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AEROSOL TRACE ELEMENT ANALYSIS USING
NEUTRON ACTIVATION AND X-RAY FLUORESCENCE

Nicholas J. Roberts

February 8, 1974

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Nicholas J. Roberts
(M.S. Thesis)^{*}

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^{*}California State University, Hayward, California.

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ABSTRACT

Throughout the year 1972, air filter samples were collected at Kellogg, Idaho, in the Coeur d'Alene mining district. These samples were analyzed to determine the concentrations of trace metallic elements in the air and to look for indications of their sources - for example, which ones are in the air as a result of the mining and smelting operations, and which are there "naturally" through being picked up by winds from the soil surface. The experimental procedures and results are given here.

The samples were analyzed for 34 elements with instrumental neutron activation analysis, and for six elements with x-ray fluorescence analysis. The enrichment of the element concentrations relative to their worldwide average concentrations in the earth's crustal rock is tabulated and discussed. Yearly average enrichment factors ranging from 0.845 to 901,000 were observed, and individual enrichment factors as high as 6,000,000 were noted. The elements observed are divided into three main groups according to their enrichment factors: those with low enrichment factors (<100), which are considered to be derived primarily from the soil; those with an intermediate enrichment factor (100 to 1000), which are considered to be of uncertain origin (soil and/or mining and smelting); and those with a high enrichment factor (>1000), which are considered to be clearly of mining/smelting origin.

Chapter 1

INTRODUCTION

Over the past several years the importance of the preservation of our natural environment has gained new meaning and significance to most Americans. One aspect of this new awareness and concern has been the emphasis on air pollution. In order to understand the significance of air pollution it is essential that we understand what the contaminants are and to what degree they are present in the air. To this end much work has been and is being done on the characterization of the constituents of aerosols. This report is concerned with only one aspect of the characterization problem, identification of trace metallic elements on air filters.

This study demonstrates that through the use of instrumental neutron activation analysis and x-ray fluorescence analysis it is possible to identify as many as 36 elements. The two techniques are discussed in detail in Chapter 2. The study also shows that it is possible to identify the source of some of the elements by applying a straightforward data reduction technique, based on the use of enrichment factors.

In the latter part of 1971 Dr. R. Ragaini of Lawrence Livermore Laboratory (LLL) made an agreement with the Department of Environmental and Community Services of

the State of Idaho to attempt to characterize the aerosol trace elements from air filter samples collected at Kellogg, Idaho. This report covers the initial work performed to identify as many trace metals as reasonably possible and to identify the sources if possible.

Throughout 1972, the State of Idaho collected air filter samples on the roof of the Kellogg City Hall. The samples were gathered for 24-hr intervals using a high-volume air sampler equipped with a recording flowmeter. The airflow through the sampler was about 1360 m^3 (cubic meters) per day. The filtering medium for all of the samples was Whatman #4 filter paper, and the observed loading ranged from 60 to $250 \text{ } \mu\text{g}/\text{m}^3$ (micrograms per cubic meter).

Kellogg is located in the Coeur d'Alene valley of northern Idaho, 75 miles east of Spokane, Washington, and 140 miles west of Missoula, Montana. The valley is very narrow and the mountains rise to an elevation of 6300 ft, with the floor of the valley at about 2000 ft above sea level. The primary industries in the valley are lumbering and mining, with mining being by far the more important one. The main products of the mining industry in the valley are lead, zinc, silver, gold, cadmium, antimony, and sulfuric and phosphoric acid. About one-half of our national output of silver and a significant portion of our lead and zinc are produced in the Coeur d'Alene valley.

Chapter 2

TRACE ELEMENT ANALYSIS

Trace element analyses of various types have long been employed as techniques for determining the elemental concentrations of the various constituents of a given sample. Until recently the practice of trace element analysis was limited to the investigation of those elements for which sensitivities of parts per million were considered adequate since tens of parts per million represented areas of interest. But with the intense interest in environmental trace element effects in recent years, it has become increasingly important to look at elemental concentrations as low as tenths of a part per million or even parts per billion. There are a number of techniques with this sensitivity presently employed for performing trace element analysis: e.g., atomic absorption, mass spectrometry, electron emission spectroscopy, x-ray fluorescence, neutron activation, charged particle activation, anodic stripping, and polarography. The combination of several of these techniques usually produces a more complete scan of the elements present in a sample than any one of the techniques is capable of by itself.

The principles of trace element analysis have been applied to the analysis of a single element in a simple matrix, to the identification of every element possible in

a sample, and to nearly all points in between. The present study was limited to the investigation of trace elements using instrumental neutron activation analysis (INAA) and x-ray fluorescence analysis (XRFA). The basic principles of each of these techniques, their relative sensitivities, and their advantages and disadvantages are discussed briefly below. The experimental technique used and the systems employed in this study are also discussed.

INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS (INAA)

This technique has been used for several years for trace element identification. Tuttle et al.¹ give a brief history of the beginning of the use of this technique. Several good books and review articles have been written to discuss the basic principles of INAA.²⁻⁴ Since its inception INAA has become increasingly more important as a tool for doing trace element analysis due to progressive improvements in its sensitivity. This improved sensitivity has been made possible by the use of high-resolution solid-state radiation detectors, improved data-reduction techniques and schemes, and increased experience in sample preparation and collection methods.

One of the primary advantages of INAA is that it is usually a nondestructive analytical technique; also, it provides the ability to look at isotopic concentrations as well

as elemental concentrations for some isotopes if required for the specific analysis.

Although INAA is primarily a nondestructive technique, in some applications it is best applied to an analysis in conjunction with some chemistry performed either before or after the irradiation. An example of this occurs when one is analyzing a sample where the trace element being sought has a short half-life and is in a matrix that contains a large amount of sodium which produces radiosodium with a half-life of 15 hr. The strong radiosodium spectrum can make the identification of small amounts of some other elements impossible. Ralston and Sato⁵ perfected a technique for selectively removing the sodium from irradiated samples such as soil and rock samples. Numerous other specific techniques have been developed for particular applications.

Although this study deals with the application of INAA to the identification of trace elements on air filters, it should be pointed out that many other uses for the technique exist in wide-ranging applications. Some of these applications are the identification and classification of archaeological artifacts,⁶ medical diagnostics,⁷ and of course the identification of air pollution particulates.⁸⁻¹¹

Most INAA today is done using thermal neutrons. To be as useful as possible, the INAA technique requires a high thermal neutron flux of the type usually found only in a nuclear reactor. Neutron fluxes of 10^{12} to 10^{14} n/cm²-sec

(neutrons per square centimeter per second) can be easily obtained at most reactor facilities, with fluxes of 10^{16} n/cm²-sec obtainable at some of the pulsed research reactor facilities.² However, pulsed reactor fluxes are useful only when looking at elements with induced activity having half-lives on the order of tenths of seconds, which complicates both the experimental procedure and the data reduction techniques. Recently some INAA has been performed using ²⁵²Cf sources,¹² and with fast neutrons having energies up to 14 MeV.¹³

Basic Principles

The procedure used for INAA is to take a sample, expose it to a neutron flux, measure the induced activity as a function of energy, and evaluate the data to quantify the elements present in the original sample. Each of these relatively simple-sounding steps has its own individual problems and each must be performed with extreme diligence and care to insure reliable results.

When a sample is placed in a neutron flux, the analysis of the results is straightforward if just one element or isotope is present. However, in most, if not all, cases there are competing activities to be considered. The amount of activity induced in the sample can be shown to be²

$$N_1(t) = m_1 N_0 \sigma_1 \phi A_1^{-1} [1 - \exp(-\lambda_1 T)] \exp(-\lambda_1 t), \quad (1)$$

where

$N_1(t)$ = decay rate of the i th isotope at a time t
following the end of the irradiation (disintegrations per second),

m_1 = mass of the parent nuclide of the i th
isotope (g),

N_0 = Avogadro's number (6.023×10^{23} atoms per
gram-atom),

σ_1 = microscopic absorption cross section for the
 i th isotopic reaction of interest (cm^2),

A_1 = atomic mass of the i th isotope (grams per
gram-atom),

ϕ = thermal neutron flux ($\text{n/cm}^2\text{-sec}$),

λ_1 = decay constant for the i th isotope (sec^{-1}),

T = irradiation time (sec),

t = time since the end of the irradiation (sec).

From Eq. (1) we can see that the induced activity of the sample (N_1) does not continue to increase indefinitely with extended irradiation, but is limited by the loss of the isotope due to radioactive decay. The maximum activity one can induce in a sample is given by the relationship

$$S_1 = m_1 N_0 \sigma_1 \phi A_1^{-1}, \quad (2)$$

which is just Eq. (1) with $T = \infty$ and $t = 0$. If one then looks at the exponential term in Eq. (1), one can see that 99.2% of the saturation activity (S_1) is reached in about seven half-lives. For maximum sensitivity then, the sample would be irradiated for seven half-lives and counted as soon after the end of the irradiation as possible.

The foregoing discussion appears to make the use of the technique straightforward until one considers that a sample is seldom composed of only one element or isotope. In practice the samples usually contain many elements and occasionally several isotopes of the same element. The activation/counting scheme employed must be chosen in such a manner as to optimize the activity of as many elements as is reasonably possible. This usually involves making two or more separate irradiations for each sample and applying various counting schedules depending on the type of sample and the elements being sought in the analysis. The irradiation schedule and counting scheme used in this study are discussed in detail below.

When a sample is exposed to a thermal neutron flux there are several possible reactions that can occur. When using thermal neutrons, the predominant reaction is the (n,γ) reaction. The types of (n,γ) reactions of interest and examples of each are given in Table 1.²

As an example of the use of the INAA technique for a single element we consider the detection of cobalt in a

sample. In Table 1, cobalt is used as the second example, and we can see that the activity one actually observes is the decay of the nickel isotope to its ground state by the emission of gamma rays. The transition half-life of the decay of the isomeric state of ^{60m}Co is 10.5 min.¹⁴ After approximately 1.25 hr of decay time only 0.7% of the ^{60m}Co produced is still present in the sample while 99.998% of the ^{60}Co produced is still present. One can also see that, since the half-life of ^{60}Co is 5.26 yr (Ref. 14), the sample could be allowed to decay for a rather extended period of time without significant loss of ^{60}Co .

Figure 1 shows the decay scheme for ^{60}Co .¹⁵ From this figure one can see that when ^{60}Co beta-decays to the excited state of ^{60}Ni there are two primary gamma rays emitted having energies of 1.1732 and 1.3325 MeV. These two gamma rays are indicative of ^{60}Co , and no other element with a similar half-life has an energy within several keV of these values. These gamma rays are then detected and counted. The number of gamma rays detected is directly proportional to the amount of ^{59}Co initially present in the sample. By the use of Eq. (1), then, the mass of cobalt in the sample can be determined. If one is only interested in a qualitative analysis it is only necessary to determine the energy and half-life of the gamma emitter to determine the constituent of the sample.

Fig. 1. Decay scheme for ^{60}Co ; energies are in MeV (after Lederer et al.15).

The Neutron Source

One of the more important tools in any study using INAA is of course the neutron source. For this study the neutron source was the Livermore Pool Type Reactor (LPTR). The LPTR is a 3-MW thermal research reactor operated for the U.S. Atomic Energy Commission by the University of California Lawrence Livermore Laboratory. The LPTR's operational characteristics are well documented in the literature^{16,17} and will not be discussed here except to the extent necessary to describe our experimental procedure.

The Detector System

Of equal importance with the ability to irradiate the samples properly is the ability to analyze the samples once they have been irradiated. Figure 2 is a block diagram of the detector system used in this study. It is built around a 30-cm³ lithium-drifted germanium Ge(Li) detector, coupled to a 4096-channel pulse height analyzer and the appropriate linear electronics.

Standard Irradiation Procedure

As discussed earlier, if one is looking for a single element the irradiation procedure is quite simple. However, for this study where an attempt was made to identify as many trace metals as possible, the irradiation and counting scheme

Fig. 2. Block diagram of INAA detector system used in this study.

was designed to give the maximum sensitivity for the wide range of elements of interest. The counting scheme outlined in Table 2 was developed and used for this study. This irradiation and counting scheme is similar to that used by others doing the same type of analyses, namely Rahn et al.,¹⁰ Dams et al.,⁸ and Zoller and Gordon.¹⁸

The data derived using the counting scheme shown in Table 2 were recorded on computer-compatible magnetic tape for permanent reference and for subsequent reduction and analysis. The procedure is effective for the identification of 35 elements in a single sample.

Table 3 gives a listing of the parent nuclide, half-life, daughter product, and energy of the gamma rays used in the analysis of the elements of interest in this study. Table 3 shows that ^{65}Zn has a gamma ray with an energy of 1115.4 keV and that ^{46}Sc has a gamma ray with an energy of 1120.3 keV. Thus if there are large amounts of both zinc and scandium in a sample it may not be possible to separate the gamma ray peaks since they would overlap when using detectors with resolutions that are currently available. Scandium has another gamma ray with an energy of 889.4 keV, and the only appreciable interference with this peak is the $^{110\text{m}}\text{Ag}$ gamma ray at 884.7 keV. By the use of curve fitting techniques and spectrum stripping it is possible to resolve large amounts of $^{110\text{m}}\text{Ag}$, ^{46}Sc , and ^{65}Zn in the same sample. A closer examination of Table 3 reveals several other

Table 2
Neutron-Irradiation and Sample-Counting
Schedule for this Study

Irradiation time	Neutron flux (n/cm ² -sec)	Cooling time	Counting time	Elements detected
2 min	2×10^{13}	4 min	500 sec	Al, V, Cu, Ti, Ca
		20 min	1000 sec	Na, Mg, Cl, Mn, Br, I, Ba, In
12 hr	4×10^{12}	20-30 hr	2000 sec	As, W, Ga, K, Cd
		6-10 days	100 min	Sm, Au, Hg, La, Sb
		20-30 days	8-12 hr	Fe, Cr, Co, Zn, Hg, Se, Ag, Sb, Ce, Eu, Sc, Th, Ni, Ta, Hf, Ba, Rb

Table 3

Parent, Daughter, Half-Life, and Energy of Observed
Gamma Rays for Elements Analyzed by INAA
Technique in this Study

Parent element exposed	Daughter isotope observed	Half-life ^a	Gamma ray energy observed ^b (keV)
Ti	⁵¹ Ti ²²	5.79 m	320.0(100)
Mg	²⁷ Mg ¹²	9.46 m	843.8(100), 1014.5(37.5)
Cu	⁶⁶ Cu ²⁹	5.10 m	1039.2(100)
V	⁵² V ²³	3.75 m	1434.3(100)
Al	²⁸ Al ¹³	2.32 m	1778.7(100)
Ca	⁴⁹ Ca ²⁰	8.80 m	3084.4(100)
Ba	¹³⁹ Ba ⁵⁶	82.9 m	165.8(100)
I	¹²⁸ I ⁵³	25.0 m	443.3(100), 526.4(9.9)
Br	⁸⁰ Br ³⁵	16.8 m	616.2(100), 665.6(17.2)
In	^{116m} In ⁴⁹	53.7 m	417.0(40.2), 1097.1(59.8), 1293.4(100)
Na	²⁴ Na ¹¹	15.0 h	1368.4(100), 2754.1(100)
Cl	³⁸ Cl ¹⁷	37.3 m	1642.7(74.5), 2167.6(100)
Mn	⁵⁶ Mn ²⁵	155.0 m	846.7(100), 1811.2(29.4)
As	⁷⁶ As ³³	26.4 h	559.1(100), 657.1(100)
W	¹⁸⁷ W ⁷⁴	23.9 h	134.2(31.6), 479.5(83.1), 618.2(23.1), 685.7(100)
Ga	⁷² Ga ³¹	14.1 h	629.9(25.5), 834.0(100), 2201.6(27.3)
K	⁴² K ¹⁹	12.4 h	1524.7(100)
Cd	¹¹⁵ Cd ⁴⁸	53.5 h	432.3(29.5), 527.9(100)
Sm	¹³³ Sm ⁶²	46.8 h	103.2(100)
Au	¹⁹⁸ Au ⁷⁹	64.7 h	411.8(100)
La	¹⁴⁰ La ⁵⁷	40.2 h	328.8(21.4), 487.0(49.4), 1596.6(100)
Fe	⁵⁹ Fe ²⁶	45.6 d	1099.3(100), 1291.5(77.0)
Cr	⁵¹ Cr ²⁴	27.8 d	320.1(100)

Continued next page

Table 3 (continued)

Parent element exposed	Daughter isotope observed	Half-life ^a	Gamma ray energy observed ^b (keV)
Co	⁶⁰ ₂₇ Co	5.26 y	1173.2(100), 1332.5(100)
Zn	⁶⁵ ₃₀ Zn	24.3 d	1115.5(100)
Hg	²⁰³ ₈₀ Hg	46.9 d	279.2(100)
Se	⁷⁵ ₃₄ Se	120. d	136.0(96.0), 264.7(100)
Ag	^{108m} ₄₇ Ag	5.00 y	434.0(100), 614.4(100), 723.0(100)
Ag	^{110m} ₄₇ Ag	255. d	657.7(100), 884.7(79.6), 937.5(36.5), 1384.2(27.7)
Sb	¹²⁴ ₅₁ Sb	60.3 d	602.7(100), 1691.1(53.2)
Ce	¹⁴¹ ₅₈ Ce	32.5 d	145.5(100)
Eu	¹⁵² ₆₃ Eu	12.7 y	121.8(100), 344.2(85.6), 1408.1(65.0)
Sc	⁴⁶ ₂₁ Sc	83.9 d	889.3(100), 1120.5(100)
Th	²³³ ₉₁ Pa	27.0 d	311.9(100)
Ni	⁵⁸ ₂₇ Co	71.3 d	811.1(100)
Hf	¹⁷⁵ ₇₂ Hf	70.0 d	343.4(100)
Hf	¹⁸¹ ₇₂ Hf	42.3 d	133.1(49.4), 482.2(100)

^aTime units are as follows: m = minutes, h = hours, d = days, y = years.

^bNumbers given in parenthesis following the gamma ray energy are the relative intensities (%) of the gamma rays.

interferences of the type discussed above which occur in a typical sample. The detection limits for 75 elements are given in Table 4, based on a maximum irradiation time of 1 hr, a thermal neutron flux of 10^{13} n/cm²-sec, and no appreciable interferences. These detection limits can therefore be thought of as theoretical limits within the state of the art.

Standardization

The standardization methods differed for short and long irradiations. The main similarity in the two methods is that both use premixed solutions containing only those elements of interest. Both have the same shortcoming, namely, that one must prepare standards of approximately the same concentrations as the samples of interest. This necessitates an estimation of the composition of the sample. However, this estimation is critical only if one is looking at samples which contain large amounts of elements that have interfering gamma rays, such as silver, scandium, and zinc as described above.

For short irradiations all samples are normalized to a "standard flux monitor." Several different types of flux monitors are used by different investigators depending on their specific application, but each is designed to do the same thing, namely, to normalize a given irradiation back to some known condition or parameter. For this study a titanium

Table 4

Detection Limits (Theoretical) of INAA Technique for 75
 Elements, Assuming a 1-hr Irradiation with a
 Thermal Neutron Flux of 10^{13} n/cm²-sec and
 No Appreciable Interferences

Limit of detection (μg)	Elements
$1-3 \times 10^{-7}$	Dy
$4-9 \times 10^{-7}$	Eu
$1-3 \times 10^{-6}$	—
$4-9 \times 10^{-6}$	Mn, In, Lu
$1-3 \times 10^{-5}$	Co, Rh, Ir
$4-9 \times 10^{-5}$	Br, Sm, Ho, Re, Au
$1-3 \times 10^{-4}$	Ar, V, Cu, Ga, As, Pd, Ag, I, Pr, W
$4-9 \times 10^{-4}$	Na, Ge, Sr, Nb, Sb, Cs, La, Er, Yb, U
$1-3 \times 10^{-3}$	Al, Cl, K, Sc, Se, Kr, Y, Ru, Gd, Tm, Hg
$4-9 \times 10^{-3}$	Si, Ni, Rb, Cd, Te, Ba, Tb, Hf, Ta, Os, Pt, Th
$1-5 \times 10^{-2}$	P, Ti, Zn, Mo, Sn, Xe, Ce, Nd
$4-9 \times 10^{-2}$	Mg, Ca, Tl, Bi
$1-3 \times 10^{-1}$	F, Cr, Zr
$4-9 \times 10^{-1}$	Ne
1-3	S, Pb
4-9	Fe

flux monitor was used and was counted for 60 sec between the 500- and 1000-sec sample counts as shown in Table 2. Several titanium flux monitors are in use, and all were run for a predetermined time and counted and found to be statistically identical. The flux monitors are placed in the same position, with respect to the sample, in the sample carrier during each irradiation. The counts from the flux standard are then ratioed to the master standard count, and all elemental counts are then ratioed up or down by the same factor. The ratioing is performed by the data reduction program, and the program "flags" any standard ratio that deviates from the master standard by more than 10%.

To calibrate the detector one puts a standard solution of known elemental composition on a filter paper, irradiates and counts the sample, and determines the gamma-ray peak area versus the mass for the standard sample. Enough samples are then made up and run to produce a peak area versus sample position for each element of interest. This matrix includes both the standard value as well as the analytical error estimate for each element in the matrix.

For the long irradiations a standard was prepared for each irradiation. The standard was then irradiated with and counted in the same position and sequence as the sample. Any flux variation that may have existed from one irradiation to another is thereby taken into account. This procedure effectively calibrates the detector for each sample run.

As a check on the effectiveness of our calibration technique, we ran several National Bureau of Standards (NBS) standards which show a very good accuracy for our technique. Table 5 gives a summary of the comparison of our technique with NBS coal and fly ash.¹⁹

Data Reduction

The data reduction for the INAA portion of this study was performed using the gamma-ray analysis programs CONSAP and DSKCON. These programs are adapted versions of a technique developed by Ralston and Wilcox¹⁷ and are identical except for their method of control. Both are written so as to be run under the Monitor system on Lawrence Livermore Laboratory's CDC 6600 computers. The accuracy of the codes has been verified by use of interlaboratory and intralaboratory comparison studies.

X-RAY FLUORESCENCE ANALYSIS (XRFA)

The XRFA technique, like the INAA technique discussed above, has also emerged as a very powerful tool in trace element analysis in the last few years. It should be pointed out that XRFA and INAA can, and should, be considered complementary and not competing techniques for trace element analysis. Each of the methods has its apparent advantages and disadvantages. The initial cost of an XRFA system is

Table 5

Comparison of Trace Elements (ppm) in Coal and Fly Ash
Samples as Determined by INAA Technique (LLL)
and by NBS

Element	Fly ash ^a		Coal ^a	
	LLL	NBS ^a	LLL	NBS ^a
As	52.3 ± 3	61 ± 3	5.0 ± 0.7	5.9 ± 0.4
Cr	126 ± 10	132 ± 5	19.3 ± 1.	22 ± 2
Mn	506 ± 23	495 ± 30	48 ± 3	47 ± 3
Se	11.6 ± 1.4	9.3 ± 1.0	3.5 ± 0.4	2.8 ± 0.2
Th	23 ± 1.3	(24)	3.0 ± 0.2	(3)
V	244 ± 24	214 ± 8	38 ± 3	35 ± 4
Fe	—	—	8180 ± 370	8600 ± 100
Co	42 ± 2	(38) ±	—	—

^aAll NBS values given are certified except for those in parenthesis, which are information values.

much lower than that of an INAA system, due to the high construction cost of a nuclear reactor, not to mention the continuing expense of operating it. On the other hand, since XRFA is an atomic process and INAA is a nuclear process, XRFA is not effective in determining isotopic concentrations or for resolving adjacent elements in the periodic table without the use of very sophisticated data-reduction schemes.

As in the case of INAA, the applications of XRFA range from the determination of a single element in a sample to the determination of as many of the constituents of a sample as is technically feasible. Some specific examples of current interest are the investigation of the so-called low lead gasolines to determine if they are really lower in lead than other gasolines,²⁰ and several investigations of the elements that are associated with air pollution studies.²¹⁻²⁴ The references given are only a sampling of those available in the literature; they are enough to give the reader an understanding of several different approaches to the investigation of air particulates.

Basic Principles

The procedure used for XRFA is to expose the sample to be analyzed to an x-ray beam so as to fluoresce the element of interest, measure the number of fluoresced x rays, and from this measurement determine the amount of the element of interest that is present in the sample.

Figure 3 is a pictorial description of the process that takes place when an incident photon interacts with an electron in an atomic shell. When the interaction depicted in Fig. 3 occurs, the resultant x ray has a well-defined energy. The pictorial representation shows only the process by which K x-rays are produced. Table 6 gives the proper labels and notation for some of the other transitions that can occur for lead and bromine, for example, depending on the incident x-ray energy as well as the values of the energy levels for the lead and bromine atoms.

The problem then is to generate an x-ray beam, expose the sample to it, and measure the characteristic x rays when they are fluoresced. The x-ray beam can be generated by either a radioisotopic source or an x-ray tube. Figure 4 shows the typical geometry for both the source- and tube-excited XRFA systems, while Fig. 5 shows the theoretical output one would expect from either of these two systems. From examination of Fig. 5 one can see that it is necessary to select a source whose coherent and incoherent scattered x rays do not interfere with the characteristic x-ray lines generated in the sample. The selection of the best source for various applications is discussed in more detail below.

The X-Ray Source

The final decision as to which of the two types of excitation should be used, radioisotopic source or x-ray tube,

Fig. 3. X-ray fluorescence process that results when a photon (exciting radiation) interacts with an electron in an atomic shell.

Table 6
Characteristic X-Ray Transitions for
Lead and Bromine

Energy level (keV)		X-ray line	Transition notation	Quantum numbers		
Bromine	Lead			i	j	n
13.474	88.005	K	α_1 α_2 β_1 β_2 β_3	0	1/2	1
1.782	15.861	L _I	β_3 β_4 γ_3	0	1/2	2
1.596	15.200	L _{II}	β_1 γ_1 η	1	1/2	2
1.550	13.035	L _{III}	α_1 α_2 β_2 γ_1 η	1	3/2	2
0.257	3.851	M _I		0	1/2	3
0.189	3.554	M _{II}		1	1/2	3
0.182	3.067	M _{III}		1	3/2	3
0.070	2.586	M _{IV}		2	3/2	3
0.069	2.484	M _V		2	5/2	3
0.027	0.894	N _I		0	1/2	4
0.005	0.764	N _{II}		1	1/2	4
0.005	0.645	N _{III}		1	3/2	4
-	0.435	N _{IV}		2	3/2	4
-	0.413	N _V		2	5/2	4
-	0.143	N _{VI}		3	5/2	4
-	0.138	N _{VII}		3	7/2	4
			K x-rays	L x-rays

Fig. 4. Excitation geometry for two types of XRF systems.

Fig. 5. Features of a typical XRF spectrum.

will generally be dictated by several factors such as cost, application, sensitivity, availability, and personal preference. The primary advantages in using tube excitation as opposed to source excitation are the tube's increased x-ray output and its ability to be turned off. The radioisotopic sources have the advantages of a more monoenergetic x-ray spectrum, lower initial cost, and reduced shielding and power requirements.

Initially the goal of this study was to undertake the development of, and demonstrate the feasibility of, a tube-excited XRFA system using equipment that was presently on hand at LLL and available for use. The system was being developed according to this plan when the detector failed, which forced a reevaluation of the best method of approaching the problem of building a tube-excited system. The system consisted of a power supply, several x-ray tubes, and a double-guard-ring Si(Li) detector developed by the Lawrence Berkeley Laboratory and described in the literature.^{24,25} Later the decision was made not to replace the detector that failed, but rather to purchase a commercially developed system based on the features of this system. Thus ended the system development phase of the present study.

For the XRFA investigations of our aerosol samples, we used a system having a radioisotopic source and built to "establish the design of an x-ray fluorescence system to determine the elemental composition of airborne particulate

matter...".²⁶ The system uses three different excitation sources. Table 7 gives the limits of detection of this system for 30 elements in terms of the mass per unit area of sample. In the determination of the detectability limits all samples were of known concentration; they were spotted on Whatman #41 filter paper and counted for 1000 sec. Figure 6 is a graphical presentation of the data in Table 7. For the elements analyzed for this study - iron, copper, bromine, strontium, zinc, and lead - the detection sensitivity of the system was of little consequence since the amount of these elements present in the samples is more than an order of magnitude greater than the detection limits claimed for the system. As can also be seen from Table 7, the ^{109}Cd source can be used to fluoresce the elements of interest.

Figures 7 and 8 show the geometrical relationship of the various components of the XRFA system used.²⁶

The Detector System

The detector employed in this XRFA system used an 80-mm² lithium-drifted silicon detector with a resolution of 190 eV for the 5.90-keV K x-ray line from a ^{55}Fe source. This energy resolution is adequate to separate adjacent elements in the periodic table for elements down to sodium ($Z = 11$). Figure 9 is a block diagram of the XRFA system.

Table 7

Detection Limits for the XRFA System
Used in this Study, as Determined
Experimentally for 30 Elements

Element	Atomic number	Detection limit (ng/cm ²)	Source
P	15	2100	⁵⁵ Fe
S	16	840	⁵⁵ Fe
Cl	17	330	⁵⁵ Fe
K	19	99	⁵⁵ Fe
Ca	20	69	⁵⁵ Fe
Sc	21	73	⁵⁵ Fe
Ti	22	40	⁵⁵ Fe
V	23	34	⁵⁵ Fe
Cr	24	120	¹⁰⁹ Cd
Mn	25	90	¹⁰⁹ Cd
Fe	26	66	¹⁰⁹ Cd
Ni	28	39	¹⁰⁹ Cd
Cu	29	34	¹⁰⁹ Cd
Zn	30	29	¹⁰⁹ Cd
As	33	19	¹⁰⁹ Cd
Br	35	15	¹⁰⁹ Cd
Rb	37	13	¹⁰⁹ Cd
Sr	38	12	¹⁰⁹ Cd
Zr	40	10	¹⁰⁹ Cd
Mo	42	12	¹⁰⁹ Cd
Cd	48	76	²⁴¹ Am
In	49	210	²⁴¹ Am
Te	52	23	²⁴¹ Am
Cs	55	42	²⁴¹ Am
Ba	56	30	²⁴¹ Am
Ce	58	34	²⁴¹ Am
Nd	60	57	²⁴¹ Am
Eu	63	130	²⁴¹ Am
Hg	80	41	¹⁰⁹ Cd
Pb	82	39	¹⁰⁹ Cd

Fig. 6. Detection limits for the XRFA system used in this study (plot of the data in Table 7).

Fig. 7. Experimental arrangement used for the XRFA investigations in this study.

Fig. 8. Detailed cutaway view of the circled area in Fig. 7, showing the exposure area and detector.

Fig. 9. Block diagram of the XRFA detector system used in this study.

Irradiation Procedure

The development of a procedure is a much easier task for XRFA than for INAA. The sample is placed on the Mylar sample holder, as shown in Figs. 7 and 8, and is counted for a long enough time to gather adequate counting statistics for the characteristic x-ray line of interest. All of the samples analyzed in this study by XRFA were exposed to the ^{109}Cd source for a counting interval of 1000 sec. In most cases the counting time for very good statistics on the zinc and lead peaks could have been substantially reduced. However, in those cases where the lead and zinc concentrations were very low, a counting time of 1000 sec was not excessive.

Standardization

The standardization or calibration of the XRFA system, described by Bonner et al.,²⁶ is very straightforward. The method is similar to that used for INAA; namely, it consists of putting a known amount of an element on a piece of filter paper and counting it with the system. The results of this count will develop a calibration factor in terms of counts/sec-ng-cm². The method of determining the geometric correction factors for different size samples is also discussed in detail by Bonner et al.²⁶

Data Reduction

The data reduction scheme used in this study is the same as that described by Bonner et al.²⁶ The method depends on establishing a background level for each channel in the analyzer based on the counts from the coherent and incoherent scatter peaks. This predetermined background is then subtracted from each channel under the peak of interest. The integration of a specific peak area is performed over an area of approximately half the maximum peak height. All calibrations are normalized over 11 channels. A peak width of 11 channels is slightly more than is desirable for the iron peak and slightly less than is desirable for the peaks of higher energy such as lead, but it is an acceptable compromise.

In the absence of significant interferences the irradiation procedure, calibration technique, and data reduction scheme are capable of measuring as many as 50 distinct elements.²⁶ However, it is almost never possible to have a sample that does not contain some interference peaks. Since one can eliminate some of the elements as not being present in most air filters, the selection of what elements to look for can be reduced. The data reduction program uses an off-line CDC 7600 computer to determine 12 elements simultaneously on an air filter. Tables 8 and 9 show typical output data for a sample from this study. Table 8 is an example of the output of the on-line computer giving the peak

Table 8

Typical On-Line Computer Output of XRFA Data for a Sample
in this Study (Retyped from Original)

	GROUP ^a	START ^b	STOP ^b	TOTAL ^c	ENERGY ^d	VALUE ^d
(Cr)	1	212	222	635	5475	77
(Mn)	1	231	241	702	5900	70
(Fe)	1	251	261	4734	6400	603
(Ni)	1	294	304	587	7425	69
(Cu)	1	317	327	1178	8025	161
(Zn)	1	340	350	7616	8600	953
(As)	1	416	426	12125	10525	1434
(Se)	1	443	453	602	11325	74
(Br)	1	471	481	760	11900	90
(Rb)	1	530	540	528	13250	62
(Sr)	1	561	571	564	14225	64
(Zr)	1	625	635	608	15725	62
(Mo)	1	693	703	615	17525	78
(Pb)	1	499	509	10753	12600	1316
(Incoherent)	1	816	836	202202	20675	10824
(Coherent)	1	876	896	39254	22150	2524

^aThe symbols in parenthesis indicate the element for which the area is set up. They are not on the original printout.

^bSTART and STOP are the limiting channel numbers for which the area is integrated for data reduction.

^cTOTAL is the total number of counts in the channels included between START and STOP. These are the numbers that are used by the off-line computer system.

^dThese columns are for information only and are not used in the reduction of the data.

Table 9

Example of Input/Output for the XRFA Off-Line Computer Program (Retyped from Original). Input Lines Are Preceded by an Asterisk; Other Lines Are Output

```

TYPE NAME OF DATA FILE
*BAZ7

TYPE SAMPLE IDENTIFICATION
*IAS-21A

TYPE CDHG, CDSE, FE, AM, OR END
*CDSE
TYPE CD.NO.1 OR CD.NO.2
*CD.NO.2
TYPE BKGD.1 OR BKGD.2
*BKGD.1

TYPE COUNTS FOR SEVEN ELEMENTS
*635 702 4734 587 1178 7616 12125
TYPE COUNTS FOR SEVEN ELEMENTS
*602 760 528 564 608 615 10753
TYPE PINC, PCOH, DAY, YEAR, AND COUNT TIME
*202202 39254 193 73 1000

SAMPLE: IAS-21A
DATA: CDSE EXCITER: CD.NO.2 BKGD.1 DATA FILE: BAZ7
YR: 73 DAY: 193 COUNT TIME: 1000
DATE OF COMPUTATION: R 07/14/73 AT 18:56:05

ELEM    MICROGRAM    ERRORa    % ERROR    GROSS CTS    BKGD    NET
CR=      -0.486      0.480      *          635        575      60
MN=       0.656      0.383     58.37      702        540     162
FL=      31.158      0.555      1.78      4734       510    4224
NI=       0.251      0.159     63.31      587        460     127
CU=       2.756      0.170      6.15      1178       434     744
ZN=      25.567      0.322      1.26      7616       416    7200
AS=      -0.592      0.411      *          12125      380    11745
SE=       0.138      0.071     51.21      602        376     226
BR=       0.635      0.070     11.01      760        371     389
RB=       0.040      0.051      *          528        362     166
SR=       0.246      0.047     19.33      564        357     207
ZR=       0.181      0.043     24.05      608        373     235
MO=      -0.015      0.050      *          615        615       0
PB=      54.950      0.559      1.02     10753      365    10388

END OF PROBLEM

```

^aError is the 1σ counting statistical uncertainty. Any uncertainty greater than 100% is listed as an asterisk. An uncertainty of 33.33% would be a 3σ uncertainty and is considered the limit of usefulness.

area and energy for the elements in the sample. The numbers given in the column headed "Total" are then used as input to the off-line computer program for the determination of the actual concentration of the elements of interest. Table 9 is an example of the input/output for the off-line computer program, showing both the information given to the computer and the data that is printed out by the computer. The entire off-line computer program is run from a remote terminal, with the output returning to the same terminal, and encompasses an elapsed time of less than 5 sec.

The analytical technique used has been verified by comparison with NBS samples and by interlaboratory comparisons. Table 10 gives the results of the NBS comparison.²⁶ An examination of the data in Table 10 shows that the comparison with NBS is within 10%; if the value for arsenic is excluded, the average difference is approximately 2.5%. A comparison with the University of California at Davis, which used alpha particle excitation, shows an overall agreement of approximately 13%.²⁶

SAMPLE PREPARATION

The samples received from the Department of Environmental and Community Services of the State of Idaho were on 8-by-10-in. Whatman #4 filter paper. The material was deposited on an area of approximately 18.25 by 23.55 cm (7.19 by 9.27 in.). Samples as large as 8-by-10-in. are very

Table 10

Comparison of Trace Elements in Orchard Leaves as Determined
by XRFA Technique (LLL) and by NBS

Trace element	Concentration found (ppm)	
	LLL	NBS
Mn	83 ± (8) ^a	91 ± (4)
Fe	283 ± (6)	300 ± (20)
Cu	12.7 ± (2)	12 ± (1)
Zn	25.0 ± (2)	25 ± (3)
Al	8.6 ± (1)	14 ± (2)
Br	9.8 ± (1)	(10) ^b
Rb	11.6 ± (1)	12 ± (1)
Sr	37.1 ± (1)	(37) ^b
Pb	43.3 ± (2)	45 ± (3)

^aThe NBS uncertainties are 2σ, and the LLL uncertainties are 1σ counting statistics only.

^bNBS does not quote uncertainties for Br and Sr; these values are not certified and are informational only.

unwieldy and contain more particulate matter than is necessary and desirable for analysis. The samples actually used for analysis in this study were 29-mm-diam circular sections cut out of the larger sheets using a special cutter designed for cutting single sheets of filter paper. The assumption was made and subsequently verified (see Ch. 3) that the material was homogeneously deposited on the filters. The cutting of samples from near the edges was avoided for obvious reasons.

Chapter 3

RESULTS AND DISCUSSION

The samples provided by the Idaho Department of Environmental and Community Services were analyzed by instrumental neutron activation analysis and x-ray fluorescence analysis using the techniques and procedures outlined in Ch. 2. A listing of the sample collection parameters is given in Table 11. The results of the analyses are discussed in the following sections.

SAMPLE HOMOGENEITY

The first item of interest was to determine if the 29-mm-diam circular sections cut from the larger sheets as previously discussed in Ch. 2 were representative of the entire sample. This was accomplished by cutting five circular sections out of each sample and comparing the results of two of these sections for the short irradiation. The values for aluminum and indium were compared for the first ten samples using two circles from the five that were cut out. The comparison of the ratios of the two counts showed that the average of the ratios was 1.002 ± 0.117 . On the basis of this data the sample sections were considered to be equivalent and the loading was considered homogeneous. Our confidence in the validity of this assumption was reinforced

Table 11

Collection Data for Samples Analyzed in this Study. Samples
Were Taken at a Location on the Roof of the City
Hall in Kellogg, Idaho

Sample No.	Collection date (1972)	Total airflow (m ³)	Particulate weight (mg)	Concentration in air (µg/m ³)
2A	01-29	1269	159.5	125.7
3A	01-31	1390	135.1	97.2
4A	02-07	1129	133.6	118.3
5A	02-15	1190	114.4	96.1
8A	03-16	1220	235.5	193.1
9A	03-24	1423	128.5	90.3
10A	04-03	1256	244.5	194.6
11A	04-13	1403	218.9	156.0
12A	04-24	1395	230.7	165.4
13A	05-05	1330	155.2	116.7
14A	05-11	1354	241.1	178.1
15A	05-19	1280	198.0	154.7
16A	05-30	1403	267.4	190.6
18A	06-19	1618	261.7	161.7
20A	07-06	1656	235.7	142.3
21A	07-13	958	216.3	225.7
27A	08-15	1585	223.8	141.2
28A	08-21	1654	199.6	120.7
30A	09-11	1657	198.5	119.8
31A	09-17	1419	255.0	179.7
33A	10-01	1283	260.3	202.9
34A	10-05	1240	203.2	163.9
36A	10-24	1181	300.2	254.2
38A	11-03	1353	122.7	90.7
39A	11-14	1160	250.6	216.1
40A	11-24	1484	189.7	127.8
41A	12-04	1450	86.4	59.6
42A	12-06	1635	109.2	66.8
43A	12-13	1192	199.8	167.6
44A	12-18	1319	158.5	120.2

by the good correlation between x-ray fluorescence and neutron activation analysis, which were carried out on different samples.

INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS (INAA)

To publish all of the data generated using the INAA technique would require several volumes. Hence, only a sample of the raw data is given here. A summary of the results of the analysis of all samples analyzed by INAA is given in Appendix A.

To give the reader a feel for the type of data that was generated for each sample, sample 21A is used as an example. The computer output for the last of the three long irradiation counts (see Table 2) is given in Appendix B. Figures 10-14 are plots of the data generated for sample 21A for each of the counting sequences. The irradiation data is shown for each spectrum presented, and insofar as practicable all peaks have been identified. Some of the peaks have not been identified and labeled because their origin is not known. These unlabeled peaks may be peaks that can be attributed to more than one element, they may be single and double escape peaks, or they may be coincidence sum peaks.

Fig. 10. INAA spectrum Q1 for sample IAS-21A. Sample data: collection date 7-13-1972, total airflow through filter 958 m^3 , mass loading of air as indicated by material trapped in filter, $226 \mu\text{g}/\text{m}^3$. SEP = single escape peak, DEP = double escape peak, AP = annihilation peak.

Fig. 11. INAA spectrum Q2 for sample IAS-21A. Sample data and abbreviations same as Fig. 10.

Fig. 12. INAA spectrum L1 for sample IAS-21A. Sample data and abbreviations same as Fig. 10.

Fig. 13. INAA spectrum L2 for sample IAS-21A. Sample data and abbreviations same as Fig. 10.

Fig. 14. INAA spectrum L3 for sample IAS-21A. Sample data and abbreviations same as Fig. 10.

X-RAY FLUORESCENCE ANALYSIS (XRFA)

As in the case of the INAA data, to publish all the XRFA data gathered in this study would require volumes. Examples of the on-line and off-line computer data for sample 21A were given in Tables 8 and 9 of Ch. 2. Figure 15 is the XRFA spectrum for sample 21A as plotted by the on-line computer. The peaks analyzed using XRFA are all identified and labeled on Fig. 15. Even though from Fig. 15 it would appear that calcium and chlorine should have been analyzed and reported, neither was used in the analysis since both are best analyzed using the ^{55}Fe source (see Table 7).

A summary of the data derived by XRFA is given in Appendix C.

SUMMARY OF INAA AND XRFA DATA

Table 12 is a summary of the data derived from both techniques, averaged over all samples. The average concentration, $\langle C \rangle$, and the range of the concentrations for the elements analyzed are given in detail in Table 12. The data were analyzed using standard statistical techniques,²⁷ namely:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i,$$

$$s = \left[\frac{1}{n-1} \left(\sum_{i=1}^n x_i^2 - n\bar{x}^2 \right) \right]^{1/2},$$
(3)

Fig. 15. XRFA spectrum for sample IAS-21A, made using ^{109}Cd source and 1000-sec exposure. Sample data same as Fig. 10.

Table 12

Summary of INAA and XRF data from this study.
All Values are ng/m³

Trace element	INAA data			XRF data			
	$\langle C \rangle$	C _{min}	C _{max}	$\langle C \rangle$	C _{min}	C _{max}	Average $\langle C \rangle$
Ti	95.7	<40.	170.	—	—	—	—
Mg	718.	264.	1270.	—	—	—	—
Cu	181.	51.7	513.	190.	55.	475.	186.
V	2.01	0.716	3.98	—	—	—	—
Al	1050.	203.	2500.	—	—	—	—
Ca	583.	80.6	1310.	—	—	—	—
Ba	35.0	<10.	106.	—	—	—	—
I	1.94	0.770	6.05	—	—	—	—
Br	91.9	23.1	244.	107.	25.1	323.	99.
In	5.79	0.0635	43.3	—	—	—	—
Na	207.	84.8	412.	—	—	—	—
Cl	498.	106.	1300.	—	—	—	—
Mn	71.3	26.	214.	—	—	—	—
As	329.	8.28	2510.	—	—	—	—
K	1110.	277.	6210.	—	—	—	—
Cd	748.	<30.	2890.	—	—	—	—
Ga	2.36	0.867	4.42	—	—	—	—
W	4.44	1.97	9.43	—	—	—	—
Sm	0.184	0.0491	0.337	—	—	—	—
Au	9.76	2.97	43.1	—	—	—	—
La	1.09	0.279	2.07	—	—	—	—
Eu	0.0663	0.0293	0.173	—	—	—	—
Se	5.23	0.644	17.6	—	—	—	—
Ce	2.07	0.961	3.96	—	—	—	—
Hg	113.	10.8	504.	—	—	—	—
Th	0.243	0.0438	0.465	—	—	—	—
Cr	6.82	2.61	14.9	—	—	—	—
Hf	0.140	0.0457	0.354	—	—	—	—
Sb	146.	5.21	1210.	—	—	—	—
Ag	10.5	0.936	36.5	—	—	—	—
Sc	0.322	0.134	0.518	—	—	—	—
Fe	1660.	739.	3170.	2010.	650.	4880.	1835.
Zn	4480.	270.	14900.	4760.	338.	15700.	4620.
Co	3.21	1.16	7.49	—	—	—	—
Sr	—	—	—	22.5	6.62	74.9	—
Pb	—	—	—	10800.	501.	30200.	—

where

$\bar{x}$ = average value of x (the mean of x),

n = number of samples analyzed in this study,

s = standard deviation.

It should be noted that, in the notation of this study, $\langle C \rangle$ is equivalent to $\bar{x}$. The graphical results of the data presented in Appendices A and C are shown in Fig. 16. The error bars indicated on some of the data in Fig. 16 are typical errors, meant to give the reader an indication of the relative magnitudes of the analytical error and the fluctuations in the concentrations measured. When the concentration plotted for a given sample represents the detection limit, an arrow pointing down has been used to indicate that the actual value is less than or equal to the plotted value (e.g., titanium in Fig. 16).

From a cursory examination of Fig. 16 one may draw several conclusions as to the possible sources of some of the elements. From Fig. 16(a,b) we can see that lead, zinc, cadmium, indium, and possibly silver, gold, selenium, antimony, and mercury have similar concentration patterns as a function of time. However, they are not correlated with the behavior of the total mass of the sample. From Fig. 16(c-e) we see several elements that tend to have a distribution similar to that of aluminum. In Fig. 16(f,g) we observe elements that do not appear to be very well related to either the lead or aluminum distribution. From the observation of

Fig. 16. Concentration of various trace elements in the air as a function of sampling date, for the air filter samples of this study taken in Kellogg, Idaho, throughout the year 1972.

Fig. 16 (continued)

Fig. 16 (continued)

Fig. 16 (continued)

the data in Fig. 16 one would conclude that the elements can be grouped into three general classes: (1) those with a pattern similar to that of lead, probably associated with the mining or smelting industry, (2) those with a pattern similar to that of aluminum and therefore probably related to the soil, and (3) those that do not seem to fall into either of the first two classes.

This generalization of the data is carried further in the discussion of enrichment factors, where the breakdown given above is further refined and justified.

The relationship between the results of XRFA and INAA is shown in Fig. 17 for copper, bromine, iron, and zinc. The solid line represents a correlation coefficient of 1.0, or perfect correlation. The linear correlation coefficients of these four elements are 0.98, 0.96, 0.93, and 0.97, respectively, for copper, bromine, iron, and zinc. For these samples a linear correlation coefficient of 0.35 is the minimum value for correlation.²⁸

ENRICHMENT FACTORS

The data presented in the foregoing section will be used here to derive for the various elements a quantity called the enrichment factor. The technique of data analysis by enrichment factors is being used by several investigators at the present time. An explanation of the technique and

Fig. 17. Correlation of INAA and XRFA results for copper, bromine, iron, and zinc. Linear correlation coefficient (LCC) values are shown for each graph. An LCC value of 0.35 or higher indicates positive correlation.

some of the underlying reasons for its use are given by Gordon et al.²⁹:

Atmospheric concentrations of elements carried on particles are usually expressed in terms of the weight of the element per m³ of air. Absolute concentrations are, of course, of prime interest from a public health point of view. However, they are difficult to use in identification of sources, since they are affected strongly by wind speed and direction, precipitation, mixing heights, distance from local sources, etc. Source emission inventories provide some information about sources, but one must use models of poor reliability to interpret such data.

Many of the uncertainties noted above can be removed by dividing the absolute concentrations of elements of interest by that of a major element such as Al or Fe. Such a normalization tends to remove variation caused by changes in total atmospheric particulate loading. One can obtain even more useful information by performing a second normalization to the crustal abundance pattern. Much suspended particulate matter is soil and rock dust injected by wind erosion. Relative concentrations of elements borne by such dust are probably the same as that of the major element used in the double normalization. Also, relative concentrations of many elements in several source materials are similar to those of crustal material. For example, the alumino-silicate portion of coal has a concentration pattern much like that of average crustal material. Thus, when an element has a large relative concentration after the double normalization, one must look for special sources or processes to find explanation for the enrichments.

The major problem with the technique described above is the selection of the element for which the normalization will be carried out. In source identification one would like to normalize to (1) an element whose concentration is easily and accurately derived, and (2) one whose origin is well known. The first of these criteria is easier to find and define than the second. For this study the element selected for the first normalization was aluminum. Aluminum was

chosen for two reasons: the data derived based on aluminum could be directly compared to other studies of this type, and, more important, the only source of aluminum could be assumed to be the soil.

The second normalization was performed using the values of crustal rock as given by Wedepohl,³⁰ which are based on worldwide averages. The obvious problem with the use of worldwide averages is not easy to overcome, since local values are usually nonexistent and their development is very complex due to local meteorological conditions. Similar techniques have been used by Rahn³¹ and Gordon et al.⁹ and more will be said about their justification when discussing the conclusions of this study.

The equation for the enrichment factor (EF) for a given element as used by Gordon et al.²⁹ can be expressed as follows:

$$EF \equiv \frac{R(\text{sample})}{R(\text{earth's crust})}, \quad (4)$$

where R is the ratio of the concentration of the given element to that of aluminum. If one calls R the elemental ratio, then the average elemental ratio $\langle R \rangle$ for an element is

$$\langle R \rangle \equiv \frac{1}{n} \sum_{i=1}^n R_i, \quad (5)$$

where n is the number of samples analyzed in the study. Hence the enrichment factor can be redefined as

$$(EF)_W \equiv \frac{\langle R \rangle}{R_W}, \quad (6)$$

where R_W is the elemental ratio for crustal rock using the values of Wedepohl³⁰ as defined earlier. This enrichment factor represents a time-averaged EF for this study.

From the definition given by Eq. (6), an enrichment factor of 1 would indicate that the element had the same elemental concentration as crustal rock. If we assume that the soil in Kellogg, Idaho, is similar to the worldwide average for crustal rock, then any element with an enrichment factor on the order of 1 can be assumed to be soil-derived. If the enrichment factor is significantly higher than 1, then either the element is highly enriched in the local soil, or it has a source other than soil, or some combination of the two applies.

The elemental ratios R for the elements and samples analyzed in this study are presented graphically in Fig. 18. A brief examination of the plots shows three distinct patterns of elemental ratios: (1) those elements that tend to display a distribution pattern similar to lead (Fig. 18(a)), (2) those elements that tend to be distributed like aluminum as shown by having an elemental ratio distribution that is nearly constant (Fig. 18(b)), and (3) those elements whose

Fig. 18. Elemental ratios (R) for the various trace elements analyzed in this study as a function of sampling date. In a given sample, R for a particular element is defined as the ratio of the concentration of that element to the concentration of aluminum in the sample.

Fig. 18 (continued)

Fig. 1P (continued)

distributions do not tend to follow either lead or aluminum (Fig. 18(c)). The differences in these three types of distributions are exemplified in Fig. 19 which compares lead, vanadium, and arsenic.

The elemental ratios were determined and averaged for all samples in the study, and used to calculate the enrichment factors as defined by Eq. (6). Table 13 lists these enrichment factors, together with the range and standard deviation of the elemental ratios and the ratio of maximum to minimum elemental ratios found for each element.

The enrichment factors given in Table 13 are used to divide the elements into two general categories in Table 14 for easier discussion, those with high enrichment factors ($EF > 100$) and those with low enrichment factors ($EF < 100$).

High Enrichment Factors

The elements with enrichment factors greater than 100 can be seen to vary quite a bit, but they fall into three well-defined groups.

The first of these groups consists of elements with very high enrichment factors ranging from a low of 8,066 for indium to a high of 901,000 for cadmium. If one looks at the products of the mining industry and local smelters he will see that the elements in this group are the principal products of the mines and smelters, the exceptions being

Fig. 19. Elemental ratios (R) for lead, arsenic, and vanadium as a function of sampling date.

Table 13

Elemental Ratios and Enrichment Factors Determined from
INAA and XRFA Data of this Study

Element	$\langle R \rangle$	ΔR	R_{min}	R_{max}	No. of samples	$\frac{R_{max}}{R_{min}}$	R_W	EF	
INAA	Ti	0.106	0.0731	0.0237	0.342	29	14.4	0.060	1.76
	Mg	0.418	0.209	0.269	0.824	10	3.06	0.178	2.35
	Cu	0.343	0.524	0.0430	2.45	30	57.0	0.00038	901.
	V	0.00231	0.00129	0.00129	0.00665	30	5.16	0.0016	1.44
	Ca	0.813	0.719	0.143	2.84	30	16.2	0.366	2.22
	Ba	0.0540	0.0579	0.0163	0.246	30	15.1	0.0075	7.20
	I	0.00316	0.00475	0.00052	0.026	30	50.0	6×10^{-6}	527.
	Br	0.173	0.242	0.0190	0.998	30	52.5	3.7×10^{-5}	4670.
	In	0.00719	0.0197	0.0000915	0.107	30	1170.	8.9×10^{-7}	8080.
	Na	0.265	0.199	0.110	0.964	30	8.76	0.313	0.845
	Cl	0.710	0.899	0.115	3.46	27	30.1	0.0041	173.
	Mn	0.0903	0.0727	0.0266	0.318	30	12.0	0.008	11.3
	As	0.470	0.732	0.00928	3.44	30	371.	2.2×10^{-5}	21,400.
	K	1.17	1.14	0.359	4.96	30	13.8	0.36	3.26
	Cd	1.17	1.71	<0.025	7.89	28	>316	1.3×10^{-6}	901,000.
	Sc	0.000444	0.000318	0.000239	0.00116	20	4.85	1.8×10^{-4}	2.47
	Fe	2.36	2.05	1.05	7.86	20	7.48	0.452	5.22
	Sb	0.294	0.664	0.00749	2.98	20	398.	2.6×10^{-6}	113,000.
	Ga	0.03340	0.00320	0.000494	0.0109	12	22.0	2.2×10^{-4}	15.4
	W	0.00582	0.00451	0.00146	0.0144	10	9.89	1.7×10^{-5}	342.3
	Sm	0.000223	0.000138	0.0000673	0.000675	24	10.0	8.4×10^{-5}	2.45
	Au	0.0180	0.0259	0.00187	0.106	24	56.7	5.1×10^{-8}	352,000.
	La	0.00135	0.000852	0.000351	0.00392	24	6.03	5.6×10^{-4}	2.40
	Eu	0.000109	0.000119	0.0000262	0.000427	20	16.3	1.8×10^{-5}	6.08
	Se	0.0101	0.0139	0.000538	0.0519	20	96.5	1.1×10^{-6}	9150.
	Ce	0.00277	0.00158	0.00129	0.00594	20	4.60	9.6×10^{-4}	2.89
	Hg	0.201	0.306	0.0201	1.24	20	61.8	3.8×10^{-7}	529,000.
	Th	0.000248	0.0000739	0.000176	0.000492	18	2.79	1.4×10^{-4}	1.77
	Cr	0.00863	0.00406	0.003330	0.0161	20	4.84	8.9×10^{-4}	9.69
	Hf	0.000185	0.000149	0.0000920	0.000642	20	6.97	3.8×10^{-5}	4.87
	Ag	0.0210	0.0292	0.00135	0.101	20	74.5	7.7×10^{-7}	27,200.
	Zn	9.80	14.3	0.226	54.1	20	239.	7.7×10^{-4}	12,700.
	Co	0.00531	0.00539	0.00120	0.0175	20	14.6	1.5×10^{-4}	35.4
XRFA	Fe	2.38	1.61	1.20	8.07	30	6.74	0.452	5.27
	Cu	0.345	0.494	0.0536	2.39	30	44.6	3.8×10^{-4}	908.
	Zn	7.79	10.3	0.299	46.8	30	157.	7.7×10^{-4}	10,000.
	Br	0.191	0.250	0.0206	1.06	30	51.4	3.7×10^{-5}	5170.
	Sr	0.0360	0.0437	0.00544	0.184	30	33.9	3.7×10^{-3}	9.72
	Pb	16.9	20.4	0.570	84.4	30	148.	1.9×10^{-4}	88,800.

Table 14

Trace Elements Detected in this Study Grouped According to Enrichment Factor, with Those Having High Enrichment Factors (>100) on Left Side and Those Having Low Enrichment Factors (<100) on Right. Based on INAA Data Except Where Otherwise Noted

High enrichment factors		Low enrichment factors	
Element	ER value	Element	ER value
Cd	901,000	Co	35.4
Hg	529,000	Ga	15.4
Au	352,000	Mn	11.3
Si ^a	113,000	Sr ^a	9.72
Pb ^a	88,800	Cr	9.69
Ag	27,200	Ba	7.20
As	21,400	Eu ^b	6.08
Zn ^b	11,400	Fe ^b	5.25
Se	9,150	HF	4.87
In	8,080	K	3.26
Br ^b	4,920	Ce	2.89
Cu ^b	905	Sm	2.65
I	527	Sc	2.47
W	342	La	2.40
Cl	173	Mg	2.35
		Ca	2.22
		Th	1.77
		Ti	1.76
		V	1.44
		Al	1.00
		Na	0.845

^aBased on XRFA data only.

^bBased on INAA and XRFA data.

mercury, arsenic, selenium, and indium. These four elements, although not among the mine and smelter products, would be expected to be enriched in the effluent of a smelter. This conclusion can be verified by looking at a comparative elemental study of a heavy metal smelter by Wesolowski et al.³²

The second group contains only two elements, copper and tungsten. Their enrichment factors are high but are much lower than those of the elements in the first group. Copper sulfate is introduced into the smelting cycle as a reagent in the flotation process for the separation of zinc-bearing minerals and the unproductive portion in the process.³³ The introduction of the copper sulfate into the smelting sequence could account for the enrichment factor of 905 observed for copper. The source of tungsten to yield the observed enrichment factor of 342 is not clear, and tungsten is not discussed in the study conducted by Wesolowski et al.³²

The third group in the category of high enrichment factors is composed of the halogens. The ones analyzed were bromine, iodine, and chlorine, having enrichment factors of 4920, 527, and 173 respectively. The origin of these halogens is not clear.

Low Enrichment Factors

It is noted in the second category of elements that all except cobalt, gallium, and manganese have enrichment

factors of less than 10. In the definition of the enrichment factor we said that an enrichment factor of the order of 1 would indicate a high probability that the element was soil-derived. In Table 14 one can see that those elements which would normally be found only in soil have enrichment factors that range from 1.44 for vanadium to 6.08 for europium. The mean value for the elements that lie in this range is 3.03 ± 1.45 , indicating that these elements are in all probability derived primarily from the soil. They would have to have enrichment factors perhaps one or two orders of magnitude higher than this before one would consider that a source other than the soil was definitely indicated.

Enrichment Factors as Source Indicators

From the foregoing discussion of the data it can be seen that one can very easily group the elements analyzed into four categories: enrichment factors less than 10, enrichment factors between 10 and 100, enrichment factors of 100 to 1000, and lastly, enrichment factor greater than 1000. Corresponding to each of these classifications (see Table 15) is a suggestion as to the possible origin (dominant source) of the element. Those with the lowest enrichment factors are shown as soil-derived; those with intermediate enrichment factors as probably soil-derived, but perhaps enriched from some other source; those with relatively high enrichment

Table 15

Trace Elements Detected in this Study Grouped by Enrichment Factor into Four Categories Considered to be Roughly Indicative of the Source of the Elements

Category	EF range	Elements	Dominant source
1	<10	Na, Al, V, Ti, Th, Ca, Mg, La, Sc, Sm, Ce, K, Hf, Fe, Eu, Ba, Cr, Sr	Soil
2	10-100	Mn, Ga, Co	Uncertain, probably soil
3	100-1000	Cl, I, W, Cu	Uncertain, probably other than soil
4	>1000	In, Se, Zn, As, Ag, Pb, Sb, Au, Hg, Cd, Br	Mines and/or smelters

factors as probably derived primarily from a source other than the soil; and those with very high enrichment factors as definitely derived from some other source than the soil (mines, smelter).

When the actual composition of the local soil becomes available, the data presented in Appendices A and C can be used to derive enrichment factors for the local environment that may shed more light on the possible sources of origin.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

The data presented here show that INAA and XRFA, when coupled with enrichment factor analysis, promise to be reliable and useful techniques in the identification of the source of trace elements in the air.

The results reported here represent only the beginning of a continuing study. Further analysis will be performed on the data presented here, and additional data are also being obtained. Some future goals of the continuation of this study are listed below:

- Perform detailed mathematical correlation on the data to determine if there are underlying correlations that are not obvious.
- Determine trace element abundances in the local soil and vegetation, as a basis for deriving better values of the enrichment factors.
- Correlate concentrations of the trace elements with meteorological data and mining and smelter operation history.
- Determine particle size distribution for the trace elements.
- Determine whether diurnal concentration patterns exist for any of the elements.

- Determine whether a sufficient sample-to-sample correlation exists for some of the elements to justify measuring one or two elemental concentrations as an "indicator" of the total particulate concentration.

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Appendix A

SUMMARY OF INAA DATA

In this appendix is presented a summary of the raw INAA data derived in this study. Tables A-1 through A-4 give the trace element concentrations found in the individual samples. The errors given are the analytical errors and do not account for errors in the sample flow rates. When a value is given as less than some number, that number represents the detection limit for that element in that particular sample.

Table A-5 gives the average concentrations of each trace element for all the samples it was found in, as well as the minimum and maximum concentrations found. The errors indicated in the values for the average concentrations are the standard deviations of the individual concentrations.

Table A-1

Trace Element Concentrations and Analytical Errors (Both in ng/m^3) Found in the INAA Investigations in this Study for a Blank Sample and Other Sample Numbers Shown. Dashes Indicate Data not Available

Trace element	Concentration and analytical error (in parenthesis) by sample No.							
	Blank	2A	3A	4A	5A	6A	7A	8A
Ti	—	—	81.4 (21.9)	70.8 (8.2)	118. (36.)	131. (53.)	56.8 (22.5)	142. (20.)
Mg	—	—	—	—	—	909. (499.)	—	—
Cu	90.03 (23)	497. (34)	291. (10)	296. (10)	89.2 (29.3)	247. (5.)	138. (19.)	217. (50.)
V	—	1.14 (0.10)	2.22 (0.02)	1.05 (0.01)	2.31 (0.13)	3.25 (0.23)	1.44 (—)	2.83 (0.48)
Al	140.8 (36)	203. (20)	334. (41.)	207. (20.)	934. (121.)	2040. (99.)	611. (90.)	1680. (250.)
Ca	5660. (150)	353 (20)	521. (79.)	305. (13.)	632. (39.)	708. (96.)	121. (—)	953. (197.)
Ba	—	24.5 (0.01)	52.5 (3.4)	<10	21.7 (2.1)	59.5 (7.4)	22.9 (6.0)	48.1 (0.4)
I	2.30 (—)	5.37 (0.74)	1.97 (0.43)	1.79 (0.40)	2.27 (0.61)	3.38 (0.83)	1.91 (0.59)	3.26 (1.14)
Br	30.0 (9)	118. (19)	119. (13.)	206. (5.)	79.7 (10.8)	86.2 (15.8)	48.4 (5.1)	67.1 (6.8)
In	0.060 (—)	3.06 (0.15)	2.52 (0.06)	1.72 (—)	1.26 (0.01)	5.46 (0.34)	1.86 (0.19)	4.50 (0.54)
Na	9610. (768.)	128 (13)	181. (14.)	108. (10.)	144. (25.)	224. (15.)	144. (39.)	307. (65.)
Cl	5730. (540.)	—	254. (38.)	357. (50.)	240. (73.)	708. (42.)	346. (45.)	455. (13.)
Mn	14.6 (—)	48.2 (3.2)	30.7 (0.7)	29.1 (—)	40.1 (0.1)	160. (6.)	43.7 (4.5)	110. (12.)
As	—	97.2 (0.6)	63.5 (0.5)	64.9 (0.7)	36.4 (0.9)	180. (7.)	62.1 (3.5)	183. (9.)
K	—	298 (38)	424 (49)	277. (—)	478. (22.)	1200. (61.)	385. (69.)	942. (15.)
Cd	—	214 (99)	304 (1)	372. (2.)	252. (17.)	528. (13.)	398. (13.)	552. (13.)
Ga	—	—	—	—	—	—	—	—
N	—	—	—	—	—	—	—	—
Sm	—	0.0491 (0.0058)	0.104 (0.006)	0.0797 (0.0078)	0.127 (0.005)	0.305 (0.008)	0.0831 (0.0099)	0.225 (0.029)
Au	—	7.11 (1.17)	7.38 (1.06)	10.7 (1.5)	2.97 (0.72)	11.2 (1.3)	8.33 (1.46)	12.8 (3.4)
La	—	0.279 (0.041)	0.533 (0.043)	0.650 (0.052)	0.685 (0.046)	1.56 (0.07)	0.562 (0.075)	1.55 (0.24)
Eu	0.02 (—)	0.0395 (0.0046)	0.0538 (0.0036)	0.0415 (0.0049)	0.0392 (0.0085)	0.0826 (0.0116)	—	—
Se	—	3.29 (0.44)	4.99 (0.70)	3.29 (0.65)	1.71 (0.01)	4.18 (0.02)	—	—
Ce	0.33 (—)	1.19 (0.20)	1.25 (0.15)	0.961 (0.185)	1.43 (0.09)	2.97 (0.21)	—	—
Hg	5.52 (1.0)	51.5 (1.5)	55.9 (1.2)	43.2 (1.4)	31.6 (0.7)	62.5 (1.5)	—	—

Continued next page

Table A-1 (continued)

Trace element	Concentration and analytical error (in parenthesis) by sample No.							
	Blank	2A	3A	4A	5A	6A	7A	8A
Th	0.04 (.0)	0.0726 (0.0464)	0.164 (0.038)	0.0438 (0.0049)	0.195 (0.025)	0.465 (0.057)	—	—
Cr	10.8 (.0)	3.17 (0.62)	4.86 (0.50)	2.85 (0.65)	5.84 (0.51)	7.48 (0.70)	—	—
Hf	—	0.0457 (0.0521)	0.0758 (56.5)	0.108 (0.049)	0.148 (0.028)	0.354 (0.062)	—	—
Sb	0.66 (—)	65.5 (0.6)	56.5 (1.1)	87.4 (0.3)	27.4 (0.2)	81.3 (0.5)	—	—
Ag	—	8.74 (1.27)	6.62 (1.41)	11.1 (1.6)	4.62 (0.52)	12.5 (1.4)	—	—
Sc	0.04 (—)	0.221 (0.184)	0.386 (0.050)	0.154 (0.041)	0.290 (0.026)	0.524 (0.118)	—	—
Fe	373 (26)	952 (241)	801 (58)	739 (82.)	1140 (30)	3170. (85.)	—	—
Zn	116 (4)	10980 (118)	4120. (45)	4350 (48)	2080 (23)	6610. (72.)	—	—
Co	1.14 (.0)	2.89 (0.05)	2.77 (0.12)	2.74 (0.07)	2.74 (0.07)	7.49 (0.05)	—	—

Table A-2

Trace Element Concentrations and Analytical Errors (Both in ng/m^3) Found in the INAA Investigations in this Study for Sample Numbers Shown. Dashes Indicate Data Not Available

Element	Concentration and analytical error (in parenthesis) by sample No.							
	11A	12A	13A	14A	15A	16A	18A	20A
Ti	56.5 (-)	152. (13.)	112. (30.)	170. (45.)	55.2 (22.3)	127. (42.1)	47.3 (23.1)	148. (35.)
Mg	-	1282. (449.)	-	347 (559)	264. (219.)	1270. (454.)	-	-
Cu	117. (-)	116. (5.)	90.0 (19.7)	170. (25.)	64.5 (12.2)	85.9 (22.3)	164. (14.)	157. (19.)
V	1.40 (-)	3.42 (0.07)	2.26 (0.27)	2.80 (0.28)	1.47 (0.29)	3.25 (0.55)	1.13 (0.17)	1.60 (0.23)
Al	620. (-)	1701. (13.)	1220. (246.)	1350. (40.)	967. (31.)	2000. (63.)	722. (24.)	1200. (38.)
Ca	264. (-)	841. (20.)	534. (255.)	371. (142.)	391. (121.)	1130. (217.)	379. (115.)	447. (133.)
Bg	20.3 (-)	46.1 (2.5)	19.8 (5.1)	45.8 (7.0)	21.7 (-)	63.2 (10.2)	42.1 (6.9)	27.9 (5.8)
I	1.66 (-)	1.79 (0.25)	1.61 (0.22)	1.31 (0.37)	1.11 (-)	1.04 (0.50)	1.18 (0.35)	1.34 (0.30)
Br	70.3 (-)	39.6 (3.6)	23.1 (8.8)	71.8 (1.7)	36.9 (-)	39.7 (1.0)	39.9 (1.0)	29.0 (0.8)
In	1.49 (-)	3.55 (0.37)	0.173 (0.025)	2.74 (0.05)	0.258 (-)	3.44 (0.08)	3.18 (0.05)	1.80 (0.03)
Na	156 (-)	318. (62.)	236. (37.)	257. (39.)	217. (-)	517. (38.)	110. (32.)	152. (32.)
Cl	129 (-)	198. (33.)	-	146. (29.)	-	153. (30.)	132. (24.)	198. (24.)
Mn	46.8 (-)	60.6 (9.5)	49.1 (6.8)	82.6 (2.0)	49.4 (-)	105. (2.)	70.0 (1.7)	51.6 (1.3)
As	67.7 (13.0)	143.7 (3.7)	11.2 (0.3)	22.7 (3.8)	22.2 (2.9)	41.1 (2.8)	19.0 (0.4)	21.7 (5.9)
K	536. (169.)	775. (20.)	583. (74.)	6210. (399.)	347. (64.)	3520. (402.)	3820. (2560.)	1560. (237.)
Cd	106. (7.)	198. (7.)	330 (-)	466. (91.)	330 (-)	538. (79.)	775. (89.)	84.6 (-)
Ga	-	-	-	-	-	-	-	-
H	-	-	-	-	-	-	-	-
Sn	0.115 (0.020)	0.167 (0.024)	0.156 (0.014)	-	-	-	-	-
Au	10.5 (2.7)	14.1 (3.1)	3.54 (1.24)	-	-	-	-	-
La	0.800 (0.177)	1.11 (0.23)	1.10 (0.16)	-	-	-	-	-
Eu	-	-	-	0.0962 (0.0306)	0.0422 (0.0095)	0.0744 (0.0050)	0.0470 (0.0024)	0.0522 (0.0045)
Se	-	-	-	4.35 (0.67)	1.89 (0.16)	3.86 (0.53)	3.53 (0.57)	4.15 (0.52)
Ce	-	-	-	2.13 (0.26)	1.50 (0.07)	3.34 (0.12)	1.42 (0.12)	2.28 (0.09)
Hg	-	-	-	110. (3.)	19.4 (0.6)	162. (2.)	78.0 (1.5)	68.7 (1.2)
Th	-	-	-	0.296 (0.074)	0.237 (0.016)	0.449 (0.050)	0.153 (0.032)	0.293 (0.024)

Continued next page

Table A-2 (continued)

Element	Concentration and analytical error (in parenthesis) by sample No.							
	11A	12A	13A	14A	15A	16A	18A	20A
Cr	—	—	—	14.9 (1.0)	8.44 (0.24)	11.7 (0.4)	4.16 (0.40)	12.2 (0.3)
Hf	—	—	—	0.119 (0.062)	0.0965 (0.0002)	0.193 (0.016)	0.0979 (0.0419)	0.148 (0.024)
Sb	—	—	—	205. (1.)	10.3 (-0)	60.7 (0.7)	85.1 (0.7)	29.4 (0.4)
Ag	—	—	—	9.18 (1.45)	1.34 (0.14)	8.54 (0.74)	7.11 (1.13)	5.26 (0.46)
Sc	—	—	—	0.345 (0.045)	0.275 (0.005)	0.518 (0.075)	0.230 (0.114)	0.350 (0.069)
Fe	—	—	—	1920. (16)	1080. (30.)	2430. (15.)	1140. (122.)	1580. (12.)
Zn	—	—	—	4550 (54)	509. (4.)	3470. (41.)	5500. (64.)	3060. (56.)
Co	—	—	—	3.43 (0.08)	1.57 (0.04)	3.85 (0.09)	1.89 (0.02)	2.61 (0.06)

Table A-3

Trace Element Concentrations and Analytical Errors (Both in ng/m³) Found in the INAA Investigations in this Study for Sample Numbers Shown. Dashes Indicate Data Not Available

Element	Concentration and analytical error (in parenthesis) by sample No.							
	21A	27A	28A	30A	31A	33A	34A	36A
Ti	161. (38.)	<42 (-)	51.8 (-)	52.4 (19.1)	133. (48.)	121. (44.)	91.4 (37.0)	<90 (-)
Hg	472. (356.)	-	958. (538.)	412. (184.)	704. (416.)	-	-	-
Cu	186. (22.)	85.1 (13.5)	160. (30.)	79.5 (10.1)	123. (25.)	179. (26.)	105. (21.)	292. (30.)
V	3.29 (0.32)	0.92 (0.14)	1.98 (0.26)	1.04 (0.15)	3.98 (0.37)	3.30 (0.34)	2.35 (0.30)	1.84 (0.28)
Al	1750. (57.)	457. (15.)	1160. (37.)	692. (23.)	2500. (78.)	1600. (51.)	1390. (45.)	924. (30.)
Ca	532. (150.)	80.6 (79.3)	614 (-)	497. (104.)	905. (180.)	647. (205.)	659. (187.)	780. (221.)
Ba	30.2 (6.2)	41.6 (7.0)	106. (36.)	21.4 (4.3)	77.4 (10.9)	47.7 (10.7)	32.9 (9.2)	45.3 (15.3)
I	1.18 (0.38)	0.77 (0.41)	<2. (-)	0.970 (0.264)	2.21 (0.54)	2.03 (0.62)	1.23 (0.47)	2.22 (0.86)
Br	34.5 (1.0)	40.7 (2.0)	53.6 (3.9)	61.5 (1.86)	85.9 (3.3)	129. (4.)	107. (3.)	118. (5.)
In	1.21 (0.02)	6.23 (0.15)	23.0 (0.7)	1.61 (0.02)	4.13 (0.10)	5.41 (0.13)	1.54 (0.04)	9.82 (0.23)
Na	274. (54.)	134. (33.)	242. (38.)	94.4 (31.3)	412. (38.)	260. (42.)	195. (43.)	113. (45.)
Cl	338. (41.)	198. (26.)	389. (45.)	106. (25.)	310. (51.)	920. (39.)	619. (36.)	1540. (51)
Mn	46.7 (1.3)	26.0 (0.8)	65.9 (2.7)	38.9 (1.0)	77.8 (1.9)	79.7 (2.0)	79.8 (2.0)	87.3 (2.3)
As	364. (44.)	1570. (24.)	2510. (10.)	453. (55.)	776. (139.)	161. (5.)	58.0 (4.2)	330. (15.)
K	900. (200.)	407. (41.)	798. (124.)	516. (142.)	1300. (123.)	999. (5.)	1190. (198.)	977. (118.)
Cd	301. (14.)	392. (11.)	285. (3.)	319. (24.)	443. (102.)	1540. (32.)	304. (8.)	2890. (77.)
Ga	0.867 (0.523)	-	-	-	1.87 (0.62)	1.77 (0.71)	2.84 (0.71)	3.57 (0.63)
W	3.39 (1.60)	-	-	1.97 (1.02)	-	2.33 (1.48)	3.73 (1.40)	4.17 (1.91)
Sr	0.247 (0.007)	0.0759 (0.0060)	0.157 (0.008)	0.135 (0.006)	0.306 (0.008)	0.200 (0.007)	0.330 (0.006)	0.246 (0.009)
Au	3.59 (1.02)	12.2 (1.3)	3.48 (1.21)	5.75 (1.04)	4.68 (1.25)	6.86 (1.12)	4.00 (0.87)	10.0 (1.3)
La	1.39 (0.07)	0.592 (0.046)	1.04 (0.06)	0.836 (0.047)	1.73 (0.07)	1.06 (0.55)	2.07 (0.06)	1.37 (0.07)
Eu	0.0459 (0.0379)	0.0448 (0.00375)	0.0571 (0.0255)	0.0293 (0.0041)	0.0921 (0.0222)	-	-	-
Se	2.81 (0.13)	5.79 (1.34)	2.34 (0.31)	3.74 (0.08)	5.94 (0.27)	-	-	-
Ce	3.29 (0.19)	1.36 (0.17)	1.75 (0.17)	1.59 (0.13)	3.23 (0.18)	-	-	-
Hg	79.9 (2.2)	152. (5.)	79.8 (2.0)	67.7 (1.6)	109. (2.)	-	-	-

Continued next page

Table A-3 (continued)

Element	Concentration and analytical error (in parenthesis) by sample No.							
	21A	27A	28A	30A	31A	33A	34A	36A
Th	0.358 (0.046)	0.121 (0.071)	0.240 (0.042)	0.163 (0.037)	0.440 (0.046)	—	—	—
Cr	8.23 (0.59)	4.72 (0.63)	6.13 (0.56)	5.80 (0.44)	8.32 (0.57)	—	—	—
Hf	0.227 (0.085)	0.0421 (0.0230)	0.117 (0.001)	0.0816 (0.0131)	0.249 (0.036)	—	—	—
Sb	22.3 (0.2)	54.3 (0.5)	89.3 (0.2)	37.1 (-0)	58.4 (0.3)	—	—	—
Ag	3.68 (0.52)	10.6 (0.8)	7.48 (1.06)	6.15 (0.67)	7.08 (0.46)	—	—	—
Se	0.508 (0.013)	0.134 (0.046)	0.277 (0.058)	0.202 (0.038)	0.658 (0.072)	—	—	—
Fe	2030. (152.)	770. (72.)	1420. (2.)	1060. (11.)	2630. (64.)	—	—	—
Zn	1790. (24.)	3820. (49.)	3350. (43.)	2290. (29.)	3750. (48)	—	—	—
Co	2.72 (0.04)	1.92 (0.12)	3.40 (0.03)	1.82 (0.21)	3.69 (0.05)	—	—	—

Table A-4

Trace Element Concentrations and Analytical Errors (Both in ng/m^3) Found in the INAA Investigations in this Study for Sample Numbers Shown. Dashes Indicate Data Not Available

Element	Concentration and analytical error (in parenthesis) by sample No.						
	38A	39A	40A	41A	42A	43A	44A
Ti	<54 (-)	101. (62.)	<75 (-)	52.9 (14.7)	123. (31.)	<120 (-)	<40 (-)
Hg	-	-	-	-	359. (262.)	-	-
Cu	138. (17.)	301. (38.)	238. (27.)	51.7 (8.4)	59.2 (13.8)	513. (51.)	168. (15.)
V	0.762 (0.146)	2.66 (0.34)	1.77 (0.24)	0.892 (0.118)	1.79 (0.23)	1.55 (0.25)	0.716 (0.131)
Al	502. (11.)	1500. (98.)	1040. (33.)	694. (22.)	1200. (38.)	406. (15.)	308. (11.)
Ca	858. (223.)	1310. (267.)	722. (194.)	556. (115.)	171. (103.)	746. (258.)	681. (130.)
Ba	<24 (-)	<42 (-)	42.6 (13.0)	15.6 (3.5)	19.3 (3.6)	-	74.6 (15.6)
I	2.28 (0.75)	4.46 (1.58)	2.78 (0.85)	0.909 (0.220)	1.32 (0.24)	<1.1 (-)	1.63 (0.84)
Br	200. (5.)	244. (8.)	195. (6.)	42.6 (1.4)	38.5 (1.5)	128. (1.)	205. (6.)
In	8.50 (0.20)	16.3 (0.3)	6.48 (0.15)	0.0635 (0.0423)	0.199 (0.000)	43.5 (1.4)	9.10 (0.47)
Na	84.8 (39.1)	271. (51.)	260. (37.)	134. (36.)	176. (32.)	269. (52.)	297. (41.)
Cl	583. (37.)	1230. (66.)	1260. (42.)	142. (26.)	138. (24.)	1300. (85.)	1070. (44.)
Mn	50.1 (1.5)	214. (5.)	107. (3.)	31.3 (0.8)	48.6 (1.2)	113. (4.)	97.8 (2.5)
As	252. (18.)	528. (55.)	419. (35.)	8.28 (1.58)	13.7 (-0)	1210. (16.)	189. (4.)
K	478. (92.)	1630. (227.)	723. (61.)	644. (112.)	529. (51.)	533. (151.)	446. (9.)
Cd	728. (38.)	2490. (128.)	2040. (209.)	-	-	1940. (28.)	2430. (15.)
Ga	2.18 (1.66)	3.86 (0.77)	2.37 (1.05)	1.59 (0.13)	0.945 (0.093)	4.42 (0.18)	1.99 (0.82)
W	-	9.43 (2.65)	6.13 (2.45)	3.47 (1.69)	-	5.34 (3.63)	4.44 (1.15)
Sr	0.0828 (0.0076)	0.225 (0.015)	-	0.315 (0.007)	0.337 (0.007)	0.138 (0.038)	0.208 (0.018)
Au	3.77 (1.20)	17.5 (2.3)	-	3.16 (0.79)	4.52 (0.77)	43.1 (4.5)	23.7 (2.9)
La	0.423 (0.052)	1.13 (0.08)	-	1.88 (0.08)	1.73 (0.07)	0.849 (0.194)	1.21 (0.11)
Eu	-	-	0.120 (0.009)	0.0362 (0.0101)	0.0323 (0.0055)	0.175 (0.011)	0.127 (0.006)
Se	-	-	12.5 (2.4)	2.03 (0.15)	0.644 (0.040)	17.6 (3.6)	16.0 (1.8)
Ce	-	-	3.96 (0.51)	1.82 (0.09)	1.90 (0.10)	2.41 (0.63)	1.68 (0.28)
Hg	-	-	309. (6.)	10.8 (0.6)	15.9 (0.6)	504. (10.)	250. (5.)

Continued next page

Table A-4 (continued)

Element	Concentration and analytical error (in parenthesis) by sample No.						
	38A	39A	40A	41A	42A	43A	44A
Th	—	—	0.305 (0.108)	0.166 (0.019)	0.214 (0.018)	—	—
Cr	—	—	5.67 (1.55)	6.87 (0.39)	7.87 (0.26)	6.55 (2.16)	2.61 (0.92)
Hf	—	—	0.187 (0.037)	0.0725 (0.0221)	0.0858 (0.0223)	0.261 (0.140)	0.0957 (0.0580)
Sb	—	—	486. (—0)	5.21 (0.25)	10.0 (0.3)	1210. (1.)	245. (—0)
Ag	—	—	29.3 (5.4)	0.936 (0.181)	1.67 (0.21)	36.5 (6.7)	31.0 (3.0)
Sc	—	—	0.290 (0.056)	0.211 (0.007)	0.257 (0.001)	0.457 (0.018)	0.185 (0.099)
Fe	—	—	2680. (349.)	901. (14.)	1320. (59.)	3100. (257.)	2420. (112.)
Zn	—	—	5770. (75.)	335. (5.)	270. (4.)	14900. (187.)	8380. (105.)
Co	—	—	3.94 (0.37)	1.16 (0.01)	1.44 (0.02)	7.09 (0.74)	5.03 (0.34)

Table A-5

Average Concentration $\langle C \rangle$ of Each Trace Element for the Samples It Was Found in by the INAA Investigations, and the Minimum and Maximum Concentrations Found. All Values Are ng/m^3 . Errors in Parenthesis at Right of $\langle C \rangle$ Values Are Standard Deviations

Trace element	Number of samples	C	C _{min}	C _{max}
Ti	29	95.7(40.5)	<40	170
Mg	10	718.(371.)	264	1270
Cu	30	181.(115.)	51.7	513
V	30	2.01(0.93)	0.716	3.98
Al	30	1050.(606.)	203.	2500.
Ca	30	583.(298.)	80.6	1310.
Ba	29	39.0(21.7)	<10	106.
I	30	1.94(1.05)	0.770	6.05
Br	30	91.9(62.5)	23.1	244.
In	30	5.79(8.64)	0.0635	43.3
Na	30	207.(82.)	84.8	412.
Cl	27	498.(432.)	106.	1300.
Mn	30	71.3(41.1)	26.0	214.
As	30	329.(549.)	8.28	2510
K	30	1110.(1270.)	277	6210
Cd	28	748.(829.)	<30	2890
Ga	12	2.36(1.12)	0.867	4.42
W	10	4.44(2.15)	1.97	9.43
Sm	24	0.184(0.090)	0.0491	0.337
Au	24	9.76(8.77)	2.97	43.1
La	24	1.09(0.49)	0.279	2.07
Eu	20	0.0663(0.0362)	0.0293	0.173
Se	20	5.23(4.64)	0.644	17.6
Ce	20	2.07(0.86)	0.961	3.96
Hg	20	113.(119.)	10.8	504
Th	18	0.243(0.125)	0.0438	0.465
Cr	20	6.82(3.25)	2.61	14.9
Hf	20	0.140(0.081)	0.0457	0.354
Sb	20	146.(274.)	5.21	1210.
Ag	20	10.5(10.0)	0.936	36.5
Sc	20	0.322(0.145)	0.134	0.518
Fe	20	1660.(815.)	739	3170.
Zn	20	4480.(3620.)	270	14900.
Co	20	3.21(1.70)	1.16	7.49

Appendix B

TYPICAL CONSAP COMPUTER OUTPUT OF XRFA DATA

An example of the computer output from the CONSAP code used in analyzing the XRFA data is shown here. The data is for sample IAS-21A, for the last count following the long irradiation (L3).

THIS IS THE DATA RUN FOR ZIP

THE STANDARD FOR THIS RUN IS NR4.

PEAK CRITERIA

REJECTED PEAKS

ANY PEAK WHICH CONTAINS ONLY A SINGLE CHANNEL

ANY PEAK WHICH CONTAINS MORE THAN 20 CHANNELS

CODE FOR ACCEPTED PEAKS

1	NORMAL	PEAK
2	DOUBLE	PEAK
3	TRIPLE	PEAK
4	QUADRUPLE	PEAK
5	QUINTUPLE	PEAK
6	HEXAD	PEAK
7	SEPTUPLE	PEAK
8	OCTAD	PEAK
9	NONA -	PEAK

***** LIBRARY USED *****

NAME (PRINT)	ENERGY	STD MASS	TI STD	CTS STD	BLANK1	BLANK2	HALF-LIFE
EU 152 1	121.80	11.70	1.00	1.00	0.	0.02	4638.68
HF 181 1	133.10	21.90	1.00	1.00	0.	0.	42.30
SE 75 1	136.00	1251.00	1.00	1.00	0.	0.	120.00
CE 141 1	145.50	3540.00	1.00	1.00	0.	0.33	32.50
SE 75 1	264.70	1251.00	1.00	1.00	0.	0.	120.00
HG 203 1	279.20	10245.00	1.00	1.00	0.	5.52	46.90
PA 233 1	311.90	414.00	1.00	1.00	0.	0.04	27.00
CR 51 1	320.10	14517.00	1.00	1.00	0.	10.82	27.00
HF 175 1	343.40	21.90	1.00	1.00	0.	0.	70.00
EU 152 1	344.20	11.70	1.00	1.00	0.	0.02	4638.68
HF 181 1	482.20	21.90	1.00	1.00	0.	0.	42.30
SB 124 1	602.70	1263.00	1.00	1.00	0.	0.66	60.30
AG110M 1	657.70	1830.00	1.00	1.00	0.	0.	255.00
AG108M 1	723.00	1830.00	1.00	1.00	0.	0.	1826.25
CO 58 1	811.10	156900.00	1.00	1.00	0.	0.	71.30
AG110M 1	884.70	1830.00	1.00	1.00	0.	0.	255.00
SC 46 1	889.30	417.00	1.00	1.00	0.	0.04	83.90
AG110M 1	937.50	1830.00	1.00	1.00	0.	0.	255.00
FE 59 1	1099.30	301620.00	1.00	1.00	0.	373.20	45.60
ZN 65 1	1115.50	34680.00	1.00	1.00	0.	115.90	24.30
SC 46 1	1120.50	417.00	1.00	1.00	0.	0.04	83.90
CO 60 1	1173.20	3540.00	1.00	1.00	0.	1.14	1921.22
FE 59 1	1291.50	301620.00	1.00	1.00	0.	373.20	45.60
CO 60 1	1332.50	3540.00	1.00	1.00	0.	1.14	1921.22
AG110M 1	1384.20	1830.00	1.00	1.00	0.	0.	255.00
EU 152 1	1408.10	11.70	1.00	1.00	0.	0.02	4638.68
SB 124 1	1691.10	1263.00	1.00	1.00	0.	0.66	60.30

STANDARD MASSES AND COUNTS BY POSITION AND ISOTOPE

	0	1	2	3	4	POSITION
EU 152	12.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
HF 181	22.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
SE 75	1251.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	13.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
CE 141	3540.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	35.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
SE 75	1251.	-0.	-0.	-0.	-0.	STANDARD MASS

	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	13.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
HG 203	10245.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	102.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
PA 233	414.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	4.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
CR 51	14517.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	145.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
HF 175	22.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
EU 152	12.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
HF 181	22.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
SB 124	1263.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	13.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
AG110M	1830.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	18.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
AG108M	1830.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	18.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
CO 58	156900.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	1569.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
AG110M	1830.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	18.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
SC 46	417.	-0.	-0.	-0.	-0.	STANDARD MASS

	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	4.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
AG110M	1830.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	18.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
FE 59	301620.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	3016.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
ZN 65	34680.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	347.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
SC 46	417.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	4.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
CO 60	3540.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	35.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
FE 59	301620.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	3016.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
CO 60	3540.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	35.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
AG110M	1830.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	18.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
EU 152	12.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
SB 124	1263.	-0.	-0.	-0.	-0.	STANDARD MASS
	1.	-0.	-0.	-0.	-0.	STANDARD COUNT
	13.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
	5	6	7	8	9	POSITION
EU 152	-0.	-0.	-0.	-0.	-0.	STANDARD MASS

	-0.	-0.	-0.	-0.	-0.	STANDARD MASS COUNT ERROR
AG103M	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
CO 58	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
AG110M	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
SC 46	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
AG110M	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
FE 59	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
ZN 65	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
SC 46	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
CO 60	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
FE 59	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
CO 60	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	STANDARD MASS STANDARD COUNT MASS ERROR COUNT ERROR
AG110M	-0.	-0.	-0.	-0.	-0.	STANDARD MASS

	-0.	-0.	-0.	-0.	-0.	STANDARD COUNT
	-0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
EU 152	-0.	-0.	-0.	-0.	-0.	STANDARD MASS
	-0.	-0.	-0.	-0.	-0.	STANDARD COUNT
	-0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR
SB 124	-0.	-0.	-0.	-0.	-0.	STANDARD MASS
	-0.	-0.	-0.	-0.	-0.	STANDARD COUNT
	-0.	-0.	-0.	-0.	-0.	MASS ERROR
	-0.	-0.	-0.	-0.	-0.	COUNT ERROR

BLANK MASS ERRORS AND ELEMENT DETECTION LIMIT

ISOTPE	MASS ONE	MASS TWO	DETECTION LIMIT
EU 152	-0.	0.	0.
HF 181	-0.	-0.	0.
SE 75	-0.	-0.	0.
CE 141	-0.	0.	0.
SE 75	-0.	-0.	0.
HG 203	-0.	1.	0.
PA 233	-0.	0.	0.
CR 51	-0.	0.	0.
HF 175	-0.	-0.	0.
EU 152	-0.	0.	0.
HF 181	-0.	-0.	0.
SB 124	-0.	0.	0.
AG110M	-0.	-0.	0.
AG108M	-0.	-0.	0.
CO 58	-0.	-0.	0.
AG110M	-0.	-0.	0.
SC 46	-0.	-0.	0.
AG110M	-0.	-0.	0.
FE 59	-0.	26.	0.
ZN 65	-0.	4.	0.
SC 46	-0.	-0.	0.
CO 60	-0.	0.	0.
FE 59	-0.	26.	0.
CO 60	-0.	0.	0.
AG110M	-0.	-0.	0.
EU 152	-0.	0.	0.
SB 124	-0.	0.	0.

STANDARD INFORMATION FOR LONG IRRADIATION

ISOTPE	ENERGY	ISOTOPE DATA		MASS ONE	MASS TWO
		NG/AG	HALF LIFE		
EU 152	121.80	2.277198E-08	4638.68	0.	0.02
HF 181	133.10	1.342337E-05	42.30	0.	0.
SE 75	136.00	5.291315E-05	120.00	0.	0.
CE 141	145.50	1.201658E-04	32.50	0.	0.32
SE 75	264.70	1.300193E-04	120.00	0.	0.
HG 203	279.20	9.067270E-04	46.90	0.	5.52
PA 233	311.90	4.031700E-05	27.00	0.	0.04
CR 51	320.10	4.943198E-04	27.60	0.	10.82
HF 175	343.40	1.333593E-05	70.00	0.	0.

EU 152	344.20	1.388540E-07	4638.68	0.	3.02
HF 181	482.20	4.666610E-05	42.30	0.	0.
SB 124	602.70	6.830874E-05	60.30	0.	0.56
AG110M	657.70	7.283501E-05	255.00	0.	0.
AG108M	723.00	5.094424E-05	1826.25	0.	0.
CO 50	811.10	5.987642E-02	71.30	0.	0.
AG110M	884.70	1.149544E-04	255.00	0.	0.
SC 46	889.30	3.946704E-06	83.90	0.	0.04
AG110M	937.50	3.207930E-04	255.00	0.	0.
FE 59	1099.30	7.379378E-02	45.60	0.	373.20
ZN 65	1115.50	5.225693E-03	24.30	0.	115.90
SC 46	1120.50	5.118448E-06	83.90	0.	0.04
CO 60	1173.20	1.050039E-05	1921.22	0.	1.14
FE 59	1291.50	1.192747E-01	45.60	0.	373.20
CO 60	1332.50	1.192116E-05	1921.22	0.	1.14
AG110M	1384.20	6.668407E-04	255.00	0.	0.
EU 152	1408.10	1.131724E-06	4638.68	0.	0.02
SB 124	1691.10	4.474656E-04	60.30	0.	0.66

ERROR DATA

NG/AD	MASS ONE	MASS TWO	PRNT FLAG	DET. LIMIT
5.679151E-10	0.	0.0035	1	0.
1.027359E-06	0.	0.	1	0.
8.997258E-07	0.	0.	1	0.
1.435327E-06	0.	0.1507	1	0.
3.662675E-06	0.	0.	1	0.
1.336188E-05	0.	0.5625	1	0.
5.691333E-07	0.	0.0191	1	0.
5.370795E-06	0.	0.3962	1	0.
9.729985E-07	0.	0.	1	0.
1.013088E-08	0.	0.0035	1	0.
7.686062E-06	0.	0.	1	0.
0.750250E-07	0.	0.1062	1	0.
1.447156E-06	0.	0.	1	0.
3.326616E-06	0.	0.	1	0.
2.572824E-03	0.	0.	1	0.
2.777644E-06	0.	0.	1	0.
4.066014E-08	0.	0.	1	0.
1.515294E-05	0.	0.	1	0.
1.318246E-03	0.	26.2600	1	0.
6.521852E-05	0.	3.7400	1	0.
5.276157E-08	0.	0.	1	0.
1.218604E-07	0.	0.0020	1	0.
2.044955E-03	0.	26.2600	1	0.
1.375962E-07	0.	0.0020	1	0.
2.372214E-05	0.	0.	1	0.
1.331079E-07	0.	0.0035	1	0.
7.032396E-06	0.	0.1062	1	0.
START TIME	85210112	45:52:01		
TAG WRD ON CARD	7050			
TAG WRD ON TAPE	7050			
NCHAN	4096			
TAG WRD ON CARD	7051			
TAG WRD ON TAPE	7051			
NCHAN	4096			

TAG WRD ON CARD 7053
TAG WRD ON TAPE 7053
NCHAN 4096

ABNORMAL PEAK. CHANNEL NO.	95	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	110	3	PEAKS
ABNORMAL PEAK. CHANNEL NO.	143	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	172	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	183	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	264	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	950	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	1187	3	PEAKS
ABNORMAL PEAK. CHANNEL NO.	1127	5	PEAKS
ABNORMAL PEAK. CHANNEL NO.	1393	3	PEAKS
ABNORMAL PEAK. CHANNEL NO.	1466	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	1894	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	2100	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	2968	2	PEAKS
ABNORMAL PEAK. CHANNEL NO.	3911	2	PEAKS

DAYS SINCE IRRADIATION:
COUNT START: 25.435 COUNT END: 25.744

1
7050 2 0 21A 06/04/73 445.00000900 0.000001 29.444096
7050

THIS IS SPECTRUM 21A
COUNT DAY 06/04/73
COUNT HR 0900
SYSTEM NUM A1
CHAN COUNT 4096
VOLUME 29.44
THIS SPECTRUM HAS 161 PEAKS

LONE
LIVE TIME 445.000
GAIN 0.0000
SIGMA 2.0
COUNT 445.000
INTEGRATED CPM IS 3183.42

RATIO OF STANDARD TO TI COUNT THIS RUN IS R.

STANDARD INFORMATION FOR SHELF POSITION 0

ISOTOPE	MASS	COUNT	MASS ERR	COUNT ERR
EU 152	12.	1.	0.	-0.
HF 181	22.	1.	0.	-0.
SE 75	1251.	1.	13.	-0.
CE 141	3540.	1.	35.	-0.
SE 75	1251.	1.	13.	-0.
HG 203	10245.	1.	102.	-0.
PA 233	414.	1.	4.	-0.
CR 51	14517.	1.	145.	-0.
HF 175	22.	1.	0.	-0.
EU 152	12.	1.	0.	-0.
HF 181	22.	1.	0.	-0.
SB 124	1263.	1.	13.	-0.
AG110M	1830.	1.	18.	-0.
AG108M	1830.	1.	18.	-0.
CO 58	156900.	1.	1569.	-0.
AG110M	1830.	1.	18.	-0.
SC 46	417.	1.	4.	-0.
AG110M	1830.	1.	18.	-0.
FE 59	301620.	1.	3016.	-0.
ZN 65	34600.	1.	347.	-0.
SC 46	417.	1.	4.	-0.
CO 60	3540.	1.	35.	-0.
FE 59	301620.	1.	3016.	-0.
CO 60	3540.	1.	35.	-0.
AG110M	1830.	1.	18.	-0.
EU 152	12.	1.	0.	-0.
SB 124	1263.	1.	13.	-0.

PEAK INFORMATION SUMMARY

	ENERGY	ISOTP.	PK AREA	BASE CT	FSD	LOW CHAN	HIGH CHAN	NANOGRAMS	PPM OR NG/VOL
1	57.62	X	348.1	20249.9	0.581	69	76	0.	0.
2	60.04	X	1185.4	19846.5	0.171	81	88	0.	0.
2	72.94	X	2308.3	21695.7	0.093	88	96	0.	0.
1	77.33	X	510.5	14137.5	0.332	94	99	0.	0.
3	82.92	X	58.3	9223.5	1.994	101	104	0.	0.
3	83.93	X	214.3	6830.0	0.552	104	106	0.	0.

3	87.13	X	382.5	13586.0	0.434	106	111	0.	0.
1	91.08	X	73.0	13404.0	2.245	111	116	0.	0.
1	94.66	X	568.4	15335.6	0.290	115	120	0.	0.
1	98.39	X	1370.3	17515.7	0.140	119	126	0.	0.
2	110.98	X	511.9	15053.3	0.342	134	140	0.	0.
2	113.72	X	233.3	10837.0	0.519	140	144	0.	0.
1	121.89	EU 152	2772.5	21525.5	0.077	143	157	1.3725E+00	4.5940E-02
2	131.30	HF 181	1148.9	12761.6	0.142	162	167	4.6320E+00	1.5734E+01
2	133.30	SE 75	2324.0	14730.6	0.077	167	173	7.9863E+01	2.7127E+00
2	142.43	X	227.3	8280.7	0.571	175	179	0.	0.
2	145.53	CE 141	3087.3	14287.6	0.058	178	184	9.7151E+01	3.2087E+00
1	185.40	X	370.4	11254.6	0.408	228	233	0.	0.
1	192.37	X	1269.9	16908.1	0.148	234	242	0.	0.
1	197.90	X	428.3	11256.7	0.354	243	248	0.	0.
2	208.64	X	545.1	11247.7	0.279	256	261	0.	0.
2	210.97	X	420.2	9429.6	0.331	261	265	0.	0.
1	216.34	X	834.6	13134.4	0.197	265	271	0.	0.
1	218.26	X	575.8	11188.2	0.263	269	274	0.	0.
1	238.89	X	640.3	11620.7	0.241	294	300	0.	0.
1	264.86	SE 75	1010.3	11027.7	0.150	325	332	8.5313E+01	2.0979E+00
1	279.48	HG 203	8527.6	12645.4	0.022	343	352	2.3570E+03	7.9873E+01
1	312.04	PA 233	1080.3	9951.7	0.128	384	391	1.0589E+01	3.5833E-01
1	320.50	CR 51	2084.5	8894.5	0.068	394	401	2.5312E+02	8.2302E+00
1	336.33	X	392.6	6464.4	0.294	415	420	0.	0.
1	344.81	HF 175	637.7	7421.3	0.195	425	431	3.5805E+00	1.2162E-01
1	365.21	X	255.5	6017.5	0.434	451	456	0.	0.
1	397.53	X	161.9	5945.1	0.678	491	496	0.	0.
1	400.46	X	275.9	5970.1	0.401	494	499	0.	0.
1	413.12	X	468.5	5843.5	0.235	510	515	0.	0.
1	419.05	X	436.2	6562.8	0.267	517	523	0.	0.
1	482.58	HF 181	582.8	6342.2	0.190	595	603	8.1686E+00	2.7747E-01
1	511.64	X	6049.8	8066.2	0.025	629	640	0.	0.
1	528.42	X	214.4	3842.6	0.415	653	658	0.	0.
1	564.61	X	1682.9	5664.1	0.068	696	704	0.	0.
1	603.26	SB 124	25810.7	8094.3	0.008	742	754	6.6606E+02	2.2602E+01
1	646.43	X	1701.1	5588.9	0.067	798	806	0.	0.
1	658.29	AG110M	991.6	5635.4	0.112	813	821	9.2171E+01	3.1308E+00
1	669.63	X	426.9	4468.1	0.227	828	834	0.	0.
1	688.13	X	188.1	3762.9	0.467	851	856	0.	0.
1	714.38	X	474.3	4024.7	0.212	883	890	0.	0.
1	723.28	AG108M	2121.8	6031.2	0.056	893	902	9.3857E+02	3.1609E+01
2	763.61	X	197.8	2441.6	0.362	945	948	0.	0.
2	764.93	X	182.8	2444.5	0.391	948	951	0.	0.
1	779.03	X	141.0	3723.0	0.618	964	969	0.	0.
1	791.34	X	153.6	3810.4	0.574	979	984	0.	0.
1	796.28	X	255.1	3841.9	0.343	985	990	0.	0.
3	833.17	AG110M	275.2	3314.1	0.303	1093	1096	4.0378E+01	1.3715E+00
3	884.76	AG110M	677.0	4120.3	0.140	1096	1100	9.9320E+01	3.3736E+00
3	889.70	SC 46	7988.5	7258.5	0.019	1100	1108	1.5256E+01	5.1686E-01
1	896.55	X	560.0	5406.0	0.190	1108	1114	0.	0.
5	899.07	X	444.3	3760.2	0.201	1112	1116	0.	0.
5	901.34	X	295.3	2897.5	0.266	1116	1119	0.	0.
5	903.10	X	233.1	2108.0	0.289	1119	1121	0.	0.
5	905.39	X	461.9	3375.4	0.185	1121	1125	0.	0.
5	907.65	X	237.3	2549.3	0.309	1125	1128	0.	0.
1	909.70	X	273.4	3679.6	0.320	1126	1131	0.	0.
1	938.42	AG110M	306.7	3322.3	0.272	1160	1167	1.2555E+02	4.2646E+00
1	969.48	X	498.9	2982.1	0.161	1197	1205	0.	0.
1	1015.15	X	71.5	1102.5	0.667	1256	1261	0.	0.
1	1045.51	X	269.6	1387.2	0.205	1292	1300	0.	0.

1	1099.62	FE 59	2460.6	1518.4	0.838	1359	1368	5.7033E+04	1.9246E+03
1	1106.52	X	144.2	886.8	0.304	1369	1374	0.	0.
3	1109.00	X	147.2	722.0	0.273	1372	1376	0.	0.
3	1115.94	ZN 65	42987.5	1617.9	0.005	1376	1387	5.2877E+04	1.7922E+03
3	1120.93	SC 46	5940.4	929.9	0.815	1387	1394	1.4713E+01	4.9841E-01
1	1173.54	CD 60	962.4	703.6	0.855	1450	1459	8.1975E+01	2.7457E+00
2	1180.55	X	93.0	267.2	0.272	1461	1464	0.	0.
2	1181.55	X	45.4	257.9	0.528	1464	1467	0.	0.
1	1291.96	FE 59	1691.4	574.6	0.832	1596	1606	6.3368E+04	2.1398E+03
1	1297.23	X	132.6	361.4	0.221	1604	1613	0.	0.
1	1326.06	X	192.1	457.9	0.173	1639	1646	0.	0.
1	1326.86	CD 60	745.3	635.7	0.060	1647	1657	8.0433E+01	2.6934E+00
1	1356.42	X	144.5	459.5	0.226	1676	1683	0.	0.
1	1368.67	X	235.5	497.5	0.149	1692	1699	0.	0.
1	1384.79	AG110M	136.2	445.8	0.235	1713	1719	1.1595E+02	3.9385E+00
1	1437.25	X	159.4	539.6	0.221	1777	1784	0.	0.
1	1461.48	X	207.5	546.5	0.174	1806	1814	0.	0.
1	1488.99	X	59.2	243.8	0.395	1842	1847	0.	0.
1	1505.19	X	42.1	216.9	0.519	1862	1867	0.	0.
2	1526.46	X	56.7	154.5	0.340	1888	1892	0.	0.
2	1527.84	X	26.2	120.0	0.739	1892	1895	0.	0.
1	1666.71	X	22.5	79.5	0.534	2062	2067	0.	0.
2	1685.97	X	19.8	48.7	0.556	2086	2089	0.	0.
2	1691.39	SB 124	3879.8	144.6	0.817	2089	2101	6.5586E+02	2.2256E+01
1	1721.81	X	31.6	55.4	0.378	2129	2134	0.	0.
1	1763.64	X	27.6	55.4	0.427	2181	2187	0.	0.
1	1830.73	X	18.3	48.7	0.589	2264	2269	0.	0.
1	1862.78	X	10.3	16.7	0.643	2427	2432	0.	0.
1	1965.97	X	8.8	15.2	0.711	2431	2436	0.	0.
1	2004.47	X	16.4	18.6	0.445	2479	2484	0.	0.
1	2010.04	X	25.3	20.7	0.324	2485	2491	0.	0.
1	2062.17	X	5.7	11.3	0.925	2550	2555	0.	0.
1	2091.65	X	356.1	29.9	0.057	2563	2593	0.	0.
1	2177.02	X	8.0	6.0	0.559	2692	2697	0.	0.
1	2182.77	X	10.9	6.1	0.439	2699	2704	0.	0.
1	2241.30	X	3.5	5.5	1.096	2771	2776	0.	0.
1	2294.19	X	26.1	5.9	0.236	2834	2841	0.	0.
1	2296.43	X	14.1	4.9	0.347	2839	2844	0.	0.
1	2334.54	X	4.9	5.1	0.795	2886	2891	0.	0.
1	2357.25	X	3.9	5.1	0.969	2914	2919	0.	0.
2	2396.79	X	2.1	2.1	1.271	2963	2966	0.	0.
2	2398.07	X	3.7	1.5	0.741	2966	2969	0.	0.
1	2405.91	X	5.2	1.8	0.577	2974	2979	0.	0.
1	2429.44	X	4.4	1.6	0.624	3003	3008	0.	0.
1	2433.49	X	4.3	1.7	0.655	3008	3013	0.	0.
1	2449.17	X	6.9	3.1	0.525	3027	3032	0.	0.
1	2477.84	X	5.1	1.9	0.580	3063	3068	0.	0.
1	2541.40	X	6.2	1.8	0.505	3140	3146	0.	0.
1	2548.38	X	3.0	1.0	0.740	3150	3155	0.	0.
1	2555.20	X	1.0	1.0	1.737	3158	3163	0.	0.
1	2558.17	X	2.0	1.0	1.031	3162	3167	0.	0.
1	2561.63	X	1.0	1.0	1.729	3166	3171	0.	0.
1	2571.97	X	3.1	0.9	0.705	3179	3184	0.	0.
1	2605.52	X	4.3	2.7	0.721	3219	3225	0.	0.
1	2614.54	X	41.0	4.0	0.171	3229	3238	0.	0.
1	2637.19	X	4.2	0.8	0.568	3259	3264	0.	0.
1	2672.91	X	2.9	1.1	0.770	3302	3308	0.	0.
1	2716.23	X	2.1	0.9	0.969	3356	3361	0.	0.
1	2755.77	X	1.4	0.6	1.137	3405	3410	0.	0.
1	2761.46	X	3.3	0.7	0.667	3412	3417	0.	0.

1 2775.00	X	3.1	0.9	0.704	3429	3434	0.	0.
1 2778.52	X	3.1	0.9	0.711	3432	3438	0.	0.
1 2787.75	X	3.7	0.3	0.565	3444	3449	0.	0.
1 2814.28	X	2.8	0.2	0.649	3476	3482	0.	0.
1 2827.29	X	2.7	0.3	0.661	3493	3498	0.	0.
1 2829.75	X	3.7	0.3	0.559	3496	3501	0.	0.
1 2837.52	X	3.7	0.3	0.564	3505	3510	0.	0.
1 2851.68	X	1.6	0.4	0.979	3523	3528	0.	0.
1 2850.09	X	4.1	0.9	0.597	3533	3538	0.	0.
1 2930.59	X	3.8	1.2	0.648	3620	3625	0.	0.
1 2941.98	X	3.1	0.9	0.714	3633	3639	0.	0.
1 2952.29	X	2.7	0.3	0.656	3647	3652	0.	0.
1 2967.22	X	2.4	0.6	0.792	3654	3670	0.	0.
1 2972.10	X	2.5	0.5	0.742	3671	3676	0.	0.
1 2987.90	X	3.7	0.3	0.570	3690	3695	0.	0.
1 2991.64	X	2.6	0.4	0.710	3694	3700	0.	0.
1 2998.16	X	1.8	0.2	0.809	3703	3708	0.	0.
1 3028.02	X	2.7	0.3	0.667	3740	3745	0.	0.
1 3038.89	X	3.8	0.2	0.542	3753	3758	0.	0.
1 3059.26	X	2.0	0.0	0.733	3778	3783	0.	0.
1 3088.60	X	1.9	0.1	0.792	3814	3819	0.	0.
1 3095.13	X	2.6	0.4	0.692	3822	3827	0.	0.
1 3106.54	X	3.0	1.0	0.758	3835	3841	0.	0.
1 3126.73	X	4.7	1.3	0.577	3861	3866	0.	0.
2 3163.38	X	3.1	0.4	0.675	3906	3909	0.	0.
2 3164.80	X	3.1	0.4	0.668	3909	3912	0.	0.
1 3167.47	X	2.5	0.5	0.747	3911	3916	0.	0.
1 3190.60	X	1.5	0.5	1.052	3939	3944	0.	0.
1 3196.32	X	4.3	0.7	0.559	3945	3951	0.	0.
1 3206.93	X	2.0	1.0	1.031	3958	3964	0.	0.
1 3222.46	X	1.1	0.9	1.490	3978	3983	0.	0.
1 3242.61	X	2.9	1.1	0.762	4003	4008	0.	0.
1 3255.97	X	2.2	0.8	0.897	4019	4024	0.	0.
1 3264.96	X	1.4	0.6	1.155	4030	4035	0.	0.
1 3280.50	X	1.8	0.2	0.818	4049	4054	0.	0.

ELEMENT CONCENTRATION SUMMARY

SAMPLE: 21A
 COLLECTION DATE: 07/13/72
 COLLECTION TIME: 24
 ANALYSIS TYPE: L3
 VOLUME TO AREA RATIO: -0.
 SAMPLING ERROR PCT: 1
 IRRADIATION DATE: 05/09/73
 CUT NUMBER: -0

IN THE TABLE BELOW A ZERO ENTRY IN THE ERROR COLUMN INDICATES THAT
 THE MINIMUM DETECTION LIMIT IS ENTERED IN THE MICROGRAM COLUMN

ELEMENT	MICROGRAM/VOL	+ MICROGRAM/VOL
EU	4.594E-05	3.785E-06
HF	1.573E-04	2.543E-05
SE	2.713E-03	2.135E-04
CE	3.289E-03	1.944E-04
SE	2.898E-03	4.432E-04
HG	7.987E-02	2.171E-03
PA	3.583E-04	4.640E-05
CR	8.230E-03	5.891E-04
HF	1.216E-04	2.533E-05
HF	2.775E-04	7.138E-05
SB	2.260E-02	3.410E-04
AG	3.131E-03	3.551E-04
AG	3.161E-02	2.722E-03
AG	1.372E-03	4.168E-04
AG	3.374E-03	4.609E-04
SC	9.169E-04	1.111E-05
AG	4.265E-03	1.177E-03
FE	1.925E+00	6.787E-02
ZN	1.792E+00	2.416E-02
SC	4.984E-04	9.099E-06
CO	2.746E-03	1.572E-04
FE	2.140E+00	7.722E-02
CO	2.693E-03	1.676E-04
AG	3.938E-03	9.373E-04
SB	2.226E-02	5.181E-04

	0	1	2	21A	3	4	5	6	7	8	9
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
50	2.	9.	2.	3.	38.	89.	296.	1003.	728.	865.	865.
60	1415.	1536.	1678.	1671.	1748.	1928.	2063.	2142.	2243.	2359.	2359.
70	2711.	2963.	2709.	2682.	2507.	2502.	2376.	2595.	2568.	2389.	2389.
80	2335.	2450.	2682.	2785.	2912.	2724.	2620.	2547.	2443.	2380.	2380.
90	3144.	2791.	2538.	2519.	2391.	2562.	2369.	2425.	2428.	2443.	2443.
100	2255.	2288.	2411.	2387.	2389.	2369.	2369.	2369.	2369.	2369.	2369.
110	2175.	2159.	2342.	2334.	2260.	2207.	2359.	2359.	2359.	2359.	2359.
120	2328.	2670.	2674.	2431.	2181.	2194.	2083.	2188.	2213.	2213.	2213.

130	2179.	2055.	2139.	2065.	2099.	2252.	2254.	2388.	2381.	2253.
140	2266.	2267.	2163.	2174.	2170.	2213.	2228.	2155.	2228.	2402.
150	3017.	3180.	2563.	2372.	2263.	2044.	2155.	2160.	2160.	2199.
160	2125.	2241.	2194.	2291.	2445.	2527.	2304.	2463.	3005.	2843.
170	2249.	2141.	2136.	2218.	2088.	2189.	2279.	2162.	2327.	2825.
180	3266.	2670.	2088.	2087.	2088.	1961.	1993.	1980.	2016.	1944.
190	2026.	1945.	2021.	1971.	1916.	1942.	1960.	1929.	1934.	1910.
200	1927.	1852.	1914.	1845.	1934.	1886.	1770.	1893.	1841.	1847.
210	1816.	1837.	1835.	1832.	1903.	1864.	1787.	1850.	1914.	1905.
220	1884.	1922.	1861.	1845.	1991.	1893.	1917.	1870.	1854.	2017.
230	1987.	1956.	1941.	1863.	1945.	1971.	2056.	2097.	2427.	2915.
240	1871.	1862.	1834.	1914.	2020.	2096.	1948.	1873.	1892.	1854.
250	1875.	1874.	1796.	1808.	1837.	1876.	1911.	1960.	2090.	2221.
260	1985.	1997.	1907.	1969.	1962.	1963.	1976.	2035.	2075.	1925.
270	2035.	1954.	1891.	1886.	1909.	1945.	1900.	1906.	1841.	1851.
280	1881.	1896.	1823.	1755.	1871.	1783.	1802.	1743.	1710.	1751.
290	1678.	1736.	1693.	1692.	1751.	1847.	1871.	1746.	1670.	1676.
300	1683.	1582.	1653.	1610.	1560.	1619.	1564.	1530.	1554.	1438.
310	1445.	1488.	1475.	1553.	1520.	1410.	1418.	1457.	1509.	1493.
320	1429.	1449.	1395.	1438.	1475.	1432.	1470.	1642.	1723.	1575.
330	1351.	1370.	1295.	1382.	1312.	1385.	1277.	1336.	1312.	1369.
340	1313.	1315.	1361.	1260.	1747.	3306.	4900.	3200.	1612.	1320.
350	1229.	1238.	1218.	1249.	1191.	1184.	1250.	1177.	1252.	1170.
360	1216.	1226.	1203.	1172.	1174.	1201.	1193.	1159.	1185.	1205.
370	1241.	1221.	1243.	1162.	1161.	1162.	1130.	1159.	1155.	1164.
380	1121.	1168.	1140.	1153.	1130.	1287.	1522.	1481.	1280.	1174.
390	1105.	1060.	1153.	1164.	1137.	1250.	1716.	1947.	1505.	1150.
400	1120.	1117.	1174.	1086.	1098.	1021.	1126.	1097.	1064.	1056.
410	1084.	1095.	1122.	1085.	1063.	1080.	1254.	1248.	1111.	1191.
420	1067.	1103.	1139.	1075.	1068.	1111.	1224.	1208.	1218.	1054.
430	1096.	1045.	1115.	1050.	1041.	1064.	1086.	1045.	1026.	1001.
440	1051.	1006.	1002.	993.	964.	1022.	1052.	1023.	1001.	975.
450	1075.	1030.	1090.	1075.	1034.	961.	1108.	948.	1027.	954.
460	1034.	1041.	1031.	1063.	1005.	1014.	1038.	984.	1020.	934.
470	1020.	1006.	1034.	1036.	1022.	1005.	1014.	950.	1033.	1024.
480	996.	1015.	1008.	996.	1010.	962.	1031.	992.	1022.	948.
490	951.	980.	1000.	1063.	972.	1061.	1079.	1060.	1011.	1050.
500	1046.	1080.	1045.	1020.	1019.	1015.	1021.	1043.	1046.	1101.
510	984.	1059.	1082.	978.	1188.	1014.	1074.	985.	1017.	1024.

1	0	1	2	3	4	5	6	7	8	9
520	1018.	958.	923.	964.	890.	929.	897.	930.	866.	859.
530	830.	885.	841.	830.	848.	824.	801.	818.	783.	822.
540	805.	797.	857.	821.	831.	843.	804.	776.	751.	832.
550	790.	822.	802.	852.	833.	786.	841.	808.	777.	772.
560	787.	796.	791.	733.	785.	756.	747.	771.	706.	722.
570	770.	761.	777.	698.	754.	748.	740.	752.	739.	722.
580	738.	729.	740.	721.	726.	729.	681.	732.	656.	732.
590	689.	745.	695.	689.	746.	715.	788.	833.	878.	713.
600	769.	722.	698.	718.	710.	697.	687.	742.	638.	721.
610	712.	667.	703.	728.	677.	724.	763.	717.	739.	622.
620	699.	660.	681.	718.	728.	675.	702.	686.	679.	712.
630	821.	1042.	1523.	1984.	2201.	1780.	1150.	869.	714.	663.
640	648.	678.	657.	686.	617.	684.	595.	669.	632.	657.
650	680.	733.	667.	639.	712.	721.	666.	652.	612.	622.
660	651.	695.	618.	641.	695.	613.	621.	622.	639.	659.
670	691.	639.	635.	608.	646.	614.	635.	665.	664.	677.
680	685.	638.	678.	625.	684.	588.	632.	664.	602.	672.
690	688.	596.	625.	625.	670.	637.	642.	698.	827.	1202.
700	1204.	826.	664.	649.	641.	647.	626.	653.	637.	631.
710	666.	577.	654.	685.	654.	598.	658.	641.	639.	613.
720	644.	649.	603.	640.	671.	620.	608.	630.	644.	610.
730	591.	668.	579.	618.	652.	661.	639.	644.	633.	657.
740	658.	637.	662.	683.	730.	1211.	4089.	9745.	9276.	5859.
750	1189.	768.	654.	398.	613.	641.	637.	606.	599.	582.
760	633.	624.	589.	596.	597.	600.	614.	599.	608.	601.
770	640.	627.	631.	634.	604.	618.	659.	641.	630.	617.
780	602.	566.	629.	685.	635.	590.	632.	623.	637.	625.
790	656.	637.	619.	610.	609.	620.	615.	655.	620.	741.
800	1045.	1296.	972.	704.	661.	588.	628.	647.	587.	624.
810	609.	657.	622.	652.	763.	943.	977.	764.	685.	603.
820	618.	603.	650.	623.	623.	649.	672.	679.	666.	768.
830	786.	710.	659.	627.	654.	654.	629.	668.	650.	629.
840	687.	686.	690.	622.	647.	614.	673.	610.	678.	629.
850	654.	656.	681.	690.	627.	630.	626.	644.	569.	693.
860	620.	609.	646.	631.	562.	585.	618.	663.	598.	627.
870	573.	640.	591.	598.	590.	620.	680.	629.	667.	654.
880	677.	643.	570.	618.	701.	701.	747.	693.	576.	595.
890	597.	618.	606.	635.	726.	969.	1399.	1201.	814.	657.
900	541.	605.	613.	636.	618.	594.	633.	650.	614.	583.
910	607.	637.	626.	637.	613.	556.	590.	624.	615.	573.
920	564.	619.	622.	603.	642.	604.	598.	626.	624.	669.
930	594.	625.	652.	608.	615.	613.	534.	604.	596.	669.
940	630.	572.	593.	649.	639.	609.	709.	678.	707.	639.
950	643.	585.	587.	581.	643.	626.	661.	645.	660.	561.
960	617.	687.	637.	589.	664.	689.	681.	635.	606.	595.
970	661.	638.	630.	652.	615.	690.	676.	618.	687.	631.
980	697.	698.	634.	617.	627.	672.	736.	745.	690.	627.
990	679.	664.	689.	728.	658.	675.	657.	714.	636.	603.
1000	654.	675.	701.	670.	683.	645.	678.	687.	718.	703.
1010	643.	741.	698.	701.	685.	697.	728.	598.	683.	683.
1020	686.	723.	745.	734.	745.	719.	668.	598.	683.	710.
1030	704.	734.	696.	711.	762.	696.	726.	761.	693.	721.

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1040	734.	750.	733.	883.	727.	711.	768.	736.	783.	750.
1050	747.	749.	722.	784.	772.	788.	798.	807.	772.	789.
1060	776.	762.	838.	910.	761.	799.	791.	917.	806.	808.
1070	833.	771.	777.	762.	822.	830.	858.	878.	855.	809.
1080	823.	844.	875.	844.	823.	809.	795.	867.	892.	841.
1090	859.	870.	301.	852.	959.	927.	1045.	1002.	979.	968.
1100	1041.	2093.	3468.	3237.	1806.	999.	820.	889.	795.	851.
1110	865.	943.	791.	822.	874.	812.	824.	843.	791.	859.
1120	776.	802.	812.	787.	748.	761.	633.	691.	637.	633.
1130	572.	574.	537.	514.	551.	517.	581.	495.	479.	538.
1140	499.	478.	480.	518.	469.	469.	465.	473.	478.	439.
1150	499.	406.	439.	437.	429.	415.	452.	410.	460.	418.
1160	429.	473.	487.	496.	458.	431.	437.	389.	395.	379.
1170	409.	410.	372.	396.	387.	403.	394.	417.	438.	377.
1180	375.	379.	372.	394.	390.	352.	379.	381.	369.	367.
1190	364.	345.	351.	347.	369.	385.	373.	375.	409.	420.
1200	452.	406.	377.	348.	321.	350.	262.	316.	338.	319.
1210	300.	304.	205.	296.	261.	297.	295.	289.	293.	266.
1220	271.	280.	267.	273.	266.	268.	277.	265.	263.	259.
1230	276.	269.	242.	232.	232.	252.	230.	248.	210.	239.
1240	237.	234.	215.	229.	243.	199.	226.	166.	210.	195.
1250	214.	192.	191.	198.	204.	206.	178.	212.	226.	167.
1260	185.	158.	182.	185.	182.	161.	183.	151.	103.	203.
1270	176.	168.	167.	171.	187.	195.	180.	187.	146.	163.
1280	129.	174.	177.	145.	153.	165.	146.	162.	165.	163.
1290	161.	162.	148.	193.	194.	238.	225.	191.	145.	161.
1300	134.	162.	147.	148.	151.	173.	154.	172.	169.	172.
1310	149.	154.	127.	171.	176.	159.	159.	198.	178.	155.
1320	162.	168.	163.	161.	170.	175.	197.	156.	152.	132.
1330	145.	165.	150.	180.	160.	185.	159.	160.	192.	128.
1340	140.	146.	157.	121.	153.	154.	183.	168.	156.	171.
1350	162.	158.	144.	157.	143.	139.	157.	159.	165.	173.
1360	266.	603.	984.	850.	414.	219.	159.	146.	150.	171.
1370	180.	192.	160.	178.	189.	169.	200.	236.	242.	357.
1380	1681.	6739.	14010.	13499.	5855.	1359.	418.	848.	1989.	2102.
1390	1127.	306.	98.	128.	104.	100.	93.	89.	93.	87.
1400	99.	101.	106.	117.	83.	93.	81.	87.	106.	96.
1410	83.	100.	92.	79.	122.	98.	90.	83.	69.	78.
1420	89.	90.	101.	89.	108.	93.	102.	70.	98.	98.
1430	98.	94.	98.	92.	72.	94.	78.	83.	76.	84.
1440	73.	67.	70.	62.	85.	76.	78.	61.	75.	63.
1450	82.	94.	158.	320.	355.	213.	127.	81.	74.	84.
1460	98.	82.	102.	91.	94.	69.	62.	60.	49.	65.
1470	71.	53.	69.	64.	64.	60.	66.	52.	60.	66.
1480	56.	74.	56.	57.	48.	58.	61.	53.	56.	56.
1490	61.	55.	68.	53.	54.	66.	70.	49.	62.	59.
1500	73.	65.	78.	62.	53.	57.	72.	61.	53.	53.
1510	62.	52.	78.	59.	62.	69.	59.	70.	60.	59.
1520	62.	60.	58.	61.	58.	70.	58.	43.	58.	59.
1530	55.	48.	63.	62.	57.	60.	50.	67.	60.	62.
1540	61.	46.	67.	47.	67.	65.	46.	62.	61.	76.
1550	57.	54.	58.	64.	62.	51.	57.	60.	61.	57.

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1550	55.	46.	73.	69.	75.	48.	67.	57.	47.	56.
1570	70.	53.	60.	51.	54.	67.	58.	60.	63.	57.
1590	50.	65.	54.	61.	49.	60.	54.	63.	59.	54.
1590	50.	62.	45.	62.	60.	40.	62.	78.	169.	313.
1600	608.	486.	223.	111.	48.	67.	67.	70.	53.	74.
1610	62.	41.	59.	70.	41.	54.	50.	43.	53.	43.
1620	43.	48.	74.	54.	48.	49.	43.	55.	60.	63.
1630	60.	60.	54.	54.	78.	61.	55.	53.	58.	65.
1640	78.	99.	115.	112.	73.	50.	70.	68.	76.	123.
1650	262.	296.	131.	98.	81.	62.	54.	71.	67.	51.
1660	59.	71.	54.	49.	61.	47.	50.	66.	60.	58.
1670	58.	58.	56.	45.	54.	63.	65.	81.	83.	63.
1680	99.	72.	58.	61.	54.	60.	64.	54.	63.	76.
1690	52.	58.	72.	83.	113.	153.	116.	70.	68.	59.
1700	64.	61.	65.	69.	75.	76.	62.	75.	72.	69.
1710	63.	60.	70.	77.	96.	104.	94.	74.	67.	53.
1720	66.	57.	67.	76.	55.	63.	61.	63.	56.	55.
1730	56.	66.	61.	70.	65.	73.	61.	70.	62.	65.
1740	82.	53.	66.	62.	72.	89.	73.	56.	70.	68.
1750	67.	74.	58.	65.	63.	78.	64.	82.	55.	48.
1760	66.	55.	76.	71.	68.	80.	63.	72.	73.	74.
1770	67.	60.	77.	69.	79.	55.	81.	63.	85.	111.
1780	124.	92.	74.	69.	73.	90.	64.	83.	82.	62.
1790	77.	92.	71.	70.	56.	70.	61.	68.	73.	62.
1800	77.	63.	72.	65.	65.	61.	72.	86.	87.	112.
1810	126.	85.	59.	65.	63.	78.	61.	67.	65.	43.
1820	55.	57.	42.	53.	43.	44.	40.	49.	58.	48.
1830	38.	42.	50.	42.	37.	42.	40.	37.	43.	43.
1840	44.	42.	41.	59.	63.	50.	48.	44.	47.	36.
1850	39.	36.	42.	36.	39.	49.	30.	42.	34.	50.
1860	46.	33.	29.	37.	64.	43.	33.	44.	43.	43.
1870	39.	36.	44.	34.	35.	36.	36.	33.	34.	30.
1880	36.	41.	35.	30.	27.	28.	26.	33.	42.	48.
1890	51.	44.	51.	29.	25.	32.	32.	37.	23.	36.
1900	27.	30.	27.	30.	32.	26.	23.	33.	40.	34.
1910	14.	35.	27.	22.	23.	21.	26.	26.	31.	31.
1920	27.	28.	29.	16.	25.	13.	28.	26.	23.	23.
1930	34.	38.	23.	23.	23.	25.	35.	31.	24.	27.
1940	14.	19.	24.	20.	20.	22.	26.	28.	17.	20.
1950	18.	25.	25.	22.	33.	23.	34.	25.	16.	23.
1960	24.	16.	10.	19.	15.	16.	22.	28.	14.	21.
1970	19.	21.	31.	17.	17.	16.	19.	21.	11.	17.
1980	8.	16.	11.	10.	22.	10.	16.	17.	11.	18.
1990	13.	6.	19.	10.	9.	9.	11.	11.	12.	18.
2000	15.	12.	11.	12.	18.	15.	13.	13.	13.	17.
2010	16.	20.	10.	16.	20.	9.	16.	10.	18.	15.
2020	14.	20.	14.	11.	12.	7.	11.	11.	12.	11.
2030	12.	18.	12.	26.	15.	29.	2.	6.	23.	16.
2040	18.	15.	15.	15.	15.	13.	17.	8.	8.	14.
2050	12.	19.	11.	17.	11.	14.	13.	16.	20.	23.
2060	19.	16.	15.	23.	21.	19.	11.	19.	15.	15.
2070	8.	16.	15.	10.	13.	23.	11.	17.	14.	17.

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2080	14.	16.	20.	9.	22.	11.	16.	26.	19.	22.
2090	33.	109.	449.	1027.	1163.	804.	282.	81.	29.	12.
2100	7.	6.	5.	17.	9.	7.	10.	5.	18.	10.
2110	4.	11.	12.	17.	10.	15.	10.	12.	8.	10.
2120	8.	10.	8.	7.	11.	12.	11.	5.	11.	11.
2130	17.	16.	12.	17.	12.	7.	9.	9.	17.	17.
2140	14.	13.	15.	13.	11.	7.	3.	16.	6.	11.
2150	7.	9.	11.	10.	7.	11.	8.	9.	7.	12.
2160	9.	5.	13.	9.	9.	10.	12.	10.	12.	10.
2170	11.	11.	10.	11.	6.	8.	3.	9.	13.	7.
2180	8.	7.	15.	16.	15.	12.	10.	10.	9.	4.
2190	17.	7.	9.	7.	15.	7.	5.	1.	12.	11.
2200	13.	3.	15.	7.	12.	3.	13.	12.	3.	10.
2210	11.	14.	11.	11.	6.	6.	9.	13.	8.	13.
2220	7.	7.	8.	8.	9.	11.	6.	10.	10.	9.
2230	6.	10.	9.	9.	7.	10.	12.	9.	6.	15.
2240	8.	7.	14.	9.	12.	9.	6.	9.	13.	7.
2250	11.	11.	9.	12.	19.	5.	9.	15.	9.	7.
2260	9.	8.	9.	5.	11.	14.	17.	11.	9.	13.
2270	6.	10.	8.	15.	11.	7.	8.	11.	4.	0.
2280	7.	11.	9.	0.	4.	16.	5.	9.	5.	2.
2290	8.	9.	6.	5.	7.	12.	7.	12.	0.	3.
2300	13.	5.	7.	13.	7.	9.	11.	7.	10.	0.
2310	5.	6.	13.	6.	8.	4.	6.	6.	5.	0.
2320	3.	3.	7.	7.	8.	7.	4.	1.	10.	0.
2330	12.	6.	8.	8.	3.	9.	6.	3.	3.	3.
2340	6.	5.	7.	10.	7.	4.	6.	0.	2.	3.
2350	8.	3.	2.	6.	11.	3.	6.	11.	0.	2.
2360	4.	7.	9.	7.	7.	8.	7.	5.	3.	6.
2370	4.	3.	7.	5.	5.	4.	9.	6.	9.	6.
2380	7.	9.	1.	3.	6.	8.	7.	5.	6.	6.
2390	10.	4.	3.	7.	4.	5.	11.	4.	2.	2.
2400	7.	3.	3.	3.	2.	3.	6.	4.	0.	2.
2410	5.	5.	4.	5.	2.	4.	9.	2.	9.	9.
2420	6.	8.	5.	7.	2.	3.	4.	7.	9.	7.
2430	3.	1.	8.	8.	3.	3.	1.	5.	10.	7.
2440	6.	2.	5.	3.	1.	1.	4.	3.	3.	4.
2450	3.	2.	6.	4.	2.	2.	2.	4.	4.	4.
2460	3.	3.	4.	5.	4.	3.	3.	1.	3.	9.
2470	4.	4.	3.	4.	4.	4.	5.	5.	3.	5.
2480	9.	8.	3.	8.	9.	5.	8.	14.	11.	4.
2490	3.	2.	3.	4.	3.	7.	3.	3.	5.	4.
2500	7.	3.	3.	4.	4.	4.	2.	4.	1.	4.
2510	3.	6.	3.	3.	4.	3.	3.	3.	1.	4.
2520	2.	3.	3.	1.	2.	2.	3.	1.	6.	4.
2530	1.	2.	2.	1.	2.	3.	4.	4.	4.	4.
2540	1.	3.	3.	3.	3.	2.	0.	1.	4.	4.
2550	2.	5.	5.	0.	2.	2.	7.	3.	1.	1.
2560	5.	2.	2.	4.	5.	4.	4.	1.	5.	1.
2570	3.	2.	4.	6.	4.	3.	1.	1.	7.	1.
2580	0.	7.	4.	2.	8.	13.	46.	91.	123.	7.
2590	19.	4.	6.	4.	4.	5.	4.	7.	5.	1.

1	0	1	2	3	4	5	6	7	8	9
2600	4.	4.	3.	3.	8.	4.	0.	1.	2.	5.
2610	2.	2.	2.	4.	1.	5.	0.	1.	1.	1.
2620	1.	3.	5.	2.	2.	0.	4.	2.	2.	1.
2630	0.	1.	1.	2.	2.	1.	1.	2.	0.	2.
2640	1.	2.	0.	3.	3.	1.	0.	4.	2.	3.
2650	1.	3.	5.	1.	3.	0.	1.	2.	2.	1.
2660	2.	3.	3.	0.	2.	4.	0.	2.	2.	2.
2670	1.	0.	1.	0.	1.	0.	4.	2.	0.	2.
2680	3.	2.	2.	0.	1.	0.	2.	2.	2.	0.
2690	0.	4.	0.	5.	3.	2.	0.	2.	4.	0.
2700	4.	3.	2.	4.	0.	1.	1.	4.	2.	1.
2710	0.	1.	2.	2.	1.	1.	2.	0.	0.	2.
2720	1.	3.	0.	2.	1.	2.	1.	4.	1.	3.
2730	0.	2.	1.	2.	2.	1.	1.	3.	1.	1.
2740	3.	1.	0.	3.	2.	2.	3.	1.	0.	1.
2750	0.	7.	1.	0.	0.	0.	2.	2.	1.	1.
2760	1.	2.	2.	2.	2.	3.	1.	2.	1.	3.
2770	0.	2.	3.	3.	1.	0.	1.	1.	2.	1.
2780	0.	2.	4.	1.	1.	2.	1.	1.	2.	1.
2790	0.	1.	2.	2.	1.	0.	0.	2.	2.	1.
2800	5.	2.	1.	4.	1.	1.	1.	0.	0.	2.
2810	1.	2.	0.	2.	1.	1.	1.	3.	2.	1.
2820	0.	2.	3.	0.	5.	0.	2.	0.	3.	0.
2830	4.	0.	2.	0.	0.	4.	5.	0.	1.	1.
2840	3.	3.	1.	0.	3.	0.	1.	1.	2.	0.
2850	2.	0.	1.	2.	2.	0.	3.	2.	2.	3.
2860	2.	2.	1.	2.	2.	3.	1.	1.	2.	2.
2870	1.	1.	1.	0.	2.	2.	3.	1.	0.	0.
2880	1.	1.	1.	0.	4.	1.	0.	3.	3.	2.
2890	1.	2.	2.	1.	1.	1.	0.	0.	1.	0.
2900	1.	2.	2.	2.	0.	2.	3.	0.	1.	2.
2910	2.	2.	1.	0.	2.	3.	3.	0.	1.	3.
2920	1.	3.	0.	1.	1.	3.	0.	3.	2.	1.
2930	1.	2.	0.	0.	0.	0.	1.	1.	0.	0.
2940	1.	0.	1.	2.	1.	0.	1.	1.	1.	1.
2950	4.	1.	1.	1.	1.	1.	1.	1.	1.	1.
2960	0.	2.	0.	0.	3.	2.	3.	1.	0.	0.
2970	2.	0.	0.	0.	0.	2.	2.	0.	5.	1.
2980	1.	0.	0.	0.	3.	1.	0.	1.	1.	0.
2990	1.	0.	1.	1.	4.	1.	0.	2.	0.	0.
3000	0.	0.	1.	1.	2.	2.	0.	0.	1.	2.
3010	2.	0.	1.	2.	0.	1.	0.	0.	0.	0.
3020	0.	1.	0.	0.	0.	1.	0.	1.	2.	3.
3030	1.	3.	2.	1.	0.	1.	2.	1.	0.	1.
3040	2.	0.	1.	1.	2.	0.	1.	3.	1.	1.
3050	3.	1.	1.	0.	1.	1.	1.	0.	0.	1.
3060	0.	2.	0.	1.	3.	2.	1.	0.	0.	0.
3070	0.	0.	1.	0.	1.	0.	1.	1.	0.	3.
3080	2.	2.	0.	1.	1.	1.	2.	3.	0.	1.
3090	2.	1.	1.	3.	1.	0.	0.	0.	2.	1.
3100	1.	3.	0.	1.	0.	1.	3.	1.	3.	0.
3110	1.	1.	0.	1.	0.	1.	0.	0.	1.	1.

1	0	1	2	3	4	5	6	7	8	9
3120	2.	0.	1.	0.	0.	1.	0.	1.	0.	0.
3130	0.	0.	1.	2.	0.	1.	1.	0.	1.	0.
3140	0.	2.	2.	2.	1.	1.	1.	0.	0.	0.
3150	0.	3.	1.	0.	0.	2.	0.	0.	0.	1.
3160	1.	0.	0.	2.	1.	0.	0.	1.	1.	0.
3170	0.	2.	0.	0.	1.	0.	1.	0.	0.	0.
3180	2.	1.	0.	1.	0.	0.	0.	0.	1.	1.
3190	0.	3.	0.	0.	1.	0.	1.	0.	0.	1.
3200	0.	0.	1.	0.	1.	0.	0.	0.	0.	0.
3210	0.	0.	1.	2.	1.	0.	1.	1.	0.	1.
3220	2.	2.	2.	0.	0.	1.	1.	0.	1.	1.
3230	2.	6.	12.	13.	5.	4.	1.	0.	0.	1.
3240	0.	1.	0.	0.	0.	0.	2.	0.	0.	2.
3250	0.	2.	1.	2.	0.	1.	0.	0.	1.	0.
3260	1.	1.	0.	2.	0.	0.	0.	0.	2.	0.
3270	0.	0.	0.	1.	0.	0.	1.	0.	2.	0.
3280	0.	2.	0.	1.	0.	1.	0.	0.	1.	0.
3290	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.
3300	0.	0.	0.	1.	1.	1.	0.	1.	1.	0.
3310	0.	0.	1.	0.	0.	0.	1.	1.	0.	0.
3320	2.	1.	0.	0.	1.	1.	1.	2.	0.	0.
3330	0.	1.	0.	1.	1.	1.	0.	3.	1.	1.
3340	0.	1.	0.	0.	0.	0.	1.	0.	0.	0.
3350	0.	1.	0.	0.	0.	0.	0.	1.	2.	0.
3360	0.	1.	1.	0.	1.	0.	1.	1.	1.	0.
3370	0.	0.	1.	0.	1.	0.	2.	1.	0.	1.
3380	1.	0.	1.	1.	0.	0.	1.	1.	2.	0.
3390	0.	2.	0.	0.	0.	0.	0.	1.	0.	0.
3400	0.	0.	1.	0.	0.	0.	1.	1.	0.	0.
3410	0.	1.	0.	1.	1.	0.	1.	0.	0.	0.
3420	0.	1.	0.	0.	1.	0.	0.	1.	0.	0.
3430	2.	1.	0.	1.	1.	1.	0.	0.	0.	2.
3440	0.	0.	0.	0.	0.	1.	2.	0.	1.	0.
3450	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
3460	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
3470	1.	0.	0.	0.	1.	0.	0.	1.	1.	1.
3480	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
3490	0.	0.	0.	0.	1.	0.	0.	1.	1.	0.
3500	1.	0.	0.	0.	0.	0.	1.	2.	0.	1.
3510	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
3520	0.	0.	0.	0.	1.	1.	0.	0.	1.	0.
3530	0.	0.	1.	0.	1.	2.	0.	1.	2.	0.
3540	0.	0.	1.	1.	0.	0.	1.	1.	0.	0.
3550	2.	0.	0.	2.	0.	3.	0.	1.	0.	1.
3560	1.	0.	2.	1.	0.	1.	0.	0.	0.	1.
3570	0.	0.	0.	0.	1.	1.	2.	0.	1.	0.
3580	0.	0.	1.	1.	1.	1.	1.	1.	1.	1.
3590	0.	0.	0.	2.	0.	2.	1.	0.	0.	1.
3600	1.	2.	0.	3.	3.	0.	1.	1.	0.	0.
3610	1.	1.	1.	1.	1.	0.	0.	0.	0.	0.
3620	0.	2.	2.	0.	1.	0.	1.	1.	1.	2.
3630	0.	0.	0.	1.	1.	1.	1.	0.	0.	0.

1	0	1	2	3	4	5	6	7	8	9
3540	0.	0.	0.	0.	0.	0.	0.	0.	2.	1.
3550	0.	0.	0.	2.	0.	0.	0.	1.	0.	0.
3560	1.	0.	0.	0.	0.	0.	0.	1.	0.	0.
3570	1.	0.	1.	1.	1.	0.	0.	0.	0.	0.
3580	0.	0.	1.	0.	1.	0.	0.	0.	0.	0.
3590	0.	0.	3.	0.	0.	1.	1.	1.	0.	0.
3700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3710	0.	0.	0.	0.	1.	0.	1.	0.	1.	0.
3720	1.	0.	1.	0.	0.	1.	0.	1.	0.	0.
3730	2.	0.	1.	0.	1.	0.	0.	0.	3.	0.
3740	0.	2.	1.	0.	0.	0.	0.	0.	1.	0.
3750	1.	0.	0.	0.	2.	2.	0.	0.	0.	1.
3760	0.	1.	0.	1.	0.	0.	0.	1.	0.	1.
3770	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
3780	1.	0.	0.	0.	0.	0.	0.	0.	0.	1.
3790	0.	0.	0.	0.	1.	0.	0.	1.	0.	0.
3800	0.	2.	0.	1.	0.	1.	0.	0.	0.	0.
3810	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.
3820	2.	0.	0.	1.	1.	0.	1.	0.	0.	0.
3830	0.	0.	0.	0.	0.	0.	1.	1.	1.	0.
3840	1.	1.	1.	2.	0.	0.	1.	0.	0.	0.
3850	0.	0.	1.	0.	1.	0.	0.	1.	1.	0.
3860	0.	0.	3.	2.	0.	1.	3.	0.	0.	1.
3870	0.	1.	1.	1.	1.	2.	0.	0.	2.	1.
3880	1.	0.	1.	2.	0.	1.	0.	1.	0.	0.
3890	2.	0.	0.	1.	0.	1.	1.	1.	0.	0.
3900	0.	2.	0.	0.	0.	1.	0.	2.	1.	3.
3910	0.	0.	2.	1.	0.	0.	0.	0.	0.	0.
3920	1.	0.	0.	0.	0.	0.	0.	0.	0.	1.
3930	0.	1.	0.	1.	0.	0.	0.	1.	0.	0.
3940	1.	1.	0.	0.	2.	0.	1.	0.	1.	0.
3950	0.	0.	2.	0.	0.	0.	0.	0.	0.	1.
3960	1.	0.	0.	0.	0.	1.	0.	0.	0.	1.
3970	1.	0.	1.	1.	0.	0.	1.	1.	0.	1.
3980	1.	0.	0.	0.	0.	0.	0.	1.	0.	1.
3990	0.	1.	1.	0.	1.	0.	0.	2.	1.	0.
4000	1.	0.	0.	0.	0.	2.	0.	1.	0.	0.
4010	1.	0.	1.	0.	0.	1.	0.	0.	0.	0.
4020	1.	1.	0.	1.	0.	1.	0.	0.	1.	0.
4030	0.	1.	1.	0.	0.	0.	0.	0.	0.	1.
4040	0.	0.	0.	0.	1.	0.	0.	0.	0.	1.
4050	1.	1.	0.	0.	1.	0.	0.	0.	1.	0.
4060	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
4070	0.	1.	2.	0.	0.	0.	0.	1.	1.	0.
4080	0.	0.	0.	0.	0.	0.	2.	0.	1.	0.
4090	1.	0.	0.	0.	1.	1.	0.	0.	0.	0.

Appendix C

SUMMARY OF XRFA DATA

In this appendix is presented a summary of the raw XRFA data derived in this study. Table C-1 gives the trace element concentrations found in the individual samples. The errors given are the analytical errors and do not account for errors in the sample flow rate.

Table C-2 gives the average concentrations of each trace element in the samples, as well as the minimum and maximum concentrations found. The errors indicated in the values for the average concentration are the standard deviations of the individual concentrations.

Table C-1

Trace Element Concentrations and Analytical Errors (Both in ng/m³) Found in the XRFA Investigations in this Study

Sample number	Concentration and analytical error (in parenthesis)					
	Fe	Cu	Zn	Br	Sr	Pb
2A	730(27)	475(15)	9460(48)	104(7)	21.1(3.3)	6370(48)
3A	727(24)	306(12)	3480(28)	120(3)	16.0(2.9)	5810(44)
4A	650(28)	278(14)	3360(31)	219(8)	12.2(3.5)	7970(57)
5A	1630(35)	123(11)	1740(22)	82.8(6.5)	9.17(3.17)	5040(44)
8A	4880(54)	277(13)	6250(40)	109(7)	52.2(4.0)	13 700(71)
9A	1490(30)	163(10)	2510(24)	56.9(5.5)	14.6(2.8)	5750(43)
10A	2570(41)	214(13)	6800(42)	62.6(7.0)	25.7(3.7)	13 000(69)
11A	2080(35)	142(10)	2630(25)	81.0(5.8)	19.6(3.0)	7370(49)
12A	2330(37)	147(10)	1640(20)	43.7(5.4)	12.0(2.9)	4820(41)
13A	1690(33)	104(10)	364(11)	25.1(5.0)	6.62(2.80)	693(18)
14A	2320(38)	168(11)	4340(32)	54.1(5.1)	28.2(3.3)	7840(52)
15A	1240(30)	77.3(9.7)	345(12)	35.0(4.3)	11.2(3.0)	756(19)
16A	2400(37)	115(10)	3070(27)	56.8(4.9)	20.8(3.1)	8390(53)
18A	1530(29)	176(10)	5070(31)	62.1(4.8)	14.5(2.8)	11 600(57)
20A	1720(30)	157(9)	2740(23)	41.3(4.0)	10.9(2.5)	5850(40)
21A	2750(49)	243(15)	2260(29)	56.1(6.2)	21.7(4.2)	4850(50)
27A	764(24)	116(10)	4180(29)	59.1(4.5)	8.32(2.81)	14 800(65)
28A	1570(29)	123(9)	3140(25)	63.0(4.6)	10.5(2.6)	9310(51)
30A	1260(27)	96.1(4.6)	2320(22)	87.3(4.8)	19.0(2.8)	8790(49)
31A	3130(41)	134(10)	2740(23)	99.6(5.5)	26.3(3.2)	9370(55)
33A	1920(38)	182(13)	2260(29)	143(7)	22.6(3.9)	25 200(96)
34A	2000(37)	129(11)	4180(29)	119(6)	17.9(3.3)	4900(43)
36A	2300(43)	257(15)	3140(25)	172(8)	41.0(4.4)	25 300(99)
38A	1110(29)	174(11)	2320(22)	216(7)	19.1(3.3)	11 200(52)
39A	4510(56)	344(16)	3760(29)	323(10)	23.7(5.0)	29 000(107)
40A	2690(39)	227(12)	8140(45)	223(7)	46.5(3.7)	19 800(77)
41A	1110(27)	53.9(8.2)	4390(34)	46.3(4.0)	7.18(2.55)	501(15)
42A	1870(30)	75.3(7.5)	15 100(63)	44.3(3.6)	11.6(2.3)	1220(20)
43A	2920(47)	451(17)	11 900(56)	208(9)	74.9(4.9)	30 200(109)
44A	2490(41)	182(13)	7740(41)	192(8)	50.9(4.2)	26 000(96)

Table C-2

Average Concentration $\langle C \rangle$ of Each Trace Element Analyzed for
by XRFA on 30 Samples in this Study, and the Minimum and
Maximum Concentrations Found. All Values Are ng/m³.
Errors in Parenthesis at Right of $\langle C \rangle$ Values Are
Standard Deviations

	Fe	Cu	Zn	Br	Sr	Pb
C	2010(1000)	190(103)	4760(3970)	107(73)	22.5(15.8)	10 800(8600)
C _{min}	630	53.9	338	25.1	6.62	501
C _{max}	4880	475	15 700	323	74.9	30 200