.623±0.030
S-4	83.30± 2.5	1.007±0.036	0.951±0.043	1.010±0.055	0.840±0.040
S-5	67.30± 2.4	0.991±0.034	0.963±0.042	1.070±0.056	0.624±0.029
F.F.	45.20± 3.2	0.905±0.041	0.878±0.046	1.310±0.076	0.752±0.043
TOTAL	912.80± 2.5	0.981±0.035	0.989±0.042	0.831±0.045	0.670±0.030

DIFFERENCE BETWEEN NUCLIDE RATIOS OF DUPLICATE SAMPLES(%)					
IMPACTOR	U-234	IH-230	BA-226	PB-210	
S-1	(0.2± 4.9)%	(16.5± 5.0)%	(5.7± 7.6)%	(9.1± 4.8)%	
S-2	(3.3± 4.2)%	(9.7± 4.9)%	(11.9± 7.4)%	(31.0± 4.4)%	
S-3	(1.2± 4.6)%	(6.5± 5.6)%	(15.9± 7.5)%	(14.8± 5.9)%	
S-4	(0.1± 5.1)%	(4.7± 6.2)%	(12.8± 7.7)%	(16.0± 6.3)%	
S-5	(0.8± 4.2)%	(13.6± 6.1)%	(19.7± 7.3)%	(43.5± 6.5)%	
F.F.	(14.9± 6.4)%	(5.9± 7.1)%	(17.3± 8.2)%	(42.9± 7.8)%	
TOTAL	(3.0± 4.9)%	(8.8± 5.9)%	(8.1± 7.6)%	(18.3± 6.0)%	

TABLE IV-2

IMPACTOR # 1	U-238	U-234	TH-230	BA-226	PB-210
SAMPLE #4	(DPM)	U-238	U-238	U-238	U-238
S-1	903.00± 1.6	0.930±0.021	0.946±0.031	0.733±0.037	0.805±0.017
S-2	707.00± 2.3	1.024±0.033	1.055±0.036	0.893±0.048	0.895±0.024
S-3	306.00± 2.0	0.997±0.028	1.033±0.034	0.954±0.050	0.833±0.022
S-4	182.00± 3.5	1.005±0.043	1.011±0.045	1.060±0.063	0.885±0.033
S-5	103.00± 2.1	0.981±0.030	1.010±0.047	1.000±0.052	0.807±0.022
F.F.	129.00± 2.4	1.023±0.035	1.054±0.041	1.140±0.061	1.016±0.028
TOTAL	2330.00± 2.4	0.981±0.032	1.004±0.039	0.870±0.047	0.854±0.024

IMPACTOR # 2	U-238	U-234	TH-230	BA-226	PB-210
SAMPLE #5	(DPM)	U-238	U-238	U-238	U-238
S-1	823.00± 2.5	0.983±0.035	1.000±0.035	0.759±0.041	0.758±0.024
S-2	563.00± 3.0	1.021±0.043	0.966±0.039	0.934±0.053	0.762±0.027
S-3	268.00± 3.0	1.007±0.043	1.045±0.041	0.918±0.114	0.754±0.026
S-4	134.00± 2.2	1.022±0.032	0.993±0.025	1.000±0.053	0.725±0.028
S-5	96.60± 2.4	1.000±0.034	1.007±0.043	1.046±0.056	0.729±0.032
F.F.	128.00± 2.1	0.992±0.030	0.914±0.031	1.000±0.052	0.820±0.030
TOTAL	2012.60± 2.6	1.001±0.037	0.991±0.036	0.874±0.062	0.759±0.028

DIFFERENCE BETWEEN NUCLIDE RATIOS OF DUPLICATE SAMPLES(%)					
IMPACTOR	U-234	TH-230	BA-226	PB-210	
S-1	(5.5± 4.2)%	(5.6± 4.9)%	(3.5± 7.4)%	(6.0± 3.8)%	
S-2	(0.3± 5.3)%	(8.8± 5.2)%	(4.6± 7.8)%	(16.1± 4.4)%	
S-3	(1.1± 5.1)%	(1.2± 5.1)%	(3.9±13.2)%	(10.0± 4.3)%	
S-4	(1.7± 5.3)%	(1.8± 5.2)%	(5.9± 8.0)%	(19.9± 5.4)%	
S-5	(2.0± 4.6)%	(0.2± 6.3)%	(4.5± 7.5)%	(10.2± 5.1)%	
F.F.	(3.1± 4.6)%	(14.2± 5.2)%	(13.0± 7.5)%	(21.3± 4.5)%	
TOTAL	(2.0± 4.9)%	(1.3± 5.4)%	(0.5± 8.9)%	(11.8± 4.6)%	

TABLE IV-3

IMPACTOR # 1	U-238	U-234	TH-230	BA-226	PB-210
SAMPLE #7	(DPM)	U-238	U-238	U-238	U-238
S-1	277.00± 1.9	0.989±0.027	1.025±0.031	0.639±0.033	0.628±0.016
S-2	354.00± 1.7	0.989±0.024	1.000±0.031	0.619±0.032	0.582±0.014
S-3	199.00± 2.4	0.990±0.034	1.005±0.027	0.663±0.036	0.613±0.019
S-4	200.00± 3.3	0.965±0.045	1.000±0.042	0.495±0.029	0.460±0.026
S-5	110.00± 2.2	1.000±0.031	1.027±0.040	0.588±0.031	0.569±0.023
F.F.	144.00± 2.3	1.000±0.033	0.924±0.033	0.476±0.025	0.557±0.021
TOTAL	1284.00± 2.4	0.988±0.034	1.000±0.035	0.592±0.032	0.574±0.022

IMPACTOR # 2	U-238	U-234	TH-230	BA-226	PB-210
SAMPLE #8	(DPM)	U-238	U-238	U-238	U-238
S-1	262.00± 2.2	0.992±0.031	1.038±0.034	0.618±0.015	0.634±0.015
S-2	333.00± 2.0	0.991±0.028	0.991±0.030	0.589±0.050	0.652±0.016
S-3	225.00± 1.5	1.004±0.021	0.996±0.031	0.658±0.033	0.618±0.018
S-4	146.00± 1.7	1.007±0.024	0.979±0.034	0.457±0.023	0.583±0.024
S-5	124.00± 3.3	1.008±0.047	0.960±0.043	0.468±0.027	0.609±0.025
F.F.	156.00± 1.6	0.994±0.022	0.929±0.034	0.524±0.027	0.586±0.014
TOTAL	1246.00± 2.1	0.998±0.030	0.990±0.035	0.572±0.032	0.621±0.019

DIFFERENCE BETWEEN NUCLIDE RATIOS OF DUPLICATE SAMPLES(%)				
IMPACTOR	U-234	TH-230	BA-226	PB-210
S-1	(0.3± 4.1)%	(1.3± 4.5)%	(3.3± 5.8)%	(0.9± 3.5)%
S-2	(0.2± 3.7)%	(0.9± 4.4)%	(5.0± 9.8)%	(11.3± 3.4)%
S-3	(1.5± 4.1)%	(0.9± 4.1)%	(0.8± 7.4)%	(0.8± 4.2)%
S-4	(4.2± 5.2)%	(2.1± 5.4)%	(8.0± 7.8)%	(23.5± 6.8)%
S-5	(0.8± 5.6)%	(6.8± 5.9)%	(22.8± 7.9)%	(6.8± 5.8)%
F.F.	(0.6± 4.0)%	(0.6± 5.1)%	(9.7± 7.3)%	(5.1± 4.4)%
TOTAL	(1.0± 4.5)%	(1.0± 4.9)%	(3.5± 7.8)%	(7.9± 4.9)%

TABLE IV-4

IMPACTOR # 1	U-238	U-234	TH-230	BA-226	PB-210
SAMPLE #10	(DPM)	U-238	U-238	U-238	U-238
S-1	139.00± 2.0	1.007±0.028	0.928±0.042	0.770±0.040	0.813±0.029
S-2	252.00± 1.5	0.988±0.021	0.940±0.032	0.873±0.044	0.853±0.024
S-3	137.00± 1.4	1.073±0.021	0.949±0.044	0.934±0.047	0.832±0.028
S-4	87.80± 1.7	1.018±0.024	0.925±0.041	1.011±0.052	0.866±0.033
S-5	46.60± 2.2	0.998±0.031	1.077±0.044	1.077±0.057	0.871±0.032
F.F.	51.70± 2.0	0.948±0.027	0.884±0.039	1.012±0.053	0.950±0.037
TOTAL	714.10± 1.8	1.010±0.026	0.943±0.040	0.905±0.046	0.851±0.031

IMPACTOR # 2	U-238	U-234	TH-230	BA-226	PB-210
SAMPLE #11	(DPM)	U-238	U-238	U-238	U-238
S-1	272.00± 1.1	1.015±0.016	0.949±0.047	0.853±0.042	0.647±0.016
S-2	105.00± 1.6	1.029±0.023	0.890±0.046	0.962±0.049	0.792±0.027
S-3	246.00± 1.3	1.016±0.019	1.045±0.052	0.959±0.048	0.720±0.018
S-4	55.10± 1.9	1.031±0.028	0.989±0.051	1.056±0.055	0.809±0.034
S-5	42.60± 2.4	1.000±0.034	0.995±0.044	1.099±0.059	0.784±0.041
F.F.	51.10± 2.0	0.982±0.028	0.818±0.036	1.022±0.053	0.896±0.052
TOTAL	771.80± 1.8	1.015±0.026	0.968±0.047	0.941±0.048	0.726±0.030

DIFFERENCE BETWEEN NUCLIDE RATIOS OF DUPLICATE SAMPLES(%)				
IMPACTOR	U-234	TH-230	BA-226	PB-210
S-1	(0.7± 3.2)%	(2.2± 6.7)%	(10.2± 7.2)%	(22.7± 4.6)%
S-2	(4.0± 3.1)%	(5.5± 6.1)%	(9.7± 7.2)%	(7.4± 4.4)%
S-3	(5.4± 2.7)%	(9.6± 6.8)%	(2.6± 7.1)%	(14.5± 4.3)%
S-4	(1.2± 3.6)%	(6.7± 6.8)%	(4.3± 7.3)%	(6.7± 5.6)%
S-5	(0.2± 4.6)%	(7.9± 6.0)%	(2.0± 7.5)%	(10.5± 6.3)%
F.F.	(3.6± 4.0)%	(7.7± 6.2)%	(1.0± 7.4)%	(5.8± 6.9)%
TOTAL	(0.6± 3.6)%	(2.7± 6.4)%	(3.9± 7.3)%	(15.9± 5.4)%

TABLE IV-5

IMPACTOR # 1	U-238	U-234	TH-230	RA-226	PB-210
SAMPLE #13	(DPM)	U-238	U-238	U-238	U-238
S-1	1360.00± 1.0	0.985±0.014	0.971±0.025	0.794±0.039	0.716±0.016
S-2	1430.00± 1.5	0.951±0.020	0.972±0.028	0.713±0.036	0.811±0.017
S-3	604.00± 1.0	0.959±0.014	0.998±0.028	0.806±0.040	0.790±0.013
S-4	295.00± 3.5	1.041±0.052	1.102±0.048	0.831±0.049	0.729±0.030
S-5	170.00± 1.0	0.988±0.014	1.065±0.030	0.812±0.040	0.771±0.020
F.F.	147.00± 2.8	0.952±0.038	0.946±0.037	0.728±0.040	0.694±0.021
TOTAL	4006.00± 2.1	0.972±0.029	0.988±0.033	0.768±0.040	0.764±0.021

IMPACTOR # 2	U-238	U-234	TH-230	RA-226	PB-210
SAMPLE #14	(DPM)	U-238	U-238	U-238	U-238
S-1	1450.00± 1.0	1.000±0.014	1.041±0.028	0.697±0.034	0.793±0.014
S-2	1060.00± 1.4	0.972±0.019	0.943±0.034	0.720±0.036	0.731±0.013
S-3	415.00± 2.0	0.961±0.027	1.024±0.034	1.014±0.204	0.783±0.023
S-4	190.00± 2.4	1.026±0.035	1.016±0.041	0.821±0.044	0.742±0.026
S-5	149.00± 2.6	0.933±0.035	1.020±0.049	0.758±0.041	0.745±0.021
F.F.	136.00± 2.0	0.934±0.026	1.044±0.036	0.680±0.066	0.779±0.025
TOTAL	3400.00± 1.9	0.982±0.026	1.006±0.037	0.752±0.076	0.767±0.021

DIFFERENCE BETWEEN NUCLIDE RATIOS OF DUPLICATE SAMPLES(%)					
IMPACTOR	U-234	TH-230	RA-226	PB-210	
S-1	(1.5± 2.0)%	(7.0± 3.8)%	(13.1± 7.0)%	(10.2± 2.8)%	
S-2	(2.1± 2.9)%	(3.0± 4.6)%	(0.9± 7.1)%	(10.4± 2.8)%	
S-3	(0.3± 3.2)%	(2.5± 4.3)%	(22.9±23.0)%	(0.8± 3.3)%	
S-4	(1.4± 6.0)%	(8.1± 5.9)%	(1.1± 8.0)%	(1.8± 5.4)%	
S-5	(5.8± 3.9)%	(4.3± 5.5)%	(6.8± 7.3)%	(3.4± 3.8)%	
F.F.	(2.0± 4.9)%	(9.9± 5.2)%	(6.8±11.0)%	(11.6± 4.4)%	
TOTAL	(1.1± 4.0)%	(1.9± 4.9)%	(2.2±11.3)%	(0.5± 3.9)%	