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The mobility of radiocesium and plutonium in Roach Lake in southern Nevada

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THE MOBILITY OF RADIOCESIUM AND PLUTONIUM
IN ROACH LAKE IN SOUTHERN NEVADA

by

Mohammadtagi Nassehzadeh-Tabriz

A thesis submitted in partial fulfillment
of the requirements for the degree of

Master of Science
in
Chemistry

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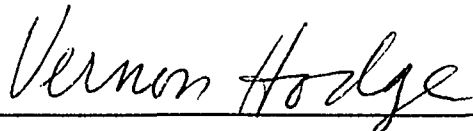
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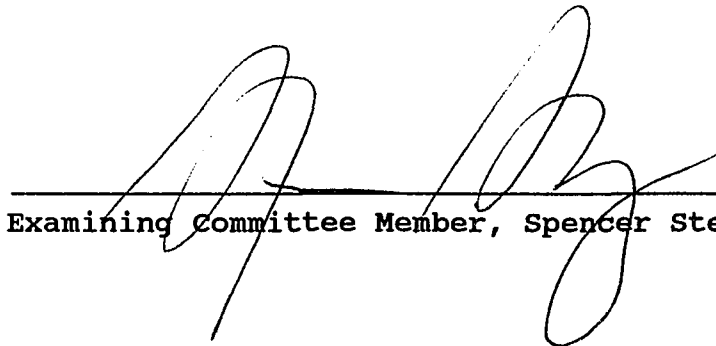
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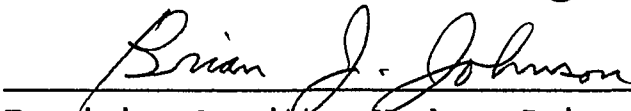
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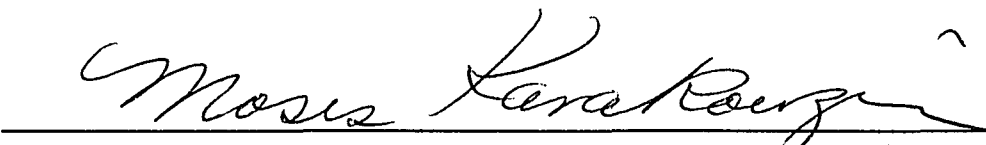
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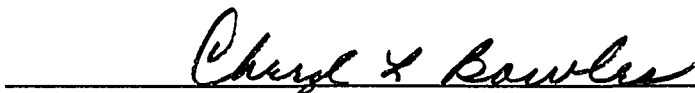
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Abstract

The concentrations of several natural and artificial radionuclides were determined in the sediment from a dry lake in southern Nevada. Five sites (designated I through V) were selected in a dry lake called Roach Lake located in Ivanpah Valley about 41 miles west of Las Vegas, Nevada. The samples were analyzed for Cs-137 and other gamma emitting radionuclides using high purity germanium detectors. The plutonium analysis was performed, after chemical separation, by the detection of its alpha particle emissions with surface barrier detectors. Strontium-90 was determined at only one site, after extraction from the samples, by measuring its daughter yttrium-90 with a gas proportional counting instrument.

In all of the locations, the concentrations of the natural radionuclides measured were relatively uniform throughout the core. In contrast, the activity of Cs-137 in site I was determined to be 0.302 pCi/g at the top layer gradually decreasing to unmeasurable concentrations (less than 0.04 pCi/g) at 5 cm below the surface. Analysis of Pu-239,240 showed an activity of 0.012 pCi/g at the top layer gradually decreasing to an unmeasurable concentration at 8 cm below the surface. A similar concentration-depth profile was observed for Cs-137 and Pu-239,240 in site IV, which was also collected at 1 cm intervals. The strontium-90 analysis, which was performed only on core (I), was found in measurable

amounts to 21 cm. Its activity in the top 9 cm was fairly uniform at about 0.06 pCi/g after which it started declining at 9 cm to an activity of about 0.02 pCi/g at the 21st cm layer from the surface.

The Pb-210 dating of samples collected from location IV conclusively demonstrated that all of the excess lead-210 was in the top three to four centimeters - most in the uppermost 0.3 cm interval. Analysis of Bi-214 suggests constancy in the Ra-226 concentration up to the surface and thus indicates atmospheric origin of the excess Pb-210.

Total activity of Cs-137, 15.5 and 9.4 mCi/km² for cores I & IV respectively, and a total activity of Pu-239, 0.725 and 0.611 mCi/km² for cores I & IV respectively compares to the global average inventory of 65 ± 20 mCi/km² Cs-137 and 1.8 ± 0.05 mCi/km² Pu-239. The lower values in the dry lake are possibly an indication of the loss of these nuclides from the lake bed or lower input due to the dry climate which would limit washout of these nuclides from the atmosphere (low rainout). The comparison of the Pu:Cs activity ratio, 0.049 for core I and 0.062 for core IV, results in much higher values than the global ratio of 0.028 ± 0.004 , which indicates the fact that the Cs-137 may be removed from the dry lake at a higher rate than Pu-239,240 or the original fallout was not typical of worldwide fallout but had a higher plutonium concentration, possibly due to testing at the Nevada Test Site.

Table of Contents

Abstract.....	iii
Acknowledgements.....	ix
Chapter I INTRODUCTION.....	1
General Information.....	2
Sources of the artificial radionuclides in the environment.....	2
Properties of plutonium.....	9
Properties of Cesium and Strontium.....	14
Dating with the natural radioactivity, lead-210...	15
Chapter II EXPERIMENTAL.....	20
Materials/equipment.....	20
Sample collection.....	21
Gamma-ray analysis.....	25
Pu-239,240 analysis.....	26
Sr-90 analysis.....	32
first method.....	32
second method.....	37
Polonium-210 analysis.....	43
Chapter III RESULTS AND DISCUSSION.....	47
Sampling location.....	48
The results for polonium-210, dating attempts.....	51
The results for the natural radionuclides (other than lead-210).....	54
The results for the artificial radionuclides.....	65
Cs-137.....	65
Pu-239,240.....	72
Cs-137/Pu-239,240 as an indicator of fallout.....	75
Sr-90.....	79
Conclusions.....	83
Appendix A.....	85
Appendix B.....	96
Appendix C.....	111
Appendix D.....	124
Appendix E.....	136
References.....	145

List of Figures

1)	Nuclear detonation yield as a result of atmospheric nuclear testings.....	6
2)	Uranium-238 decay chain.....	16
3)	The gamma spectroscopy system at the Lockheed Environmental systems and Technologies Co.....	22
4)	The alpha spectroscopy system.....	23
5)	The alpha/beta counting system.....	23
6)	Photograph of the steel corer.....	24
7)	Procedure flow diagram for plutonium analysis.....	28
8)	Procedure flow diagram for total strontium analysis.....	33
9)	Procedure flow diagram for Sr-90 analysis.....	38
10)	Procedure flow diagram for polonium-210 analysis...	45
11)	Diagram of the polonium plating cell.....	46
12)	Roach Lake, Ivanpah Valley, Nevada.....	48
13)	Geological map of the Roach Lake, Clark county, NV.	49
14)	Photograph of core I after 2 cm partitioned off....	50
15)	Photograph of core I after fourteen 1 cm layers partitioned off.....	50
16)	Chart of depth against ln activity of lead-210 in site IV (second analysis).....	53
17)	Diagrammatic representation of uranium-238 decay series.....	55
18)	Spectrum of the uranium-238 decay series.....	56
19)	Activity concentration profile of uranium-238 decay series for site I.....	57
20)	Activity concentration profile of uranium-238 decay series for site IV.....	58

21)	Activity concentration profile of uranium-235 in sites I & IV.....	59
22)	Spectrum of the thorium-232 decay series.....	60
23)	Activity concentration profile of thorium-232 decay series for site I.....	62
24)	Spectrum of potassium-40.....	63
25)	Activity concentration profile of K-40 in sites I & IV.....	64
26)	Activity concentration profile of Cs-137 in sites I & IV.....	66
27)	Activity concentration profile of Cs-137 in site VI.....	67
28)	Distribution profile of Cs-137 in a grassland in Bellagio, Northern Italy.....	69
29)	Activity concentration profile of plutonium-239 in sites I & IV.....	73
30)	Activity concentration profile of strontium-90 in site I.....	81

List of Tables

I)	Natural radionuclear isotopes and their origin.....	3
II)	Sources of artificial radioactivity in the environment.....	4
III)	Ionic potentials for plutonium in different oxidation states.....	12
IV)	The constituents of the gamma-ray reference standard and their individual energies and activities.....	27
V)	Total activity measured by the gamma-ray analysis of the diluted reference standard.....	27
VI)	The amounts of sample and nitric acid used in leaching the samples from site I for Pu-239 analysis.....	29
VII)	Results of the Pu-239 analysis from site I.....	74
VIII)	Results of the Pu-239 analysis from site IV.....	74
IX)	Plutonium and radiocesium in soil from global fallout-"Background Values".....	77
X)	Results of the Sr-90 analysis from site I.....	80
XI)	Total Sr-90 concentration in different soil layers measured from 1987-1990.....	80

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Chapter I

INTRODUCTION

The above ground testing of nuclear weapons at the Nevada Test Site and at the other sites around the world, primarily in the 1950's and early 1960's, added many man-made radioactive elements to the surface of the earth, either to the oceans or to the land. Several of the artificial nuclides, such as cesium-137 (Cs-137), plutonium-239,240 (Pu-239,240), and strontium-90 (Sr-90) have radioactive decay halflives long enough to serve as useful tracers of environmental phenomena, such as tracing ocean water movement (1), uptake of these elements in animals and plants (2), and movement of these elements in soil (3). The research reported in this thesis resulted from attempts to gather data to determine whether or not a desert dry lake (playa), which is surrounded by hills, would: 1) act as a basin and accumulate higher than normal amounts of Cs-137, Pu-239,240 and Sr-90 from the above ground testing, due to short periods of intense rain, which are common in the desert, and which could wash material off of the hills into the lake; 2) have a sedimentation rate high enough to develop a concentration/depth/time profile (chronological

record or historical record) of artificial fallout, and, 3) be a vessel where these chemically different elements would be redistributed, relative to one another, possibly during the short times each year when the dry lake is covered with water.

General Information

Radionuclides are generally placed in two groups, natural and artificial. Table I shows the major radionuclides in the environment. The U-238 and Th-232 series isotopes present in the dry lake soil samples were measured in this study along with Sr-90, Cs-137 and Pu-239,240.

Sources of the Artificial Radionuclides in the Environment

The major human activities that have introduced artificial radioactivities into the environment are found in Table II. The major source of artificial radionuclides in the atmosphere has been due to the above ground nuclear weapons testing. Much of the radioactive material from the explosions entered the stratosphere and was eventually deposited into the troposphere. Via meteorological processes, this radioactivity was ultimately deposited as worldwide fallout on the earth's surface (5). It may take as long as two years for stratospheric debris injected into the high stratosphere to produce high concentrations in ground level air (6). These ground level air concentrations are usually constant for a period of about three years before beginning to decline (7).

Table I Radioactive isotopes in the Environment (4)

Origin		Isotopes
N A T U R A L	U-238 Decay Series	Th-234, Pa-234m, U-234, Th-230, Ra-226, Rn-222, Po-218, Pb-214, At-218, Bi-214, Po-214, Tl-210, Pb-210, Bi-210, Po-210, Tl-206
	Th-232 Decay Series	Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Po-212, Tl-208
	U-235 Decay Series	Th-231, Pa-231, Ac-227, Th-227, Fr-223, Ra-223, Rn-219, Po-215, Pb-211, At-215, Bi-211, Po-211, Tl-207
	Produced in atmosphere by spallation	C-14 Be-7, Be-10 H-3
	Terrestrial	K-40
Artificial		Sr-90, Cs-137, Pu-239,240

Table II Sources of artificial radioactivity in the environment

Major Source	Example
The weapons industry (military)	Fallout from nuclear explosions Wastes from fuel production Stockpiled weapons
The electrical power industry	Wastes from fuel production Spent fuel storage Cooling water releases Fuel reprocessing
The medical industry	Research Treatment/Diagnosis
Miscellaneous Sources	Satellite electricity production Smoke alarms Food sterilization

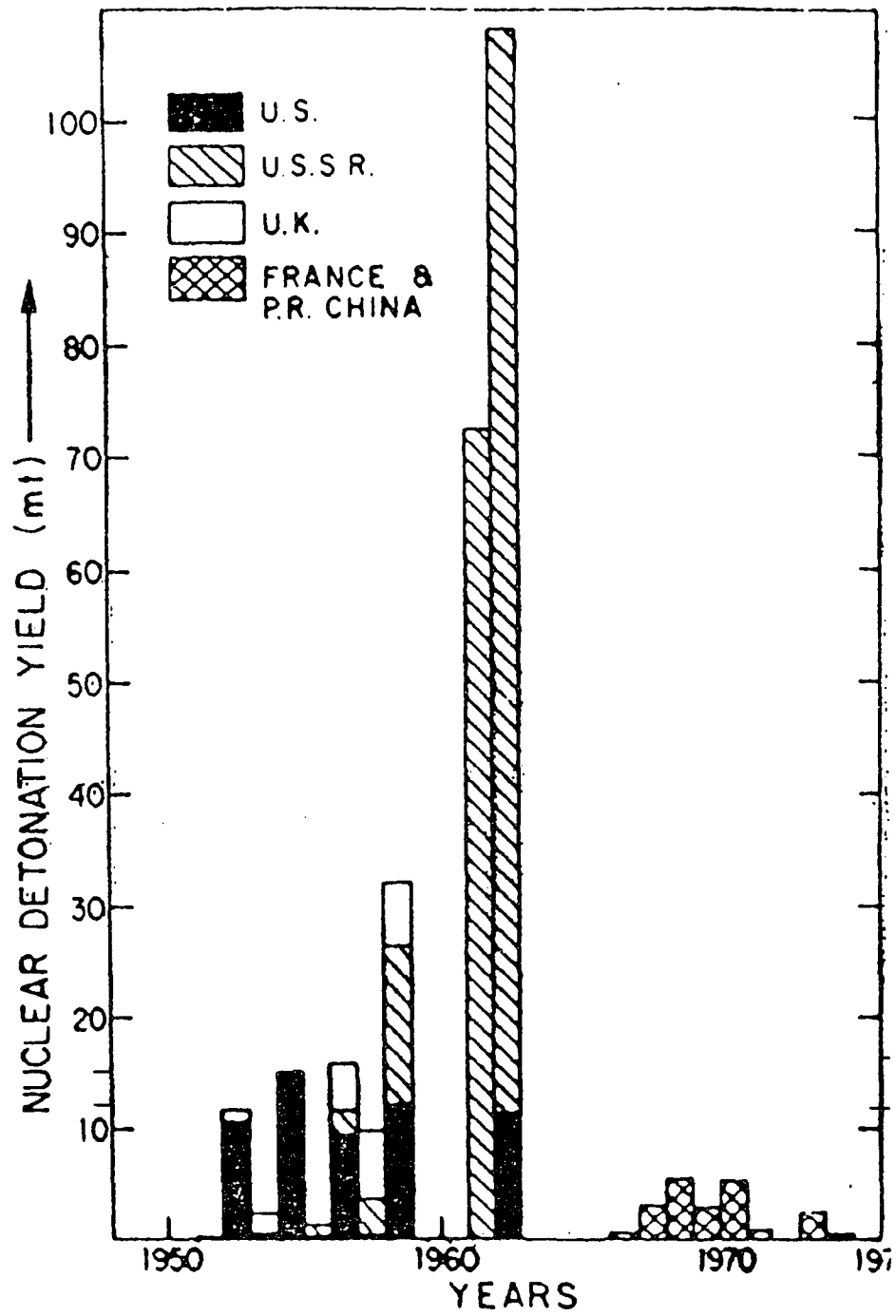
An uneven spread of fallout from above ground nuclear testings is reported from measurements of air concentrations of radionuclides in several parts of the world. About 80% of weapons fallout has settled in the northern hemisphere between latitudes 40°N and 70° N because the major above ground testing occurred in the northern hemisphere. Close to 400 nuclear weapons were detonated above ground between 1945 and 1975 (8). Until 1952, the bombs were of low energy yield and as a result most of the nuclear debris was confined to the troposphere. 1952 was the start of the detonation of the thermonuclear devices which were high yield bombs . The debris from these bombs was injected into the stratosphere. Between

1961 and 1962, the United States and Soviet Union detonated many of these high yield bombs in the atmosphere. In 1963, there was agreement between the United States, the Soviet Union and the United Kingdom to suspend atmospheric testing (the Limited Test Ban Treaty). However, in 1964, the People's Republic of China detonated its first nuclear weapon and together with France, South Africa and India, several above ground weapons tests were conducted sporadically until 1975 (7).

Fig. 1 shows nuclear detonation yield, in megatons by country and year as a result of above ground nuclear testings. As can be seen, the moratorium started in November 1958 and was ended by U.S.S.R. in September 1961. All atmospheric nuclear detonations that took place before and after the moratorium period are classified as having occurred in the pre- and post- moratorium periods respectively. After 1963, the nuclear testings were performed underground except for a few cases of above ground testings that were performed by France and China who did not sign the Limited Test Ban Treaty (9).

The amount of the transuranic elements including plutonium that was released into the environment due to the above ground nuclear weapons testing is not well known (7). One reason for this is that the amount of plutonium left after an explosion varies according to the incompleteness of the fission chain-reaction (7).

Fig. 1 Nuclear detonation yield as a result of atmospheric nuclear testings



The fallout nuclides Cs-137 and Sr-90 (fission products), and Pu-239,240 (activation products) are present worldwide in soil samples from weapons testing fallout. Over the period 1962 - 1974, the ratio of Pu-239,240 to Cs-137 remained consistently about 0.02. Measurements taken at Chilton in UK, which have a similar pattern to those taken at Richland WA, in the USA show a peak concentration of Pu-239,240 of 6.7×10^{-4} pCi m⁻³, occurred in 1963, falling to about 2.7×10^{-5} pCi m⁻³ in 1974 and about 2.7×10^{-6} pCi m⁻³ in 1979 (10). The pattern of deposition for Pu-239 is the same as that for the fission products.

By estimation, about 1.08×10^{17} pCi of Pu-239,240 have remained on the test sites used by the Western countries (5). Measurements of plutonium in the surface soil in different parts of the world indicates varying estimates of the global deposition, for example, from 4.62×10^{17} (5) to 3.24×10^{17} pCi (4.2×10^6 g) (11). Large amounts of Pu-241, a β -emitting isotope, were released simultaneously with Pu-239,240. Pu-241 with a relatively short half-life of 14.4 years decays to produce Am-241. When total decay of Pu-241 has occurred, the activity of Am-241 will exceed that of Pu-239. The amounts of the higher isotopes of americium, curium, berkelium, californium and einsteinium produced are insignificant compared to plutonium (7).

Plutonium-238 is another isotope of plutonium that exists in a significant amount in the environment. This is mostly due to a particular incident in 1964 when a nuclear-powered

navigational satellite (Systems Nuclear Auxiliary Power (SNAP) device) burned up in the Southern hemisphere as it re-entered the earth's atmosphere (7). About 1.68×10^{16} pCi of Pu-238 were released compared to about 8.92×10^{15} pCi estimated to be derived from weapons testing.

There has been several other incidents of radioactivity releases which have resulted in local contamination of the environment. During 1962, three US THOR missiles were destroyed in flight due to malfunction. Some Pu-239 was dispersed over the Pacific Ocean near to Johnston Island (12). In the same year, about 4.62×10^{16} pCi of Pu-238 and 3.24×10^{13} pCi of Pu-239 were dropped into the Pacific Ocean near Tonga Trench when an Appolo lunar probe aborted in flight. It is believed that the plutonium has since remained intact in its containers at the bottom of the ocean (13).

During 1966, an American B-52 bomber which was carrying nuclear weapons, exploded during re-fueling at an altitude of 8500 meters. Two of the four nuclear weapons aboard fell on ground near Palomares, Spain. Impact with the ground resulted in their breaking, as well as the ignition of part of their core components which caused detonation of the chemical explosive in the trigger mechanism. Plutonium and uranium were spread over about 500 hectares, but the amount dispersed remains classified information. One estimate is that as much as 2.7×10^{12} pCi of Pu-239 may have been scattered (12).

Another B-52 bomber carrying nuclear weapons crashed on

ice in an Arctic bay at Thule in Greenland in 1968. The explosion of the plane upon resulted in scattering debris over about 12 hectares. Much of the surface activity was removed in a clean up operation but it is estimated that about 2.7×10^{13} pCi of weapons grade material were deposited on the shore and bottom sediments (14, 12).

Another source of the transuranic elements in the environment is the accidental releases of these elements that occurred from laboratories and plants manufacturing nuclear weapons. One of those incidents was at Rocky Flats, Colorado, where about 1.38×10^{13} pCi of transuranic elements leached into the area soil from storage tanks and a small quantity leaked into the atmosphere during a fire (7). Another incident was at the Mound Laboratory, Ohio, where nearly 5.4×10^{12} pCi of Pu-238 was released into water draining from the site. About 2.7×10^{11} pCi of Pu-238 also leaked into the atmosphere (7).

Properties of Plutonium

Plutonium, an alpha emitter, is an extremely toxic radioelement whose fate in the environment is not well understood (15). Direct exposure to plutonium from the atmosphere can happen externally, when a person's body is completely immersed in a "cloud " of contaminated air, or internally, in which case the exposure is due to the inhalation of the contaminated air. Inhalation exposures result from re-suspension of the previously deposited

materials and also from the radioactive materials being directly injected into the air. This is thought to be the main pathway to man in case of accidental plutonium releases to the atmosphere (7).

High concentrations in air would create an immediate and acute inhalation hazard to persons entering an area before all particulate matter has settled to the ground. The extent of hazard is determined by the concentration of airborne plutonium particles, the individual's respiratory rate, duration of exposure, and particle size distribution of the radioactive fallout. The particle size distribution of atmospheric aerosols has important health implications since pulmonary deposition of suspended particles is inversely proportional to their size (7).

Plutonium forms compounds with a wide variety of elements. The compounds of +III, +IV and +VI oxidation states are the ones that a radiochemist is concerned with, and the insoluble compounds are of primary interest. One of the complex situations in the chemistry of plutonium is the tendency of Pu IV to form polymeric forms in dilute acid or neutral solutions by hydrolysis (15). The polymeric form can be quite intractable in many reactions, and may be difficult to destroy. It is basically the formation of colloidal aggregates in Pu(IV) solutions by successive hydrolysis reactions. The polymer is thought to form with oxygen or hydroxyl bridges and the reaction is known to be irreversible

(15). $\text{Pu}(\text{OH})_4$ forms when the reaction proceeds to completion. The formation of $\text{Pu}(\text{IV})$ polymer is favored by an increase in the plutonium concentration and temperature or by a decrease in the acidity. The presence of strong complexing anions inhibit the formation of polymer (15). Polymer is formed when solutions are diluted with water because of the existence of transient regions of high pH, even though the final acidity may be high enough to prevent the formation of the polymer (15).

The most likely chemical form of plutonium in the deposited fallout particles is plutonium dioxide. The solubility of this compound or its hydrolyzed products is probably the most important factor which determines any subsequent migration of the plutonium from the particles (7). The behavior of plutonium in soils is dictated by processes that influence the chemistry of $\text{Pu}(\text{IV})$ ion (16). It is assumed that higher oxidation states are reduced to $\text{Pu}(\text{IV})$, which hydrolyses to produce insoluble products. Only when $\text{Pu}(\text{IV})$ is stabilized by naturally-occurring ligand such as humic and fulvic acid can the plutonium remain in the soluble state (16). Formation of complex ions in aqueous solutions with anionic ligands is an important feature of the aqueous chemistry of plutonium. The ability of an ion to form complexes is dependent on the magnitude of the ionic potential which may be defined by the equation

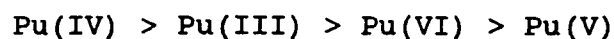
$$d = z/r$$

where, z is the ionic charge and r is the radius of the ion. Table III shows the values of the ionic potentials for Pu in different oxidation states (15).

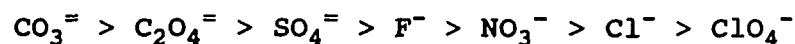
Table III Ionic potentials for plutonium in different oxidation states (15)

Cation	Ionic radius Å	IonCharge	Ionic potential
Pu^{+4}	0.90	4+	4.44
Pu^{+3}	1.03	3+	2.91
PuO_2^{+2}	0.81	2+	2.47
PuO_2^{+1}	0.87	1+	1.15

The relative tendency of plutonium ions to form complexes can be written as:



Generally, anions with a single charge form weaker complexes with plutonium than do multiply charged anions (16). The order of complex forming ability with some anions is as follows:



Hydrolysis and complex formation are competing reactions which may be observed as the displacement of the H_2O molecules in

the hydration sphere by the OH^- or the anionic ligand (15). There is very little unhydrolyzed plutonium in most soils. A typical soil analysis showed only 0.01% in solution and much of this was in the colloidal form (16).

Plutonium deposited on soil surfaces from weapons fallout moves very slowly downwards after the initial rapid penetration. It is estimated that it moves to a depth of 5 cm for every 5 year cycle (18). A recent review of plutonium migration in North European soils indicates that downward migration rates from the soil surface range from 0.1 to 1 cm per year. Using a residence time model, it is predicted that the migration rate is reciprocal of the residence time (17).

According to studies done on the vertical movement of plutonium in soils at the site of the first weapons tests in New Mexico, in light porous soils with a water intake of about 200 mm h^{-1} the plutonium was uniformly distributed down to a 30 cm depth. However, it was concentrated in the first 2.5 cm in clay soils with a water intake of about 100 mm h^{-1} (18). Soils collected from the Nevada Test Site, showed a similar pattern with 95% of the plutonium remaining in the top 5 cm in many of the core samples taken (16). Several studies in the United States and in the United Kingdom have confirmed that the presence of clay particles in soil greatly increases plutonium retention in soil (19,20).

Properties of Cesium and Strontium

The sorption behavior and migration of strontium and cesium have been studied in a number of occasions (21-25). The distribution coefficient between solid samples and water has been usually used to study the migration of these radionuclides in geological media (22). The distribution coefficient can vary by several orders of magnitude depending on physical and chemical conditions such as nuclide concentration, particle size, and coexisting ions (25). The distribution coefficient will become more reliable as a good indicator for interaction with geological media provided that several parameters affecting the sorption of nuclides are clarified (26). In a study, dependence of the distribution coefficient on the radionuclide concentration has been examined and a regularity in the distribution coefficient at trace concentrations has been exhibited in connection with the cation exchange capacity for cesium of individual samples (27). Also, in the same study, the sorption behavior of the cesium and strontium on representative minerals and rocks was investigated under comparable conditions (27). According to this study, both of these nuclides have little tendency to form complexes and may be normally present as soluble cations in water over relatively wide pH regions (26).

According to a number of other studies, that are quite contradictory to the above hypothesis, cesium-137 is strongly adsorbed on clay and organic particles and is

"nonexchangeable" (28-33). These reports suggest that this property of Cs-137 make it unique as a tracer for studying erosion and sedimentation (34).

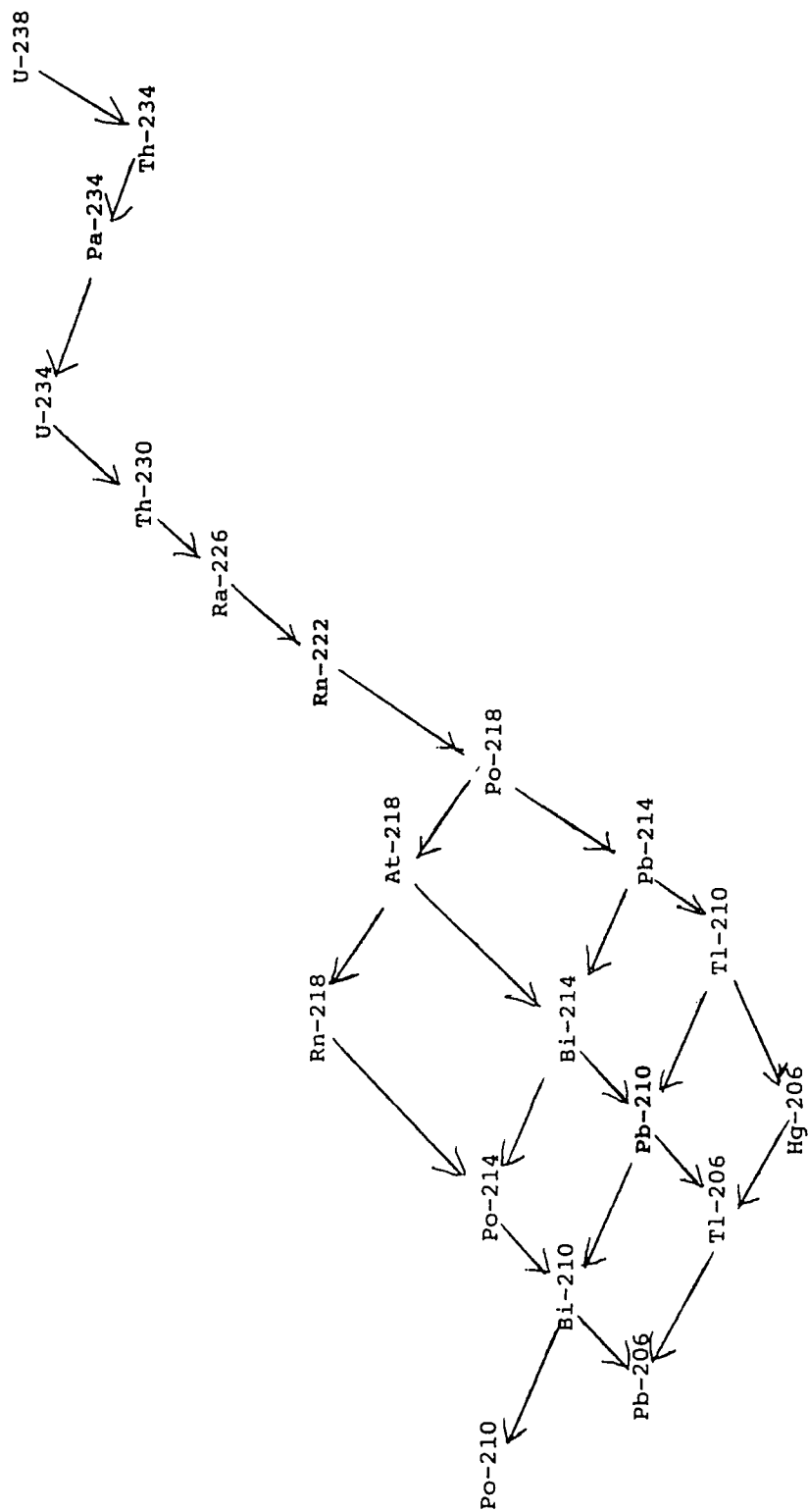
Cesium-137 in soils can be due to direct deposition from the atmosphere, re-deposition of eroded soil particles, wash-off from vegetation, turnover from vegetation, and deposition from water on floodplain and coastal regions. Cesium-137 is a strong gamma-ray (662 keV) emitter which makes it a relatively easy radionuclide to measure, since it does not require any chemical separation or preparation (35).

Dating with the natural radioactivity, Lead-210

The development of the lead-210 technique was initiated by Goldberg (36) and first applied to the dating of lake sediment by Krishnaswami et al. (37). The lead-210 technique is based on the existence of a continuous atmospheric flux of Rn-222 from land surfaces giving rise to lead-210 through radioactive decay processes (38).

As can be seen from Fig. 2, radon-222 is one of the products of the uranium-238 decay chain. It escapes into the atmosphere at a rate of about 42 atoms per minute per square centimeter of land surface. Then, it decays to lead-210 through a series of short lived daughters. Lead-210 is readily returned to the soil or water from the atmosphere via rain or snow and has a residence time of about 10 days (38).

Fig. 2 **Uranium-238 decay chain (38)**



The activity of unsupported lead-210 then decreases as a function of time at a rate controlled by its radioactive decay half-life of 22.26 years. This allows dating of anoxic lake reservoir or sediment back about 200 years. The activity of the lead-210 usually decreases to a constant background level at the deeper sections of the sediment because of the radon-222 decay before expulsion into the atmosphere (38). The constant background level of the lead-210 activity, the supported lead-210, is subtracted out for dating purposes.

The sedimentation rate can be calculated provided that a constant sedimentation rate is assumed (38). The depth of sediment is plotted against the natural log of measured lead-210 activity in order to determine the sedimentation rate (38). The time elapsed since deposition of a sample of sediment at a depth d below the surface can be calculated from the activity of lead-210, provided that the initial input of this isotope has remained constant:

$$Pb_A = Pb_A^0 * e^{-\lambda t}$$

λ = decay constant of lead-210

$(3.11 \cdot 10^{-2} \text{ year}^{-1})$

Pb_A^0 = activity at the surface

($d = 0$)

Pb_A = activity of lead-210 per unit weight of sample at
depth, d

t = age of the sample

$$t = \frac{1}{\lambda} \ln \left(\frac{Pb_A^0}{Pb_A} \right)$$

$$s = \frac{d}{t}$$

$$t = \frac{d}{s}$$

where, s = sedimentation rate

$$\ln(Pb_A) = -d \frac{\lambda}{s} + \ln(Pb_A^0)$$

This is the equation of a straight line with $\ln(Pb_A)$ on the
y-axis and d on the x-axis.

$$m = -\frac{\lambda}{s}$$

therefore,

$$s = -\frac{\lambda}{m}$$

The lead-210 can be measured by low background beta spectroscopy or high resolution gamma spectroscopy systems. However most gamma detectors do not have the necessary sensitivity to measure lead-210. Another method is to measure the alpha decay of its grand-daughter polonium-210, which grows in, for example, in a sediment core, reaching equilibrium with lead-210.

Chapter II

EXPERIMENTAL

Materials/equipment

All chemicals used in this project were reagent grade or better. All reagents and standards were made with double de-ionized water and they were given a one year shelf life.

All chemicals were purchased from VWR Scientific Co. Los Angeles, California. The anion exchange resin, AG 1-X8 100-200 mesh, and 20 ml chromatographic columns were purchased from Bio-Rad Laboratories, Hercules, California. The Pu-242 tracer, certificate number SRM4334E and undiluted activity of 26.37 Bq/g, was obtained from the National Institute of the Standards and Technology, (Gaithersburg, MD) and Po-208 tracer was obtained from the United States Environmental Protection Agency (Env. Monitoring and Systems Laboratory, Las Vegas, NV). The mixed radionuclide gamma-ray reference standard was purchased from Amersham Corporation, Arlington Heights, IL. Gamma counting was performed with EG&G Ortec GEM Series high purity germanium (HPGe) detectors (76.9 mm in diameter, 81.3 mm in length and end cap beryllium crystal 4 mm) with the EG&G Ortec 92X SPECTRUM MASTER pulse height analyzer at the

Lockheed Environmental Systems and Technologies Co. (See Fig. 3). Display, storage of the data, and analysis of the spectral data were performed with an EG&G Ortec Omnigam gamma ray spectrum analysis software which provides in depth analysis of the spectra generated by the 92X SPECTRUM MASTER hardware.

Alpha counting was performed with EG&G Ortec 576-A dual alpha spectrometers with alpha surface barrier detectors (450 mm²) at the Lockheed Environmental Systems and Technologies Co. (See Fig. 4). These system provide two completely independent alpha spectrometry channels. Each of these channels includes a sample holder, vacuum chamber, detector, bias supply, preamplifier, amplifier, biased amplifier, test pulser, and discriminator. At Lockheed, a sixteen channel alpha spectroscopy system containing 32 detectors is configured by utilizing EG&G model 920-16 SPECTRUM MASTER which collects the counting data from the detectors and communicates it to the PC through a router.

Beta counting was performed on a Tennelec LB4000 gas proportional alpha/beta counter provided by Lockheed Environmental Systems and Technologies Co. (Fig. 5). Sample digestion was performed with a microwave digestion oven, CEM MDS 2000 (CEM Corporation, Matthews, North Carolina) at Lockheed Environmental Systems and Technologies Co.

Sample Collection

Five undisturbed locations in the Roach Lake were chosen at

three different times. Site I was selected towards the center of the dry lake. A pit of about 30 cm in depth was dug. One side of the pit was shaved into a flat wall carefully without disturbing the top layer. One cm layer were collected from the top down to 29 cm (the surface area of the layer being around 1600 cm²). Each sample was placed into a plastic bag and labelled with its layer number and site designation. The sample weights and corresponding surface areas are found in Appendix A.

Fig. 3 The Gamma Spectroscopy System at the Lockheed Environmental Systems and Technologies Co.

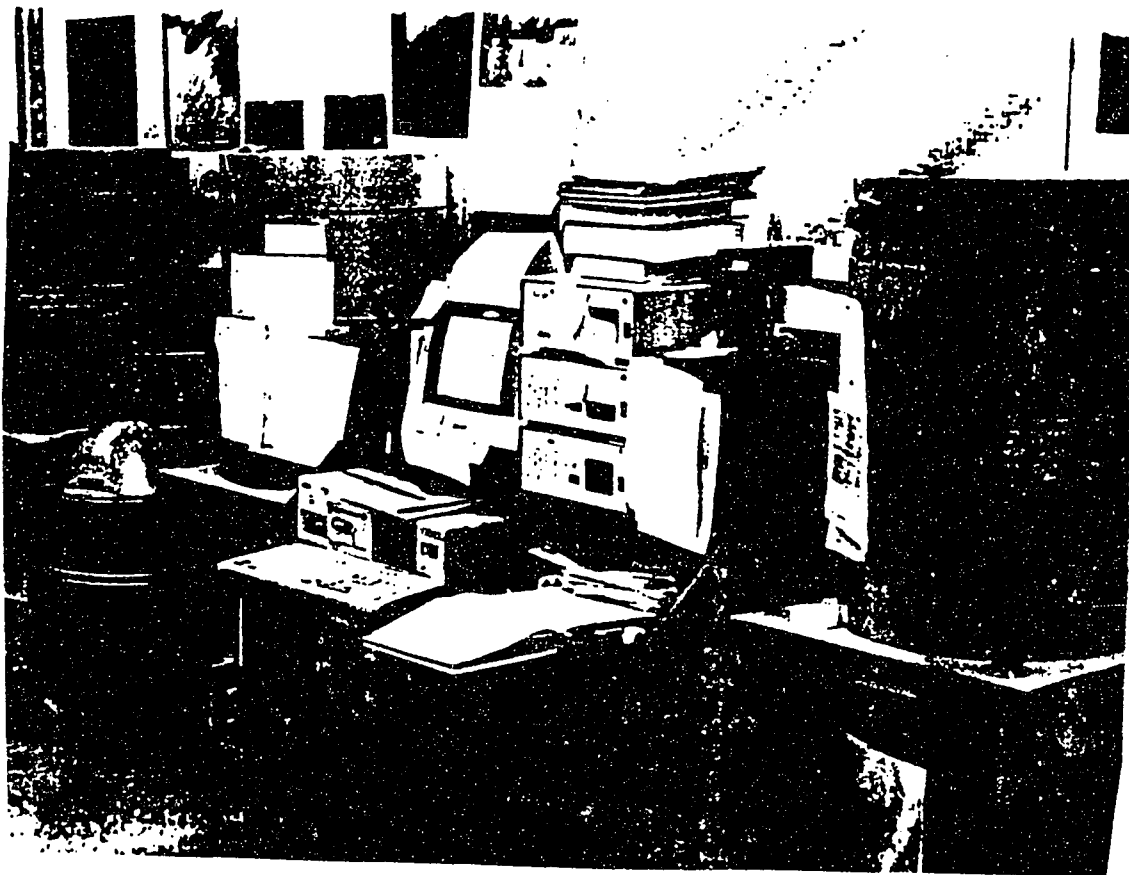


Fig. 4 **The Alpha Spectroscopy System**

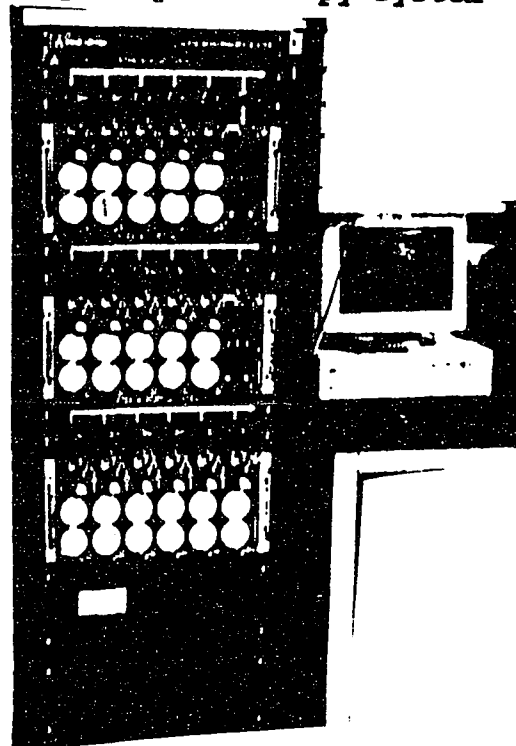
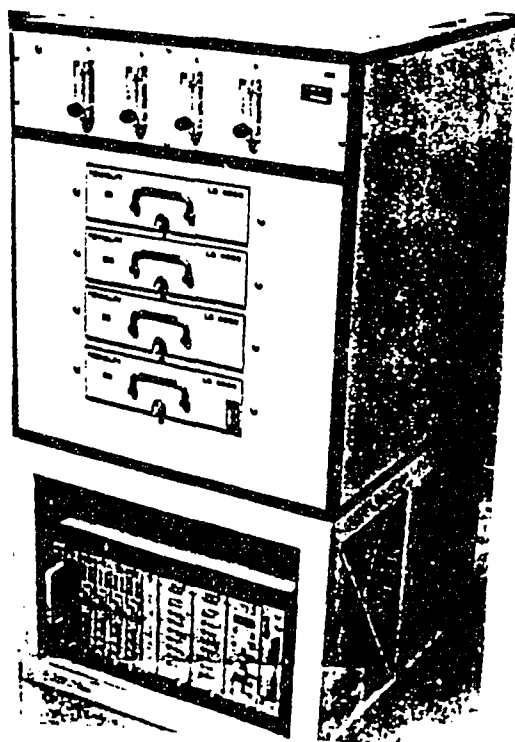


Fig. 5 **The Alpha/Beta Counting System**



Two other sites, II and III, were chosen near the first site, I. A different sampling technique was used in these two locations. Samples were collected using a steel auger of 10 cm in height and about 5 cm in diameter attached to a five foot handle (Fig. 6). Therefore the samples were collected at 10 cm thickness layers up to 90 cm and were gamma counted in order to measure the activity at a lower depth than measured in site I.

Site IV was also chosen towards the center of the dry lake. The sampling technique used for this core was similar to the technique used for site I, 1 cm layers were taken down to 60 cm.

Fig. 6 Photograph of the Steel Auger



Site V was near the southern edge of this particular dry lake. Only peal samples (approximately 3 mm thick) were collected from the top surface of this location using a large blade. The last location, site VI, was selected in the adjacent dry lake in California, the Ivanpah Lake, that connects to the southern end of the original dry lake, the Roach Lake. The Roach Lake appears to drain into the Ivanpah Lake in California. The sampling technique used was similar to sites I and IV. One cm layers were sectioned down to 6 cm.

Gamma-Ray Analysis

Standard preparation

A standard was prepared, by Mr. Nee Van Nuyen at the radiochemistry section of the Lockheed analytical laboratory, in the same geometry as the samples (tuna can) (39).

An empty tuna can and its lid were weighed and the weight was recorded. One portion each of iron powder and alumina were mixed in such a ratio that the final density was approximately equal to the density of the dry lake sediment. The mixture was filled into a 200 ml tuna can.

One ml of a dilution of the QCY-48 standard was spiked into the tuna can. This mixed radionuclide gamma-ray reference standard consists of a solution in 4N HCl of the ten radionuclides listed in Table IV (39). A dilution was prepared by adding 5.415 g of the standard to a 50 ml volumetric flask and diluting to mark with 4N HCl. The total activity was

calculated based on this dilution, Table V (39). Five ml of the standard in Table V was slowly added into the mixture while mixing and heating under infrared lamp until dry. The tuna can was sealed and reweighed.

Sample analysis

Once samples were collected, they were taken to the Lockheed radioanalytical laboratory where they were weighed and dried in an oven at 110 °C overnight. Then they were ground and passed through a 20 mesh sieve making sure that all passed through. They were mixed and a portion of each layer of the samples was placed into separate 200 ml tared tuna cans, 8.5 cm in height and 16.8 cm in diameter. The tuna cans were sealed and all of the information including the net weight of the sample and the layer depth were recorded on each can. The net weights can be found in appendix A. The sediment samples were counted for 20,000 seconds (333 min).

Pu-239,240 Analysis

Sediment layers were aliquoted into 2000 ml beakers and each sediment sample spiked with 1 ml of 2.63 pCi/ml Pu-242 standard and then 8M HNO₃ was slowly added while mixing (Fig. 7). A few drops of n-octanol were added to eliminate foaming (45). The amounts of sample and nitric acid used are found in Table VI.

The beakers were covered with watch glasses and boiled for two hours. They were allowed to cool down for about 45

Table IV The constituents of the gamma ray reference standard and their individual energies and activities

Radionuclide	γ-ray energy (keV)	γ-rays per second per gram of standard	Dilution factor
Am-241	59.5	1122	121.51
Cd-109	88.0	727	78.73
Co-57	122.1	664	71.91
Ce-139	165.9	814	88.16
Hg-203	279.2	2292	248.22
Sn-113	391.7	2414	261.44
Sr-85	514.0	4523	489.84
Cs-137	661.6	2771	300.10
Y-88	898.0	7087	767.52
Co-60	1173.3	3841	415.98
Co-60	1332.5	3844	416.31
Y-88	1836.0	7511	813.44

Table V Total activity measured by the gamma-ray analysis of the diluted reference standard

Radionuclide	γ-ray energy (keV)	r/s/ml of solution
Tin-113	391.7	261.436
Strontium-85	514.0	489.841
Cesium-137	661.7	300.099
Yttrium-88	898.0	767.522
Cobalt-60	1173.0	415.980
Cobalt-60	1338.0	416.305
Yttrium-88	1836.0	813.441

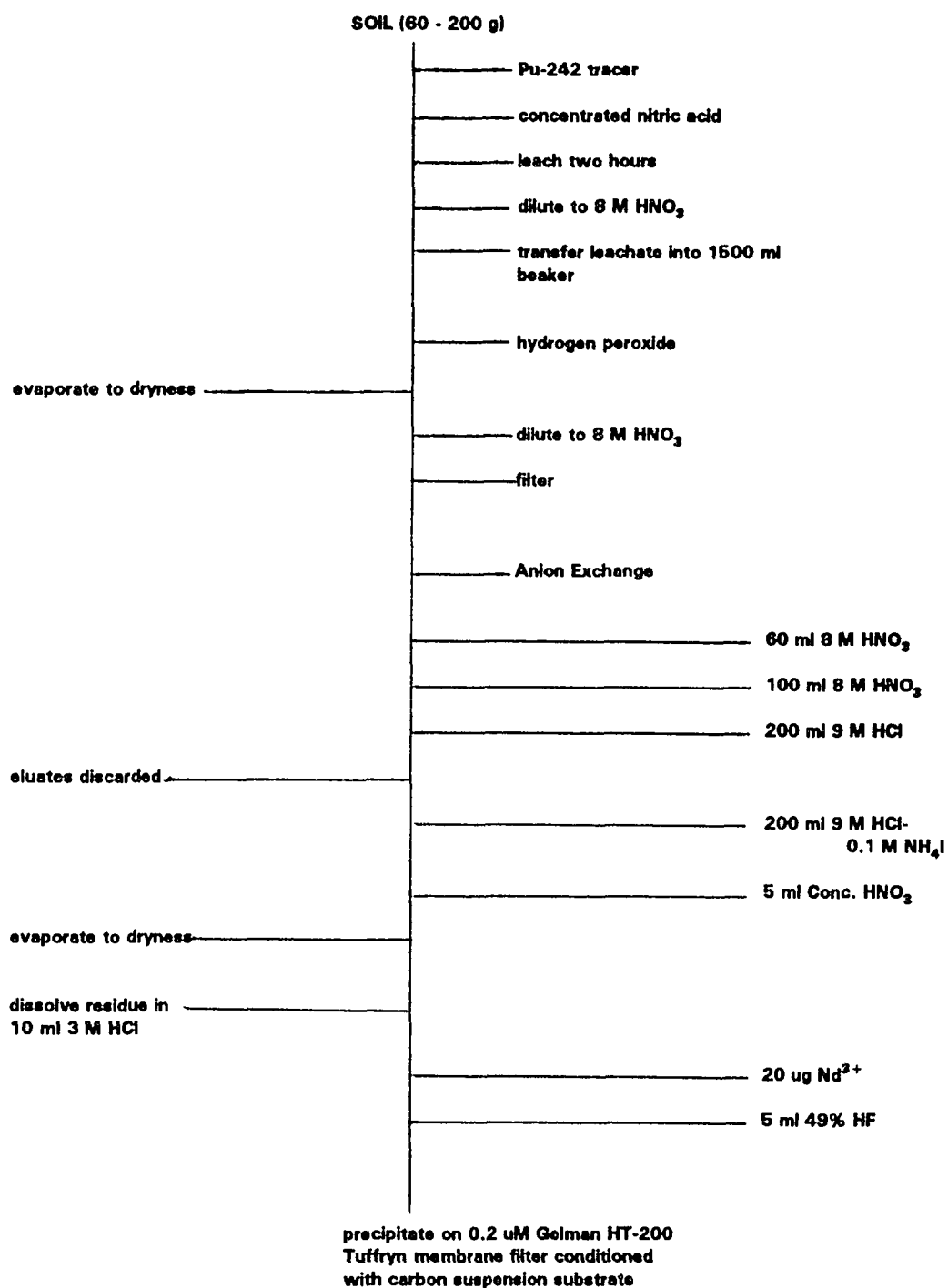
Fig. 7 Procedure Flow Diagram for Plutonium Analysis

Table VI

Sediment layer (cm)		Weight (g)	8M HNO ₃ (ml)
#1	0 - 1	95.43	600
#2	1 - 2	75.25	600
#3	2 - 3	69.67	800
#4	3 - 4	66.01	1000
#5	4 - 5	82.00	1200
#6	5 - 6	76.90	600
#8	7 - 8	204.79	600
#10	9 - 10	209.57	600
#12	11 - 12	201.83	600
#13	12 - 13	209.72	600

minutes. The samples were transferred into 250 ml centrifuge tubes in three fractions and centrifuged at 2800 rpm for about 5 minutes. The supernate were captured in clean 1500 ml beakers. The remaining precipitate at the bottom of the tubes were transferred back to their original beakers using 2 M HNO₃. The volumes were raised to ~600 ml with 2 M HNO₃. The beakers were covered with watch glasses and the contents boiled for one hour. The samples were allowed to cool and their supernate were captured after centrifugation as before and added to the previous leachate (40).

Fifty ml of 30% H₂O₂ was added dropwise to each leachate. After the bubbling ceased, an additional 10 ml of 30% H₂O₂ was added to each sample. The samples were evaporated down to dryness. Six hundred ml 8 M HNO₃ was added to the residues.

After all of the residues were in suspension, the samples were filtered through 12.5 cm Whatman glass microfiber filters using Buchner funnels. Residues on the filters were rinsed with 8M HNO_3 and were discarded. At this point the samples were ready for anion exchange chromatography.

Ten large columns (30cm x 1.5cm) were set up on a rack. They were filled to the top with Bio-Rad AG 1-X8 anion exchange resin (100 - 200 mesh chloride form). The resin columns were allowed to drain and after they settled down, they were packed down with frits resulting in a column of resin ~30 cm in height (41).

The prepared anion exchange columns were preconditioned with 60 mL of 8 M HNO_3 . Samples were loaded into the 200 mL column reservoirs with 8 M HNO_3 used to rinse the beakers. After the samples completely passed through the columns, leaving the plutonium fixed to the resin in the ionic form of $\text{Pu}(\text{NO}_3)_6^-$, the columns were rinsed with 100 mL of 8 M HNO_3 and the eluates were discarded into the waste. Then, the columns were washed with ~200 mL of 9 M HCl in order to remove the thorium in the sample. The eluates were also discarded as acid waste. Clean beakers labelled with sample ID number were placed under the columns and the plutonium was eluted with 200 ml quantities of 9 M HCl -0.1 M NH_4I solution. Five mL of conc. HNO_3 was added to each of the eluants. They were transferred to a hot plate and evaporated down to dryness. They were wet ashed once with 5 mL of conc. HNO_3 to remove all of the white

salts due to NH_4Cl . The residue was dissolved in 10 ml of 3M HCl and transferred to a 50 ml polypropylene centrifuge tube (41).

Twenty μg of Nd^{3+} was added to each of the 50 ml polypropylene centrifuge tubes containing the plutonium followed by 5 ml of 49% HF producing a fine precipitate. They were mixed and allowed to sit for ten minutes. While samples were sitting, the screens and chimneys on a filtering apparatus were rinsed with 2 M HNO_3 then with reagent grade water with the vacuum on. The vacuum was turned off and a 0.2 μM Gelman HT-200 Tuffryn membrane filter purchased from Gelman Sciences Co., Ann Arbor, Michigan, was placed on top of each screen. The chimneys were replaced. About 5 ml of well shaken carbon substrate solution was dispensed onto the membrane. Carbon substrate solution is the solution that conditions the Tuffryn membrane filter for adsorption of the actinides. This solution is prepared by diluting 40 ml of HF to 1000 ml with deionized water and adding to it, 80 ml of 12M HCl, 4 ml of 10 mg/ml NdCl_3 and 40 ml of carbon suspension solution, and finally diluting the solution up to 2000 ml. The carbon suspension solution is prepared by fuming ten 47 mm GA-6 Metrical filters with 10 ml of concentrated H_2SO_4 in a beaker for 10 minutes and diluting the solution up to 500 ml with deionized water. The vacuum was turned on, then turned off. After all of the solution had passed, the samples were slowly poured down the wall of their appropriate chimneys followed by

rinsing the test tubes one time with 2 ml of nanopure water and adding it to the filter (41). The vacuum was turned on and the sides of the chimneys were rinsed with nanopure water. The vacuum was turned off and the filters were transferred to a labelled petri dish. The filters were dried under the heat lamp for about 5 minutes and while filters under the heat lamp, stainless steel disks were labelled on one side and then they were turned over and sprayed with adhesive. Samples were removed from the heat lamp and glued carefully to their corresponding disks. Samples were returned to the petri dish and placed back under the heat lamp for 5 minutes (41).

Then, the samples were counted by alpha spectrometry system for 24 hours. The energy and efficiency calibration on the alpha spectrometry system is performed at least annually using a multi point calibration source.

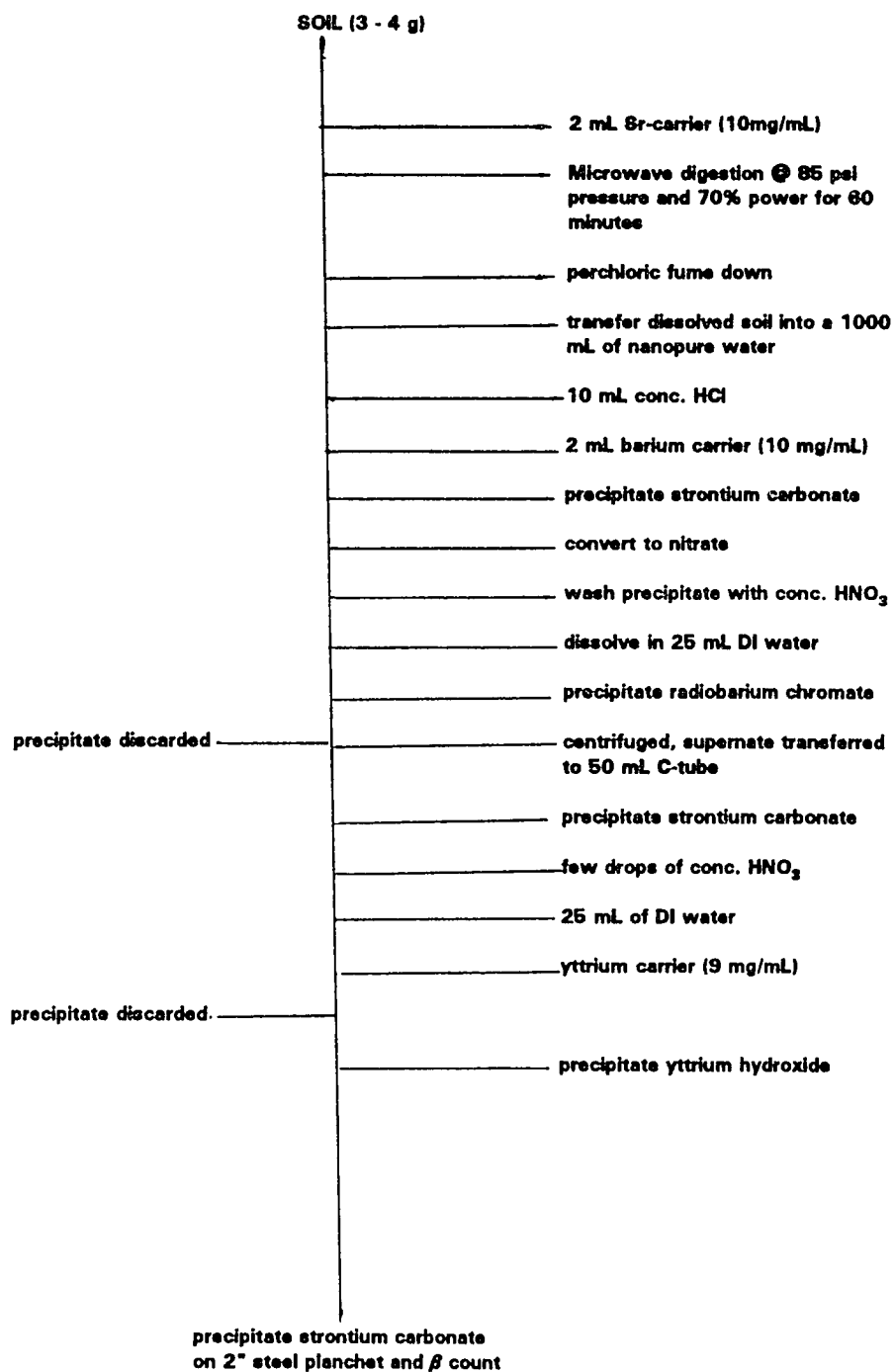
Sr-90 Analysis

First method:

Sr-90 in the dry lake sediments was measured by analyzing the samples for total strontium (Sr-89 + Sr-90) beta activity, and since the half-life of Sr-89 is only 50.52 days as opposed to 29.1 years for Sr-90, this measurement would result in the activity concentration of only Sr-90 in the sediment.

As seen in Figure 8, 3 to 4 g of each dried sediment layer was measured into separate microwave digestion vessels (42). 2 ml of strontium nitrate solution (10mg/ml), which is

Fig. 8 Procedure Flow Diagram for Total Strontium Analysis



used as the carrier of the strontium, 5 ml of conc. HNO_3 , 5 ml of 49% HF and 3 ml of conc. HCl were added to each sample. They were mixed and let sit until any visible reaction subsided. A new pressure membrane was placed in the cap and the vessels were sealed. The vessels were placed on the turntable. One of the samples that seemed to be the most reactive was connected to the pressure sensor. Pressure control was set to 85 psi and the power was set to 70% (42). Then samples were digested for 60 minutes (42).

After the digestion was complete, the samples were allowed to cool until the pressure was below 5 psi. The vessels were carefully vented and the liquid was carefully transferred into a labelled teflon beaker using concentrated HNO_3 .

To each of the teflon beakers were added 5 ml of conc. HClO_4 and 5 ml of 49% HF. The beakers were placed on a hot plate inside the perchloric hood. The beakers were heated at 200 °C - 300 °C until white acid fumes started appearing. The treatment was repeated two more times until the samples completely dissolved. They were transferred into 1000 ml of reagent grade water. To each sample were added 10 ml of conc. HCl and 2 ml of barium carrier in the form of barium chloride (43). Three drops of phenolphthalein solution was added to the beakers and 6 N NaOH was added while stirring to phenolphthalein endpoint (43). Then, 50 ml of 2 N Na_2CO_3 was added to each sample and the mixture was boiled on the hot

plate for about an hour. The beakers were covered with watch glasses. After one hour, the stirring bars were retrieved and the mixtures were allowed to set overnight for the precipitate to settle (43).

The next day, as much of the clear supernate as possible was decanted and discarded as waste and the precipitate at the bottom of the beakers were transferred into separate 50 ml centrifuge tubes using pH 10 reagent grade water. The samples were centrifuged and the supernate was discarded as waste. The precipitates were dissolved in 5 ml of 4 N HNO_3 (43). Any undissolved solids were centrifuged and discarded. Fifteen mL of fuming HNO_3 was added to each solution while stirring. The solutions were placed in ice water bath until white strontium nitrate precipitate settled. They were centrifuged, the supernate was discarded as acid waste and the precipitate was washed with 20 ml of conc. HNO_3 (43).

The strontium nitrate precipitates were dissolved in 25 ml of reagent grade water. Two drops of methyl red indicator was added and 6 M NH_4OH was added dropwise until yellow end point. Then the pH was adjusted back to a red color by addition of 5.8 M CH_3COOH dropwise. Five ml of ammonium acetate buffer solution was added to each sample. Two ml of 0.5 M Na_2CrO_4 was added followed by heat digestion for 30 minutes. The reaction mixture was cooled, centrifuged and the supernate was transferred into a clean 50 ml centrifuge tube discarding the barium chromate residue. Two ml of 15N NH_4OH

was added to the sample stirring well. The samples were heated in the hot water bath for 15 minutes. Then 5 ml of 2 N Na_2CO_3 was added, stirring well, after which the samples were heated in the water bath until the strontium carbonate precipitates settled to the bottom of the tube. The tubes were cooled in ice water bath, centrifuged and the supernate was discarded. A few drops of conc. HNO_3 were added to dissolve the precipitates and the solutions were diluted up to 25 ml with nanopure water, stirring vigorously. One drop of 1% Triton and 1 ml of yttrium carrier (9 mg/ml) were added to each sample. Yttrium hydroxide was precipitated by adding 5 ml of 15 N NH_4OH , in excess, followed by stirring and heating of the samples in the hot water bath for 20+ minutes. The samples were cooled, centrifuged and the supernates were transferred into clean 50 ml tubes. The mid point in time between the addition of the ammonium hydroxide and the completion of centrifugation was recorded as the start of the yttrium ingrowth (43).

Five ml of nanopure water was added to the tube containing the yttrium hydroxide precipitate. The samples were stirred, centrifuged and the supernates were added to the initial supernates and the precipitates discarded as solid waste. Five ml of 2 N Na_2CO_3 was added to each of the samples followed by heating in the hot water bath while stirring until precipitates settled. They were allowed to cool, centrifuged and the supernates were discarded into the waste. The

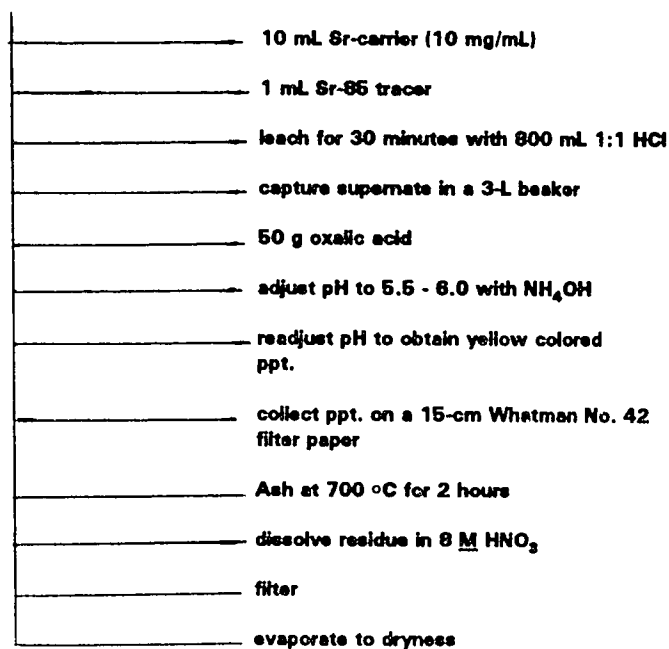
precipitates were washed twice with 15 ml of reagent grade water and was finally washed onto tared 2" planchets using 5 ml of water and 5 ml of ethanol. The planchets were heated to dryness, reweighed and beta counted for 500 minutes. Since the strontium activity was found to be very close to the background, therefore it was necessary to use much higher aliquot to get better detection.

Second method:

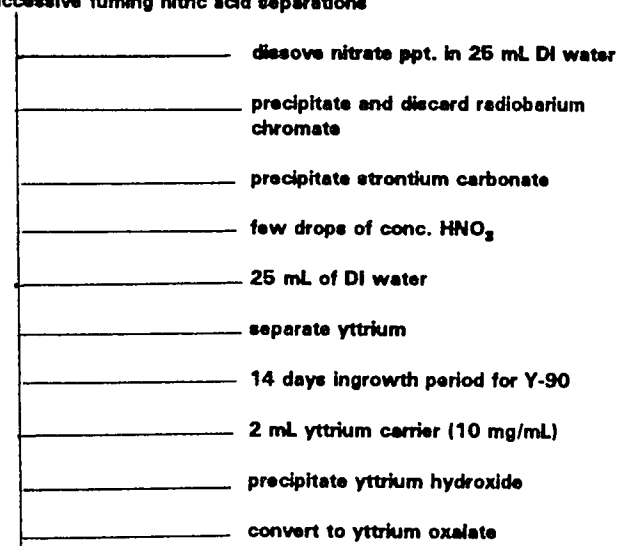
In the second method, shown in Fig. 9, much larger samples were used. Ninety to 200 g of the ground samples were weighed into 2-L beakers containing a magnetic stirrer. Ten ml of Sr-carrier solution (10 mg/ml) and 1 ml of Sr-85 tracer solution (2702 pCi/g as of 12/08/93) was added to each sample. The beakers were placed on a stirrer/hot plate. Eight hundred ml to 1000 ml of 1:1 HCl was added slowly with continuous stirring. A few drops of n-octanol were added to control frothing and continued stirring for 30 minutes. The beakers were removed from the hot plate and allowed to cool and the insoluble materials allowed to settle for about 2 hours (44). The samples were transferred into 250 ml centrifuge tubes in three fractions and centrifuged at ~2800 rpm for about 5 minutes. The supernates were captured in clean 3000 ml beakers. The remaining precipitates at the bottom of the tubes were transferred back to their original beakers using 2 M HNO₃. The volumes were raised to ~600 ml with 2 M HNO₃ and

Fig. 9 Procedure Flow Diagram for Strontium-90 Analysis

SOIL (90 - 200 g)



dissolve residual salt in DI water,
transfer into 250 mL C-tube and perform
successive fuming nitric acid separations

 β count

boiled for 1 hour under a watch glass. Samples were allowed to cool and their supernates were captured and added to the previous leachates (44).

The leached sediments at the bottom of the centrifuge tube were washed one more time with 8 M HNO_3 , centrifuged and the supernates were added to the beakers containing the leachates. The beakers were placed on the stirrer/hot plate to stir and warm the solution. Fifty g of $\text{H}_2\text{C}_2\text{O}_4$ (oxalic acid) was added to each sample and stirring was continued until the salt completely dissolved. Then the pH was adjusted to 5.5 - 6.0 with NH_4OH (44).

In all cases a brown colored solution resulted from the presence of $\text{FeO}(\text{OH})$ which was corrected by adding more oxalic acid and readjusting the pH to produce a milky solution (44). The beakers were removed from the hot plate and allowed to stand at room temperature for several hours. The samples were filtered with suction into 3-L filter flasks using 15-cm Whatman No. 42 filter papers in a Buchner funnels. The beakers were washed through the filter with nanopure water. The vacuum was turned off and the filter papers and precipitates were transferred into 150 ml platinum dishes. The filterates were discarded and the platinum dishes were placed in a 110°C oven to dry the filters. The platinum dishes were placed in a $450\text{--}500^\circ\text{C}$ muffle furnace for 2 hours. The temperature was raised slowly to 700°C and ashing continued for 2 hours. Then, the dishes were removed from the furnace and cooled to room

temperature. The residues were transferred to 250 mL beakers and the dishes were rinsed using 1:1 HNO_3 (44).

The residues were dissolved in a minimum of 8 M HNO_3 and 6 drops of H_2O_2 were added to facilitate the dissolution. The resulting solutions were placed on the hot plate and boiled gently after which they were removed from the hot plate and cooled to room temperature. The insoluble material in the samples were removed from the sample by suction filtering the sample through a double 7-cm glass fiber filter into 250-ml filter flask. The beakers and the filters were washed with minimal amount of 1:1 HNO_3 followed by nanopure water. The vacuum was turned off and filters were discarded. The filtrates were returned to their 250 ml beakers, the filter flasks were rinsed with nanopure water and the rinsings were added to the beakers. Then they were gently evaporated down to dryness (44). Sequential fuming nitric acid separation of strontium was performed on the samples.

The strontium nitrate precipitates were dissolved in 25 ml of reagent grade water (43). Two drops of methyl red indicator was added and the solutions were neutralized until a yellow end point with 6 N NH_4OH . Then, the pH was adjusted back to red color by adding 5.8 N CH_3COOH dropwise. Five ml of ammonium acetate buffer solution was added to each sample (43). The samples were heated in hot water bath. Two ml of 0.5 M Na_2CrO_4 was added and digested in the hot water bath for 30 minutes. The samples were cooled, centrifuged and the

supernates transferred into clean 50 ml centrifuge tubes, discarding the barium chromate residues. Two ml of 15 N NH_4OH was added to the samples with stirring. The samples were heated in the hot water bath for 15 minutes (43). Then 5 ml of 2 N Na_2CO_3 was added, stirring well, and heating was continued in the water bath until strontium carbonate precipitates settled to the bottom of the tubes. They were cooled in an ice water bath, centrifuged and the supernates were discarded. A few drops of conc. HNO_3 was added to dissolve the precipitates, then the solutions were diluted up to 25 mL with nanopure water, stirring vigorously (43). One ml of yttrium carrier (9 mg/ml) was added to each sample and, while stirring and heating, 5 ml of 15 N NH_4OH was added in excess to the each solution until yttrium hydroxide precipitated. The samples were cooled, centrifuged and the supernates were transferred into a clean 50 ml tubes. The mid point in time between addition of ammonium hydroxide addition and completion of centrifugation was recorded as the start of the yttrium ingrowth. Five mL of nanopure water was added to the tubes containing the yttrium hydroxide precipitates. The mixtures were stirred, centrifuged and the supernates were added to the initial supernates and the precipitates discarded as solid waste (43). Five ml of nanopure water was added to the tube containing the yttrium hydroxide precipitate. The samples were stirred, centrifuged and the supernates were added to the initial supernates and the precipitates discarded as solid

waste. Five ml of 2 N Na_2CO_3 was added to each of the samples followed by heating in the hot water bath while stirring until precipitates settled. They were allowed to cool, centrifuged and the supernates were discarded into the waste. The strontium carbonate precipitates were dissolved in 5 mL of 6 N HNO_3 .

The samples were added 20 ml of 1 N HNO_3 and were set aside for 14 days for the y-90 ingrowth. After 14 days, 2 ml of yttrium carrier (10 mg/ml) was added to the samples. They were boiled to expel any dissolved carbon dioxide and were cooled to room temperature (43). The yttrium was precipitated as yttrium hydroxide by adding 10 ml of 15 N NH_4OH to the centrifuge tubes, stirring and heating in a hot water bath. The resulting mixtures were cooled, centrifuged and the supernates were decanted into 60 ml nalgene bottles for the Sr-85 tracer recovery measurement. The time of the last precipitation was recorded as the end of the Y-90 ingrowth and the beginning of the Y-90 decay. The precipitates were dissolved in 0.5 ml of 1:1 HNO_3 and diluted up to 10 ml with nanopure water. Yttrium was reprecipitated by dropwise addition of 5 ml of 15 N NH_4OH . The tubes were centrifuged and the supernates were discarded (43).

The precipitates were dissolved with 5 ml of 4 N HNO_3 and heated for a few minutes in a water bath. Five ml of 5% oxalic acid was added while stirring. Three to 4 drops of 0.04% Thymol Blue solution was added and the samples were diluted to

20 ml with nanopure water with stirring. The solution's pH was adjusted to pH2 by dropwise addition of 15 N NH_4OH while stirring, until the solution's color changed to slight pink. The solutions were heated in a water bath for a few minutes to coagulate precipitates, cooled in an ice-bath, centrifuged and the supernates were discarded. Ten mL of water, 6 drops of 1 N HNO_3 and 6 drops of 5% ammonium oxalate were added with heating and occasional stirring. The mixtures were cooled, centrifuged and the supernates discarded as waste (43). The precipitates were slurried into tared 2" flat planchets using 5 ml of nanopure water and 5 ml of ethanol gradually while drying under a heat lamp to determine the yttrium yield. The weight of the precipitates were recorded and they were beta activity counted for 500 minutes (43).

Polonium-210 Analysis

As shown in Fig. 10, 2 to 3 g of each dried sediment layer was measured into separate microwave digestion vessels and to each were added 0.5 ml of polonium-208 tracer (15.11 dpm/g, Ref. Date: 07/13/92), 5 ml of conc. HNO_3 , 5 ml of 49% HF and 3 ml of conc. HCl. The mixtures were stirred and let set until any reaction subsided. A new pressure membrane was placed in the caps and the vessels were sealed. The vessels were placed on the turntable. One of the samples that seemed to be most reactive was connected to the pressure sensor. Pressure control was set to 85 psi and the power was set to

70%. The samples were digested for 60 minutes. After the digestion was complete, the samples were allowed to cool until the pressure was below 5 psi. The vessels were carefully vented and the liquid was carefully transferred into a labelled teflon beaker using concentrated HNO_3 (42).

Five ml of conc. HClO_4 and 5 ml of 49% HF were added to each sample. The beakers were placed on a hot plate inside the perchloric hood and heated until white fumes started appearing. The procedure was repeated two more times until the samples completely dissolved. Then, the residue were evaporated down twice with 10 mL of conc. HNO_3 . The final residues were dissolved in ~10 mL of 0.1M HCl and fast filterred onto nickel disks inside plating cells which consists of a copper base which contains the nickel disk and a reservoir that screws into the base holding the the disk in place (Fig. 11). Polonium was plated by spinning the sample in the reservoir for two hours at 70 °C. The disks were taken out and rinsed with ethanol, let to dry and counted on the alpha spectroscopy system for 4 - 12 hours (45).

Fig. 10 Procedure Flow Diagram for Polonium-210 Analysis

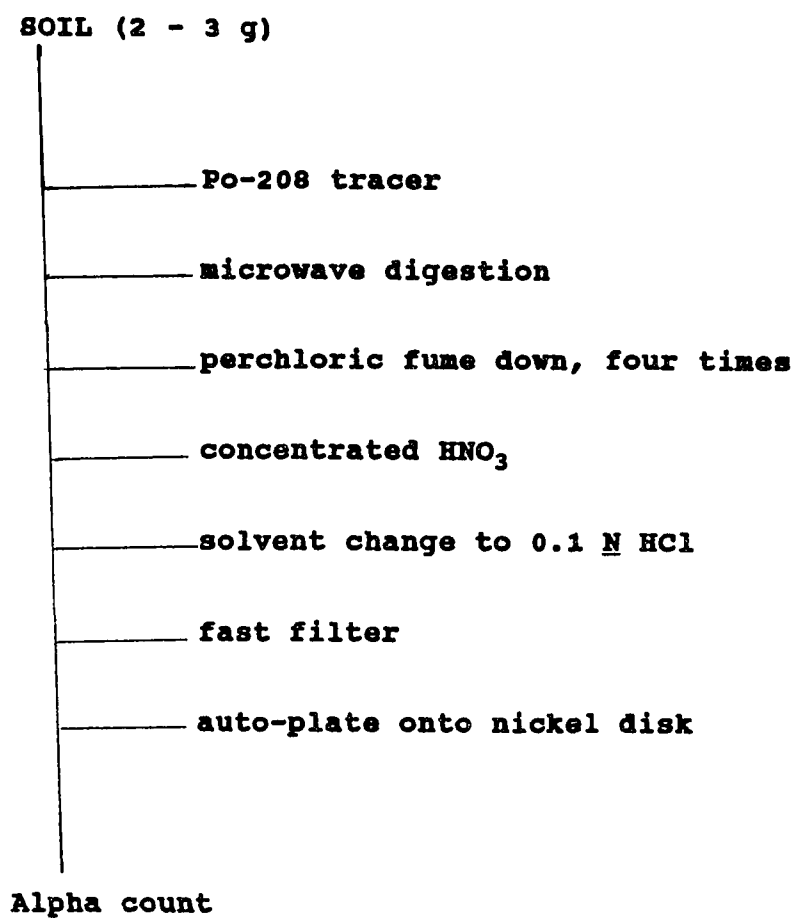
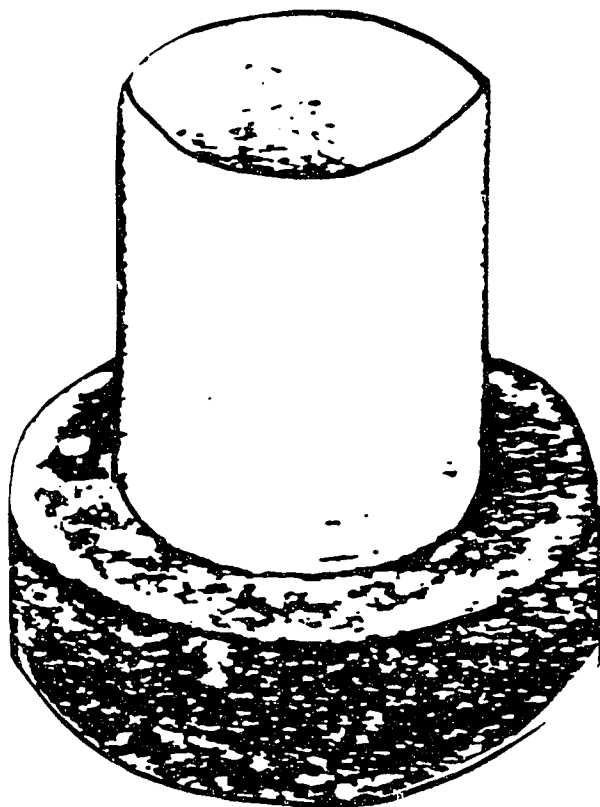


Fig. 11 Diagram of Polonium Plating Cell



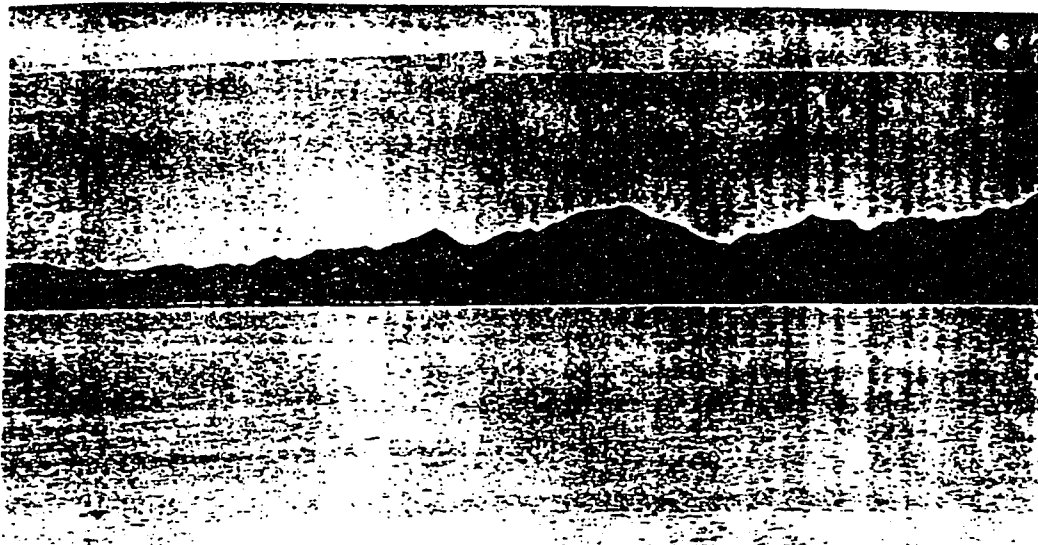
Chapter III

Results and Discussion

The dry lake chosen for study is called Roach Lake and is located 41 miles west of Las Vegas, Nevada. This dry lake is near the California border and east of highway I-15. This particular dry lake was selected among several other dry lakes in the area because at the time of the initial sampling, there were no visible signs of mechanical disturbance of the sediments by motor vehicles or other activities by man. The lake is surrounded by Lucy Gray mountain range on the east and highway I-15 on the west. (Fig. 12).

Five sites (designated I through V) were selected in the lake bed.

Fig. 12 Roach Lake, Ivanpah Valley, Nevada



Sampling Location

Fig. 13 shows a geological map of the area under study (46). As it can be seen, the particular dry lake, Roach Lake, which is located inside Ivanpah Valley about 41 miles west of Las Vegas near the Nevada-California border, is surrounded by the Lucy Gray mountains on east, Highway I-15 on the west and connected with the Ivanpah Lake (in California) on the south. The method of sample collection at site I are shown in figures 14 and 15.

Fig. 13 Geological Map of the Roach Lake, Clark County, Nevada (46)

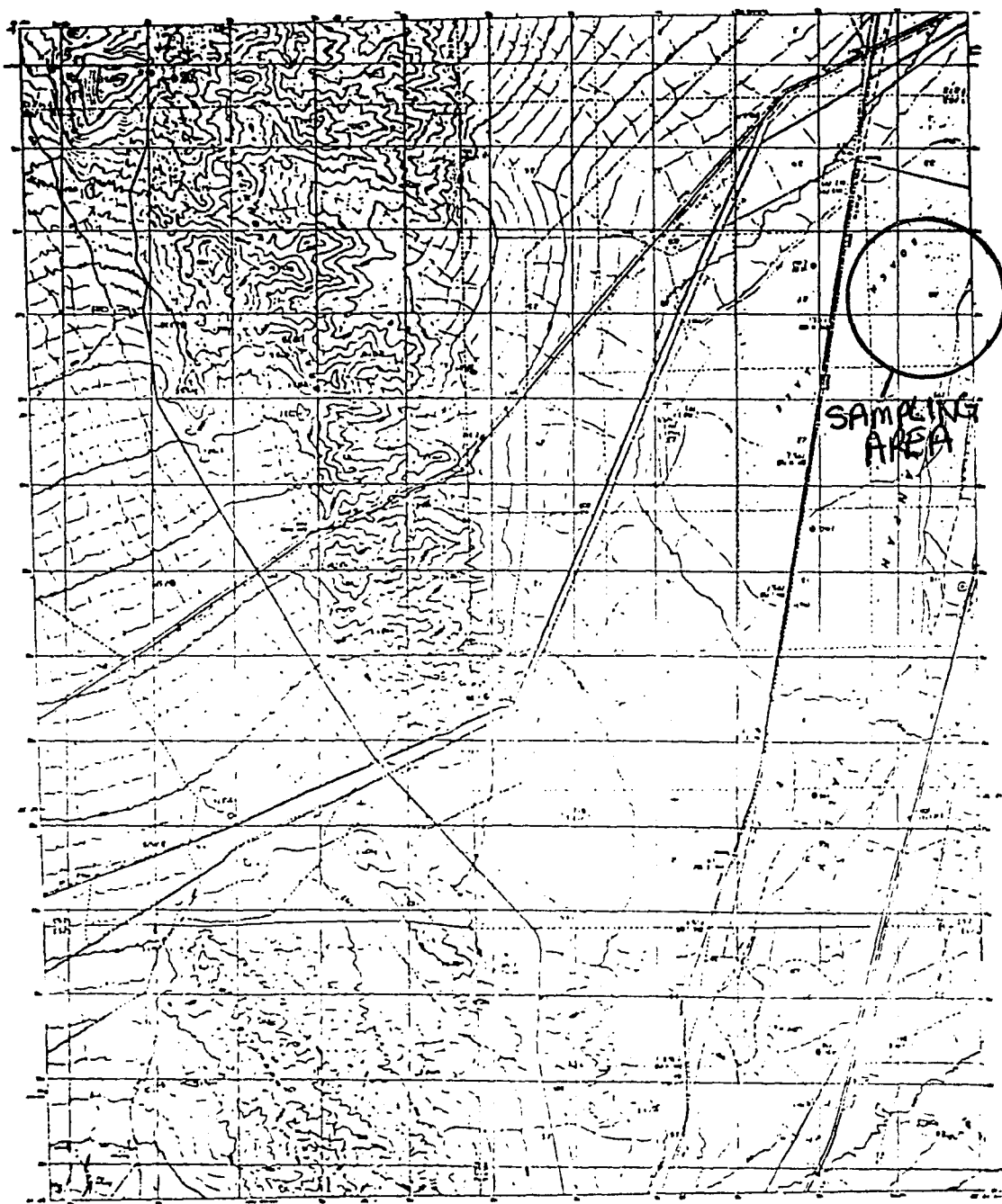


Fig. 14 Photograph of Core I after 2 cm partitioned off



Fig. 15 Photograph of Core I after fourteen 1 cm layers partitioned off



The objective was to determine the vertical concentration profile of the radionuclides (radiocesium, radiostrontium, and plutonium) in the dry lake bed sediments. Since, the dry lake is surrounded by hills, it was assumed that the lake might act as a basin, collecting water and sediment from the surrounding hills during the brief intense rains that are common in the desert. If true, the radioactive fallout from weapons testing, more than 30 years ago, might be buried deep in the lake sediment, covered by many centimeters of recent sediment. Therefore, radioactivity concentration profile in the top few centimeters were determined for core I. It was thought that this would give a rough idea of the sedimentation rate.

The samples collected from two sites (I & IV) were assayed for lead-210 in an attempt to age date the intervals. The activity of the lead-210 in the samples was determined by measuring the activity of its grand daughter polonium-210 by alpha spectroscopy.

The results for polonium-210, dating attempts-

The results from the initial analysis of Po-210 of samples from sites I and IV are shown in Appendix A. The initial analyses of these samples showed uniform activity throughout the cores with slightly higher activity at the upper layers, which is possibly the indication of the unsupported Pb-210 which comes from the atmosphere.

The analysis of Po-210 in sediments from core IV (which

was taken at 1 cm intervals) was performed by both high resolution gamma spectroscopy and the Po-210 alpha method. Both results suggested that the Pb-210 concentration was uniform throughout the core below 3 to 4 cm and that the sedimentation rate is almost zero.

After analyzing the samples for the natural radionuclides by gamma-ray spectroscopy, the details of which are in the following section, it was noticed that the values obtained for Ra-226 are calculated to be more than twice the values for the lead-210. This looked erroneous; because lead-210 and Ra-226 are both in the same, uranium-238, decay chain and are expected to have equal activity concentrations in the sediment. Therefore, the lead-210 analysis was repeated once more on the samples from location IV (Appendix A). The activity concentration profile for unsupported lead-210 from this particular analysis is shown in figure 16. This profile suggests a sedimentation rate of 0.06 cm/year as calculated below:

slope, $m = -0.51$

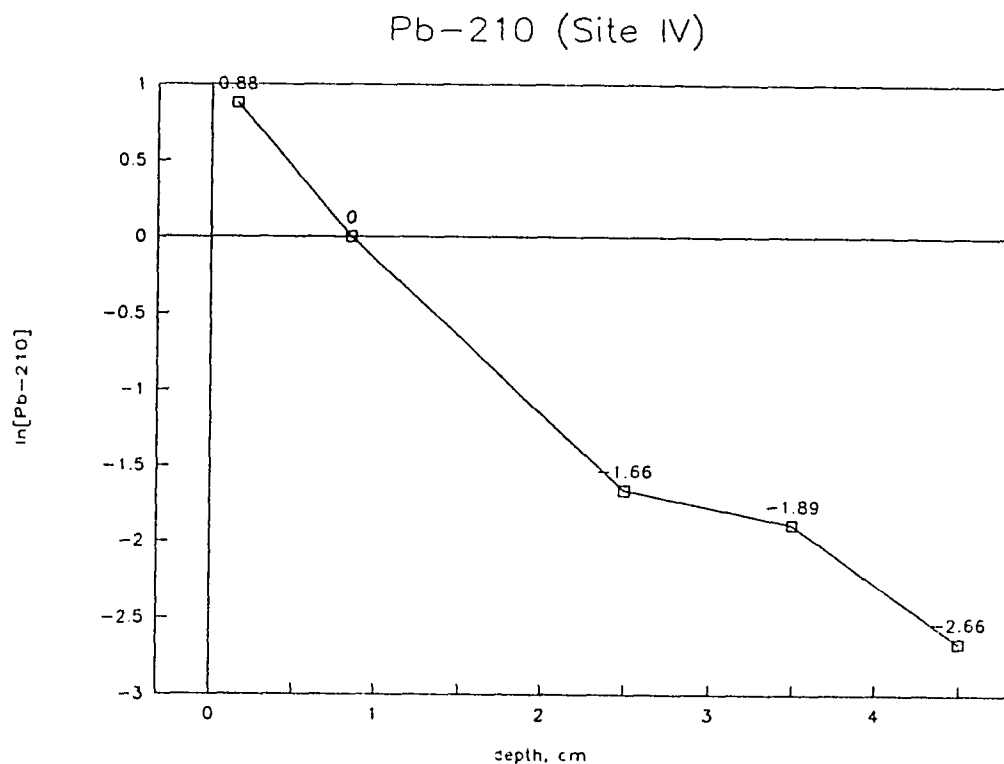
y-intercept = -2.94

therefore the sedimentation rate,

$$s = -\frac{\lambda}{m} = -\left(\frac{0.031}{-0.510}\right) = 0.06 \text{ cm/yr}$$

In support of this profile, analysis of the peal, the top 3 mm, showed that the majority of the activity (3.83 pCi/g), in the top 2 cm is in the top 3 mm. Thus, the effective sedimentation rate is very slow.

Fig. 16 Chart of Depth Against Ln Activity of unsupported Lead-210 in Site IV



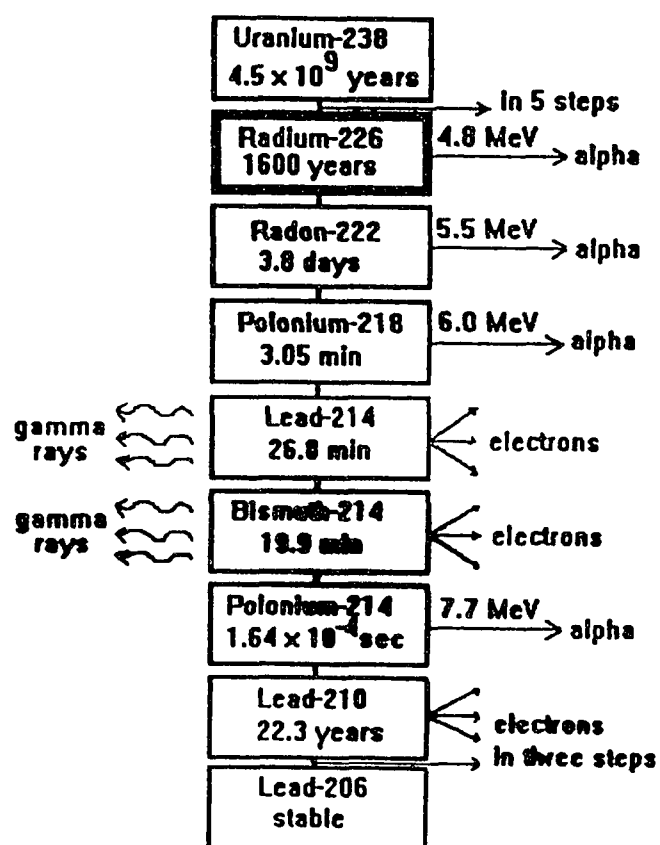
The results for the natural radionuclides (other than Pb-210)-

Fig's. 17 and 18 show diagrammatic representation and spectrum of U-238 decay series. Uranium-238 is an alpha emitting radionuclide with a half life of 4.5×10^9 years which decays to Ra-226 and some short lived gamma emitting radionuclides including Th-234, Rn-222, Pb-214 and Bi-214 (4). Fig. 19 and 20 illustrate the change in activity of a few of the gamma emitting radionuclides of this series with depth for sites I and IV respectively. As can be noticed, the activity of these nuclides are uniform throughout the core between 1 and 2 pCi/g. Therefore, gamma measurement of Pb-214 and Bi-214 can be an indirect method of measurement for Ra-226 and therefore U-238, assuming that all of the daughters are in equilibrium.

Uranium-235 an alpha and gamma emitter with a half-life of 7.1×10^8 years and generally exists at very low concentrations in the soil, 0.7% by weight of the total uranium which is 99.3% U-238. Fig. 21 shows U-235 activity concentration profile in soil to be uniform and very low in concentration (almost zero), as expected.

Fig. 22 shows the spectrum of the thorium-232 decay series. Thorium-232 is an alpha emitter with a half-life of 1.4×10^{10} years. Among its daughters are Ra-228 with a half-life of 6.7 years, Ac-228 a gamma emitter with a half-life of 6.13 hr, Pb-212 a gamma emitter with a half-life of 10.6 hr, and Bi-212 a gamma emitter with a half-life of 60.5 min (4).

Fig. 17 **Diagram of Uranium-238 Decay Series**



Uranium
Decay
Chain

Fig. 18 Spectrum of the Uranium-238 Decay Series (4)

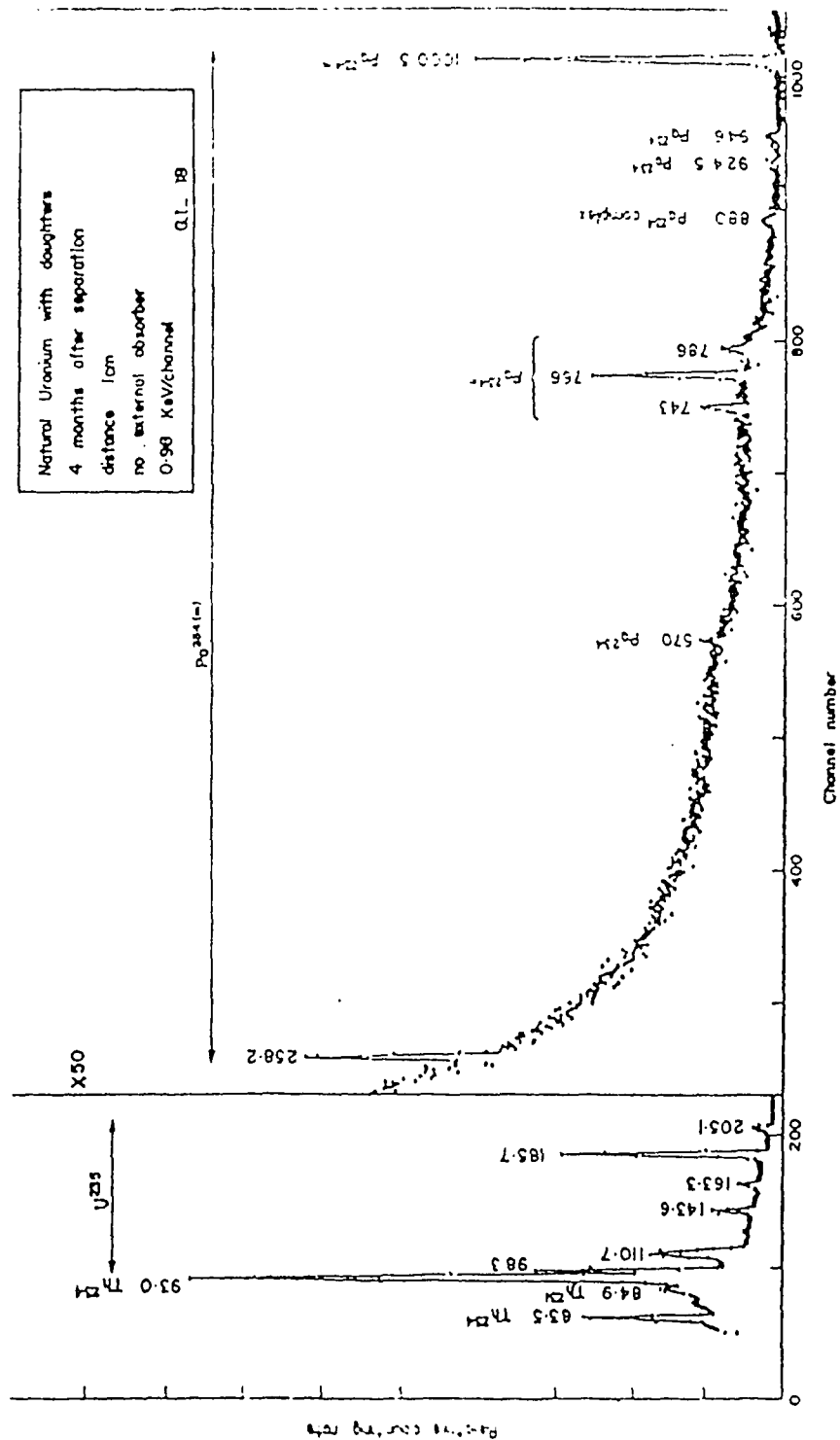


Fig. 19 Activity Concentration Profile of Uranium-238 Decay Series for Site I

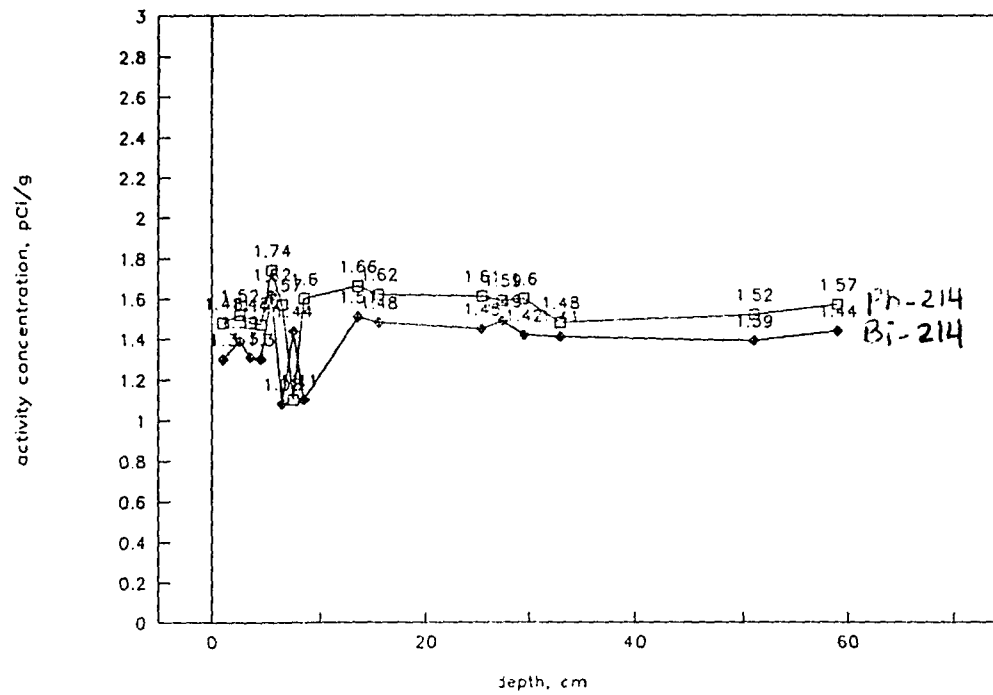


Fig. 20 Activity Concentration Profile of Uranium-238 Decay Series for Site IV

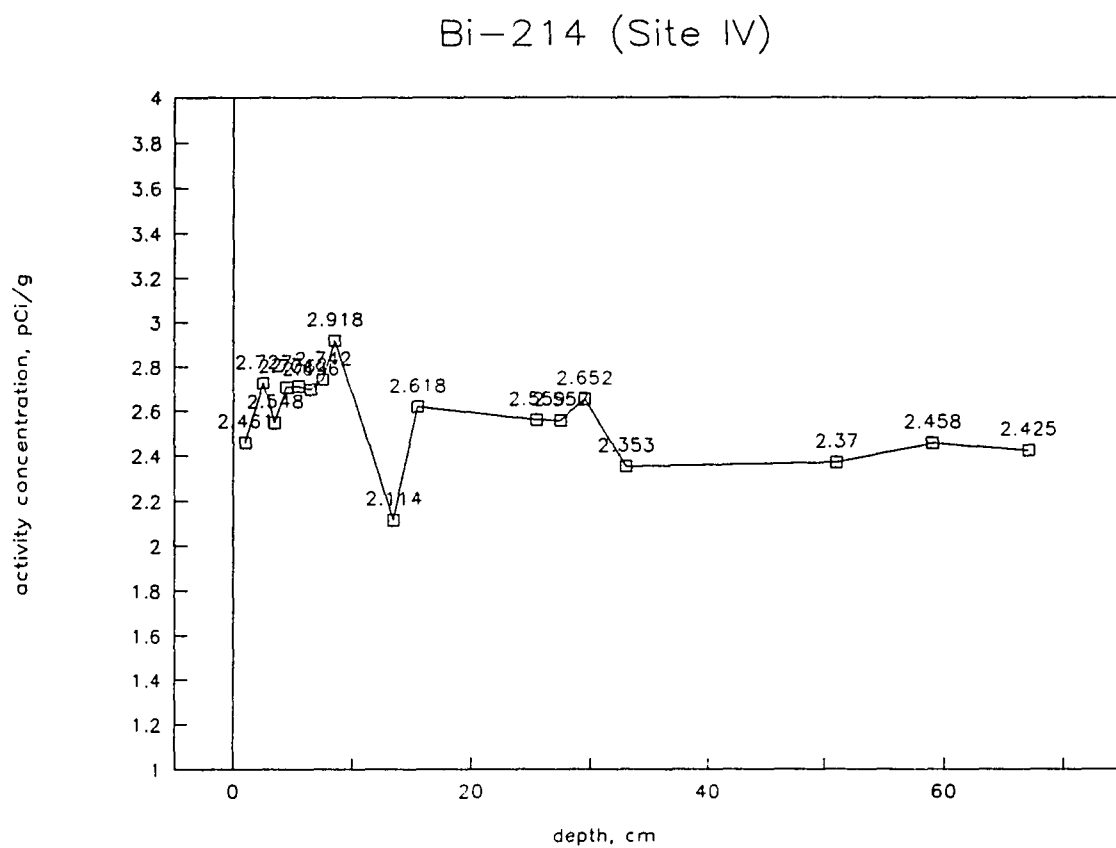


Fig. 21 Activity Concentration Profile of Uranium-235 in Site I

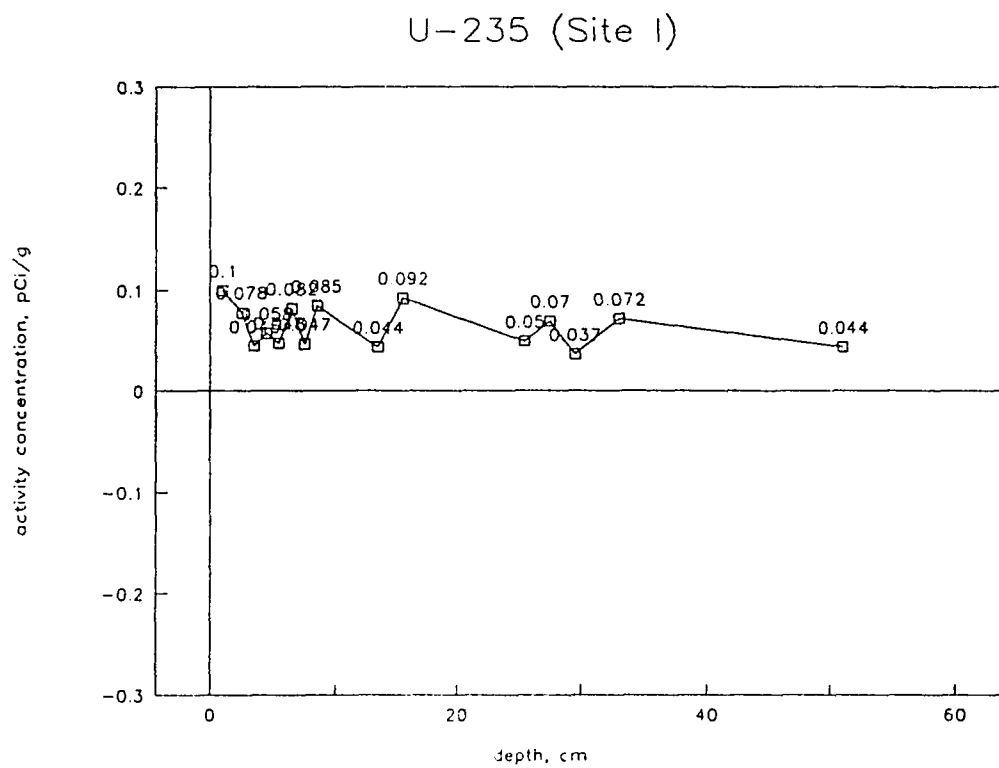
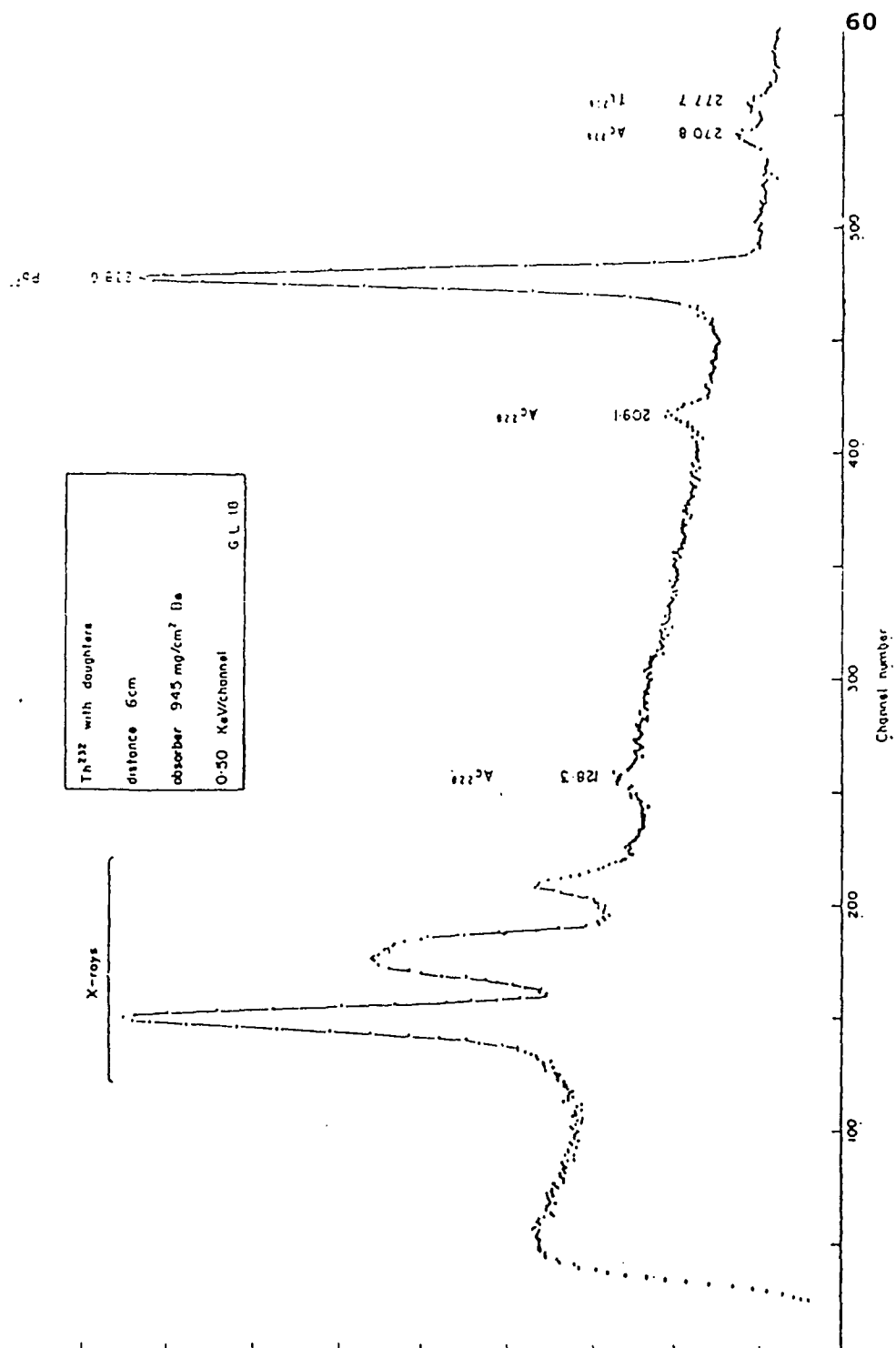


Fig. 22 Spectrum of the Thorium-232 Decay Series (4)

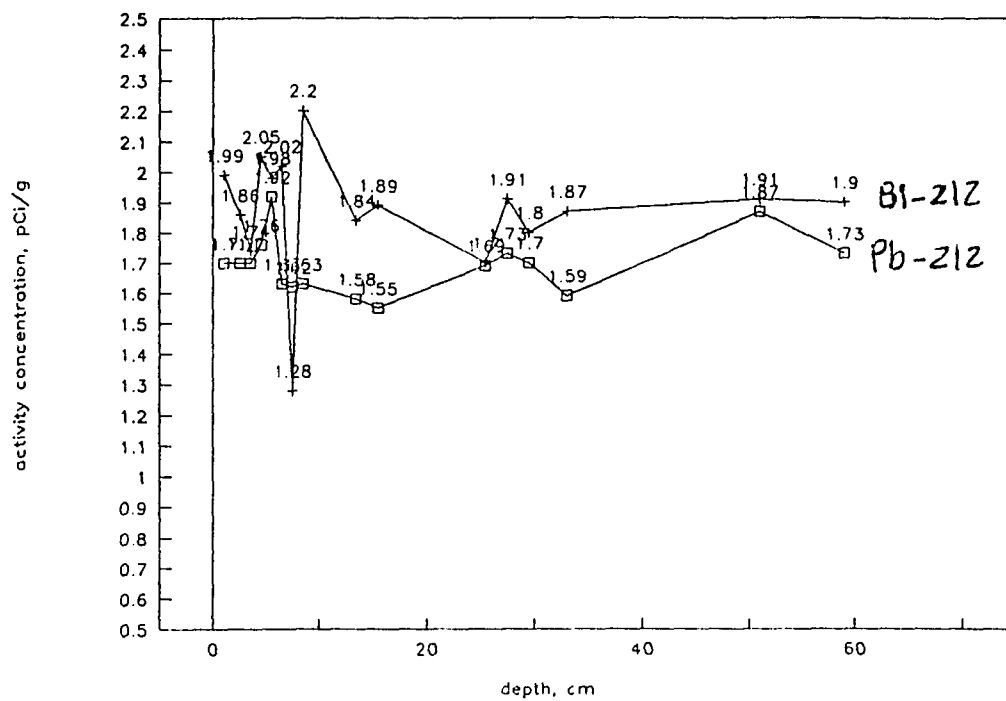


The activity concentration profiles of these nuclides in the dry lake sediments are represented in Fig. 23. As in U-238 decay series, all of these nuclides appear to be in equilibrium and therefore equal in activity between 1.5 and 2 pCi/g range.

K-40 is another important natural radionuclide of terrestrial origin with a half-life of 1.26×10^9 years that exists by itself and does not have any radioactive daughters (4). The spectrum for this nuclide is shown in Fig. 24 and its activity concentration profile in the dry lake sediments are shown in Fig. 25. The concentration of K-40 is measured to be about 20 pCi/g throughout the core for site I and about 40 pCi/g for location IV.

As can be noticed, the profile of all of the natural radionuclides in the sediments are uniform and this is a good indication that the dry lake bed has either remained undisturbed or has been thoroughly mixed. Both cases would result in uniform natural nuclide activity concentration.

Fig. 23 Activity Concentration Profile of Thorium-232 Decay Series for Site I



APPLIED GAMMA-RAY SPECTROMETRY

Fig. 24 Spectrum for Potassium-40 (4)

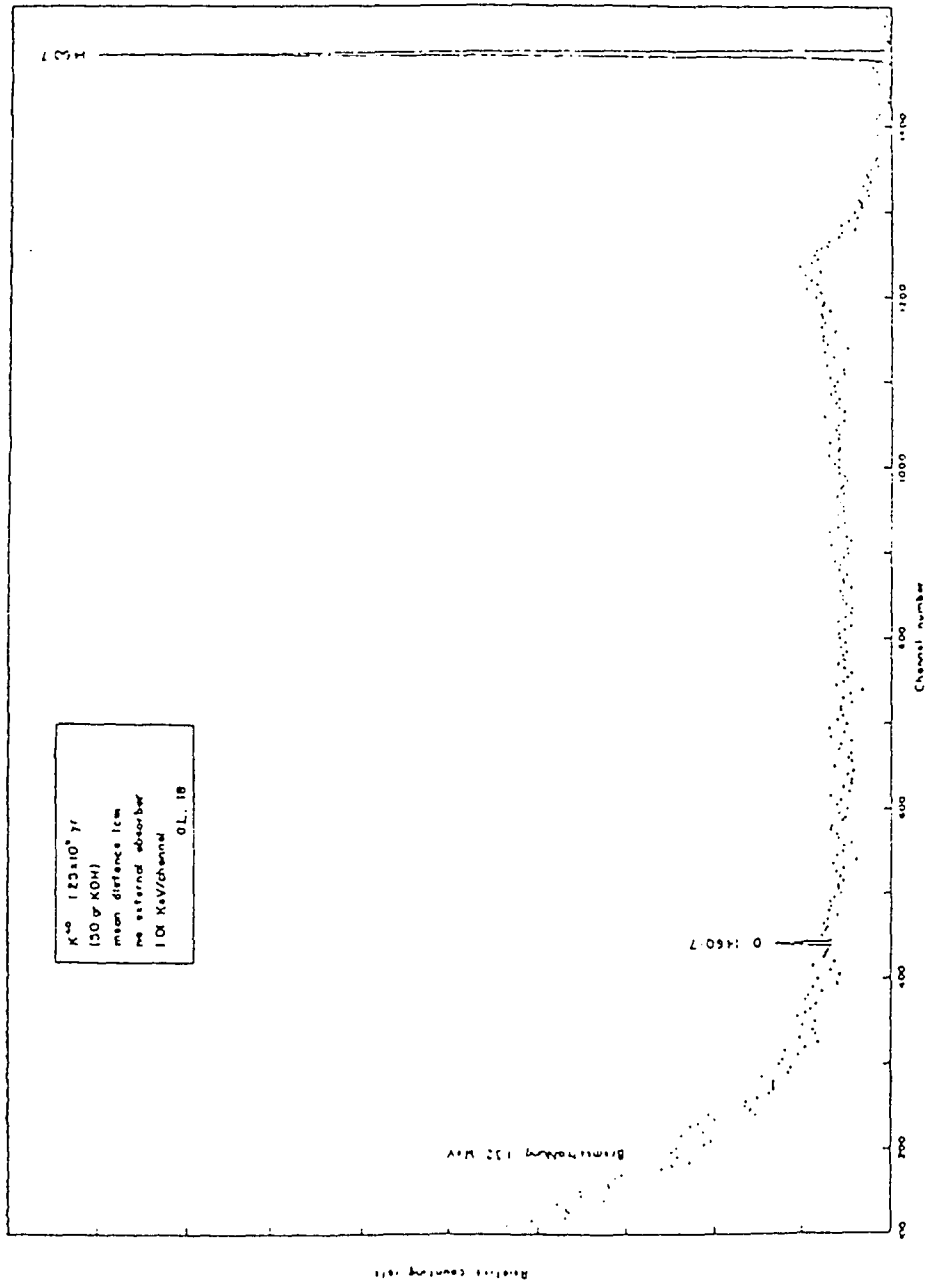
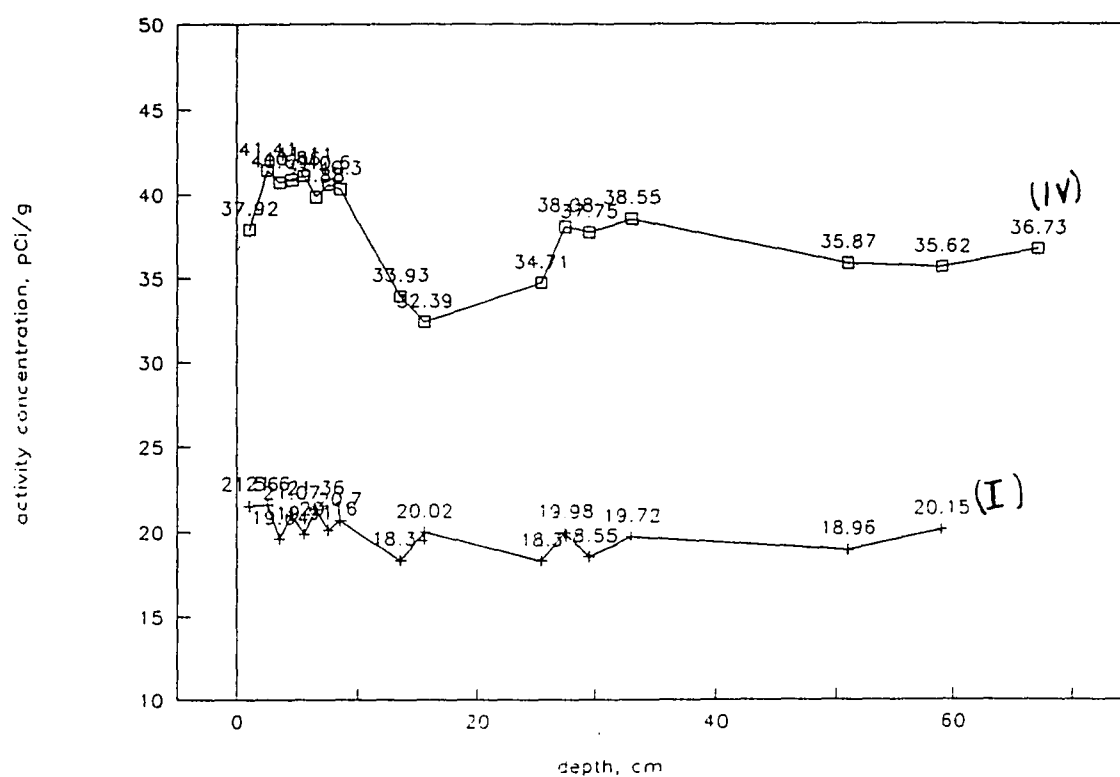


Fig. 25 Activity Concentration Profile of Potassium-40 in Sites I & IV



The results for the artificial radionuclides-

Cesium-137

The artificial radionuclides that were looked for by the gamma spectroscopy software included Co-60, Cs-134, Cs-137, Mn-54, Eu-152, Eu-154, Eu-155, Ru-106, Ag-110m, Sb-125 and Am-241. Only the Cs-137 was found at detectable concentrations. Cobalt-60, Ru-106, Ag-110m and Cs-134 were not detected because of their relatively short half-life of 5.271 years, 1.020 years, 249.8 days and 2.065 years respectively and the long time from their production in weapons testing.

The activity of the Cs-137 for sample cores collected from sites I and IV is recorded in Appendix A in terms of pCi/g which also includes the calculated values for the activity in terms of mCi/km²/cm. As can be noticed, unlike the natural radionuclides which are uniform throughout the core, Cs-137 is highest in activity at the top layer and gradually decreases to a constant background level at the 6th cm interval below the surface. (Fig. 26 & 27)

Some surface sediment that had curled up like a peal was collected from the southern edge of the lake (site V). The result of the gamma spectroscopy analysis of the samples is represented in Appendix A. The concentration in the 0.3 cm peal sample is 2 to 3 times higher than in the 0 - 1 cm layer of core I and core IV.

Fig. 26 Activity Concentration Profile of Cesium-137 in Locations I & IV

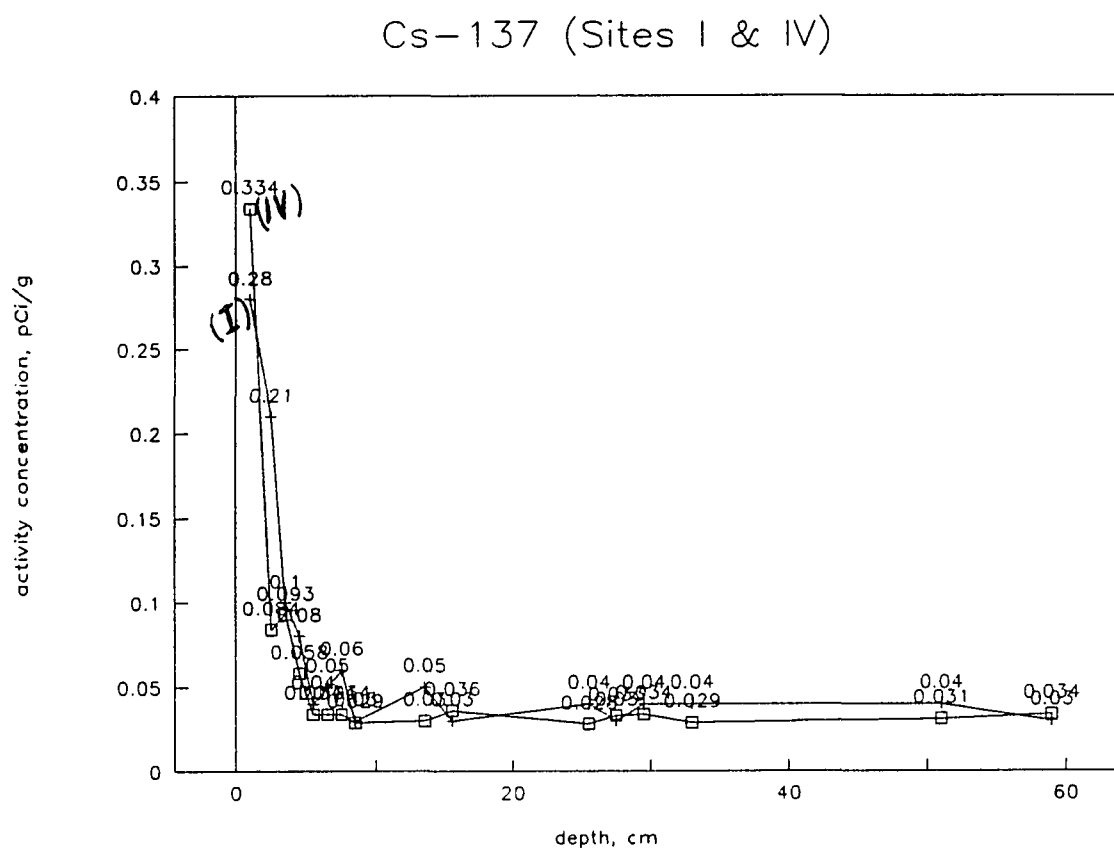
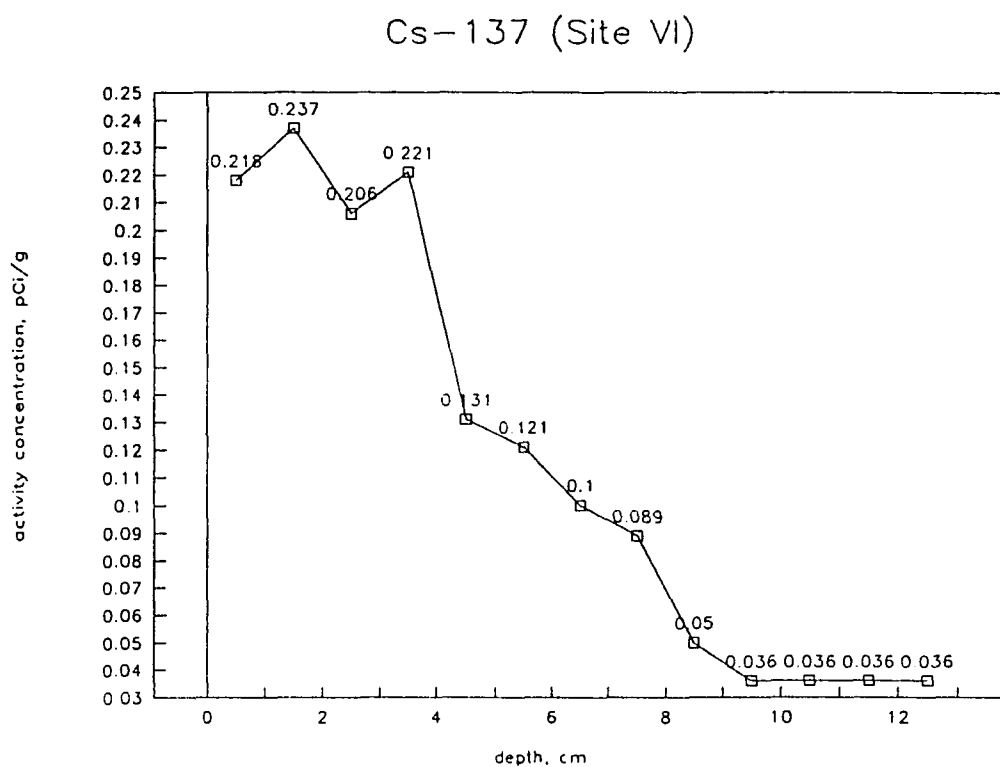


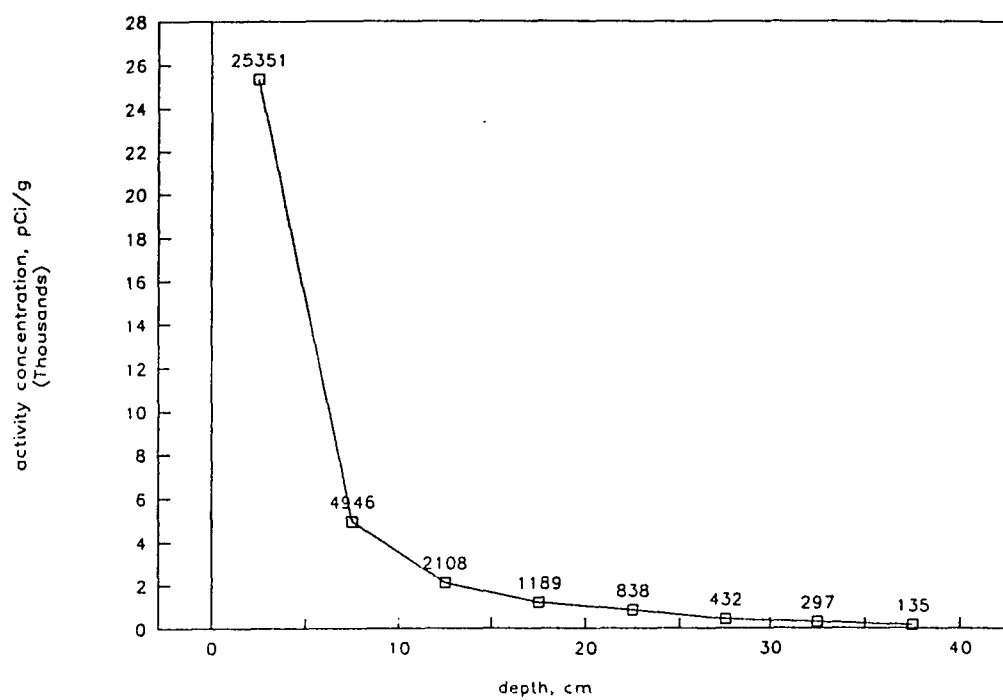
Fig. 27 Activity Concentration Profile of Cesium-137 from Site VI



The gamma spectroscopy analysis of a core from an adjacent lake in California (site VI) resulted in a profile similar to that of location I and IV (Appendix A). This single results suggest that there is a higher inventory in this core since the activity/gram of Cs-137 is decreasing much more slowly, still 0.1 pCi/g at 6 cm in depth. The distribution profile of the Cs-137 in the dry lake sediment was compared to one reported for the Cs-137 distribution measured by P. Chamard et al., in 1993, along a soil profile in a grassland, located near Bellagio in the North of Italy where the vertical distribution of Cs-137 in soil was shown to be due to the Chernobyl accident, in Russia, in 1986 (47).

Comparing the vertical distribution of Cs-137 in the soil profile in Bellagio, Italy (Fig. 28) with that of dry lake sediment profile in locations I and IV, we can see that they are very similar. Thus, it appears that this particular dry lake is not acting as a normal basin with high sedimentation rate like we had expected and is acting similar to normal soil with high clay content. The results gained from the gamma spectroscopy analysis of the 10 cm layer samples collected from locations II and III which were sampled to 90 cm showed no Cs-137 activity in the deeper sediments. The only Cs-137 activity detected in these analyses were at the top 10 cm layer. This confirmed the fact obtained by the lead-210 dating analysis that there had been a minimal sedimentation rate since the nuclear weapons testing fallout years and the

Fig. 28 **Distribution Profile of Cesium-137 in a Grassland**
in Bellagio, Northern Italy (47)



activity in the sediment has remained at the top without being covered up by the further sedimentation washed from the surrounding hills.

Therefore, as in the works of J. Ritchie et al. in 1990, the Cs-137 content in this dry lake can be used to study the erosion and sediment accumulation rates and patterns (34). This can be done by simply comparing Cs-137 content of the soil to the average global fallout inventory.

A vertical concentration profile of Cs-137 similar to the ones for cores I and IV was also observed in 1991 at the Hanford Site, located in arid southeastern Washington. According to this study, the top 5 cm of soil contained 99% of Cs-137 (48).

As shown in Appendix A, the total Cs-137 activity calculated from the samples from location I & IV are 15.5 and 9.4 mCi/km² respectively. These values are significantly lower than the global average value for Cs-137 activity which is 65 + 20 mCi/km² (48). This could result from one or both of the following phenomena. One is that the Cs-137 is gradually lost (washed away) from the lake to the lower elevations. There are two scenarios that can be evoked to explain the low inventory of Cs-137 by loss from the lake to lower elevations. First as mentioned in the introduction, Cs-137 having a little tendency to form complexes may be normally present as soluble cations in water over a relatively wide pH range. Also the distribution between solid particles and water has been

usually employed for evaluation of the migration of radionuclides in geological media. A study was done by Keneichi Akiba et al. in 1989 on the sorbtion behavior of cesium on representative minerals and rocks under comparable conditions (27). The dependence of the distribution coefficient on the cesium concentration was examined and a regularity in the distribution coefficient at trace concentrations was exhibited in connection with the cation exchange capacity for cesium of individual samples. The results showed that the distribution coefficients of cesium between the geologic materials and water decreased with increasing concentration and they approached a constant value at low concentrations. Therefore, from these results a hypothesis can be made that after each lake is filled up, the fraction of the cesium is dissolved in the water based on the total concentration of the cesium in the sediment and gradually lost by flowing to the surrounding area of lower elevation, i.e. to the adjacent large dry lake in California (Ivanpah Lake).

The second scenario, and more probable, which has been evoked by several authors (28-33), is that Cs-137 binds tightly to the fine clay particles at the surface and is simply lost from the lake due to erosion (34). A few data for the Cs-137 deposition near Las Vegas support the low deposition argument (49).

Moreover, the fragment of data from core VI, taken from

the adjacent, lower elevation dry lake, Ivanpah Lake, in California, suggests that the Cs-137 inventory may be higher since there is at least four times more Cs-137 at the 5-6 cm interval, implying that radiocesium may be present at significantly lower depths in the vertical profile. More work is needed to substantiate this observation.

Another possibility would be that there is simply lower Cs-137 input to Southern Nevada, due to lower rain fall in the desert environment.

Plutonium-239,240

Plutonium analysis was performed on core samples from locations I and IV in the dry lake. The analysis of the samples resulted in a activity concentration-depth profile similar to that of Cs-137, a gradual decrease in activity. The Pu-239,240 activity in location I showed that the highest concentration of 0.012 pCi/g at the top layer gradually decreasing and reaching the background level at the 8th cm layer below the surface (Fig. 29). Plutonium has a similar profile in core IV, starting at 0.010 pCi/g at the surface, exponentially decreasing to background level at 8 centimeters depth. (Appendix A)

Activities of the Pu-239,240, for samples from sites I and IV, are shown in terms of pCi/g in Appendix A. Tables VII and VIII show the Pu-239,240 activities in terms of pCi/kg and mCi/km²/cm for locations I and IV in mCi/km²/cm. The

Fig. 29 Activity Concentration Profile for Plutonium-239 in Sites I & IV

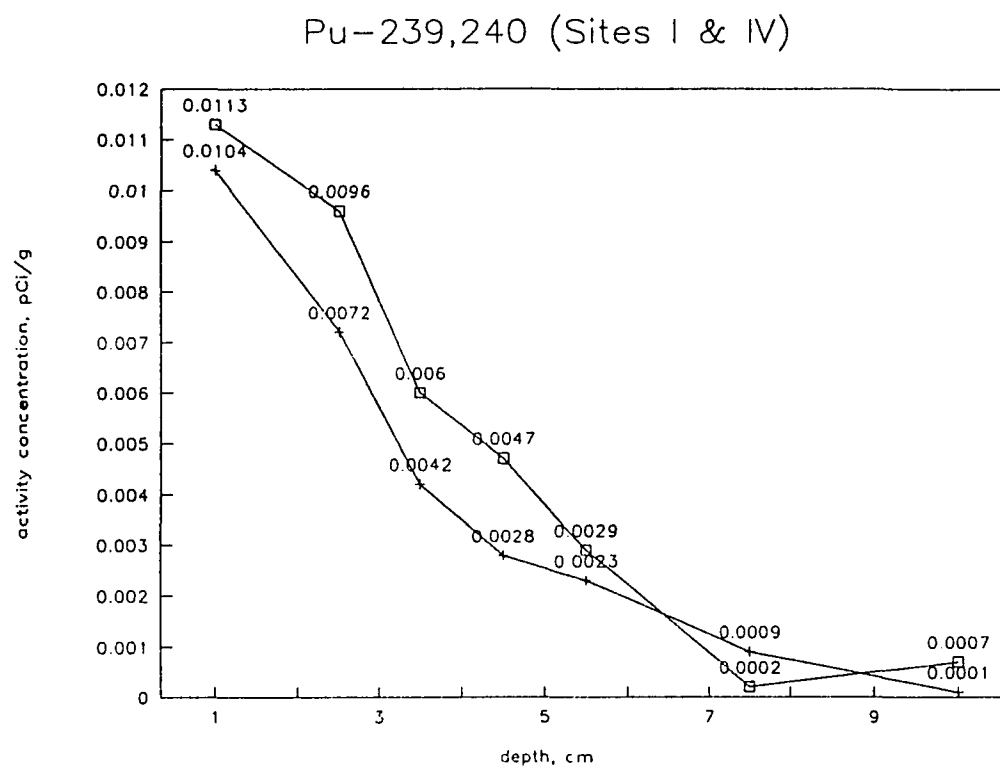


Table VII Results of the Plutonium-239,240 Analysis from Site I

Depth (cm)	pCi/kg	mCi/km ² /cm	Pu/Cs
0 - 1	11.5 ± 0.2	0.275 ± 0.005	0.038 ± 0.004
1 - 2	11.1 ± 0.8	0.104 ± 0.007	0.043 ± 0.006
2 - 3	9.6 ± 0.6	0.157 ± 0.010	0.046 ± 0.007
3 - 4	6.0 ± 0.5	0.078 ± 0.007	0.062 ± 0.019
4 - 5	4.8 ± 0.5	0.068 ± 0.009	0.057 ± 0.022
5 - 6	3.0 ± 0.4	0.040 ± 0.006	-
7 - 8	0.2 ± 0.5	0.003 ± 0.009	-

Table VIII Results of the Plutonium-239,240 Analysis from Site IV

Depth (cm)	pCi/kg	mCi/km ² /cm	Pu/Cs
0 - 2	10.3 ± 0.1	0.139 ± 0.001	0.062 ± 0.011
2 - 3	7.2 ± 0.1	0.134 ± 0.001	0.085 ± 0.003
3 - 4	4.2 ± 0.1	0.080 ± 0.001	0.045 ± 0.002
4 - 5	2.8 ± 0.1	0.043 ± 0.002	0.049 ± 0.003
5 - 6	2.3 ± 0.1	0.045 ± 0.002	0.069 ± 0.004
6 - 7	0.8 ± 0.1	0.013 ± 0.002	-
7 - 8	0.9 ± 0.1	0.012 ± 0.001	-
8 - 9	0.1 ± 0.1	0.002 ± 0.001	-
9 - 11	0.1 ± 0.1	0.002 ± 0.001	-

comparison of the total Pu-239,240 activity of 0.725 mCi/km^2 for location I and 0.47 mCi/km^2 for location IV to that of the global average, $1.8 \pm 0.05 \text{ mCi/km}^2$ show lower values (48). Tables VII and VIII also represent the Pu/Cs ratio at the top 5 cm layers of the cores I and IV. As can be noticed, the ratio of Pu to Cs is lowest at the top layer which gradually increases to a maximum value at the lower layers.

As can be seen in Fig. 29, the activity concentration profile of Pu-239,240 is quite similar to the Cs-137 activity concentration profile.

Cs-137/Pu-239,240 ratio as an indicator of fallout:

In an attempt to assess the impact, if any, of operations at Rocky Flats, a report was prepared by the Rocky Mountain Universities Consortium (RMUC) (50). This study was titled "Background Soils Characterization Program" (BSCP) and was aimed at establishing a credible range of values for the background concentration of plutonium in soils in Colorado and determine if the plutonium in soils was derived from worldwide fallout or partially from activities at the Department of energy's Rocky Flats Plant (50).

In this report, the activity ratio of cesium-137 to plutonium was used as an indicator of the background in soil as well as using the activity concentration inventories of Pu-239,240 or plutonium mass isotope ratio (Pu-240/Pu-239) (50).

One of the primary goals of the report was to summarize

published reports of the levels of plutonium in background soils. The results of the literature search for background values for the deposition of Cs-137 and plutonium in mCi/km^2 , the activity ratio of Cs-137 to Pu-239,240, and the mass ratio of Pu-240 to Pu-239 are in Table IX (50). Cesium-137 concentrations have been decay corrected to January 1, 1994. From Table IX, it can be noted that, there is a quite uniform deposition of the plutonium in "background" sites. They range from a low of 1.2 mCi/km^2 in Scotland and England to a high of 2.2 mCi/km^2 in Utah. All of the values measured for plutonium in the United States are within the average deviation for each study, i.e., 1.6 ± 0.5 , 1.6 ± 0.6 , 1.8 ± 0.4 , 1.7 ± 0.5 and 2.2 ± 0.5 , all in mCi/km^2 , the average being $1.8 \pm 0.5 \text{ mCi/km}^2$. The range of the worldwide plutonium deposition values at the different sites is from 0.6 mCi/km^2 to 4.4 mCi/km^2 (50). The Cs-137 "background" activity deposition values, corrected to January 1, 1994, are also uniform throughout the globe. The values for the United States are: 57 ± 16 , 64 ± 27 and $74 \pm 16 \text{ mCi/km}^2$, with an average of $65 \pm 20 \text{ mCi/km}^2$. The site range is from 20 mCi/km^2 to 141 mCi/km^2 (50).

The Cs-137 to plutonium activity ratio for all "background" sites worldwide is also very uniform: 36 ± 3 , 38 ± 5 , 36 ± 5 and 35 ± 6 , with an average of 36 ± 5 (corrected to January 1, 1994, for the decay of Cs-137). This ratio was used successfully in assessment of the impact of fuel reprocessing plant in Scotland and England (51). The plutonium mass ratio

Table IX Plutonium and Radiocesium in Soil from Global Fallout--"Background Values" (50)

Specimens	No. of Sites	Year	Background (Bq/kg)		Decay	Notes
			Pu-239 ^a	Pu-240 ^a		
U.S. wide Most in Utah, New Mexico, Arizona, Nevada	70	1983-87	1.6±0.5	57±16	36±3	taken as 0.16
Worldwide	57	1970-71	-	-	-	0.18
San Francisco New York Cape Cod	11	1972-73	1.6±0.6 (0.8-2.4)	64±27 (20-90)	38±5	-
Mostly Utah	31 ^b	1971-74	1.8±0.4 ^c	52 and 110 2 only	23 and 33 2 only	0.17 and 0.14
Scotland England	6	1977	1.2±0.1 (1.0-1.4)	48±6 (42-61)	36±5	-
Worldwide 26°N to 47°N	19	1970-71	1.7±0.5 (0.7-2.6)	-	-	-
Utah	43	1979	2.2±0.5 (1.3-4.4)	74±16 (42-16)	35±6	0.15±0.02 (0.11-0.18)

^a Pu-239+ activity = Pu-239 + Pu-240

^b Cs-137 activity corrected for decay to 1 Jan 94

^c Activity ratio

^d Mass ratio

^e Pu-239 + Pu-240 activity after NTS contribution subtracted

of Pu-240 to Pu-239 averages 0.16±0.02, somewhat lower than the first published value of 0.18

(52), possibly indicating the influence of the Nevada Test Site.

During the summer of 1994, 15 BSCP soil samples were analyzed by UNLV for plutonium (Pu-239,240) and Cs-137. The results indicated a mean activity ratio of Cs-137/plutonium of 38 ± 3 , strongly suggesting all of these soil samples are typical background soils which have obtained their plutonium and cesium from worldwide fallout from nuclear weapons testing (53).

According to the report (50), the plutonium/Cs-137 activity ratio may be relatively unaffected by weathering processes over the last 30 years. The Pu/Cs activity ratios for cores I and IV are included in tables VII and VIII. The gradual increase in Pu/Cs ratio represents the fact that Cs-137 has a lower tendency to migrate downward than Pu-239,240 and tends to be retained by the clay particles longer than Pu-239,240. This phenomenon is also presented by E. Hardy, HASL (54). He studied the depth distribution of global fallout Sr-90, Cs-137 and Pu-239,240 in sandy loam soil. The first of a series of depth profile soil samples had been analyzed for Sr-90, Cs-137, and Pu-239,240. Cesium-137 showed the least tendency to migrate downward followed by the Pu-239,240 and Sr-90, in that order.

The comparison of the Pu/Cs activity ratio, 0.049 for core I and 0.062 for core IV, to that of global average ratio of 0.028 ± 0.004 shows a much higher value. From these results

and from the assumption that the Pu/Cs ratio is normally unaltered by the weathering process (based on the data obtained from the analysis of the samples from Rocky Flats study (50)), two conclusions can be made. The first hypothesis is that cesium and plutonium are both lost from the dry lake bed to the surrounding area, with cesium at a significantly faster rate than plutonium.

The second hypothesis is that, there has been more Pu-239,240 input from the Nevada Test Site, due to its proximity to sampling site., that at the sites in Colorado (58) and around the world. This is supported weakly by two data points in the literature from the Pu/Cs ratio in the Las Vegas area (49). From the data in this thesis, no conclusions can be made in support of either hypothesis.

Strontium-90

Strontium-90 was analyzed for samples from core I only. Results are shown in Table X. As seen from Fig. 30, its vertical concentration profile differs from that of cesium and plutonium. Strontium-90 concentrations remain uniform at about 0.06 pCi/g range down to 6 cm after which the concentration decreases (exponentially) to a constant level. Strontium-90 exhibits a higher tendency to migrate downward in the sediment than either cesium or plutonium. As mentioned above, this concept was also observed by several authors (54, 55). (See Table XI)

Table X Results of Strontium-90 Analysis from site I

Depth (cm)	Sample 1	Sample 2	Sample 3	Sample 4
0 - 1	0.051 ± 0.005	0.007	1.222	5.926 ± 0.830
1 - 2	0.069 ± 0.006	0.008	0.514	4.753 ± 0.713
2 - 3	0.063 ± 0.005	0.006	0.824	4.108 ± 0.657
3 - 4	0.065 ± 0.004	0.005	0.681	1.840 ± 0.570
4 - 5	0.058 ± 0.004	0.004	0.672	1.766 ± 0.671
5 - 6	0.062 ± 0.003	0.004	0.670	-
8 - 9	0.060 ± 0.003	0.004	0.429	-
14 - 15	0.031 ± 0.003	0.008	0.143	-
16 - 17	0.041 ± 0.003	0.008	0.226	-
20 - 21	0.020 ± 0.004	0.008	0.167	-

Table XI Total Sr-90 concentrations in different soil layers measured from 1987 to 1990 and Chernobyl contribution (47)

Soil layer (cm)	1987		1989		1990	
	Total	Chernobyl	Total	Chernobyl	Total	Chernobyl
0 - 5	1270	460	1027	378	973	405
5 - 10	351	54	460	54	460	54
10 - 15	270	27	270	27	297	27
15 - 20	189	-	189	-	216	-
20 - 25	135	-	108	-	135	-
25 - 30	81	-	81	-	54	-
30 - 35	54	-	54	-	54	-
35 - 40	54	-	27	-	27	-

Fig. 30 Activity Concentration Profile for Strontium-90 in Site I

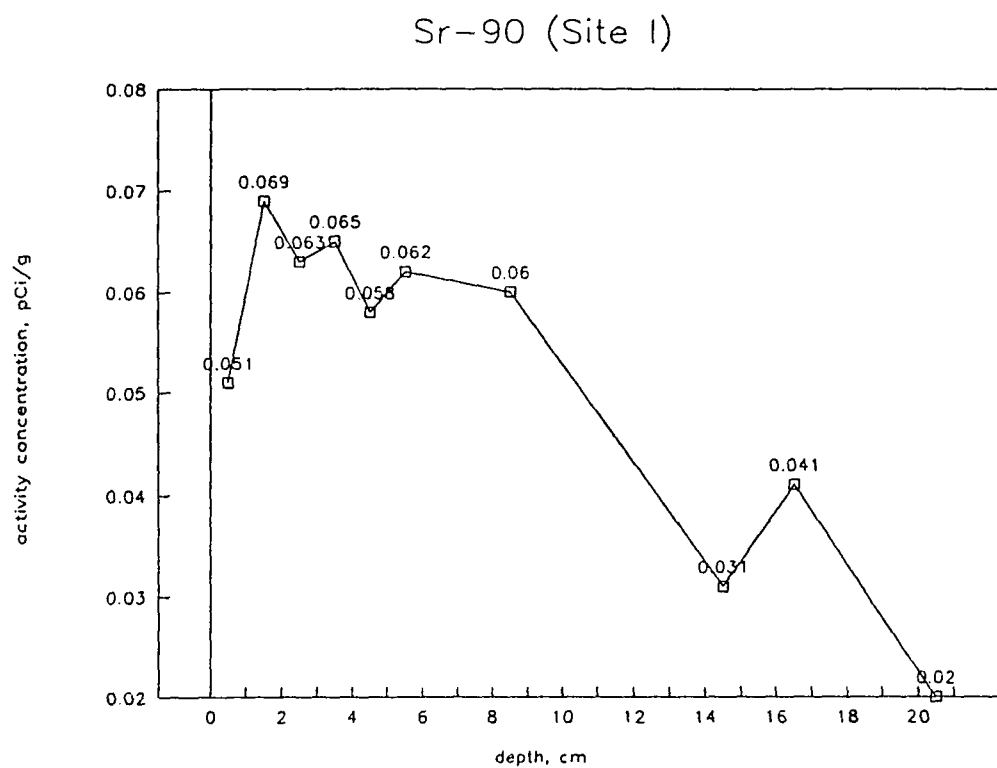


Table X also shows the activity of the Sr-90 in terms of mCi/km²/cm, and the ratio of the Cs-137 activity to Sr-90 activity in the dry lake. The comparison of the total activity of the Sr-90, 5.548 mCi/km² to the global average of 18.87 mCi/km² shows a loss in the activity of the Sr-90 from the lake bed and the comparison of the Cs-137 to Sr-90 ratio in the dry lake, 3.68 to that of the global average of 1.7 shows an exceptionally high rate of loss of Sr-90 compared to Cs-137 and Pu-239,240. Thus, not only does strontium migrate vertically, it appears to be more readily washed out of the lake than cesium or plutonium.

As detailed in the introduction, strontium has a similar sorption behavior on geological media as cesium and is present in water as uncomplexed cation, showing a little tendency to form stable complexes and hydrolysis products in a relatively wide pH region. This may be argued as the reason for the relatively easy migration of strontium in the sediments.

Conclusions

The activity of the artificial radionuclides including Cs-137, Pu-239,240 and Sr-90 in all of the sampling sites showed a decrease in the activity concentration with depth in the core, the highest activity being at the surface. The gamma activity of Cs-137 in the surface sediments contributes less than one percent of that due to natural radionuclides. The alpha activity of plutonium in the surface sediments of the lake also contributes less than one percent of the total alpha activity relative to natural sources. The total activity inventory, mCi/km², of the artificial radionuclides, Cs-137, Pu-239,240 and Sr-90, in sites I and IV were calculated and found for three nuclides to be lower in value compared to the average global inventories. The lower values could be an indication of the loss of these nuclides from the lake bed, or, simply, lower input due to the dry climate which would limit washout of these nuclides from the atmosphere (low rainout). The Pu:Cs activity ratios of 0.049 for core I and 0.062 for core IV, are much higher than the average global ratio of 0.028 ± 0.004 , which may indicate that Cs-137 is removed from the dry lake at a higher rate than Pu-239,240, or, that the weapons fallout in southern Nevada was not typical of worldwide fallout but had a higher plutonium concentration, possibly due to the proximity of the Nevada Test Site.

Analysis of the natural nuclides from the uranium and thorium decay series, and radiopotassium, show that their

concentrations are reasonably constant with depth, in contrast to the artificial radionuclides and the Pb-210 that comes from fallout. Plutonium and radiocesium are confined to the upper 6 cm of sediment. Strontium appears to penetrate to about twice the depth. This type of profile is similar to those found for soil in the 1970's and suggests that all of these nuclides are still in the top layers of soil and have not penetrated downwards as predicted by early authors.

Data for natural Pb-210 suggest that the sedimentation rate is very slow (0.06 cm/year). All of the excess Pb-210 activity appears to be confined to the top three to four centimeters. Most of the Pb-210 is in the upper most 0.3 cm interval. Analysis of the bismuth-214 suggests constancy in the radium-226 concentration up to the surface indicating atmospheric origin of the excess lead-210. This is substantiated by the fact that the peak fallout activities are not buried deep in the sediments.

Another interpretation is that the upper sediments are mixed yearly, when it rains, and the fallout radioactivities for some reason rise to the top as the sediments dry out. If mixing does occur, these two dissimilar elements appear to stay together, possibly because they are firmly bound to some component of the sediment material, or that they are formed together in the high temperatures of the weapons explosions and not easily separated. However, strontium is for some reason more mobile.

Appendix A

This section includes the collection data, the net weight of the samples used for the gamma-ray analysis, and the results of polonium-210 analyses, Cs-137 analyses and plutonium-239,240 analyses.

Collection Data (site I)

depth (cm)	surface area (cm ²)	total weight (grams)
0 - 1	1600	3832
1 - 2	1600	1490
2 - 3	1600	2616
3 - 4	1600	2096
4 - 5	1600	2316
5 - 6	1600	2160
6 - 7	1600	1751
7 - 8	1600	1857
8 - 9	1600	1429
9 - 10	1600	1943
11 - 12	1600	2014
12 - 13	1600	1262
13 - 14	1600	2168
14 - 15	1600	954
15 - 16	1600	1711
16 - 17	1600	1129
17 - 18	1600	1061
19 - 20	975	2009
20 - 21	975	1666
21 - 22	975	1219
22 - 23	975	1293
23 - 24	975	1280
24 - 25	975	1421
25 - 26	975	1781
26 - 27	975	1602
28 - 29	975	2039

Collection Data (site IV)

depth (cm)	surface area cm ²	total weight (grams)
0 - 2	900	2417
2 - 3	900	1686
3 - 4	900	1716
4 - 5	900	1375
5 - 6	900	1739
6 - 7	900	1501
7 - 8	900	1235
8 - 9	900	1387
9 - 11	900	2770
12 - 13	900	1270
13 - 14	900	1185
14 - 15	900	1076
15 - 16	900	962
16 - 17	900	1165
17 - 18	900	1136
18 - 19	900	529
19 - 20	900	1084
20 - 21	900	1300
21 - 22	900	1698
22 - 23	900	890
23 - 24	900	1174

Collection Data (site IV) cont.

depth (cm)	surface area (cm ²)	total weight (grams)
24 - 25	900	912
25 - 26	900	1496
26 - 27	900	1173
27 - 28	900	834
28 - 29	900	1151
29 - 30	900	1002
30 - 32	900	1630
32 - 34	900	1905
34 - 36	900	2309
36 - 38	900	1828
38 - 40	900	1567
40 - 42	900	2413
42 - 44	900	2652
44 - 48	900	2987
48 - 50	900	1967
50 - 52	900	1677
52 - 54	900	1934
54 - 56	900	1843
56 - 58	900	1524
58 - 60	900	1362
60 - 62	900	1327

Samples from Site I Contained in Tuna Can for Gamma-Ray Analysis

Sediment layer (cm)	Aliquot weight (grams)
0 - 1	213.14
1 - 2	208.22
2 - 3	249.91
3 - 4	213.98
4 - 5	207.22
5 - 6	208.70
6 - 7	205.24
7 - 8	210.23
8 - 9	244.47

Samples from Site IV Contained in Tuna Can for Gamma-Ray Analysis

Sediment layer (cm)	Aliquot weight (grams)
0 - 2	161.46
2 - 3	141.22
3 - 4	152.54
4 - 5	135.75
5 - 6	129.56
6 - 7	130.54
7 - 8	136.15
8 - 9	133.70

Results of Polonium-210 Analysis from Site I

sediment layer (cm)	aliquot (g)	Po-208 activity (pCi)	Po-208 recover y (%)	Po-210 activit y (pCi/g)
0 - 1	2.00	2.00	55.68	1.244
1 - 2	2.16	2.28	50.29	1.374
3 - 4	2.00	2.00	53.98	1.142
8 - 9	2.00	2.02	45.82	1.137
9 - 10	2.00	2.00	111.85	1.134
14 - 15	2.00	2.00	111.01	0.981
19 - 20	4.00	1.87	43.00	0.686
24 - 25	2.00	2.00	102.15	1.045
25 - 26	2.47	2.27	92.01	1.016
28 - 29	2.00	2.00	112.41	1.049
29 - 30	4.07	1.87	65.40	0.634

Results of Polonium Analysis from Site IV (First Analysis)

sediment layer (cm)	aliquot (g)	Po-208 recovery (%)	Po-210 activity (pCi/g)
5 - 6	2.03	50.96	0.853
7 - 8	2.04	112.73	1.536
8 - 9	2.04	89.05	0.795
9 - 11	2.04	82.83	0.705
17 - 18	2.10	70.89	0.955
21 - 22	1.99	104.66	0.977
23 - 24	2.10	95.71	0.842
27 - 28	2.13	126.79	0.939
32 - 34	2.11	67.93	0.747
40 - 42	2.01	80.38	0.844
44 - 48	2.05	109.46	1.068
54 - 56	2.04	109.72	1.055
58 - 60	2.01	113.87	1.067
62 - 64	2.23	121.10	0.921
66 - 68	2.04	121.85	0.818

Results of Polonium Analysis from Site IV (Second Analysis)

Sediment layer (cm)	Po-210 activity pCi/g
0 - 2	2.46
2 - 3	1.65
3 - 4	1.61
4 - 5	1.53
5 - 6	1.36
6 - 7	1.53
7 - 8	1.44
8 - 9	1.47
13 - 14	1.33
15 - 16	1.30
17 - 18	1.54
23 - 24	1.21
40 - 42	1.36
44 - 48	1.48
50 - 52	1.72
58 - 60	1.54

Results of the Cesium-137 Analysis from Site I

Depth (cm)	pCi/g	mCi/km ² /cm
0 - 1	0.30 ± 0.03	7.2 ± 0.7
1 - 2	0.26 ± 0.03	2.4 ± 0.3
2 - 3	0.21 ± 0.03	3.4 ± 0.5
3 - 4	0.10 ± 0.03	1.3 ± 0.3
4 - 5	0.08 ± 0.03	1.2 ± 0.5
5 - 6	<0.04	-

Results of Cesium-137 Analysis from Site IV

Depth (cm)	pCi/g	mCi/km ² /cm
0 - 2	0.334 ± 0.006	4.48 ± 0.08
2 - 3	0.084 ± 0.003	1.57 ± 0.06
3 - 4	0.093 ± 0.003	1.77 ± 0.06
4 - 5	0.058 ± 0.002	0.89 ± 0.03
5 - 6	0.034 ± 0.001	0.66 ± 0.02
6 - 7	0.034 ± 0.001	0.66 ± 0.02
7 - 8	0.034 ± 0.001	0.66 ± 0.02
8 - 9	0.029 ± 0.002	0.56 ± 0.03
9 - 10	0.030 ± 0.002	0.58 ± 0.03
10 - 11	0.036 ± 0.002	0.70 ± 0.03

Results of Cesium-137 Analysis from Site V

Depth (cm)	Activity (pCi/g)	MDA (pCi/g)
peel sample from surface (0.3 cm)	0.614 ± 0.003	0.026

Results of Cesium-137 Analysis from Site VI

Depth (cm)	Activity (pCi/g)	MDA (pCi/g)
0 - 1	0.218 ± 0.003	0.020
1 - 2	0.237 ± 0.003	0.021
2 - 3	0.206 ± 0.003	0.021
3 - 4	0.221 ± 0.003	0.024
4 - 5	0.131 ± 0.003	0.022
5 - 6	0.121 ± 0.003	0.023
6 - 7	0.100 ± 0.003	0.023
7 - 8	0.089 ± 0.003	0.024
8 - 9	0.050 ± 0.003	0.024
9 - 10	<0.036	0.024

Results of the Plutonium-239,240 Analysis from Site I

Sediment layer (cm)	Sample aliquot (g)	% Pu-242 recovery	Pu activity (pCi/g)
0 - 1	95.43	73	0.0115 ± 0.0002
1 - 2	75.25	39	0.0111 ± 0.0008
2 - 3	69.67	73	0.0096 ± 0.0006
3 - 4	66.01	69	0.0060 ± 0.0005
4 - 5	82.00	57	0.0047 ± 0.0001
5 - 6	76.90	36	0.0029 ± 0.0004
7 - 8	204.79	78	0.0002 ± 0.0001
9 - 10	209.57	43	0.0004 ± 0.0002
10 - 11	201.83	09	0.0009 ± 0.0008
11 - 12	209.72	53	0.0002 ± 0.0001

Results of the Plutonium-239,240 Analysis from Site IV

Sediment layer (cm)	Sample aliquot (g)	Pu-239 activity (pCi/g)
0 - 2	2358.20	0.0104 ± 0.0001
2 - 3	1622.50	0.0072 ± 0.0001
3 - 4	1648.90	0.0042 ± 0.0001
4 - 5	1304.30	0.0028 ± 0.0001
5 - 6	1660.60	0.0023 ± 0.0001
6 - 7	1414.60	0.0008 ± 0.0001
7 - 8	1165.50	0.0009 ± 0.0001
8 - 9	1296.10	0.0001 ± 0.0001
9 - 11	2636.40	0.0001 ± 0.0001

Appendix B

This section includes the raw data and two sample spectra from the alpha spectroscopy measurement of the polonium-210.

EG&G ORTEC ALPHAMAT A16-B1 Ver 1.017
21-Jun-94 07:54:58
ALI (576 A)

Det 24 HCB 2 Seq 3 Analysis Method: ROI, Relative
Slope Recalibration
Sample ID:
Channel File: 3-4 Original Gain: 2997.19 ± 8.85 *Chn
Recalibrated: 2997.19 ± 8.85 *Chn
Sample Date: 21-Jun-94 Efficiency: 0.1508
Sample Time: 05:15pm Background: 81494170
Live Time: 43200.00 Bkg Date: 20-Jun-94 01:24pm
Real Time: 43200.50 Bkg Lv Tm: 86400.00
Volume Total: 1.00 Total Eff: 0.1510
Volume Aliquot: 1.1600 Chem Recov: 0.5950
Tracer CPM: 4.20

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	258.0	5105.00	1	0.10
2	266.0	5100.00	0	0.00

Analytes

Nuclide	ROI	ROI	Peak	Gross	Bkg	Net	CPM
Num Name KeV	Start	End	Number	Counts	Counts	Counts	
1 Po-210 5105.0	258	279	1	400.0	14.0	386.0	0.54

Tracer

Name	ROI	ROI	Peak	Gross	Bkg	Net	FWHM
KeV	Start	End	Number	Counts	Counts	Counts	
Tracer Po-208 5100.0	235	266	2	469.0	3.0	466.0	

Analyzed by: _____

Checked by: _____

E060-RTM: ALPHAMAT A14-B1 Ver 1.01y
 24-Jun-94 10:15:10
 A11 (576 A)

Det 22 PCB 2 Seg 6 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID:
 Channel File: 17-18 Original Cal: 2885.64 ± 8.95 *Chn
 Recalibrated: 2885.64 ± 9.00 *Chn
 Sample Date: 24-Jun-94 Efficiency: 0.2312
 Sample Time: 09:55am Background: 82294172
 Live Time: 14400.00 Bkg Date: 20-Jun-94 01:34pm
 Real Time: 14400.16 Bkg Lv Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.1639
 Volume Aliquot: 2.1000 Chem Recov: 0.7089
 Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	349.7	5105.00	1	0.00
2	346.0	5100.00	0	0.00

Analytes

Nuclide	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1 Po-210	5105.0	256	277	1	177.0	14.0	174.7	0.73

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-210	5100.0	193	354	2	170.0	6.0	169.2	

Analyzed by: _____

Checked by: _____

0040 LPTED ALPHAMAT A16-B1 Ver 1.11y
24-Jun-94 11:55:10
ALI (576 A)

Det 21 MDS 2 Seg 5 Analysis Method: POI, Relative
Slope Recalibration
Sample ID:
Channel File: 11-22 Original Cal: 2876.69 + 8.99 *Chn
Recalibrated: 2876.69 + 9.04 *Chn
Sample Date: 24-Jun-94 Efficiency: 0.2503
Sample Time: 09:55am Background: B2194172
Live Time: 14400.00 Bkg Date: 20-Jun-94 01:24pm
Real Time: 14400.16 Bkg Lv Tm: S6400.00
Volume Total: 1.00 Total Eff: 0.2620
Volume Aliquot: 1.9900 Chem Recov: 1.0466
Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	258.6	5105.00	1	0.00
2	246.0	5100.00	0	0.00

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	DPM
1	Po-210	5105.0	156	177	1	276.0	29.0	271.2	1.13

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-210	5100.0	133	154	2	271.0	4.0	270.1	

Analyzed by: _____

Checked by: _____

LSRG RTED ALPHAMAT A15-B1 Ver 1.017
 24-Jun-94 11:55:57
 ALI (178 A)

Set 25 MCB 2 Seg 9 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID:
 Channel File: 17-28 Original Cal: 1884.70 + 8.95 *Chn
 Recalibrated: 1884.70 + 9.01 *Chn
 Sample Date: 24-Jun-94 Efficiency: 0.1559
 Sample Time: 09:55Am Background: 51594172
 Live Time: 14400.00 Bkg Date: 20-Jun-94 01:24pm
 Real Time: 14400.15 Bkg LV Tm: 36400.00
 Volume Total: 1.00 Total Eff: 0.1245
 Volume Aliquot: 2.1000 Chem Recov: 1.2679
 Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	248.7	5105.00	1	0.00
2	248.0	5100.00	0	0.00

Analytes

Nuclide Num	Name	KeV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Po-210	5105.0	256	277	1	148.0	14.0	135.7	1.44

Tracer

Name	KeV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-210	5100.0	200	254	2	335.0	7.0	328.8	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-B1 Ver 1.31y
 24-Jun-94 14:11:11
 AL1 (576 A)

Det 27 MCB 2 Seg 11 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID:
 Channel File: 32-34 Original Cal: 2960.50 ± 8.81 *Chn
 Recalibrated: 2960.50 ± 8.88 *Chn
 Sample Date: 24-Jun-94 Efficiency: 0.2399
 Sample Time: 09:55am Background: 82794172
 Live Time: 14400.00 Bkg Date: 20-Jun-94 01:24pm
 Real Time: 14400.16 Bkg Lv Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.1630
 Volume Aliquot: 2.1100 Chem Recov: 0.6793
 Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	264.0	5305.00	1	0.00
2	241.0	5100.00	0	0.00

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Po-210	5305.0	251	272	1	140.0	16.0	127.3	0.57

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-210	5100.0	223	249	2	169.0	5.0	168.2	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A14-B1 Ver 1.01y
24-Jun-94 07:56:51
ALI (575 A)

Det 11 MCB 2 Seg 6 Analysis Method: ROI, Relative
Slope Recalibration

Sample ID:
Channel File: 40-42 Original Cal: 2985.64 + 8.95 *Chn
Recalibrated: 2885.64 + 9.11 *Chn

Sample Date: 20-Jun-94 Efficiency: 0.2112

Sample Time: 05:15pm Background: 82294.72

Live Time: 43200.00 Bkg Date: 20-Jun-94 01:24pm

Real Time: 43200.52 Bkg Lv Tm: 86400.00

Volume Total: 1.00 Total Eff: 0.1859

Volume Aliquot: 1.0100 Chem Recov: 0.8038

Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	265.5	5105.00	1	0.00
2	241.0	5100.00	2	0.00

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Po-210	5105.0	252	273	1	507.0	13.0	500.5	0.70

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-210	5100.0	230	251	2	577.0	1.0	575.5	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT 425-B1 Ver 1.01y
24-Jun-94 11:57:06
ALL (576 A)

Det 31 MCB 2 Seq 15 Analysis Method: ROI, Relative
Slope Recalibration

Sample ID:
Channel File: 44-48 Original Cal: 2807.04 + 8.84 *Chn
Recalibrated: 2807.04 + 8.85 *Chn

Sample Date: 24-Jun-94 Efficiency: 0.2161
Sample Time: 09:55am Background: 81194172
Live Time: 14400.00 Bkg Date: 20-Jun-94 01:24pm
Real Time: 14400.16 Bkg Lv Tm: 86400.00

Volume Total: 1.00 Total Eff: 0.2166
Volume Aliquot: 2.0500 Chem Recov: 1.0946
Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	282.1	5105.00	1	0.00
2	259.0	5100.00	0	0.00

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CFM
1	Po-210	5105.0	259	290	1	278.0	8.0	276.7	1.15

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-208	5100.0	246	267	2	245.0	5.0	244.2	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-B1 Ver 1.01y
24-Jun-94 13:55:47
AL1 (576 A)

Det 24 MGB 2 Seq 8 Analysis Method: ROI, Relative
Slope Recalibration
Sample ID:
Channel File: 54-56 Original Cal: 2897.19 ± 8.85 *Chn
Recalibrated: 2897.19 ± 8.81 *Chn
Sample Date: 24-Jun-94 Efficiency: 0.2538
Sample Time: 09:55am Background: 82494172
Live Time: 14400.00 Bkg Date: 20-Jun-94 01:24pm
Peak Time: 14400.16 Bkg Lv Tm: 86400.00
Volume Total: 1.00 Total Eff: 0.2784
Volume Aliquot: 2.0400 Chem Recov: 1.9972
Tracer DPM: 4.00

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	273.2	5105.00	1 0.00
2	250.0	5100.00	0 0.00

Analytes

Nuclide	ROI	ROI	Peak	Gross	Bkg	Net	CPM
Num Name keV Start End Number Counts Counts Counts							
1 Po-210 5105.0 260 281 1 321.0 18.0 313.0 1.33							

Tracer

Name	ROI	ROI	Peak	Gross	Bkg	Net	FWHM
keV Start End Number Counts Counts Counts							
Tracer Po-203 5111.0 217 258 2 289.0 4.0 287.1							

Analyzed by: _____

Checked by: _____

EO60 CRTEC ALPHAMAT A16-B1 Ver 1.01y
 24-Jun-94 10:56:10
 All 1175 A1

Det 26 MCB 2 Seg 10 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID:
 Channel File: 58-60 Original Cal: 2897.02 - 8.92 *Chn
 Recalibrated: 2897.02 - 8.99 *Chn
 Sample Date: 24-Jun-94 Efficiency: 0.2584
 Sample Time: 09:55am Background: 82694172
 Live Time: 14400.00 Skg Date: 20-Jun-94 01:24pm
 Real Time: 14400.16 Skg LV Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.2941
 Volume Aliquot: 2.0100 Chem Recov: 1.1387
 Tracer DPM: 4.10

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide		
1	267.8	5305.00	1	0.00	
2	245.0	5100.00	0	0.00	

Analytes

Nuclide Num Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Skg Counts	Net Counts	CPM
1 Po-210	5305.0	255	276	1	329.0	16.0	314.0	1.40

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Skg Counts	Net Counts	FWHM
Tracer Po-205	5100.0	232	253	2	324.0	2.0	300.0	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31y
 24-Jun-94 13:56:52
 AL1 (576 A)

Det 29 MCB 2 Seg 13 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID:
 Channel File: 62-64 Original Cal: 2927.51 + 8.91 *Chn
 Recalibrated: 2927.51 + 8.90 *Chn
 Sample Date: 24-Jun-94 Efficiency: 0.2229
 Sample Time: 09:55am Background: B2994172
 Live Time: 14400.00 Bkg Date: 20-Jun-94 01:24pm
 Real Time: 14400.16 Bkg Lv Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.2699
 Volume Aliquot: 2.2300 Chem Recov: 1.2110
 Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide		
1	267.0	5305.00	1	0.00	
2	244.0	5100.00	0	0.00	

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Po-210	5305.0	254	275	1	298.0	14.0	295.7	1.23

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-208	5100.0	231	252	2	280.0	9.0	278.5	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31y
 24-Jun-94 13:55:34
 AL1 (576 A)

Det 23 MCB 2 Seg 7 Analysis Method: ROI, Relative
 Slope Recalibration

Sample ID:
 Channel File: 66-68 Original Cal: 2913.59 + 8.89 *Chn
 Recalibrated: 2913.59 + 8.89 *Chn

Sample Date: 24-Jun-94 Efficiency: 0.2413
 Sample Time: 09:55am Background: 82394172
 Live Time: 14400.00 Bkg Date: 20-Jun-94 01:24pm
 Real Time: 14400.16 Bkg Lv Tm: 86400.00

Volume Total: 1.00 Total Eff: 0.2941
 Volume Aliquot: 2.0400 Chem Recov: 1.2185
 Tracer DPM: 4.30

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide	
1	269.0	5305.00	1	0.00
2	246.0	5100.00	0	0.00

Analytes

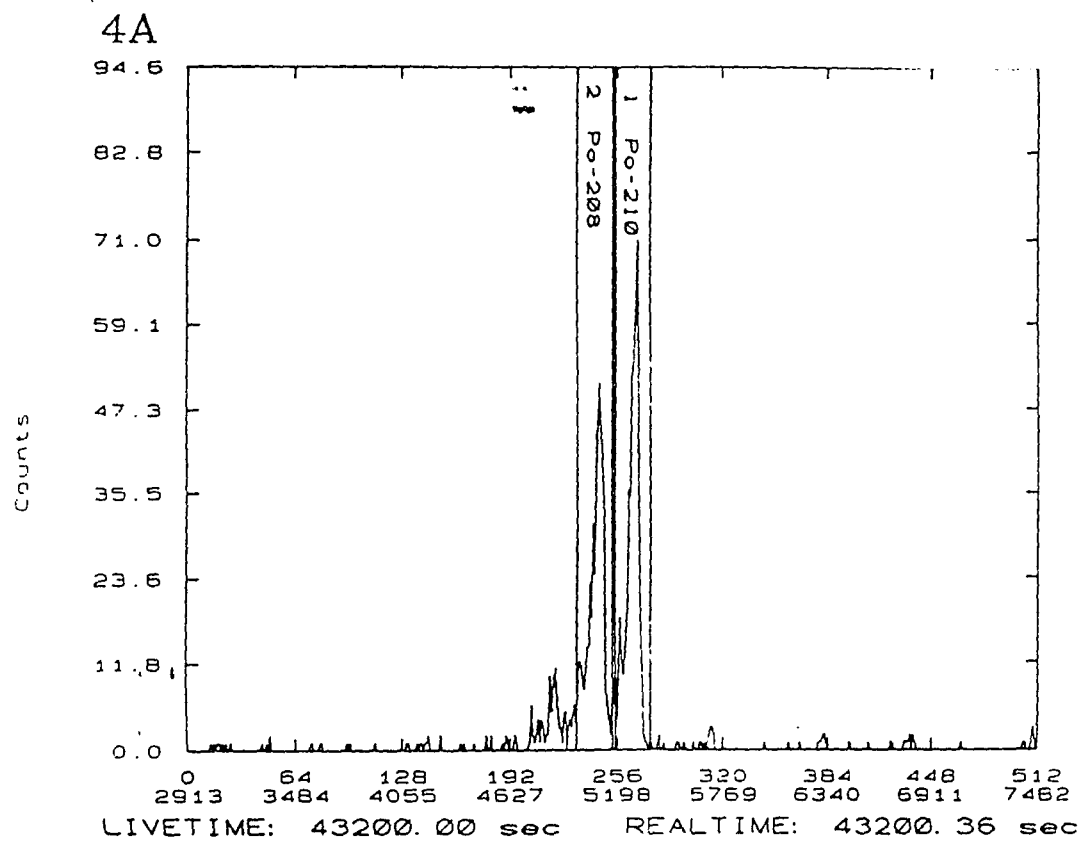
Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Po-210	5305.0	256	277	1	265.0	14.0	262.7	1.09

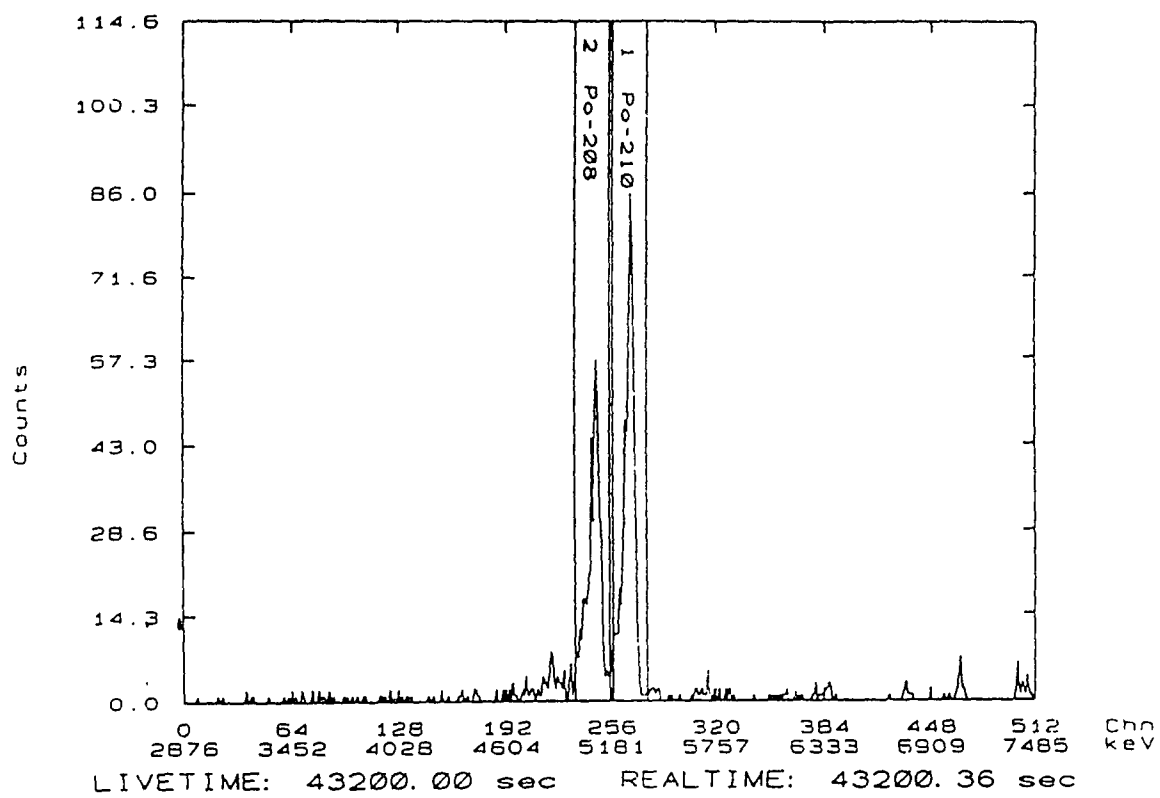
Tracer

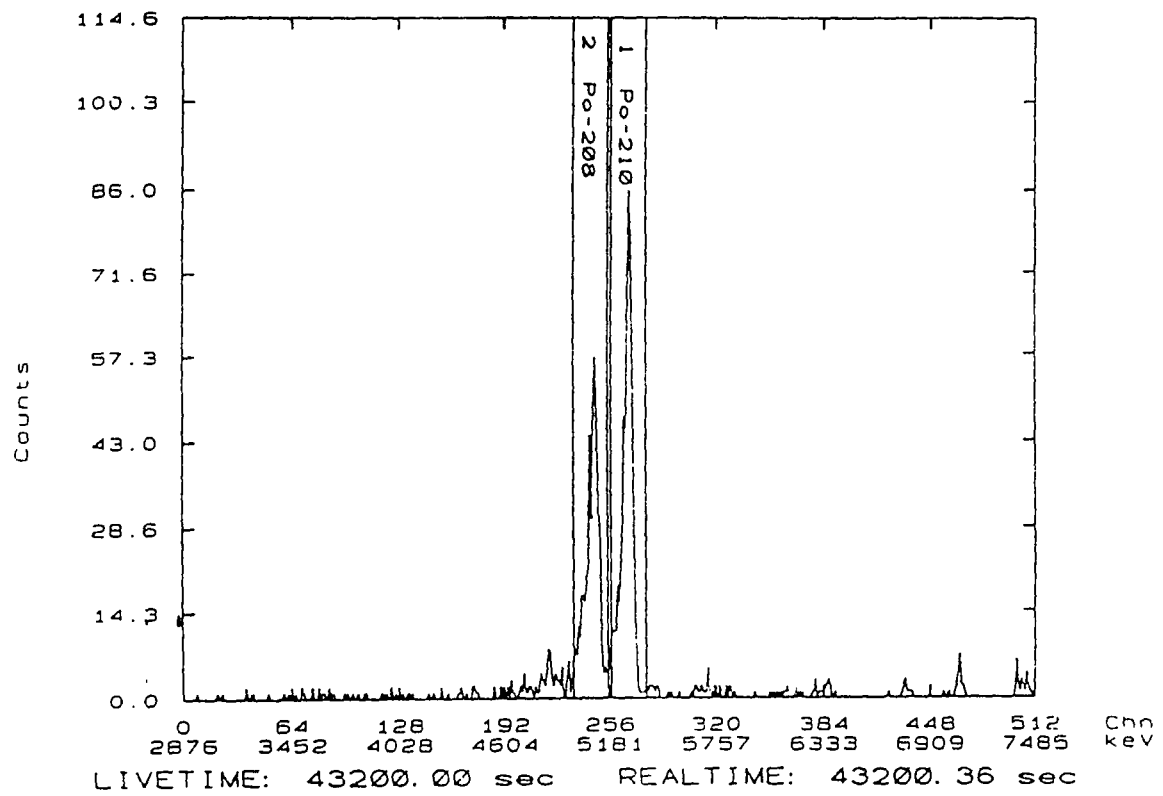
Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Po-208	5100.0	233	254	2	304.0	3.0	303.5	

Analyzed by: _____

Checked by: _____

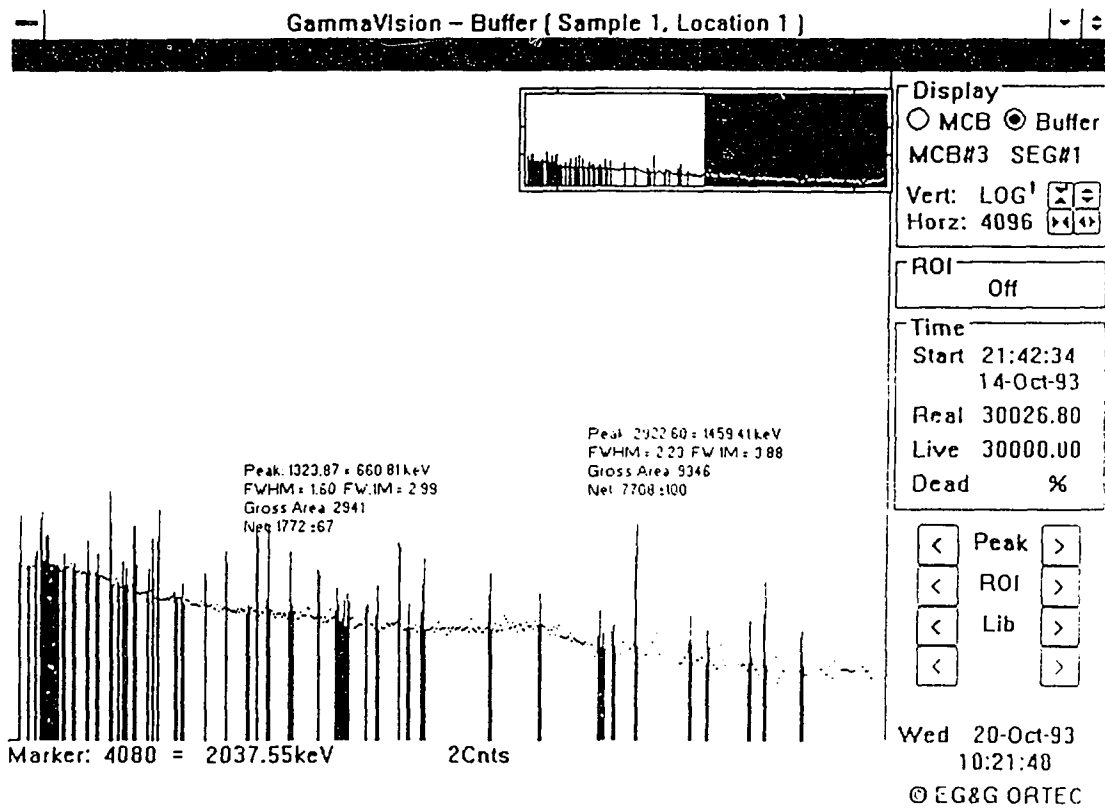


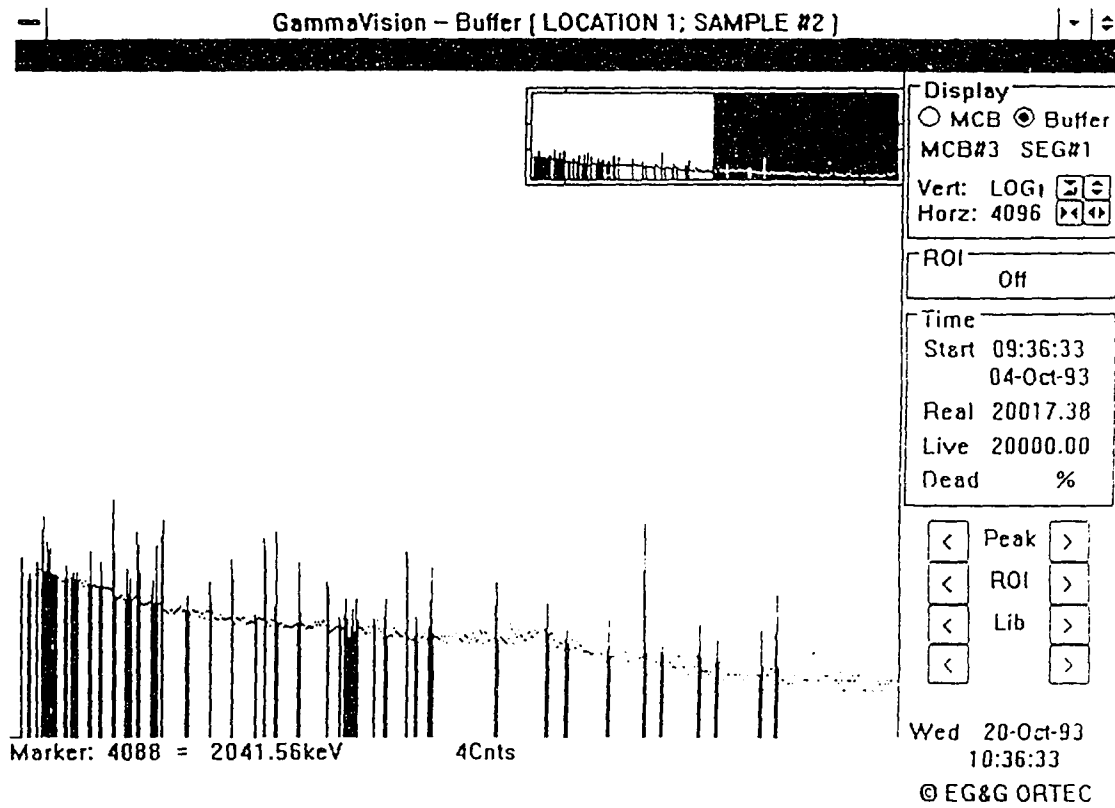


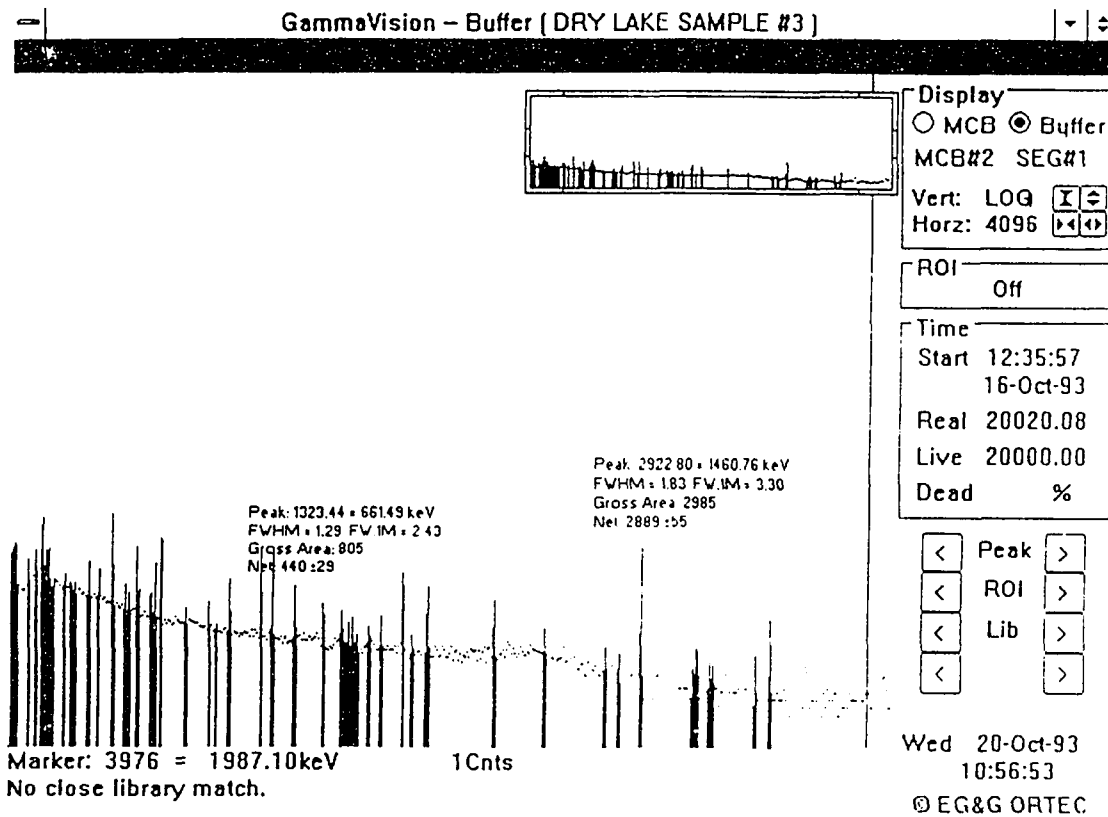


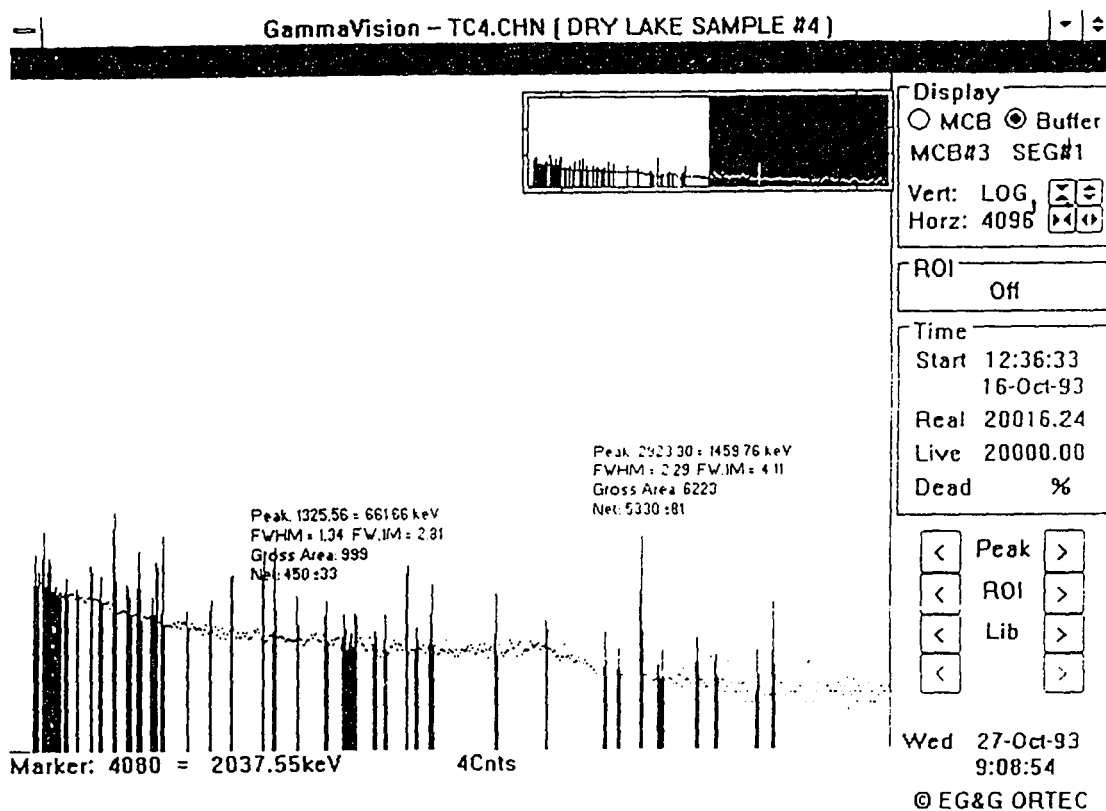
Appendix C

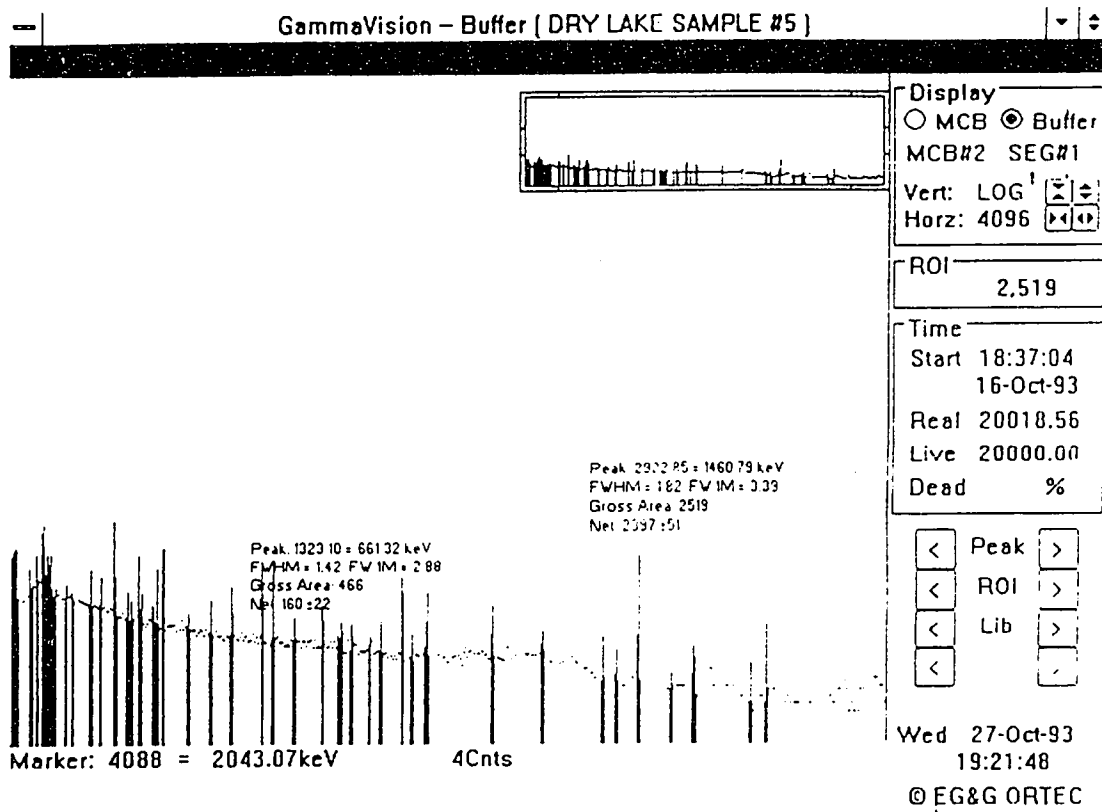
This section includes the spectra from the gamma-ray analysis of the samples from site I.

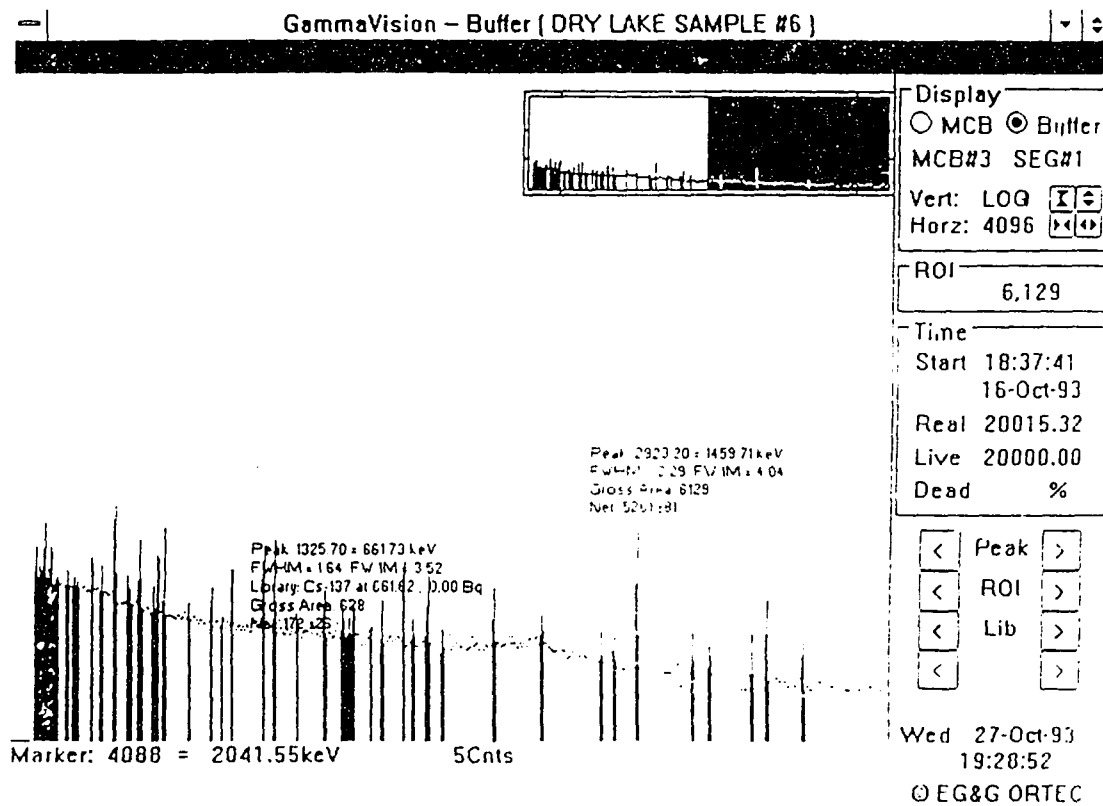


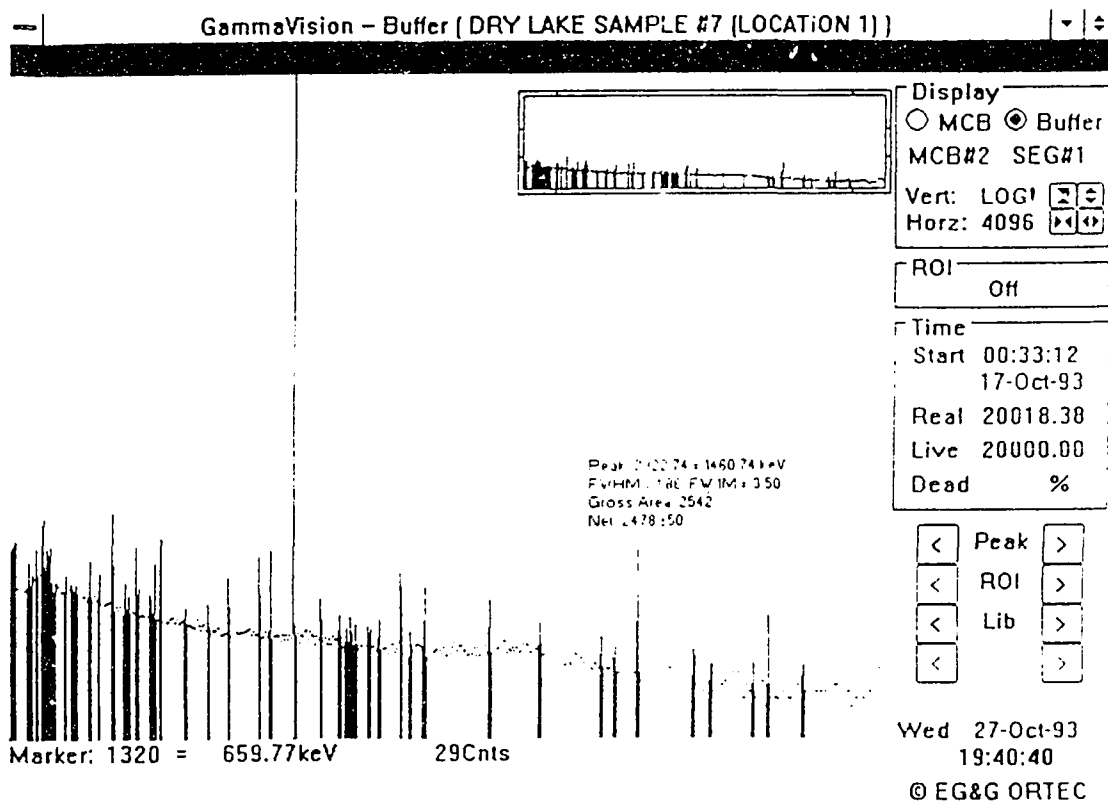


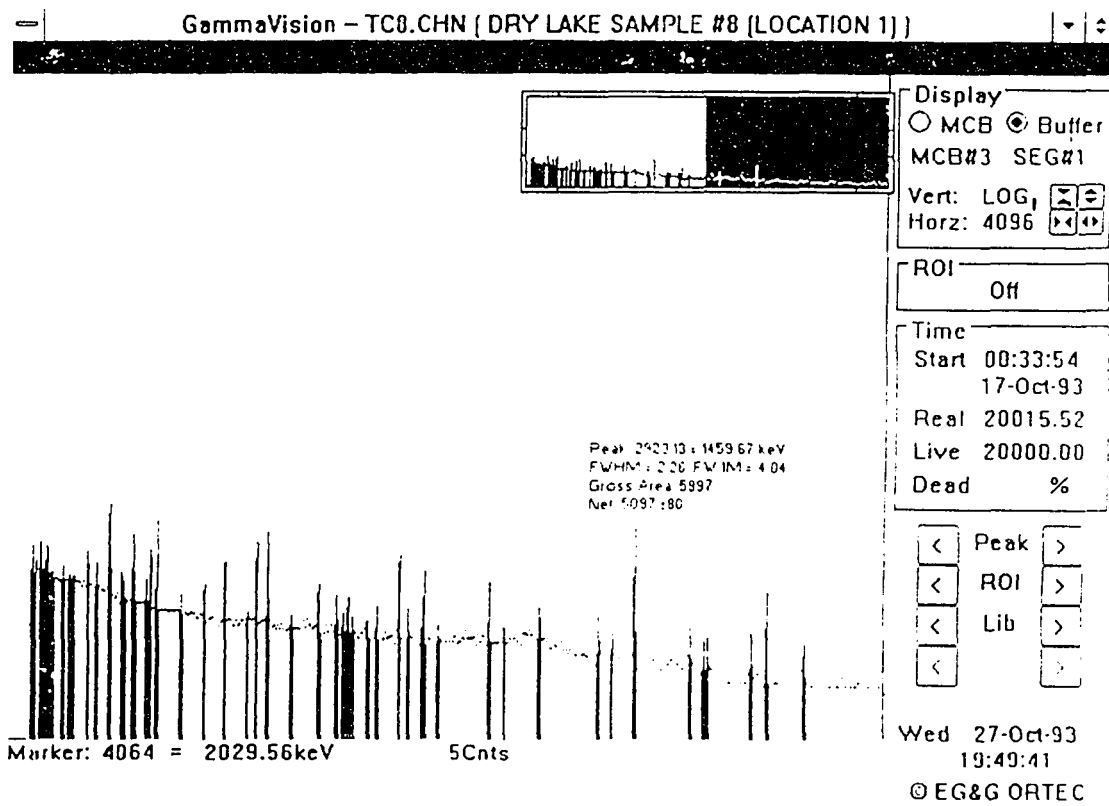


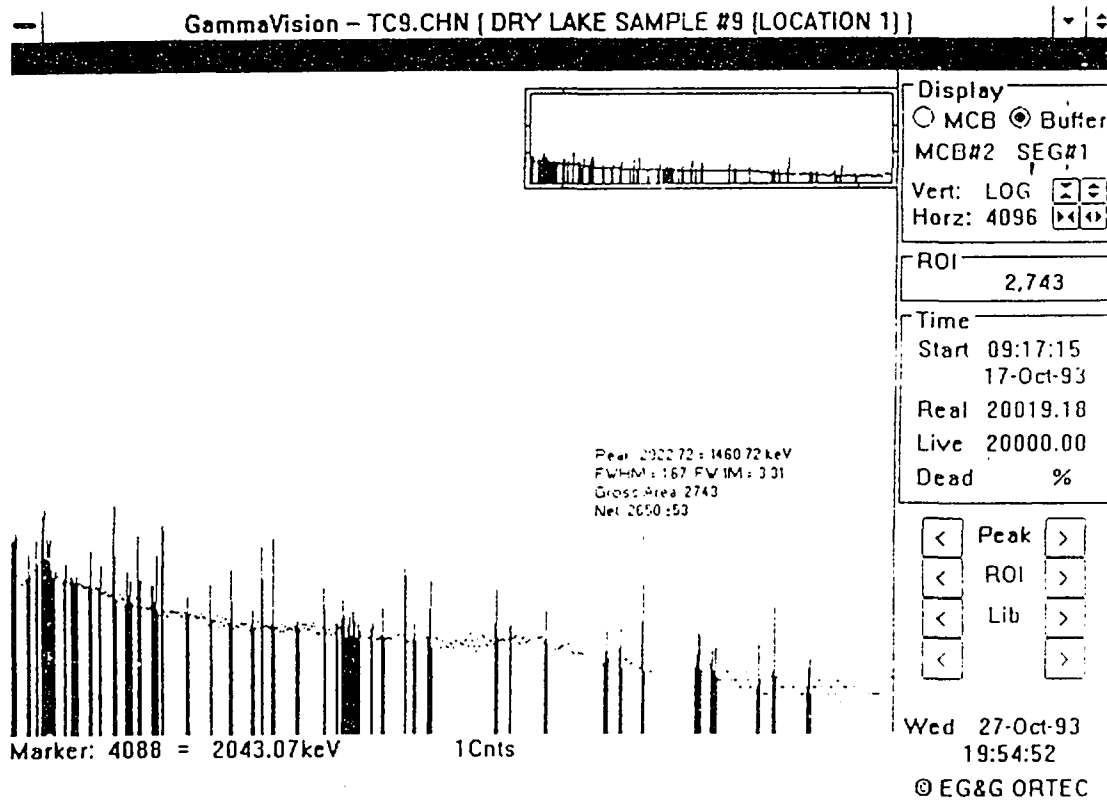


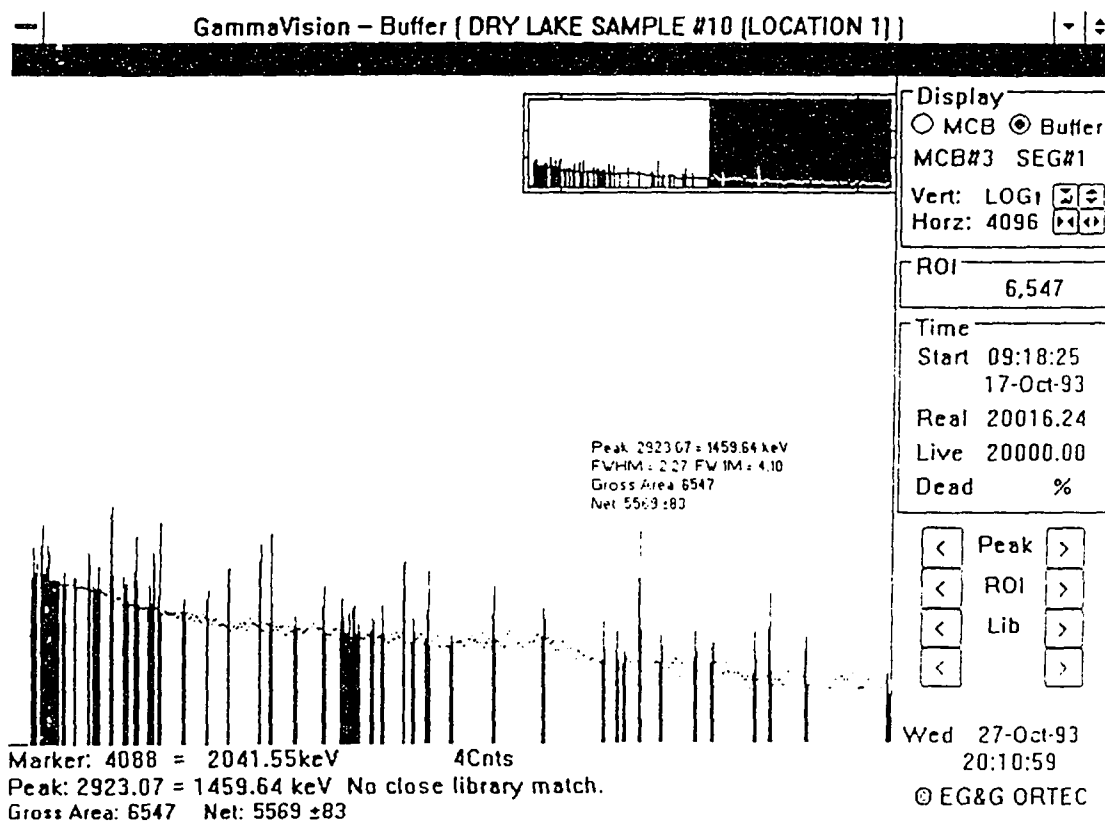




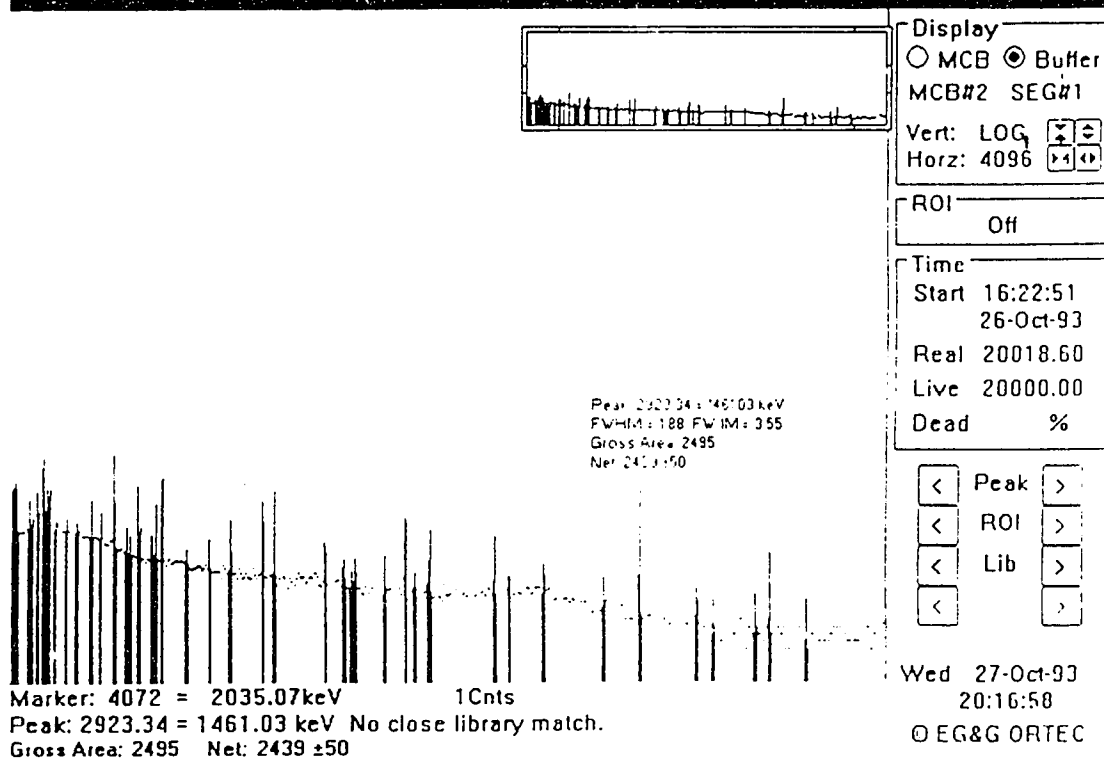








GammaVision - TC12.CHN (DRY LAKE SEDIMENTATION SAMPLE #12, LOCATION 1)



GammaVision - TC13.CHN (DRY LAKE SAMPLE #13, LOCATION 1)



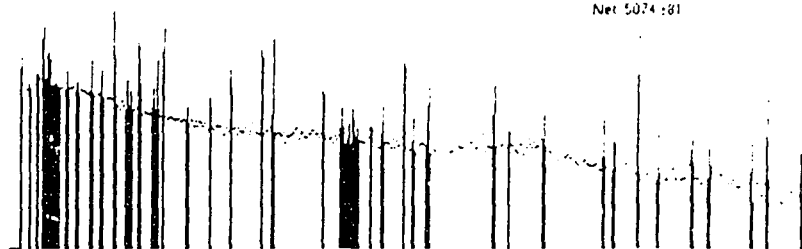
Display
☐ MCB ☒ Buffer
 MCB#3 SEG#1
 Vert: LOG
 Horz: 4096

ROI
 Off

Time
 Start 12:57:04
 26-Oct-93
 Real 20016.80
 Live 20000.00
 Dead %

Peak: 2922.59 = 1459.41 keV
 FWHM: 214 FWHM: 3.85
 Gross Area: 6140
 Net: 5074 ±81

< Peak >
 < ROI >
 < Lib >
 < >



Marker: 4080 = 2037.55 keV 5Cnts
 Peak: 2922.59 = 1459.41 keV No close library match.
 Gross Area: 6140 Net: 5074 ±81

Wed 27-Oct-93
 20:20:46
 © EG&G ORTEC

Appendix D

This section includes the raw data and a sample spectrum from the plutonium-239,240 analysis of the samples from site I.

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31x
 17-Dec-93 17:58:49
 SYSTEM 1 (576 A)

Det 17 MCB 3 Seg 1 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID: # 1
 Channel File: A122WR Original Cal: 3974.92 + 4.79 *Chn
 Recalibrated: 3974.92 + 4.93 *Chn
 Sample Date: 16-Dec-93 Efficiency: 0.2098
 Sample Time: 05:56pm Background: B1793347
 Live Time: 86400.00 "Bkg 10-Dec-93 06:15pm
 Real Time: 86401.36 Bkg Lv Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.1522
 Volume Aliquot: 95.4300 Chem Recov: 0.7254
 Tracer DPM: 5.84

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	309.4	5499.00	1
2	239.6	5155.50	2
3	188.0	4901.00	0

"

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	PU-238	5499.0	276	310	1	78.0	1.0	77.0	0.05
2	Pu-239	5155.5	199	242	2	535.0	6.0	529.0	0.37

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer PU-242	4901.0	148	190	3	1280.0	0.0	1280.0	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31x
 23-Nov-93 20:02:50
 SYSTEM 1 (576 A)

Det 16 MCB 1 Seg 16 Analysis Method: ROI, Relative
 Slope Recalibration

Sample ID: #2
 Channel File: AD8468 Original Cal: 2888.64 + 8.99 *Chn
 Recalibrated: 2888.64 + 9.10 *Chn

Sample Date: 22-Nov-93 Efficiency: 0.2607
 Sample Time: 08:02pm Background: B1693324
 Live Time: 86400.00 "Bkg 19-Nov-93 08:46pm
 Real Time: 86400.64 Bkg Lv Tm: 86400.00

Volume Total: 1.00 Total Eff: 0.1024
 Volume Aliquot: 1.0000 Chem Recov: 0.3928
 Tracer DPM: 5.58

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	286.9	5500.00	1
2	248.4	5150.00	2
3	221.0	4900.00	0

"

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Pu-238	5500.0	270	291	1	40.0	16.0	<u>24.0</u>	0.02
2	Pu-239	5150.0	225	252	2	280.0	5.0	<u>275.</u>	0.19

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Pu-242	4900.0	195	224	3	827.0	4.0	<u>823.0</u>	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31x
 17-Dec-93 19:18:03
 SYSTEM 1 (576 A)

Det 23 MCB 3 Seg 7 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID: # 3
 Channel File: A122WW Original Cal: 3973.22 + 4.79 *Chn
 Recalibrated: 3973.22 + 4.83 *Chn
 Sample Date: 16-Dec-93 Efficiency: 0.2186
 Sample Time: 05:56pm Background: B2393347
 Live Time: 86400.00 "Bkg 10-Dec-93 06:15pm
 Real Time: 86401.36 Bkg Lv Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.1616
 Volume Aliquot: 69.6700 Chem Recov: 0.7391
 Tracer DPM: 5.84

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	315.7	5499.00	1
2	244.6	5155.50	2
3	192.0	4901.00	0

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	PU-238	5499.0	288	323	1	31.0	5.0	26.0	0.02
2	Pu-239	5155.5	208	252	2	341.0	2.0	339.0	0.24

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer PU-242	4901.0	155	198	3	1360.0	1.0	1359.0	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31x
 17-Dec-93 17:56:19
 SYSTEM 1 (576 A)

Det 26 MCB 4 Seg 2 Analysis Method: ROI, Relative
 Slope Recalibration

Sample ID: # 4
 Channel File: A122X0 Original Cal: 3996.36 + 4.79 *Chn
 Recalibrated: 3996.36 + 4.89 *Chn

Sample Date: 16-Dec-93 Efficiency: 0.2149
 Sample Time: 05:56pm Background: B2693347
 Live Time: 86400.00 "Bkg 10-Dec-93 06:15pm
 Real Time: 86400.62 Bkg Lv Tm: 86400.00

Volume Total: 1.00 Total Eff: 0.1489
 Volume Aliquot: 66.01 Chem Recov: 0.6928
 Tracer DPM: 5.84

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	307.2	5499.00	1
2	237.0	5155.50	2
3	185.0	4901.00	0

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	PU-238	5499.0	276	310	1	34.0	2.0	32.0	0.02
2	Pu-239	5155.5	197	242	2	186.0	0.0	186.0	0.13

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer PU-242	4901.0	147	189	3	1255.0	3.0	1252.0	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31x
 17-Dec-93 17:56:29
 SYSTEM 1 (576 A)

Det 27 MCB 4 Seg 3 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID: # 5
 Channel File: A122X4 Original Cal: 4014.94 + 4.85 *Chn
 Recalibrated: 4014.94 + 5.01 *Chn
 Sample Date: 16-Dec-93 Efficiency: 0.2240
 Sample Time: 05:56pm Background: B2793347
 Live Time: 86400.00 "Bkg 10-Dec-93 06:15pm
 Real Time: 86400.62 Bkg Lv Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.1274
 Volume Aliquot: 82.0000 Chem Recov: 0.5686
 Tracer DPM: 5.84

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	296.4	5499.00	1
2	227.8	5155.50	2
3	177.0	4901.00	0

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	PU-238	5499.0	262	296	1	62.0	2.0	60.0	0.04
2	Pu-239	5155.5	187	230	2	162.0	0.0	162.0	0.11

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer PU-242	4901.0	137	179	3	1072.0	1.0	1071.0	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.31x
 17-Dec-93 17:56:09
 SYSTEM 1 (576 A)

Det 25 MCB 4 Seg 1 Analysis Method: ROI, Relative
 Slope Recalibration

Sample ID: # 6
 Channel File: A122X8 Original Cal: 4006.00 + 4.83 *Chn
 Recalibrated: 4006.00 + 4.84 *Chn

Sample Date: 16-Dec-93 Efficiency: 0.2209
 Sample Time: 05:56pm Background: B2593347
 Live Time: 86400.00 "Bkg 10-Dec-93 06:15pm
 Real Time: 86400.62 Bkg Lv Tm: 86400.00

Volume Total: 1.00 Total Eff: 0.0805
 Volume Aliquot: 76.9000 Chem Recov: 0.3645
 Tracer DPM: 5.84

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	308.6	5499.00	1
2	237.6	5155.50	2
3	185.0	4901.00	0

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	PU-238	5499.0	283	318	1	7.0	4.0	3.0	0.00
2	Pu-239	5155.5	202	247	2	60.0	0.0	60.0	0.04

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer PU-242	4901.0	149	192	3	686.0	9.0	677.0	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.30
 11-Nov-93 03:58:22
 SYSTEM 1 (576 A)

Det	4	MCB	1	Seg	4	Analysis Method:	ROI, Relative Slope Recalibration
Sample ID:				#8			
Channel File:				AD8033		Original Cal: 2815.96 + 9.06 *Chn	
						Recalibrated: 2815.96 + 9.10 *Chn	
Sample Date:				10-Nov-93		Efficiency: 0.2513	
Sample Time:				07:58pm		Background: B0493310	
Live Time:				28800.00		Bkg Date: 05-Nov-93 05:41pm	
Real Time:				28800.48		Bkg Lv Tm: 86400.00	
Volume Total:				1.00		Total Eff: 0.1949	
Volume Aliquot:				1.0000		Chem Recov: 0.7758	
Tracer DPM:				89.32			

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	294.9	5500.00	1
2	256.4	5150.00	2
3	229.0	4900.00	0

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Pu-238	5500.0	282	303	1	7.0	16.0	1.7	0.00
2	Pu-239	5150.0	236	264	2	13.0	4.0	11.7	0.02

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Pu-242	4900.0	206	235	3	8359.	3.0	8358.	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.30
 11-Nov-93 03:58:42
 SYSTEM 1 (576 A)

Det	5	MCB	1	Seg	5	Analysis Method:	ROI, Relative Slope Recalibration
Sample ID:				#10			
Channel File:				AD8034		Original Cal: 2821.59 + 9.08 *Chn	
						Recalibrated: 2821.59 + 9.20 *Chn	
Sample Date:				10-Nov-93		Efficiency: 0.2490	
Sample Time:				07:58pm		Background: B0593310	
Live Time:				28800.00		Bkg Date: 05-Nov-93 05:41pm	
Real Time:				28800.48		Bkg Lv Tm: 86400.00	
Volume Total:				1.00		Total Eff: 0.1074	
Volume Aliquot:				1.0000		Chem Recov: 0.4313	
Tracer DPM:				89.32			

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	291.2	5500.00	1
2	253.1	5150.00	2
3	226.0	4900.00	0

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Pu-238	5500.0	278	299	1	12.0	35.0	0.3	0.00
2	Pu-239	5150.0	233	261	2	5.0	6.0	3.0	0.01

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Pu-242	4900.0	203	232	3	4606.	6.0	4604.	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.30
 11-Nov-93 03:58:57
 SYSTEM 1 (576 A)

Det 6 MCB 1 Seg 6 Analysis Method: ROI, Relative
 Slope Recalibration

Sample ID: #12
 Channel File: AD8035 Original Cal: 2804.07 + 9.30 *Chn
 Recalibrated: 2804.07 + 9.44 *Chn

Sample Date: 10-Nov-93 Efficiency: 0.2543
 Sample Time: 07:58pm Background: B0693310
 Live Time: 28800.00 Bkg Date: 05-Nov-93 05:41pm
 Real Time: 28800.46 Bkg Lv Tm: 86400.00

Volume Total: 1.00 Total Eff: 0.0229
 Volume Aliquot: 1.0000 Chem Recov: 0.0900
 Tracer DPM: 89.32

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	285.5	5500.00	1
2	248.4	5150.00	2
3	222.0	4900.00	0

Analytes

Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Pu-238	5500.0	273	294	1	12.0	20.0	5.3	0.01
2	Pu-239	5150.0	228	256	2	7.0	9.0	4.0	0.01

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Pu-242	4900.0	199	228	3	984.0	9.0	981.0	

Analyzed by: _____

Checked by: _____

EG&G ORTEC ALPHAMAT A26-BI Ver 1.30
 11-Nov-93 03:59:08
 SYSTEM 1 (576 A)

Det 7 MCB 1 Seg 7 Analysis Method: ROI, Relative
 Slope Recalibration
 Sample ID: #13
 Channel File: AD8036 Original Cal: 2809.84 + 8.76 *Chn
 Recalibrated: 2809.84 + 8.82 *Chn
 Sample Date: 10-Nov-93 Efficiency: 0.2116
 Sample Time: 07:58pm Background: B0793310
 Live Time: 28800.00 Bkg Date: 05-Nov-93 05:41pm
 Real Time: 28800.48 Bkg Lv Tm: 86400.00
 Volume Total: 1.00 Total Eff: 0.1127
 Volume Aliquot: 1.0000 Chem Recov: 0.5327
 Tracer DPM: 89.32

Peak Analysis Results

Peak Number	Final Channel	Final Energy	Nuclide
1	305.0	5500.00	1
2	265.3	5150.00	2
3	237.0	4900.00	0

Analytes

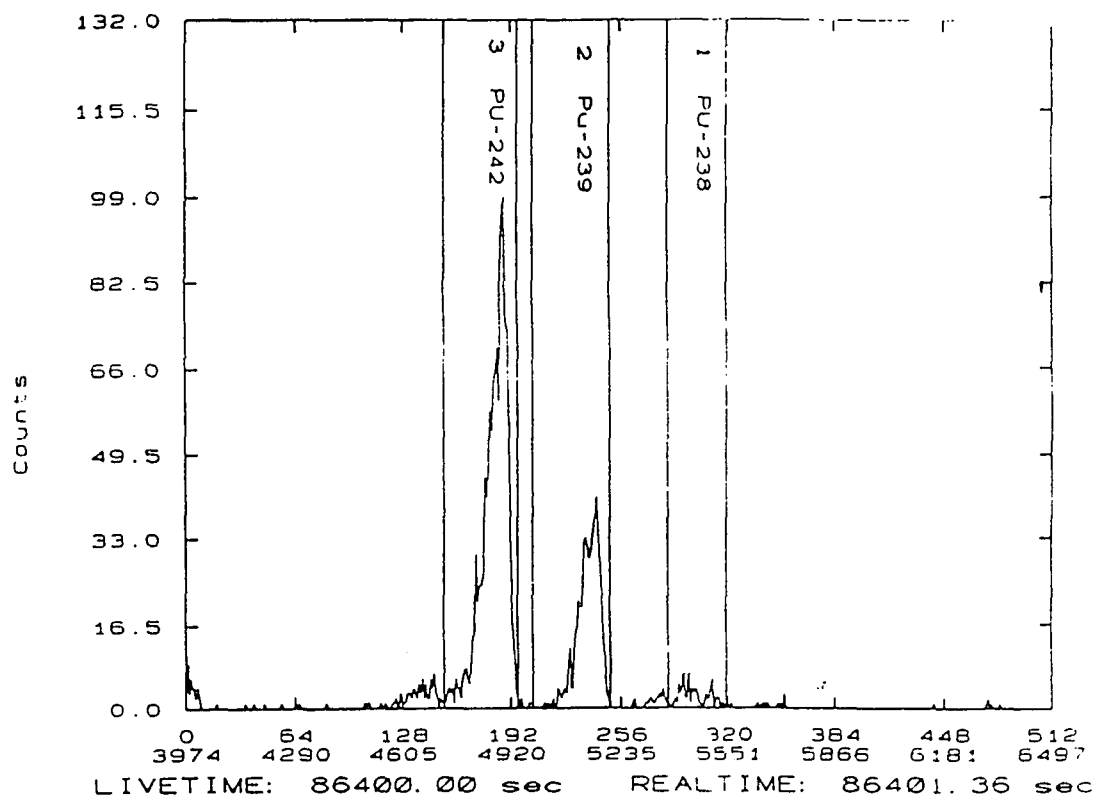
Nuclide Num	Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	CPM
1	Pu-238	5500.0	292	313	1	8.0	11.0	4.3	0.01
2	Pu-239	5150.0	245	273	2	7.0	5.0	5.3	0.01

Tracer

Name	keV	ROI Start	ROI End	Peak Number	Gross Counts	Bkg Counts	Net Counts	FWHM
Tracer Pu-242	4900.0	214	243	3	4832.	0.0	4832.	

Analyzed by: _____

Checked by: _____



Appendix E

This section includes the raw data from the total strontium and strontium-90 analysis of the samples from site I.

LOCKHEED ANALYTICAL LABORATORY
 SAMPLE PREPARATION LOG FOR STRONTIUM ANALYSIS
 TOTAL STRONTIUM - LAL-91-SOP-0065T

WORK ORDER : N/A
 CUST GROUP : N/A
 LAL PREP NO : MIKE_65

DATE ASSIGNED : N/A
 DATE DUE : N/A
 ASSIGNED ANALYST : M. TABRIZ

PARENT LAL ID	NO	QC	CHILD LAL ID	ALLOQUOT VOLUME (L)	SR CARRIER (mL)	BA CARRIER (mL)	YTTRIUM SEP DATE	YTTRIUM SEP TIME	PLANCHET TARE WT (grams)	PLANCHET GROSS WT (grams)	STRONTIUM WEIGHT (grams)
#1	1		MIKE1	4.21	2.0	2.0	02/27/94	13:10	9.4629	9.5020	0.0391
#5	2		MIKE2	4.22	2.0	2.0	02/27/94	13:10	9.1977	9.2241	0.0264
#4	3		MIKE4	4.87	2.0	2.0	02/27/94	13:10	9.4243	9.4414	0.0171
#2	4		MIKE5	4.43	2.0	2.0	02/27/94	13:10	9.2151	9.2343	0.0192
#3	5		MIKE6	4.43	2.0	2.0	02/27/94	13:10	9.4178	9.4618	0.0440
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
	14										
	15										
	16										

Note - *** indicates the sample weight falls outside the absorption curve.

Comments SR-CARRIER CALIBRATION VALUE: 0.043 G/2 ML.

preservation () balance cal () reagents () pipets cal () separation time () data entry ()

Date Completed :
 Analyst's Signature : _____

Supervisor's Signature : _____

LOCKHEED ANALYTICAL LABORATORY

COUNT DATA FOR STRONTIUM ANALYSIS

TOTAL STRONTIUM - LAL-91-SOP-0065T

LAL PREP NO : MIKE_65

[illegible]

COMMENTS: _____

```
inst run log ( )      inst maint log ( )      calibration ( )      inst check ( )      inst bkg ( )      rgt blink ( )
LCS ( )      replicates ( )      calcs ( )
```

Date Completed : _____
Analyst's Signature : _____

Supervisor's Signature : _____

LOCKHEED ANALYTICAL LABORATORY
SAMPLE PREPARATION LOG FOR STRONTIUM ANALYSIS
STRONTIUM BY YTTRIUM - LAL-91-SOP-0065Y

WORK ORDER : 976-21210
 CUST GROUP : N/A
 LAL PREP NO : MIKE.SR

DATE ASSIGNED :
 DATE DUE :
 ASSIGNED ANALYST :

PARENT LAL ID	NO	QC	CHILD LAL ID	YTTRIUM CARRIER (mL)	YTTRIUM PRECIP DATE	YTTRIUM PRECIP TIME	FILTER TARE WT (grams)	FILTER GROSS WT (grams)	YTTRIUM WEIGHT (grams)	Sr-85 Tracer Counts
#1	1		MIKE1	2.0	05/16/94	09:20	9.01	9.0773	0.0673	784
#2	2		MIKE2	2.0	05/16/94	09:20	9.4066	9.4689	0.0623	837
#3	3		MIKE3	2.0	05/16/94	09:20	9.5241	9.5856	0.0615	1021
#4	4		MIKE4	2.0	05/16/94	09:20	8.9044	8.967	0.0626	655
#5	5		MIKE5	2.0	05/16/94	09:20	8.6356	8.6968	0.0612	1027
#6	6		MIKE6	2.0	05/16/94	09:20	8.9633	9.023	0.0597	957
	7									
	8									
	9									
	10									
	11									
	12									
	13									
	14									
	15									
	16									

Note: *** Indicates the sample weight falls outside the absorption curve.

Sr-85 STD = 1531
 BKG = 162

Comments: Yttrium carrier is 91-606-201-46, .067 mg for 2 mL.

Date Completed :

Analyst's Signature :

Supervisor's Signature :

LOCKHEED ANALYTICAL LABORATORY
SAMPLE PREPARATION LOG FOR STRONTIUM ANALYSIS
STRONTIUM BY-YTTRIUM - LAL-91-SOP-0065Y

WORK ORDER : N/A
CUST GROUP : N/A
LAL PREP NO : MIKE.SR

DATE ASSIGNED : N/A
DATE DUE : N/A
ASSIGNED ANALYST : M. TABRIZ

PARENT LAL ID	NO	QC	CHILD LAL ID	ALLOUT VOLUME mL	SR CAPPER (mL)	BA CAPPER (mL)	YTTRIUM SEP DATE	YTTRIUM SEP TIME	PLANCHET TARE WT (grams)	PLANCHET GROSS WT (grams)	STRONTIUM WEIGHT (grams)
#1	1		MIKE1	92.97	10.0	N/A	05/03/94	12:00	N/A	N/A	N/A
#2	2		MIKE2	82.95	10.0	N/A	05/03/94	12:00	N/A	N/A	N/A
#3	3		MIKE3	92.45	10.0	N/A	05/03/94	12:00	N/A	N/A	N/A
#4	4		MIKE4	172.8	10.0	N/A	05/03/94	12:00	N/A	N/A	N/A
#5	5		MIKE5	129	10.0	N/A	05/03/94	12:00	N/A	N/A	N/A
#6	6		MIKE6	149.33	10.0	N/A	05/03/94	12:00	N/A	N/A	N/A
	7										
	8										
	9										
	10										
	11										
	12										
	13										
	14										
	15										
	16										

Comments : Sr-85 Tracer: 1 mL of 93-474-64-1, 4930 dpm/mL on 3/18/94

Date Completed : _____
Analyst's Signature : _____

Supervisor's Signature : _____

LOCKHEED ANALYTICAL LABORATORY
 SAMPLE PREPARATION LOG FOR STRONTIUM ANALYSIS
 STRONTIUM BY YTTRIUM - LAL-91-SOP-0065Y

WORK ORDER : 976-21210
 CUST GROUP : N/A
 LAL PREP NO : 065_mike

DATE ASSIGNED :
 DATE DUE :
 ASSIGNED ANALYST : mike

PARENT LAL ID	NO	QC	CHILD LAL ID	ALLOQUOT VOLUME (L)	SR CARRIER (mL)	BA CARRIER (mL)	YTTRIUM SEP DATE	YTTRIUM SEP TIME	PLANCHET TARE WT (grams)	PLANCHET GROSS WT (grams)	STONTIUM WEIGHT (grams)
14-15	1		14-15	100.600	10.0		06/16/94	18:00	N/A	N/A	N/A
16-17	2		16-17	100.900	10.0		06/16/94	18:00	N/A	N/A	N/A
20-21	3		20-21	100.510	10.0		06/16/94	18:00	N/A	N/A	N/A
8-9	4		8-9	100.120	10.0		06/16/94	18:00	N/A	N/A	N/A
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
	14										
	15										
	16										

Comments : Sr-85 Tracer: 1 mL of 93-474-64-1, 4930 dpm/mL on 3/18/94
 Sr-90 LCS: 1 mL of 93-474-30-1, 28.74 pCi/mL on 8/01/90

Date Completed :
 Analyst's Signature : _____

Supervisor's Signature : _____

LOCKHEED ANALYTICAL LABORATORY
 SAMPLE PREPARATION LOG FOR STRONTIUM ANALYSIS
 STRONTIUM BY YTTRIUM - LAL-91-SOP-0065Y

WORK ORDER : 976-21210
 CUST GROUP : N/A
 LAL PREP NO : 065_mike

DATE ASSIGNED : _____
 DATE DUE : _____
 ASSIGNED ANALYST : _____

PARENT LAL ID	NO	QC	CHILD LAL ID	YTTRIUM CARRIER (mL)	YTTRIUM PRECIP DATE	YTTRIUM PRECIP TIME	FILTER TARE WT (grams)	FILTER GROSS WT (grams)	YTTRIUM WEIGHT (grams)	Sr-85 Tracer Counts
14-15	1		14-15	2.0	06/24/94	16:15	9.7156	9.78	0.0644	800
16-17	2		16-17	2.0	06/24/94	16:15	9.5823	9.6451	0.0628	721
20-21	3		20-21	2.0	06/24/94	16:15	9.6562	9.7206	0.0644	801
8-9	4		8-9	2.0	06/24/94	16:15	9.7327	9.7968	0.0641	773
	5									
	6									
	7									
	8									
	9									
	10									
	11									
	12									
	13									
	14									
	15									
	16									

Note - *** indicates the sample weight falls outside the absorption curve.

Sr-85 STD = 1068
 BKG = 118

Comments: Yttrium carrier calibration value: 0.064 g/2 mL.

Date Completed : _____

Analyst's Signature : _____

Supervisor's Signature : _____

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