U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# Spectral radiometric and total-field magnetic survey of the McDermitt calderas, NV-OR --Summary

by

U.S. Geological Survey

Open-File Report 82-323-A

1982

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## FIGURES



## PLATES

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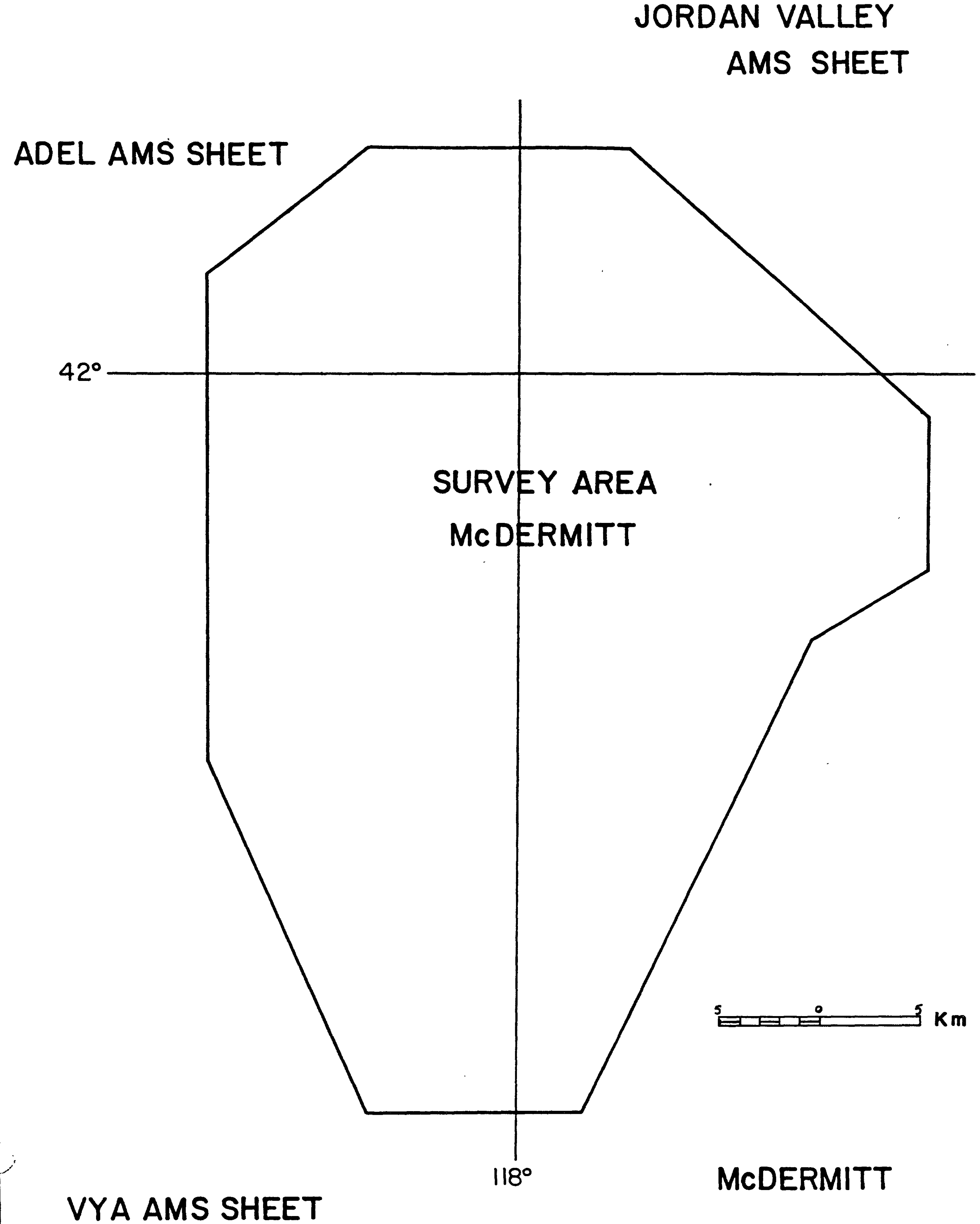



FIGURE 1

## PREFACE

In November, 1980, a helicopter-bourne geophysical survey of the McDermitt calderas, Nevada and Oregon, was flown on contract for the U.S. Geological Survey by High Life Helicopters, Inc., 167-15 South Meridan St., Puyallup, WN 98371. Magnetic and spectral radiometric fields were measured on east-west flight lines nominally spaced one-third mi. (one-half km) apart, and nominally draped at 400 ft (122 m) ground clearance. Approximately 1600 line-miles (2575 line-km) of data were collected. The data were processed and contoured by QEB, Inc., 363 S. Harlan St., Lakewood, CO 80226, a subsidiary of High Life Helicopters, Inc.

This Open-File report contains the following products of that survey:

(a) Four maps at 1:62,500 scale showing flight-line numbers and locations superposed on a topographic base.
(b) Four contour maps at 1:62,500 scale showing residual magnetic field. The International Geomagnetic Reference Field has been removed from this field.
(c) Four contour maps at 1:62,500 scale of the Bi-214 spectral peak showing equivalent uranium (eU) concentrations in parts per million (ppm).
(d) A report by QEB, Inc. describing equipment used, data collection and reduction procedures, and products delivered under conditions of the contract.

As described in the QEB report, other products were prepared besides the contour and flight-line location maps presented here. These include sheets showing stacked data profiles which plot the following information for each flight line:

(a) Total gamma-ray counts
(b) K-40 as percent potassium (%K)
(c) Bi-214 as parts per million equivalent uranium (ppm eU)
(d) Tl-208 as parts per million equivalent thorium (ppm eTh)
(e) Bi-214/Tl-208 as ppm eU/ppm eTh
(f) Bi-214/K-40 as ppm eU/%K
(g) Tl-208/K-40 as ppm eTh/%k
(h) Total intensity magnetic field in nanoTeslas (nT)
(i) Radar altimeter

Paper copies of these sheets are available within Open-File Report 82-323-B. Each sheet shows all of the parameters listed above for one particular flight line, plotted at 1:62,500 scale. To order, contact U.S. Geological Survey, Open-File Services Section (OFSS), Box 25046, MS 306, Federal Center, Denver, CO 80225, or telephone (303) 234-5888. When ordering, specify sheet number(s): The number of the sheet is the same as the number of its flight line. The sheets are numbered 1 through 93, and 94 for TL1, 95 for TL2, and 96 for TL3.

A nine-track digital tape of processed data for all the flight lines in this survey is also available. The contents and format of this digital tape are described in Appendix A. Copies of the tape may be purchased from the National Geophysical and Solar-Terrestrial Data Center, NOAA/EDIS/NGSDC, Code D62, 325 Broadway, Boulder, CO 80303. Telephone (393) 497-6338.

# INTRODUCTION

High Life Helicopters Inc./QEB Inc. have completed for the United States Geological Survey (USGS) an airborne reconnaissance gamma-ray spectrometric and total field magnetic survey over the McDermitt area of northern Nevada.

Data collection was done during November, 1980 by High Life Helicopters Inc. using an Aerospatiale Lama 315B helicopter equipped with a gamma-ray spectrometer and a magnetometer. Data reduction and analysis were done at QEB Inc.'s data processing facility in Lakewood, Colorado.

The objective of the survey was to provide analog and digitally recorded total field magnetic, radometric, and altimeter data within the area surveyed.

This report describes the equipment used, gamma-ray spectrometer calibration, survey methods, data reduction methods, data presentation, and the results.

## SUMMARY

High Life Helicopters Inc./QEB Inc. have completed an airborne reconnaissance gamma-ray spectrometric and total field magnetic survey in the McDermitt area of northern Nevada. An Aerospatiale Lama helicopter (U.S. Registry No. N49537) equipped with a gamma-ray spectrometer and a proton precession magnetometer collected the data. The gamma-ray spectrometer had 2048 cubic inches of sodium iodide crystals in the downward-looking detector and 320 cubic inches of sodium iodide crystals in the upward-looking detector. The magnetometer in the aircraft was a Geometrics Model G-803 proton precession magnetometer with a nominal sensitivity of .25 gammas. A total of 1600 line miles of radiometric and magnetic data were collected in the area. Visual techniques were used in navigation, and flight path film was obtained for subsequent precise position determination.

Spectrometer data were corrected for aircraft and cosmic background, Compton scattering in the detector crystals, atmospheric radon, and altitude. Statistical methods were used to determine the statistical validity of the spectrometer data. The magnetometer data were corrected for the diurnal variations in the total field.

Stacked profiles of the radiometric, magnetic, and ancillary data were prepared. Contour maps of the residual magnetic field data were prepared at a scale of 1:62,500.

# EQUIPMENT

## AIRCRAFT

The aircraft used to carry the gamma-ray spectrometer, the magnetometer, and associated electronic equipment was an Aerospatiale SA 315B Lama helicopter, U.S. Registration No. N49537. The Lama is manufactured in France by Societe National Industrielle, and is designed to haul heavy loads in rugged terrain. It operates economically and safely under the most rigorous requirements, so is an ideal aircraft for gamma-ray spectrometer surveys, which must be conducted with heavy payloads, at low speed, and at low altitudes.

The Lama is powered by an 870 SHP Turbomeca Artouste IIIB turboshaft engine, fueled from a 151.3 U.S. gallon (573 liter) fuel tank mounted in the center section of the fuselage. The main rotor is driven through a planetary gear-box with provision for free wheel on autorotation. A take-off drive for the tail rotor is mounted at the lower end of the main gearbox, and a torque shaft connects the latter to a small gearbox that houses the pitch control mechanism, and on which the tail rotor is mounted. Cyclic and collective pitch are power-controlled. Rotors consist of a three-blade main rotor and an antitorque rotor. The main blades are all-metal, are of constant chord, have hydraulic drag-hinge dampers, and are mounted on articulated hinges.

The light metal framework cabin is glazed, but the center and rear of the fuselage behind the cabin have an open triangular framework. The cabin seats a pilot and one passenger side by side and three more passengers behind the pilot. The landing gear is made up of skids with removable wheels. Provision is also made for pneumatic floats for operation over water, and for inflatable emergency flotation gear. The aircraft can carry crystal packs weighing up to 2,204 lbs (1000 Kg) mounted on external slings. The Lama is a versatile aircraft, which can be adapted for used in rescue operations, liason duties, training, agriculture, and aerial photography. External dimensions, performance, and weight specifications are listed below.

## EXTERNAL DIMENSIONS

| | |
|---|---|
| Main Rotor diameter | 36' 1-3/4" |
| Tail Rotor diameter | 6' 3-1/4" |
| Main Rotor Blade chord (constant) | 13.8" |
| Length overall, both Rotors turning | 42' 4-3/4" |
| Length of fuselage | 33' 8" |
| Height overall | 10' 1-3/4" |
| Skid track | 7' 9-3/4" |

## GENERAL PERFORMANCE SPECIFICATIONS BASED ON SEA LEVEL STANDARD CONDITIONS

| | | | | | |
|---|---|---|---|---|---|
| At Gross Weight | lb | 3,310 | 4,310 | 4,200 | 5,070 |
| Empty Weight | lb | 2,216 | 2,216 | 2,216 | 2,216 |
| Useful Load | lb | 1,094 | 2,084 | 1,984 | 2,854 |
| Sling Load (max) | lb | - | - | - | 2,500 |
| Cruise Speed | mph | 118 | - | 55 | 75 |
| Top Speed, Vne | mph | - | 130 | - | - |
| Useable Fuel US | gal | 146 | 146 | 46 | 46 |
| Service Ceiling | ft | (23,000) | 17,000 | 18,370 | 10,800 |
| HIGE Ceiling | ft | (23,000) | 16,730 | 17,600 | 9,220 |
| HOGE Ceiling | ft | (23,000) | 15,170 | 16,100 | 5,000 |

WEIGHT SPECIFICATIONS FOR GEOPHYSICAL SURVEYS

| | Weight (lbs) |
|---|---|
| LAMA empty weight | 2216 |
| Maximum useable fuel | 900 |
| Sensor Electronics | 850 |
| Pilot | 160 |
| Navigator | 160 |
| Total | 4286 |

## SENSORS

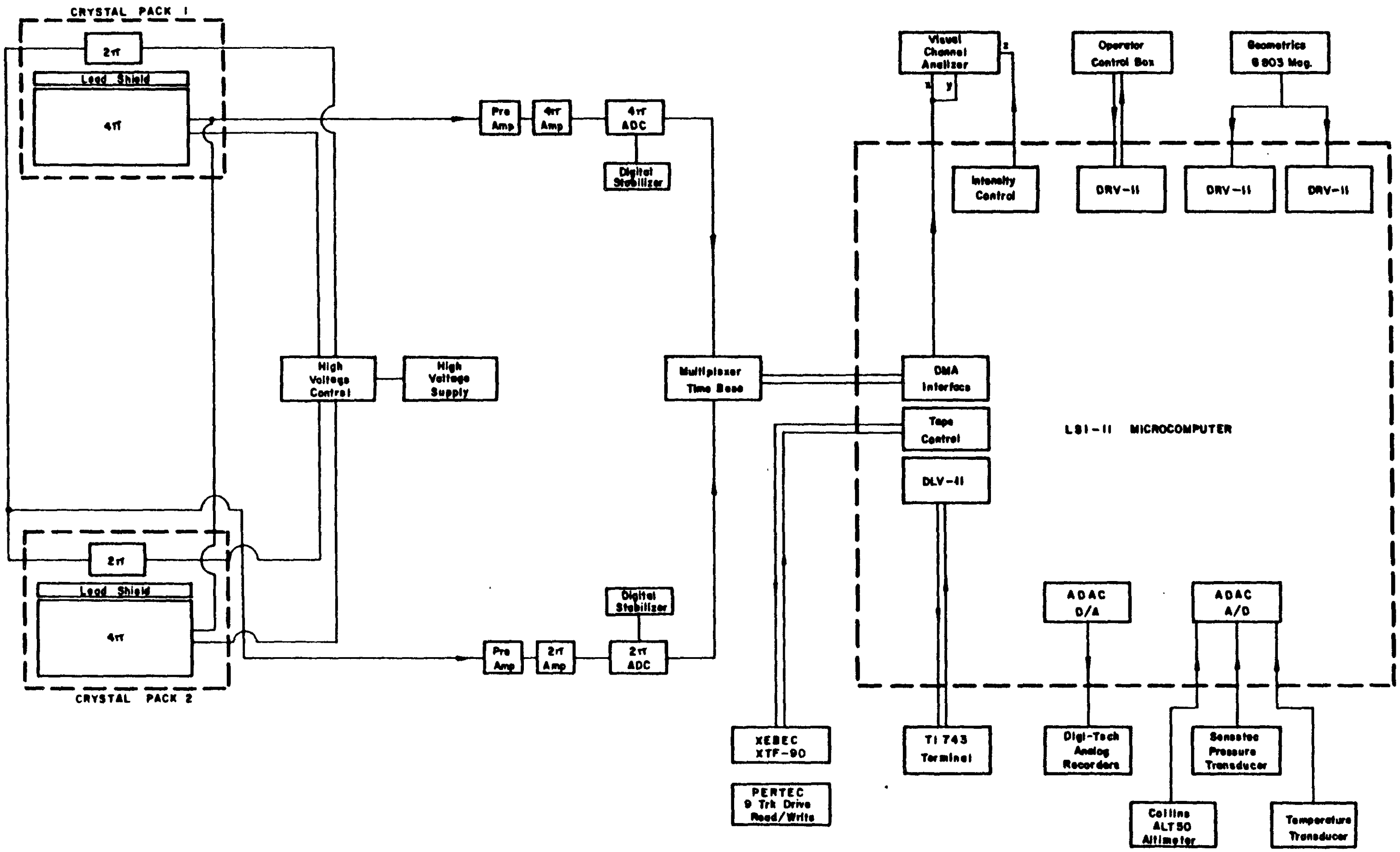
The geophysical sensor system with associated electronics used in the survey was System #1 in Lama N49537. A summary of the system is presented below, and the schematic diagram of the system is in Figure 1.

### System #1 - Lama N49537 (Figure 1)

### Geophysical Sensors

1. Crystal Gamma-ray Detectors: Downward-looking, eight (8) sodium iodide crystals manufactured by Harshaw Chemical Co., Solon, Ohio. These are arranged in two packs, each containing four (4) crystals, mounted fore and aft on the under-side of the aircraft on bomb shackles fitted with a quick-release mechanism. Each crystal has a volume of 256 cubic inches for a total volume of 2048 cubic inches in the downward-looking detector.

2. Crystal Gamma-ray Detectors: Upward-looking, two (2) sodium iodide crystals with a volume of 160 cubic inches each. One was mounted on top of each downward-looking crystal pack.




High Life Helicopters, Inc. /QEB Inc.
System Block Diagram
Lama Helicopter N 49537

FIGURE 2

3. Towed-bird proton precession magnetometer, Geometrics Model G803, with a sensitivity of .25 gammas.

Ancillary Equipment

1. Radar Altimeter - Collins ALT-50.
2. Barometric Altimeter - Sensotec Pressure Transducer.
3. Recording Temperature Transducer.
4. Tracking Camera - Automax 35 mm Framing Camera (Automax Industries, Woodland Hills, California).

Geophysical Console Equipment

1. A Geometrics G-714 Airborne Data Acquistion system is used to digitize and process all data from the sensors. The G-714 provides, along with its support equipment, analog to digital conversion, analog and digital gain stabilization, and formatting for the magnetic tape equipment.

2. Geometrics G-800 Gamma-ray Spectrometer System.

3. Geometrics G-900 Sensor Interface and Power Supply.

4. Geometrics G-803 Magnetometer with .25 gammas sensitivity.

Recording Equipment

1. Kennedy 9-track digital tape deck recording at 800 bpi.

The system records:

a. 512 channels of gamma-ray spectrometer data (256 down and 256 up),

b. Total magnetic intensity,

c. Fiducial number from data system and camera,

d. Altitude from radar and barometric altimeters,

e. Time (days, hours, minutes, seconds),

f. Outside temperature,

g. "Label" information - date, survey area, and flight number.

2. Geometrics GAR-6 channel chart recorder.

## DATA PROCESSING

QEB Inc. uses a Hewlett-Packard 1000 computer to process the geophysical data. The HP-1000 has a Fast Fortran Processor, 512K bytes of CPU memory, and 120 mega-bytes of on-line disc memory. Input/Output devices include three HP-7970B tape-drives, an HP-2648A graphics terminal, two HP-2621A CRT terminals, and an HP-2608A graphics printer.

Peripheral equipment used in the data processing includes:

1) A Calcomp 936 Drum Plotter
2) A Calcomp 915 Plotter Controller
3) A Talos BL648B Digitizer

The Calcomp Plotter can be driven either on-line by the HP-1000, or off-line by the Calcomp 915 Plotter Controller controlled from tapes generated by the HP-1000.

The Calcomp 915 Plotter Controller is a programmable device consisting of a central processing unit (CPU), a memory unit, a read-write magnetic tape cartridge unit, and a read-only magnetic tape unit (MTU). The 915 Plotter Controller can accommodate as many as five peripheral input-output devices on-line.

The MTU reads a data tape created by the HP-1000. The CPU and a system program read into memory from a tape cartridge, then convert the data on the tape into commands that drive an output device, e.g. the 936 Plotter.

The Talos BL648B Digitizer converts the coordinates of the physical position of pen or cursor on the activated digitizer surface into a digital output that can be entered through a remote terminal into the HP-1000 computer. The Talos BL648B has an active digitizing area of 48 X 36 inches.

DATA PROCESSING FLOW CHART
(USGS)

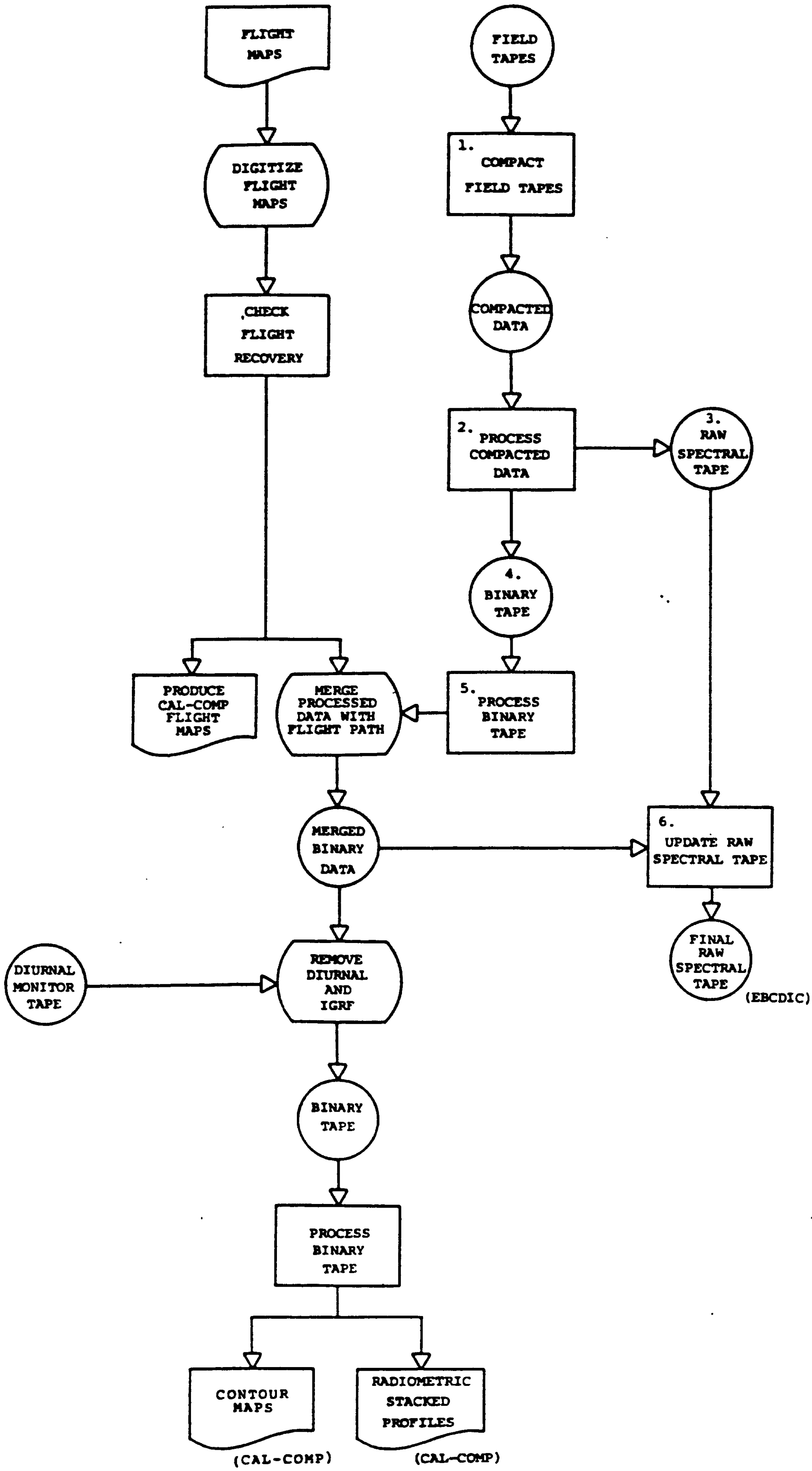





FIGURE 3

# SYSTEM CALIBRATION

## COSMIC AND BACKGROUND

Background effects due to the natural radioactivity of the aircraft frame, geophysical equipment and other ancillary devices may be calculated from a series of high altitude sorties. To demonstrate this, consider the count rate at Energy E due to Compton scattering from a higher energy photon E'. For a constant elevation Z, we may write:

$$I(E,Z) = R(E';E,Z) + I_B(E) \tag{1}$$

where:

| | |
|---|---|
| $I(E,Z)$ | is the count rate at energy E and altitude Z |
| $R(E',E,Z)$ | is the count rate at energy E and altitude Z due to a higher energy photon E', |
| $I_B(E)$ | is the desired aircraft background (independent of Z). |

For a given channel Ch, we may write for the high altitude test:

$$\int_{Ch} I(E,Z)\,dE = \int_{Ch}\int_{3MEV}^{6MEV} R(E';E,Z)\,dE\,dE' + \int_{Ch} I_B(E)\,dE \tag{2}$$

where the double integral term on the right hand side of (2) represents the cosmic contribution of the count rate measured in channel Ch. We must now specify the functional form for $R(E';E,Z)$ in order to solve for the cosmic and background effects. We made two assumptions regarding this function:

a) R is a function of the difference between the photon at energy E' and the lower energy level E,

$$R(E'-E,Z) = R'(E'-E,Z) \tag{3a}$$

b) R' can be separated into the product of two functions

$$R'(E'-E,Z) = P(E',Z)Q(E) \tag{3b}$$

Assumption (3a) postulates that the effect at lower energies depends only upon the energy <u>difference</u> between E' and E. A suggested functional form for R' is exponential, i.e:

$$R'(E'-E,Z) = f(Z) \exp (C(E'-E) \tag{4}$$

The form (4) seems to be born out experimentally. Whatever the relative merits of assumption (a), assumption (b) is critical to our analysis. We assume that R' can be separated into the product of a function of E' and Z with a function only of E. This assumption will allow us to treat the cosmic correction and background problem as a linear effect.

Substituting equation (3b) into (2), we find:

$$\int_{Ch} I(E,Z)dE = \int_{3MEV}^{6MEV} P(E'Z)dE' \int_{Ch} Q(E)dE + \int_{Ch} I_B(E)dE \tag{5}$$

Equation (5) can be written in the functional form for any channel:

$$Y = A * X + B \tag{6}$$

where

$Y = \int_{Ch} I(E, Z)dE$ Is the measured count rate at altitude

Z in channel Ch.

$X = \int_{3MEV}^{6MEV} P(E'Z)dE'$ is the measured cosmic count rate at altitude Z.

$A = \int_{Ch} Q(E)dE$ is a dimensionless quantity which weights the cosmic count rate to indicate the integral count rate within a channel Ch due to cosmic energies. A is also referred to as the cosmic correction ratio.

$B = \int_{Ch} I_B(E)dE$ is the background in counts per second.

The quantities A and B are determined by a least squares analysis of channel data over the suite of five flight altitudes.

## SYSTEMS CONSTANTS

System constants were determined at the DOE Walker Field test pads and at the Lake Mead Test Range. The test areas at these sites contain known concentrations of potassium, uranium, and thorium. The concentrations of elements in the five pads at Walker Field are shown in the table below:

ELEMENT CONCENTRATION IN THE

WALKER FIELD PADS

| Pad | | K | U | Th |
|---|---|---|---|---|
| 1. | Background/Matrix | 1.45% | 2.19 ppm | 6.26 ppm |
| 2. | (K) | 5.14% | 5.09 ppm | 8.48 ppm |
| 3. | (U) | 2.03% | 30.29 ppm | 9.19 ppm |
| 4. | (Th) | 2.10% | 5.14 ppm | 45.33 ppm |
| 5. | Mixed | 4.11% | 20.39 ppm | 17.52 ppm |

Full spectral data were measured and digitally recorded above each of the calibration pads at Walker Field. Data were collected over each pad during a five minute interval. A sample rate of one full scan per second - 256 channels for the down-crystal, and 256 channels for the up-crystal - gave a total of 300 spectral measurements per calibration pad. Since the calibration measurements were taken over a comparatively short time period, it was assumed that the individual pad measurements contain not only the effects of the pad itself; but the aircraft background - constant for a particular aircraft; cosmic background - constant over the measurement period; and the local background Bi-air etc. When the Background/Matrix pad count rate values were subtracted from the values obtained over the other pads; the aircraft, the cosmic, and the local backgrounds were eliminated. The pad concentrations were similarly modified by subtracting the Background/Matrix concentration from each of the remaining four pads to give the differential element concentration.

DIFFERENTIAL ELEMENT CONCENTRATIONS

WALKER FIELD PADS

| | Pad | K | U | Th |
|---|---|---|---|---|
| K - Matrix | 2-1 | 3.69% | 2.90 ppm | 2.22 ppm |
| U - Matrix | 3-1 | 0.58% | 28.10 ppm | 2.93 ppm |
| Th - Matrix | 4-1 | 0.56% | 2.95 ppm | 39.07 ppm |
| Mixed - Matrix | 5-1 | 2.66% | 18.20 ppm | 11.26 ppm |

The count rate over pads 2 through 5 could then be related directly to the differential concentrations of the elements in these pads.

## Sensitivity Coefficients - Theory

It can be demonstrated that the observed count rate of a spectrometric system is a function not only of the mean ground level abundance of radioactive elements, but also of other parameters such as crystal geometry, flight altitude, equivalent optical path length, etc.

Consider the response of an ideal spectrometer (one with infinitely precise resolving power) to gamma-ray excitation from a radioactive ground source.

For a given monochromatic energy $E_o$:

$$I(E_o) = \varepsilon \int_S \frac{I' A e^{-\mu R}}{R^2} dS \tag{1}$$

where

| | |
|---|---|
| $I(E_o)$ | Is the theoretical count rate at energy $E_o$. |
| $\varepsilon$ | Is the photo-detector efficiency at energy $E_o$. |
| $A$ | Is the solid angle response of the spectrometer system. |
| $\mu$ | Is the attentuation constant of the medium through which the photon of energy $E_o$ passes. |
| $R$ | Is the distance from an elemental ground surface of area dS to the photo-detector. |
| $I'$ | Is the surface count rate which is propor- |

tional to the ground level abundance of radioactive elements at Energy $E_o$.

The relative simplicity of (1) is deceiving, since complicated interactions such as Compton scatter in the ground and in the air are assumed to be approximated by the simple exponential attenuation coefficient $\mu$. A further complication is that any spectrometer system has less than ideal resolving power. Thus, the more or less monochromatic energies from ground sources are "smeared" over a broad range of energy levels. This "smearing" is due to photon-crystal interactions (Compton scatter), amplifier drift, thermal effects, etc. The observed spectra can now be written as:

$$I'(E_o;E) = I(E_o)R(E_o;E) \qquad (2)$$

where

| | |
|---|---|
| $I'E_o;E)$ | Is the observed count rate at energy $E$ due to monochromatic source at energy $E_o$. |
| $I(E_o)$ | Is the intensity of the monochromatic emitter. |
| $R(E_o;E)$ | Is the crystal response function due to a monochromatic input photon. |

## Sensitivity Coefficients Applicable to the Walker Field Test Pads

Let us now relate this theoretical discussion to the Walker Test Field Test Facility measurements. Assuming that the air attenuation constant was invariant over the measurement period and that the pad geometrics were similar, then from equation (1) we may write:

$$I(E_o) = C(E_o)\rho(E_o)$$

where

$C(E_o)$ Is a proportionality constant for a given energy $E_o$.

$\rho(E_o)$ Is the ground level concentration of radioactive elements of energy $E_o$.

Let us consider the expected count rates from the Walker Field pads.

From Equations (2) and (3), we may write:

$$I'_j(E_k,E_u,E_T;E) = C(E_k)R(E_k;E)\rho(E_k,j) + C(E_u)R(E_u;E)\rho(E_u,j) +$$

$$C(E_T)R(E_T;E)\rho(E_T,j) + B(E) \qquad (4)$$

where

$E_k = 1.46$ MeV ($K_{40}$ Photopeak),

$E_u = 1.76$ MeV ($Bi_{214}$ Photopeak),

$E_T = 2.62$ MeV ($Tl_{208}$ Photopeak),

$\rho(E_k,j)$ = Concentration of $K_{40}$ in the j pad,

$\rho(E_u,j)$ = Concentration of $U_{238}$ in the j pad,

$\rho(E_T, j)$ = Concentration of $Th_{232}$ in the j pad,

$B(E)$ = Background Count rate

$I'(E_k, E_u, E_T; E)$ = Observed Count Rate at E Due to concentrations of $K_{40}, U_{238}$, and $Th_{232}$.

If we let

${}^{k}I'_j$ = Count Rate of K channel measured on pad j.

${}^{u}I'_j$ = Count Rate of U channel measured on pad j.

${}^{T}I'_j$ = Count Rate of Th channel measured on pad j.

Then we may write a set of 3 matrix equations for each channel measurement

K CHANNEL

$$\begin{pmatrix} {}^{k}I'_2 \\ {}^{k}I'_3 \\ {}^{k}I'_4 \\ {}^{k}I'_5 \end{pmatrix} = \begin{pmatrix} \rho(E_k, 2) & \rho(E_u, 2) & \rho(E_T, 2) \\ \rho(E_k, 3) & \rho(E_u, 3) & \rho(E_T, 3) \\ \rho(E_k, 4) & \rho(E_u, 4) & \rho(E_T, 4) \\ \rho(E_k, 5) & \rho(E_u, 5) & \rho(E_T, 5) \end{pmatrix} \begin{pmatrix} {}^{k}s_k \\ {}^{k}s_u \\ {}^{k}s_t \end{pmatrix} + B_k \qquad (5a)$$

U CHANNEL

$$\begin{pmatrix} {}^{u}I'_2 \end{pmatrix} \qquad \begin{pmatrix} \rho(E_k, 2) & \rho(E_u, 2) & \rho(E_T, 2) \end{pmatrix}$$

$$\begin{pmatrix} {}^{u}I'_3 \\ {}^{u}I'_4 \\ {}^{u}I'_5 \end{pmatrix} = \begin{pmatrix} \rho(E_k,3) & \rho(E_u,3) & \rho(E_T,3) \\ \rho(E_k,4) & \rho(E_u,4) & \rho(E_T,4) \\ \rho(E_k,5) & \rho(E_u,5) & \rho(E_T,5) \end{pmatrix} \begin{pmatrix} {}^{u}s_k \\ {}^{u}s_u \\ {}^{u}s_t \end{pmatrix} + B_u \qquad (5b)$$

<u>Th CHANNEL</u>

$$\begin{pmatrix} {}^{T}I'_2 \\ {}^{T}I'_3 \\ {}^{T}I'_4 \\ {}^{T}I'_5 \end{pmatrix} = \begin{pmatrix} \rho(E_k,2) & \rho(E_u,2) & \rho(E_T,2) \\ \rho(E_k,3) & \rho(E_u,3) & \rho(E_T,3) \\ \rho(E_k,4) & \rho(E_u,4) & \rho(E_T,4) \\ \rho(E_k,5) & \rho(E_u,5) & \rho(E_T,5) \end{pmatrix} \begin{pmatrix} {}^{T}s_k \\ {}^{T}s_u \\ {}^{T}s_T \end{pmatrix} + B_T \qquad (5c)$$

where

$$\begin{aligned} {}^{L}s_M &= \int_L C(E_M)\,R(E_M;E)\,dE \\ L,M &= K,U,T \end{aligned} \qquad (6)$$

We can interpret (6) as the weighted sum of the crystal response in channel L, due to an elemental impure photon in channel M. Clearly, if L is of higher energy than M, we would expect a value of (6) to be nearly zero. The units of ${}^{L}s_M$ are counts/sec/elemental concentration.

The set of matrix equations (5a) through (5c) represents a set of 12 equations with 9 unknown variables ${}^{L}s_M$. To solve these equations the count rates measured on pads 2 through 5 were fit in a least square sense. The background values $B_k$, $B_u$, $B_{Th}$, were estimated from averaged measurements from pad 1.

The differential concentrations, as supplied by Bendix Field Corporation, are tabulated on page 12. Only data for the down crystals were used in the least squares analysis.

For each pad measurement, a matrix equation may be written relating the observed count rate to the elemental concentration by the least squares sensitivity matrix. Thus, from (5a), (5b), and (5c):

$$\begin{pmatrix} {}^{k}I'_{j} \\ {}^{u}I'_{j} \\ {}^{T}I'_{j} \end{pmatrix} = S \cdot \begin{pmatrix} \rho(E_k;j) \\ \rho(E_u;j) \\ \rho(E_T;j) \end{pmatrix} \quad \begin{pmatrix} B_k \\ B_u \\ B_T \end{pmatrix} \tag{7a}$$

where

$$S = \begin{pmatrix} {}^{k}s_{k} & {}^{k}s_{u} & {}^{k}s_{T} \\ {}^{u}s_{k} & {}^{u}s_{u} & {}^{u}s_{T} \\ {}^{T}s_{k} & {}^{T}s_{u} & {}^{T}s_{T} \end{pmatrix} \tag{7b}$$

Upon inverting (7a), the elemental concentrations may be solved for in terms of the observed count rates.

$$\begin{aligned} \rho(E_k,j) &= S_3\ \left(({}^{k}I'_{j} - B_k) - {}^{k}\phi_u({}^{u}I'_{j} - B_u) - {}^{k}\phi_T\ ({}^{T}I'_{j} - B_T)\right. \\ &= S_3^k\ I\ \mathrm{corr} \end{aligned} \tag{8a}$$

$$\rho(E_u,j) = S_2(({}^{u}I'_{j} - B_u) - {}^{u}\phi_T\ ({}^{T}I'_{j} - B_T) - {}^{u}\phi_k\ ({}^{k}I'_{j} - B_k))$$

$$= S_2 \, {}^{u}I_{corr} \tag{8b}$$

$$\rho(E_T, j) = S_1 \left( ({}^{T}I'_j - B_T) - {}^{T}\phi_k \, ({}^{k}I'_j - B_k) - {}^{T}\phi_u \, ({}^{u}I'_j - B_u) \right)$$

$$= S_1 \, {}^{T}I_{corr} \tag{8c}$$

Where ${}^{k}I'_{corr}$, ${}^{u}I_{corr}'$ and ${}^{T}L'_{corr}$ are the Compton and background corrected count rates for k, u, and T respectively; $S_3$, $S_2$, and $S_1$ are the inverse sensitivities of the crystal packs relative to k, u, T, respectively. The quantities ${}^{M}\phi_L$ are the full stripping Compton coefficients (dimensionless) which relate the effect in channel M of a photon in channel L.

Both Compton coefficients and sensitivities are determined from a least squares regression on count rates measured on pads 2 through 5. Pad 1 is used as a reference pad to establish the background count rates.

## ATMOSPHERIC RADON CORRECTION

For notational purposes, we designate the count rates measured at Lake Mead in the following form.

$$\text{Count Rate} = {}^{(U.D.)}(K, U, T, C)_{(L, W)} \tag{1}$$

Where K, U, and T refer to the Potassium, Bismuth, and Thallium channels respectively.

The superscripts (U.D.) refer to the up ($2\pi$) and down ($4\pi$) crystals respectively. The subscripts (L, W) refer to count rates measured over land and water respectively. The prime (') indicates that the count data are corrected for background and stripped. The raw data are unprimed.

For example, ${}^{u}U_W$ refer to the raw data in the Bismuth channel measured by the 2π crystal over water.

Consider the four experimental situations encountered at Lake Mead.

WATER

$$^{D}U_{W} = Bi_{A} + {}^{D}B_{u} + {}^{u}\phi_{k}\ ({}^{D}K_{W} - {}^{D}B_{k}) + {}^{u}\phi_{T}\ ({}^{D}T_{W} - {}^{D}B_{T}) + \text{Cosmic } 4\pi \qquad (2a)$$

$$^{U}U_{W} = {}^{\phi}{}_{B}\ Bi_{A} + {}^{U}B_{u} + \text{Cosmic } 2\pi \qquad (2b)$$

LAND

$$^{D}U_{L} = Bi_{A} + {}^{D}B_{u} + U_{G} + {}^{u}\phi_{k}\ ({}^{D}K_{L} - {}^{D}B_{k}) + {}^{u}\phi_{T}\ ({}^{D}T_{L} - {}^{D}B_{T}) + \text{Cosmic } 4\pi \qquad (3a)$$

$$^{U}U_{L} = {}^{\phi}{}_{B}Bi_{A} + {}^{U}B_{u} + B_{o}\ (Z)\ {}^{D}U'_{L} + C_{o}\ {}^{D}T'_{L} + \text{Cosmic } 2\pi \qquad (3b)$$

Where $Bi_A$ is the count rate due to atmospheric bismuth within the channel. It is assumed that the $Bi_A$ level is invariant over land or water (perfect atmospheric mixing). $Bi_A$ can; however, vary with survey altitude.

$^{(U,\ D)}B_{(k,\ u,\ T)}$ are the up and down backgrounds (established by the high altitude tests).

Cosmic 2π (4π) are the cosmic corrections for the Bi channel.

$U_G$ is the count rate in the Bi channel due to ground sources,

$B_o(Z), C_o$ are the counts observed in the upward-looking Bi channel per downward-looking count in "stripped" U and T respectively,

$\phi_B$ is the fraction of $Bi_A$ detected by the $2\pi$ crystals with respect to the $4\pi$ crystals.

$B_o$ and $C_o$ are the fraction of $U_G$ detected by the $2\pi$ crystals, with respect to the $4\pi$ crystals.

To determine $Bi_A$ over land, we first calculated $\phi_B$ from the over water data. From equations (2a) and (2b) we have:

$$\phi_B = \frac{{}^{U}U_W - {}^{U}B_u - \text{Cosmic } 2\pi}{{}^{D}U_W - {}^{D}B_u - \text{Cosmic } 2\pi} \qquad (4)$$

A linear least squares fit established the altitude of $\phi_B$.

Similarly, we can determine the altitude dependence of $B_o$ and $C_o$.

The value of $B_o(0)$ and $C_o(0)$ were established at the Walker Field Test Facility.

With $B_o$ and $C_o$ estimated, the air effect on the bismuth channel may be written:

$$Bi_A = \frac{U_{up} - B_o\,(Z)\,U'_L - C_oT_L'}{\phi_B\,(Z) - B_o\,(Z)} \qquad (5)$$

Where:

$U_{up}$ is the count rate from the upward-looking detector corrected for cosmic and background effects.

| | |
|---|---|
| $B_o(Z), C_o$ | are the counts observed in the upward-looking Bi channel per downward-looking in "stripped" U and T respectively. |
| $\phi_B(Z)$ | is the $4\pi$ to $2\pi$ geometric ratio. |
| $U_L'$ | is the Compton Scatter corrected Bi count rate ($4\pi$ detector). |
| $T_L'$ | is the Compton Scatter corrected Tl count rate. |

# DATA COLLECTION

## PRODUCTION SUMMARY

A total of 1600 line-miles of spectrometric and magnetic data was collected in the area flown for this project. Table 1 summarizes the flight information for the area.

TABLE 1

| AREA | DATE COMMENCED | DATE COMPLETED | LINE-MILES | AIRCRAFT |
|---|---|---|---|---|
| McDermitt | 11/04/80 | 11/08/80 | 1600 | N49537 |

In the McDermitt area, flight lines were flown east-west at quarter-mile spacing, and tie lines were flown perpendicular to the flight lines (see flight line maps accompanying report).

## FLIGHT PROCEDURES

### Operating Parameters - System #1 - N49537

1. Data sampling rates of the system elements are shown below:

| SYSTEM ELEMENT | |
|---|---|
| 8 Downward-looking crystals (Total volume of 2048 cu. ins. | 1 second (256 channels and cosmic) |
| 2 Upward-looking crystals (Total volume of 320 cu. ins.) | 1 second (256 channels and cosmic) |
| Live Time ($4\pi$) system | 1 second (Binary output) |

| | |
|---|---|
| Live Time ($2\pi$) system | 10 second (Binary output) |
| Geometrics G-803 Magnetometer (.25 gamma sensitivity) | 1 second (BCD output) |

Ancillary Sensors

| | |
|---|---|
| Collins ALT-50 Altimeter | |
| Sensotec Pressure Transducer | |
| Temperature Transducer | |
| Radar Altimeter | |
| Clock (hours, minutes, seconds) | 1 second (Binary output) |
| Automax 35 mm framing camera | 3 seconds |

2. At the end of a line, the summed spectra for both the $4\pi$ system and the $2\pi$ system were written to magnetic tape. The purpose was to ensure channel resolution and photopeak stability in subsequent processing.

3. Lama nominal ground speed was 90 m.p.h. With a downward crystal volume of 2048 cu. ins., the ratio V/v = 22.76 cu. ins./m.p.h. This average speed was not exceeded except when dictated for aircraft safety.

DAILY SYSTEM CALIBRATION

System #1 - Lama N49537

Pre-flight Checks

a. Cesium sources were positioned at the same point on both the $4\pi$ and $2\pi$ detector crystals each day to peak each photo-multiplier tube. The oscilloscope display and LSI-II microcomputer output indicated the optimum peak setting.

b. The full cesium spectrum was displayed on the cathode-ray tube (CRT) for both upward-looking and downward-looking crystals to calculate the cesium resolution.

c. Thorium sources were used to verify the high energy end of the spectrum for the upward-looking and downward-looking crystals. The output is displayed on the CRT or the LSI-II.

d. The full thorium spectrum for the downward-looking crystals was displayed to verify the location of the K40 and the thorium photopeaks.

<u>In-flight Checks</u>

a. Each day, prior to production flying, a test line approximately 5 miles long was flown at the planned survey altitude. Data from the test line were examined to ensure + 10% repeatability of the total counts.

b. During production flying, the visual display units were carefully monitored to detect changes in data quality.

<u>Post-flight Checks</u>

a. Pre-flights checks were repeated to ensure that no malfunction in the data system occurred during the data collection.

## FLIGHT PATH RECOVERY

Aircraft track was established by visual in-flight identification of prominent ground features by the operator. At the end of each production flight, all mislocations were adjusted by correlating the 35 mm photos with USGS topographic map sheets. Final posting of flight track pick-points was done on 1:62,500. scale topographic map sheets.

# DATA PROCESSING

## PRE-PROCESSING

By "pre-processing", we refer to those procedures that are applied to the field data and flight line locations to prepare them for final processing, merging and output. Steps in this "pre-processing" stage included field data tape editing and compacting, flight line location verification, and generation of preliminary data reports. The reader is referred to the data processing flow chart, Figure 2, which accompanies this report, and which illustrates the steps described below.

### Field Tape Compacting and Editing

A check of the field data tapes by computer is necessary to verify data collection and recording quality. The summed spectral data for both $4\pi$ and $2\pi$ crystals were first read from a series of merged field tapes. The centroids of channel photopeaks for each flight line were next calculated from these data, and a linear equation that relates the photo energy, in MeV, to the channel number was derived from the centroid calculation is of the form:

$$E = E(0) = dE/dch \times ch$$

Where E(0) is the apparent energy at channel zero, and ch is the channel number (0-255). This procedure was not applied if the survey line was too short (less than 10 minutes duration) to establish adequately smooth summed spectral data for photopeak calculations. Next the summed or "stacked" spectral data were used to calculate the resolution for K,U,Th photopeaks. Both photopeak linearity and resolution were used to establish the acceptability of the spectrometer data.

Next, the data within each flight line were checked for correct one (1) second and ten (10) second scan lengths. Erroneous scan lengths were flagged, and the spectral data for the erroneous scans were not used in the subsequent data analysis. In addition to these editing steps, the ancillary data (altimeter, pressure, and temperature) were computed from the transducer analogue voltage output. The data from each scan were used to extract one second channel window data fields, and these data fields were corrected for system "dead time". At the end of this stage of the data processing, two computer tapes were written (items 3 and 4 of Figure 2). Item 3 is a partially written RAW SPECTRAL TAPE (see Appendix A) containing all of the required data entries exclusive of the location information. Item 4 is a tape written in internal binary code. This tape contains all of the required entries for further processing. Full spectral data were not written on this tape, as these are contained on the partial RAW SPECTRAL TAPE.

In producing item 4, a series of computer generated histograms was produced for each survey line. Typically, these histograms summarize data recorded on the K, U, and Th channels ($4\pi$ and $2\pi$), together with ancillary data (altimeter, pressure, and temperature).

Editing was next performed on the binary tape. Further checking consisted of rereading (with unnecessary flight data removed); and searching for and removing unrealistic gradients, transients, spikes, etc. The acceptability of questionable data segments was reviewed and corrections performed. The result of this procedure was an edited tape, which has "clean" data available for step 5 of the data processing (Figure 2).

## Flight Line Recovery

Determining actual flight-line location is a crucial task in the data processing. It is accomplished primarily by using photographs taken in flight. After the flight film is developed, a photo interpreter correlates the photo-data with the flight navigator's visual location picks on the NTMS map sheets. Actual aircraft locations were determined from the flight films and transferred to a base map with the fiducial numbers of the corresponding photographs. Once data transfer to the base map was complete, fiducial numbers and locations along each flight line were digitized, and an automated computer routine checked the consistency of these data. This was done by calculating the average distance between fiducials, and establishing that this distance was approximately constant along a given flight line. After computer verification, map coordinates for each photo pick point and the beginning and ending points of each flight line were calculated and a computer plot of these points made and checked against the field plot. Any discrepancies were noted, and the misplaced pick points relocated from the flight film. The procedure was repeated until consistency was achieved.

Once the flight line data was verified, a mylar transparency of the flight lines was prepared on the Cal Comp 915 at a scale of 1:62,500. This transparency was then overlain on the geologic base map and each map unit digitized so that each sample fell within a single unit.

## RADIOMETRIC DATA PROCESSING

The "cleaned" data require a number of corrections and statistical evaluation before data plots can be produced. These corrections were done in step 5 (Figure 2), and include:

1. Aircraft and cosmic background corrections,
2. Compton stripping,
3. Atmospheric radon correction
4. Altitude corrections,
5. Statistical adequacy criteria.

The constants used in the correction procedures were obtained in calibration tests at the Walker Field Test Pads and the Lake Mead Dynamic Test Range.

### 1. Aircraft and Cosmic Background Corrections

Aircraft background, and cosmic correction ratios for the Lama helicopter are listed below:

AIRCRAFT AND COSMIC BACKGROUND CORRECTIONS - #N49537

| CHANNEL WINDOW | AIRCRAFT BACKGROUND COUNTS/SEC | COSMIC CORRECTION RATION (DIMENSIONLESS) |
|---|---|---|
| K-40 ($4\pi$) | 6.02 | .2092 |
| Bi-214 ($4\pi$) | 2.52 | .1825 |
| Tl-208 ($4\pi$) | 2.37 | .2176 |
| TOTAL COUNT | 64.68 | 3.4579 |
| Bi-214 ($2\pi$) | | .2143 |

### 2. Compton Stripping

Compton Scattering corrections to the $4\pi$ data were made using the following stripping coefficients.

RADIOELEMENT SENSITIVITY CONSTANTS NORMALIZED TO 400 FEET

SYSTEM #1 - LAMA N49537

| Radioelement | Sensitivity Constant |
|---|---|
| K40 | 78.46 counts/sec/% |
| Uranium | 9.23 counts/sec/ppm eU |
| Thorium | 4.92 counts/sec/ppm eTh |

## MAGNETIC DATA PROCESSING

Steps in reduction of the magnetic data consisted of diurnal variation correction, common magnetic datum tieing, and removal of regional magnetic fields defined by the International Geomagnetic Reference Field (IGRF).

The IGRF model used to correct the observed data was that adopted by the International Association of Geomagnetism and Aeronomy, Division I study group at Grenoble, France on September 4, 1975. The spherical harmonic coefficients adopted by IAGA were used to generate the theoretical magnetic field at 20 points in each quadrangle. A theoretical least squares polynomial surface in UTM coordinates was then set to fit the theoretical reference field. Letting X = Easting and Y + Northing, the theoretical IGRF field was fitted to a residual error of less than 0.1 gammas by the following series expansion in X and Y:

$$T_{IGRF} = 40060.35 + 0.91443\ (X - 740.73) + 3.8216(Y-2974.4) \text{ gammas.}$$

The residual magnetic field ($T_{RES}$) is defined as:

$$T_{RES} = T_{OBS} - T_{IGRF}$$

where

$T_{OBS}$ is the observed field.

A ground based magnetometer monitored diurnal variations of the magnetic field during the airborne operation. Data were sampled at 4-second intervals at a sensitivity of one quarter gamma and were recorded along with time code on analogue tapes. Editing was performed to remove data spikes, man-made magnetic events, and extraneous readings. A profile display was made as a check to determine visually that all necessary editing had been performed. The edited, compacted diurnal data were time coded to match the airborne data, (see Figure 3) densified to a one (1) second sample interval and subtracted from the airborne data.

Magnetic differences in the resultant diurnally corrected plots between tie lines and flight lines at intersections were treated by a tieing program. Individual line biases were calculated for both tie and profile lines. These biases were caused by changes of ground based magnetometer location, aircraft magnetization, and effects due to differential aircraft heading.

As a final check on the validity of the magnetic data, a printer plot map was generated and analyzed to locate exceptional tieing and/or location errors.

Both the IGRF and diurnal corrections were then applied to the merged binary tape. This completed the data processing stage of the analysis. Data on the merged binary tape was then ready for display and final presentation.

## DATA PRESENTATION

The results of the survey are presented on maps and stacked profiles as follows:

1. Flight path location map - Flight line and tie line paths together with fiducial numbers are plotted for each area on a photo-mosaic base at a scale of 1:62,500.

2. Stacked Profiles - Reduced radiometric, magnetic, and ancillary data are presented on profiles vertically stacked relative to a reference line and at a scale of 1:62,500. The following information is presented on these profiles:

   a. Total gamma-ray counts
   b. K40 as percent potassium (%K)
   c. Bi214 as parts per million equivalent uranium (ppm eU)
   d. Tl208 as parts per million equivalent thorium (ppm eTh)
   e. Bi214/Tl208 as ppm eU/ppm eTh
   f. Bi214/K40 as ppm eU/%K
   g. Tl208/K40 as ppm eTh/%K
   h. Total Intensity Magnetic Data
   i. Radar Altimeter

# APPENDIX A—TAPE FORMATS

## RAW SPECTRAL DATA TAPE

The RAW SPECTRAL DATA is unlabeled nine track, 2400 foot reel length, 800 BPI, NRZI, odd parity. All data are recorded as EBCDIC characters. Each tape contains identification, header, and data records. The block length is 6600 characters.

The first physical block on tape is a literal alphanumeric listing for the Fortran formats and data items. This listing allows a user to unambiguously read and interpret all of the data contained on the tape.

The second physical block is organized as follows:

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | A40 | QUADRANGLE NAME AS PROJECT IDENTIFICATION |
| 2 | A20 | NAME OF SUBCONTRACTOR (HIGH-LIFE/QEB) |
| 3 | 14 | APPROXIMATE DATE OF SURVEY (MONTH, YEAR) |
| 4 | I1 | AERIAL SYSTEM IDENTIFICATION CODE |
| 5 | A20 | AIRCRAFT IDENTIFICATION BY TYPE AND FAA NUMBER |
| 6 | I3 | BFEC CALIBRATION REPORT NUMBER |
| 7 | F6.3 | 4PI SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL PLACES IN SECONDS |
| 8 | F6.3 | 2PI SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL PLACES IN SECONDS |
| 9 | I3 | NUMBER OF CHANNELS (0-3MEV) FOR 4PI SYSTEM |
| 10 | I3 | NUMBER OF CHANNELS (0-3MEV) FOR 2PI SYSTEM |
| 11 | I3 | NUMBER OF FLIGHT LINES ON THIS TAPE |
| 12 | I4 | FIRST FLIGHT LINE NUMBER OF THIS TAPE |
| 13 | I6 | FIRST RECORD NUMBER OF FIRST FLIGHT LINE |

| | | |
|---|---|---|
| 14 | I3 | JULIAN DATE (DAY OF YEAR) FIRST FLIGHT LINE WAS COLLECTED |
| 15-17 | I4,I6,I3 | REPEAT OF ITEMS 12-14 FOR SECOND FLIGHT LINE ON THIS TAPE |
| * | * | * |
| * | * | * |
| * | * | * |
| 306-308 | I4,I6,I3 | REPEAT OF ITEMS 12-14 FOR 99TH FLIGHT LINE OF THIS TAPE |

The third and following physical blocks are organized as follows:

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | I1 | AERIAL SYSTEM IDENTIFICATION CODE |
| 2 | I4 | FLIGHT LINE NUMBER |
| 3 | I6 | RECORD IDENTIFICATION NUMBER |
| 4 | I6 | GMT TIME OF DAY (HHMMSS) |
| 5 | F8.4 | LATITUDE TO FOUR DECIMAL PLACES IN DEGREES |
| 6 | F8.4 | LONGITUDE TO FOUR DECIMAL PLACES IN DEGREES |
| 7 | F6.1 | TERRAIN CLEARANCE TO ONE DECIMAL PLACE IN METERS |
| 8 | F7.1 | TOTAL MAGNETIC FIELD INTENSITY TO ONE DECIMAL PLACE IN GAMMAS |
| 9 | A8 | SURFACE GEOLOGIC MAP UNIT CODE |
| 10 | I4 | QUALITY FLAG CODES |
| 11 | F4.1 | OUTSIDE AIR TEMPERATURE TO ONE DECIMAL PLACE IN DEGREES CELSIUS |
| 12 | F5.1 | OUTSIDE AIR PRESSURE TO ONE DECIMAL PLACE IN MMHG |
| 13 | F5.3 | LIVE TIME COUNTING PERIOD TO THREE DECIMAL PLACES IN SECONDS |
| 14 | I4 | SUMMED RAW OUTPUT FROM COSMIC CHANNELS (3-6 MEV) IN COUNTS |
| 15 | I4 | RAW OUTPUT FROM CHANNEL 1 IN COUNTS |

| | | |
|---|---|---|
| 16 | I4 | RAW OUTPUT FROM CHANNEL 2 IN COUNTS |
| * | * | * |
| * | * | * |
| * | * | * |
| 270 | I4 | RAW OUTPUT FROM CHANNEL 256 IN COUNTS |

## SINGLE RECORD REDUCED DATA TAPE

THE SINGLE RECORD REDUCED DATA TAPE is unlabeled nine track, 2400 foot reel length, NRZI, odd parity. All data are recorded in EBCDIC characters. Each tape contains identificatiom, header and data records.

The block length is 6900 characters.

The first physical block on tape is literal alphanumeric listing of the Fortran formats and data items. This listing allows a user to unambigously read and interpret all of the data contained on the tape.

The second physical block is organized as follows:

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | A40 | QUADRANGLE NAME AS PROJECT IDENTIFICATION |
| 2 | A20 | NAME OF SUBCONTRACTOR (HIGH-LIFE/QEB) |
| 3 | I4 | APPROXIMATE DATE OF SURVEY (MONTH,YEAR) |
| 4 | I1 | NUMBER OF AERIAL SYSTEMS USED TO COLLECT DATA FOR THIS QUADRANGLE |
| 5 | I1 | AERIAL SYSTEM IDENTIFICATION CODE FOR FIRST SYSTEM |
| 6 | A20 | AIRCRAFT IDENTIFICATION BY TYPE AND FAA NUMBER FOR FIRST SYSTEM |
| 7 | F6.1 | NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO TERRESTRIAL POTASSIUM (K-40) TO ONE DECIMAL PLACE IN CPS PER PERCENT K FOR FIRST SYSTEM |
| 8 | F6.1 | NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TERRESTRIAL URANIUM (BI-214) TO ONE DECIMAL PLACE IN CPS PER PPM EQUIVALENT U |

| | | |
|---|---|---|
| 9 | F6.1 | NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO TERRESTRIAL THORIUM (TL-208) TO ONE DECIMAL PLACE IN CPS PER PPM EQUIVALENT TH |
| 10 | I6 | BLANK FIELD (999999) |
| 11 | F6.3 | 4PI-SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL PLACES IN SECONDS FOR FIRST SYSTEM |
| 12 | F6.3 | 2PI-SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL PLACES IN SECONDS FOR FIRST SYSTEM |
| 13 | I3 | NUMBER OF CHANNELS (0-3MeV) IN 4PI SYSTEM FOR FIRST AERIAL SYSTEM |
| 14 | I3 | NUMBER OF CHANNELS (0-3MeV) IN 2PI SYSTEM FOR FIRST AERIAL SYSTEM |
| 15-24 | (SAME) | REPEAT OF ITEMS 5-14 FOR SECOND AERIAL SYSTEM |
| * | * | * |
| * | * | * |
| * | * | * |
| 85-94 | (SAME) | REPEAT OF ITEMS 5-14 FOR NINTH AERIAL SYSTEM |
| 95 | I3 | NUMBER OF FLIGHT LINES ON THIS TAPE |
| 96 | I4 | FIRST FLIGHT LINE NUMBER ON THIS TAPE |
| 97 | I6 | FIRST RECORD NUMBER OF FIRST FLIGHT LINE |
| 98 | I3 | JULIAN DATE (DAY OF YEAR) FIRST FLIGHT LINE DATA WAS COLLECTED |
| 99-101 | I4,I6,I3 | REPEAT OF ITEMS 96-98 FOR SECOND FLIGHT LINE ON THIS TAPE |
| * | * | * |
| * | * | * |
| * | * | * |
| 390-392 | I4,I6,I3 | REPEAT OF ITEMS 96-98 FOR 99TH FLIGHT LINE ON THIS TAPE |

The third and following physical blocks are organized as follows:

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | I1 | AERIAL SYSTEM IDENTIFICATION CODE |

| | | |
|---|---|---|
| 2 | I4 | FLIGHT LINE NUMBER |
| 3 | I6 | RECORD IDENTIFICATION NUMBER |
| 4 | I6 | GMT TIME OF DAY (HHMMSS) |
| 5 | F8.4 | LATITUDE TO FOUR DECIMAL PLACES IN DEGREES |
| 6 | F8.4 | LONGITUDE TO FOUR DECIMAL PLACES IN DEGREES |
| 7 | F6.1 | TERRAIN CLEARANCE TO ONE DECIMAL PLACE IN METERS |
| 8 | F7.1 | RESIDUAL (IGRF REMOVED) MAGNETIC FIELD INTENSITY TO ONE DECIMAL PLACE IN GAMMAS |
| 9 | A8 | SURFACE GEOLOGIC MAP UNIT CODE |
| 10 | I4 | QUALITY FLAG CODES |
| 11 | F6.1 | APPARENT CONCENTRATION OF TERRESTRIAL POTASSIUM (K-40) TO ONE DECIMAL PLACE IN PERCENT K |
| 12 | F4.1 | UNCERTAINTY IN TERRESTRIAL POTASSIUM TO ONE DECIMAL PLACE IN PERCENT K |
| 13 | F6.1 | APPARENT CONCENTRATION OF TERRESTRIAL URANIUM (BI-214) TO ONE DECIMAL PLACE IN PPM EQUIVALENT U |
| 14 | F4.1 | UNCERTAINTY IN TERRESTRIAL URANIUM TO ONE DECIMAL PLACE IN PPM EQUIVALENT U |
| 15 | F6.1 | APPARENT CONCENTRATION OF TERRESTRIAL THORIUM (TL-208) TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH |
| 16 | F4.1 | UNCERTAINTY IN TERRESTRIAL THORIUM TO ONE DECIMAL PLACE IN EQUIVALENT TH |
| 17 | F6.1 | URANIUM-TO-THORIUM RATIO TO ONE DECIMAL PLACE IN PPM EQUIVALENT U PER PPM EQUIV-ALENT TH |
| 18 | F6.1 | URANIUM-TO-POTASSIUM RATIO TO ONE DECIMAL PLACE IN PPM EQUIVALENT U PER PERCENT K |
| 19 | F6.1 | THORIUM-TO-POTASSIUM RATIO TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH PER PERCENT K |
| 20 | F8.1 | GROSS GAMMA (0.4-3.0 MeV) COUNT RATE TO ONE DECIMAL PLACE IN COUNTS PER SECOND |
| 21 | F6.1 | UNCERTAINTY IN GROSS GAMMA COUNT RATE TO ONE DECIMAL PLACE IN COUNTS PER SECOND |

| | | |
|---|---|---|
| 22 | F5.1 | ATMOSPHERIC BI-214 4PI CORRECTION TO ONE DECIMAL PLACE IN PPM EQUIVALENT U |
| 23 | F4.1 | UNCERTAINTY IN ATMOSPHERIC BI-214 4PI CORRECTION TO ONE DECIMAL PLACE IN PPM EQUIVALENT U |
| 24 | F4.1 | OUTSIDE AIR TEMPERATURE TO ONE DECIMAL PLACE IN DEGREES CELSIUS |
| 25 | F5.1 | OUTSIDE AIR PRESSURE TO ONE DECIMAL PLACE IN MMHG |

# APPENDIX B-PRODUCTION SUMMARY

| Date | Production/Remarks |
|---|---|
| 11/04/80 | 318.0 line miles |
| 11/05/80 | 477.6 |
| 11/06/80 | 352.5 |
| 11/07/80 | 160.0 |
| 11/08/80 | 291.9 |