Geology
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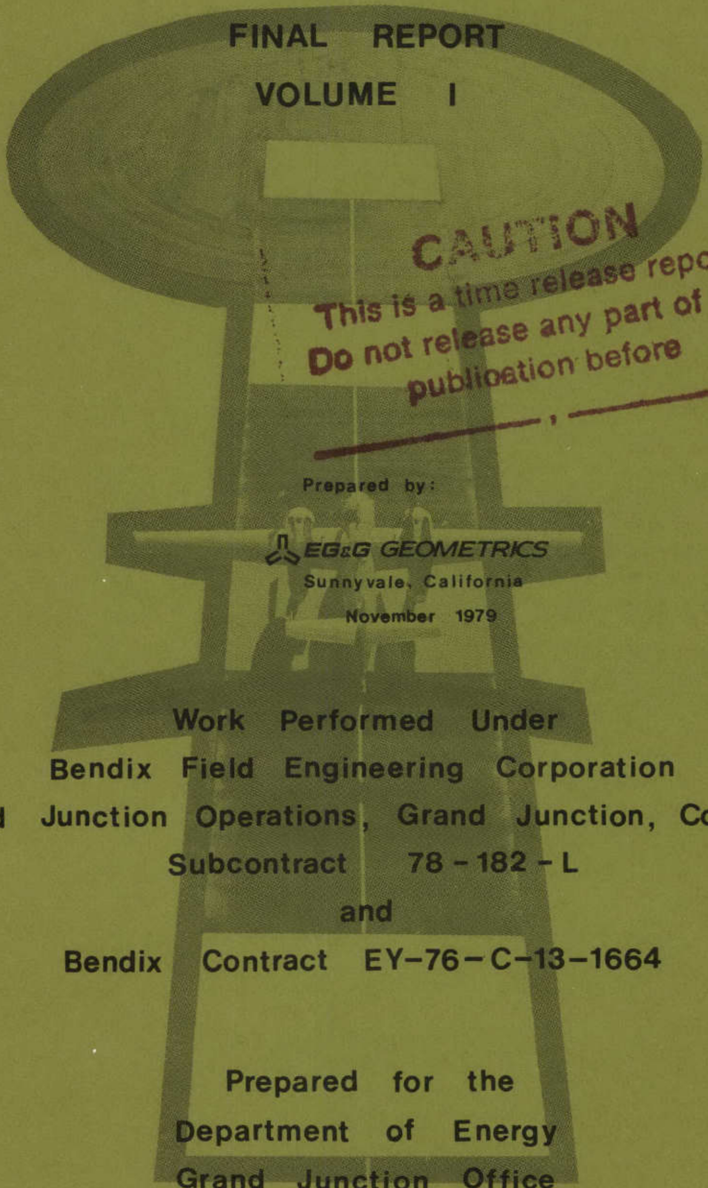
# AERIAL GAMMA RAY AND MAGNETIC SURVEY
## RATON BASIN PROJECT
## THE RATON AND SANTA FE QUADRANGLES OF NEW MEXICO



FINAL REPORT
VOLUME I

CAUTION
This is a time release report.
Do not release any part of this
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_______ , _______

Prepared by:

EG&G GEOMETRICS
Sunnyvale, California
November 1979

Work Performed Under
Bendix Field Engineering Corporation
Grand Junction Operations, Grand Junction, Colorado
Subcontract 78-182-L
and
Bendix Contract EY-76-C-13-1664

Prepared for the
Department of Energy
Grand Junction Office
Grand Junction, Colorado 81502

# DISCLAIMER STATEMENT

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# ABSTRACT

In 1978, EG&G geoMetrics collected 4955 line miles of high sensitivity airborne radiometric and magnetic data in New Mexico within the Raton and Santa Fe quadrangles. These quadrangles represent part of the Raton Basin Project.

All radiometric and magnetic data for the two quadrangles were fully reduced and interpreted by geoMetrics, and are presented as three volumes; one Volume I covering both quadrangles and separate Volume II's for the individual quadrangles.

Over 50 percent of the survey area is covered by flat lying Mesozoic and Cenozoic deposits of the southern Great Plains Province. The western and southern portions of the area contain a combination of Precambrian and Paleozoic igneous and metamorphic rocks. These rocks occur primarily within and in close proximity to the Sangre de Cristo Mountains and late Cenozoic volcanic deposits occur to the west of the mountains and in the Las Vegas Volcanic region.

Uranium deposits are scattered throughout the region, but none are known to be economic at the time of this report.

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# INTRODUCTION

## General

Under the U.S. Department of Energy's (DoE), National Uranium Resource Evaluation (NURE) Program, EG&G geoMetrics conducted a high sensitivity airborne radiometric and magnetic survey of the Raton and Santa Fe 1:250,000 quadrangles within the State of New Mexico (see Figure 1). The data collection and processing were conducted under requirements set forth in Bendix Field Engineering Corporation specification 1200-B (December, 1977). The objectives of the (DoE)/ NURE program, of which this project is a small part, may be summarized as follows:

> "To develop and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States." (DoE)

As an integral part of the DoE/NURE Program, the National Airborne Radiometric Program is designed to provide cost effective, semi-quantitative reconnaissance radioelement distribution information to aid in the assessment of regional distribution of uraniferous materials within the United States.

All Airborne data collected during the course of this project were done so utilizing an Aerospatiale SA315B "Lama" helicopters (U.S. Registry No. N47319), herein designated Lama I, and an S2F Grumman Tracker (U.S. Registry No. N9AG). The S2F used 4096 cubic inches of NaI crystal and the Lama used 2304 cubic inches of NaI crystal. Both aircraft utilized high sensitivity proton magnetometers (0.25 gamma).

This final report is organized in two logical sections: (a) Volume I, containing the survey description, specifications, data processing methods, interpretation methods, and regional geologic overview, (b) Volume II, one for each of the quadrangles surveyed. Each Volume II contains a detailed geologic summary, interpretational section, interpretation map, standard deviation maps, pseudo-contour maps, flight line and geologic base map, individual corrected profiles, computer map unit histograms and statistical tables.

All data processing, statistical analyses, and interpretation were performed at the geoMetrics computer facility, Sunnyvale, California. After processing, the corrected data were statistically evaluated to define those areas which were radiometrically anomalous relative to other areas within each computer map unit. Standard deviation maps and radiometric and magnetic profile data were first evaluated individually and then integrated into a final interpretation map for each NTMS quadrangle.

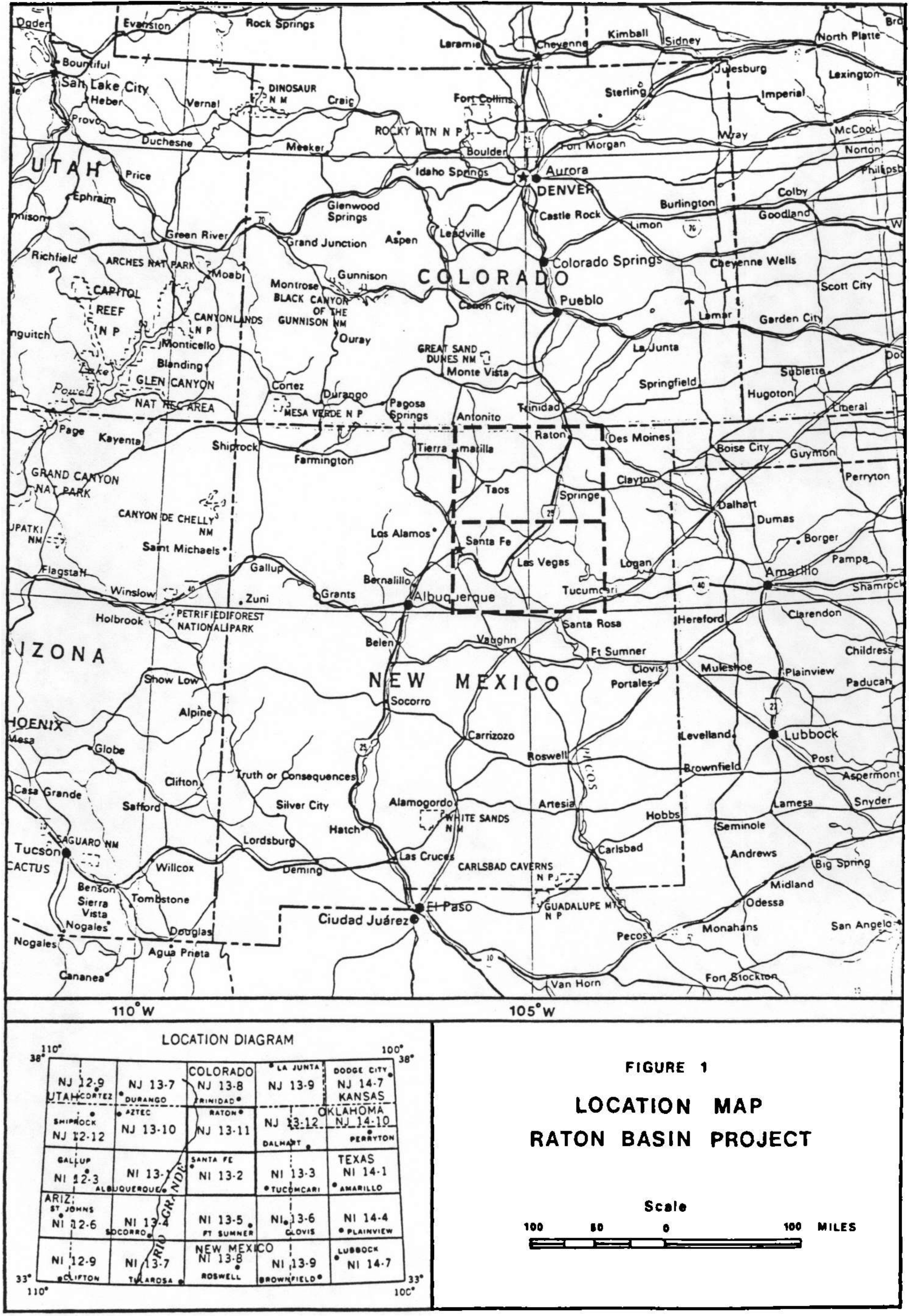


FIGURE 1

LOCATION MAP
RATON BASIN PROJECT

Corrected profiles of all radiometric variables (total count, potassium, uranium, thorium, uranium/thorium, uranium/potassium, and thorium/potassium ratios), magnetic data, radar altimeter data, barometric altimeter data, air temperature, and airborne bismuth contributions are presented as profiles in Volume II of this report. Single record and averaged data are presented on microfiche at 1.0 second sample intervals, corrected for Compton Scatter, referenced to 400 foot mean terrain clearance at Standard Temperature and Pressure (STP), and corrected for atmospheric bismuth, in Appendix C of Volume I. Digital magnetic tapes are available from geoMetrics containing raw spectral data, single record data, magnetic data, and statistical analysis results.

## Regional Geology

The area covered by the two 1 x 2 degree map sheets contains portions of the Southern Rocky Mountains, Southern Great Plains, and Basin-Range Physiographic Provinces.

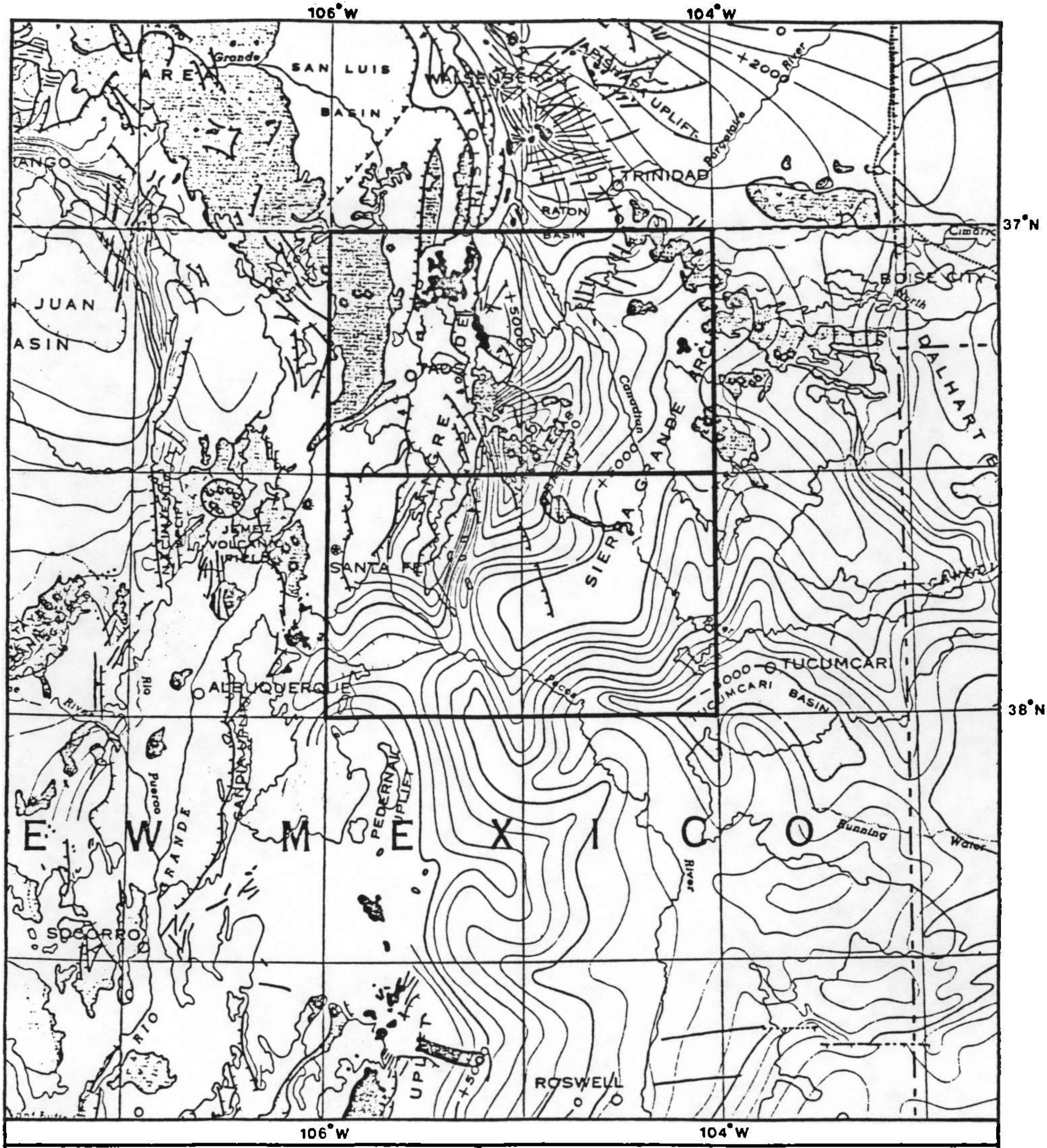
The Southern Rocky Mountains are here represented by the Sangre de Cristo Range, an uplifted block of Precambrian metamorphics, Paleozoic sedimentary rocks and Cenozoic volcanics. West of the Sangre de Cristo Range, the Rio Grande Rift Zone strikes southward where it merges with block-faulted terrain typical of the Basin-Range Province. In the study area, the rift zone is dominated by Cenozoic volcanics and young surficial deposits (alluvium). East of the Rockies are a series of small basins and associated structures of the Great Plains Province. Though dominated by flat to gently dipping Mesozoic, and Cenozoic sediments, the region is partially overlain by shallow intrusives and extrusives of Cretaceous through Quaternary age. The basic structural configuration of the area is shown in Figure 2.

Mapped faults occur as thrust faults forming the boundaries of the Sangre de Cristo Range and related complex faulting within the uplift itself. Some normal faults are mapped in the rift zone area.

Uranium prospects and/or claims are scattered throughout both quadrangles. Most occur in either the Sangre de Cristo Range, or are associated with igneous rocks of the Great Plains or Basin-Range Provinces. No current production figures for any of these claims could be found at the time of this report (See Figure 3). Uranium of the Coyote District was determined to be uneconomic at the time of its discovery (Robertson, 1976).

## Interpretation

A complete interpretation of the geophysical data for each of the two quadrangles is contained in Volume II of this report.



After
USGS and AAPG
Tectonic Map of the United States
by
Cohee and others (1962)

FIGURE 2

## TECTONIC STRUCTURE MAP
## RATON BASIN PROJECT

Scale 1:2,500,000

25 0 25 50 75 MILES

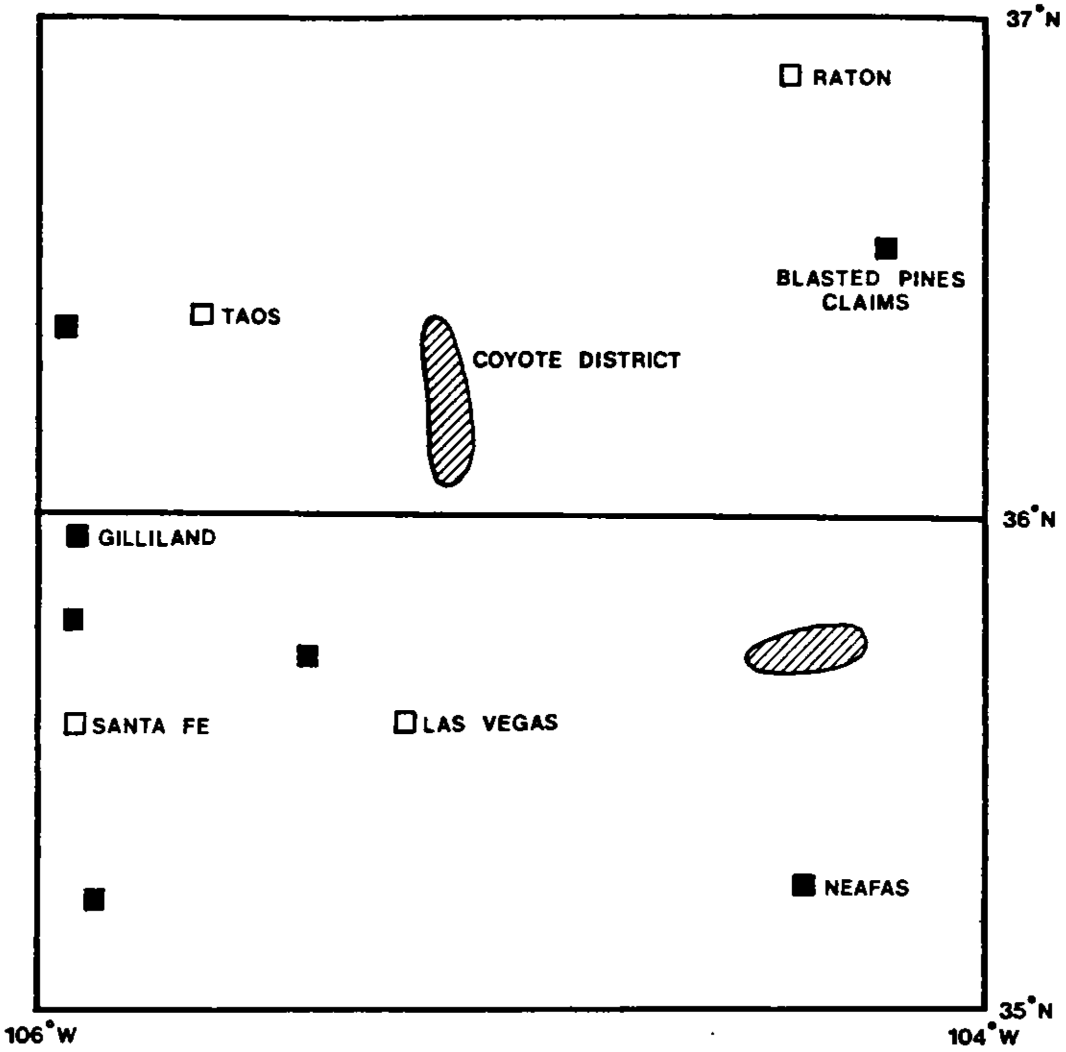


FIGURE 3

URANIUM CLAIMS AND PROSPECTS - RATON BASIN PROJECT
RATON AND SANTA FE QUADRANGLES

APPROXIMATE SCALE

■ – MINE, CLAIM, OR PROSPECT

▨ – MINING DISTRICT, OR AREA OF NUMEROUS MINES CLAIMS AND/OR PROSPECTS

☐ – TOWNS

# OPERATIONS

## PRODUCTION SUMMARY - RATON BASIN

For the two quadrangles, a total of 2249 line miles, excluding reflights and overlaps and missing data were flown by the Tracker and 2706 line miles were flown by the helicopter. The production summary presented below and the detailed daily production in Appendix B describes a third of the total project. The Raton Basin Project, of which these quadrangles are a part, covered four other 1° x 2° quadrangles which are covered in separate reports.

Prior to the start of the survey operations, the two aircraft were calibrated on the DoE test pads and Dynamic Test Rangeat Lake Mead. The S2F Tracker was calibrated in June, 1978 and Lama I was calibrated in July, 1978. Data collection within this portion of the project was initiated by S2F on October 16, 1978 from Santa Fe, New Mexico. Lama I began operations from Taos on October 18. The S2F completed its portion on October 19. Lama I finished on November 5. (See Figure 4).

Throughout the course of the overall project, the average ground speed maintained by the helicopter was 70 mph. The Tracker's speed ranged from 130 to 140 mph.

Overall, in excess of 95% of the data collected were within the specification limits (a sample altitude statistical distribution is shown in Figure 5).

## DATA COLLECTION PROCEDURES

### Operating Parameters/Sampling Procedures

This survey was conducted using data collection parameters summarized below:

1. Data sampling was performed by a time-based system using 1.0 second sample intervals. All sensor data with analog output were digitally sampled at each scan based upon the clock timing rate of 1.0 seconds. The data so collected are the instantaneous values of the altimeter, temperature, pressure, and magnetometer parameters determined at the time of the data scan, but represent a count time of 1.0 seconds for the gamma ray spectrometer data.

2. The helicopter's objective ground speed was 70 mph and the Tracker's was 135 mph. Neither one of the objective speeds was exceeded unless dictated by safety.

3. For the Lama, the downward looking crystal volume was 2,048 cubic inches providing an objective V/V (crystal volume in

cubic inches divided by ground speed in miles per hour) of 29.3 at 70 m.p.h. The S2F used 3584 cubic inches of downward looking crystal yielding the objective V/V ratio of 26.5.

4. The upward looking crystal volume was 256 cubic inches for the Lamas and 512 cubic inches for the S2F.

## Navigation/Flight Path Recovery

Profiles were flown east-west at 6 miles (9.6 kilometers) spacing in Raton and at 3 miles (4.8 kilometers) spacing in the Santa Fe quadrangle. North-south tie lines were flown at at 24 miles (38.4 kilometers) spacing in Raton and 12 miles (19.2 kilometers) spacing in Santa Fe.

Navigation was accomplished using a combination of visual and doppler navigation techniques in the fixed wing and visual in the rotary wing aircraft. Flight lines were drawn on 1:250,000 scale NTMS quadrangle sheets for the S2F and on 1:24,000 quadrangles for the Lama. The pilot/navigator utilized these maps to provide visual navigation features. Flight lines were generally started and ended visually for both the Lama and the S2F. While doppler was used to fly a straight line between end points in the S2F, visual methods were utilized for the Lama.

Simultaneously, a 35 mm tracking camera was used to record actual flight position. This camera's fiducial numbering system was directly synchronized to the digital recording system such that a one-to-one correlation between position and data could be made. Upon completion of a data collection flight, the 35 mm film was processed and actual flight path positions located on the appropriate scale map sheets. At the boundaries of the fixed wing/rotary wing areas, flight lines were flown by both the S2F and the Lama with overlaps of 1 mile over the best available terrain (see Figure 4).

## Infield System Calibration

Due to the complex nature of both the systems and the required data interpretation, much emphasis was placed on infield calibration of each data collection system. The objective of this calibration was to ensure continuous high quality of the data collected. The daily calibration procedures used are set forth in the following summary check list:

A. Pre Flight

1. Use cesium sources (same positioning on crystals every day), peak each Photomultiplier tube/crystal using the digital split-window detector of the GR-800. Then using thallium sources, repeat the tuning of the individual crystals.

2. Run full cesium spectrum on analog recorder for both down and up looking crystals. Calculate the cesium resolution (see sample in Figure 9). Run spectrum out past the K40 peak on down crystals for centering evaluation of K40 peak.

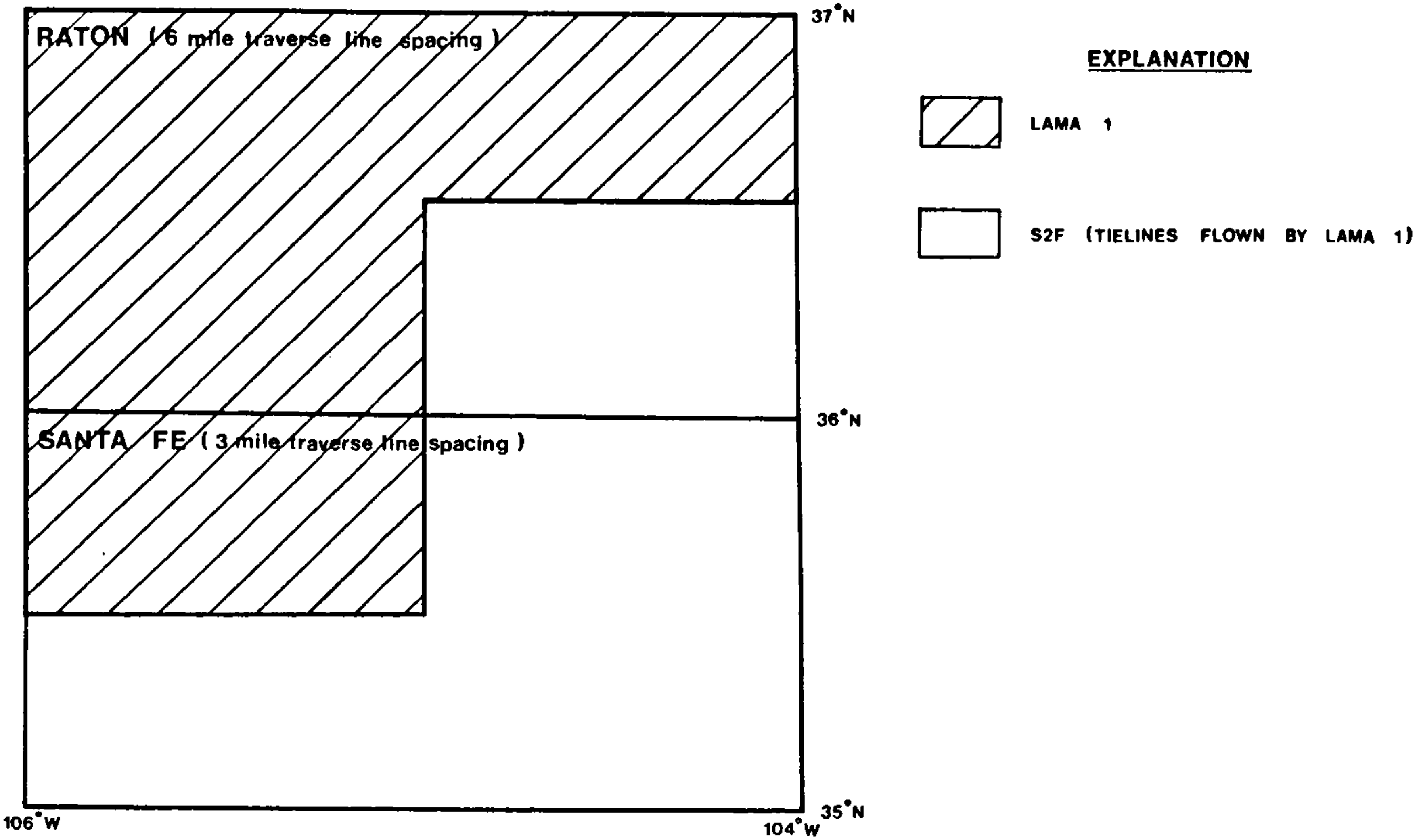


FIGURE 4

DIAGRAM OF FIXED WING AND HELICOPTER SURVEY AREA

RATON AND SANTA FE QUADRANGLES

```
                         NUMBER OF OCCURRENCES

 <  150.00H   0 | ****
TO  200.00H  16 | *****************
TO  250.00H  19 |********** ** **
TO  300.00H  22 |***********************
TO  350.00H  75 |**********************************************************************************
TO  400.00H  99 |***************************************************************************************************
TO  450.00H  94 |************************************************************************************************* **
TO  500.00H  81 |****************************************************************************************
TO  550.00H  35 |*************************************** **
TO  600.00H  30 |************ ********************** **
TO  650.00H  14 |**********************
TO  700.00H  10 |**************** **
TO  750.00H   6 |******* ** ***
TO  800.00H   2 |**** ** ****
TO  850.00H   2 |**********
TO  900.00H   2 |**********
TO  950.00H   2 |**********
TO 1000.00H   1 | *********
TO 1050.00H   0 |
TO 1100.00H   0 |
TO 1150.00H   0 |
 > 1150.00H   0 |

(GROUND CLEARANCE IN FEET)

THE MINIMUM RADAR ALTMTR IS 147.500 FEET
THE MAXIMUM RADAR ALTMTR IS 975.000 FEET
THE AVERAGE RADAR ALTMTR IS 424.336 FEET
THE STANDARD DEVIATION  IS  123.4900 FEET
```

Figure 5
Typical Radar Altimeter
Statistical Summary
Histogram for Single
Flight Line

3. Finally, run full thorium spectrum of down crystals on analog recorder. Check for centering of K40 and Th peaks in spectrum.

4. Repeat 1-3 until system is within contract specifications.

B. During Flight

1. Run test line at survey altitude (400 ft), for approximately five miles, prior to production data collection (record both analog and digital).

2. Prior to production data collection, the above data are evaluated to ensure ± 20% limits on total count compared to first test flight from that base of operations.

3. During production data collection, monitor radon analog data for unusual increases. Visually correlate these with temperature and barometric pressure.

4. Upon completion of production data collection, refly test line at survey altitude (400 ft). Record both analog and digital.

C. Post Flight

1. Verify test line total count within ± 20% of first test line at that base of operations.

2. Using cesium sources (same position as pre-flight), run full cesium spectrum for both down and up crystals (allow it to record through the K40 peak in the down crystals). Repeat the procedure using thallium sources and examine the Tℓ208 window.

3. Calculate the resolution of down and up crystal pack.

4. Determine shift, if any, in K40 peak position.

# DATA COLLECTION SYSTEM

## ROTARY WING AIRCRAFT

The helicopter used for the survey is an Aerospatiale SA315B LAMA, Registry No. N47319 (Code System No. 06). The SA315B LAMA was originally designed and built by Societe Nationale Industrielle Aerospatiale of France to meet the requirements of the Indian Armed Forces for a medium-sized helicopter capable of working in the Himalayas. In that the craft was initially designed to haul heavy payloads in rugged mountainous terrain, its overall performance and safety features make it ideal for low level, rotary-wing airborne geophysical survey work. There is virtually no other medium-sized rotary-wing aircraft which can carry the adequate payload at the necessary constant low airspeeds and tight terrain clearances and still maintain a wide envelope of safety, all while operating economically. Performance data for the SA315B LAMA (both general and in its present geophysical survey configuration) are given below:

Type: Turbine-driven general purpose helicopter.

Rotor System: Three-blade main and antitorque rotors. All metal main rotor blades, of constant chord, are on articulated hinges, with hydraulic drag-hinge dampers.

Rotor Drive: Main rotor driven through planetary gearbox, with free-wheel for autorotation. Take-off drive for tail rotor at lower end of main gearbox, from where a torque shaft runs to a small gearbox which supports the tail rotor and houses the pitch-change mechanism. Cyclic and collective pitch controls are powered.

Fuselage: Glazed cabin has light metal frame. Center and rear of fuselage have a triangulated steel-tube framework.

Landing Gear: Skid type, with removable wheels for ground maneuvering. Pneumatic floats for normal operation from water, and emergency flotation gear, inflatable in the air, are available.

Power Plant: One 870 shp Turbomeca Artouste IIIB turboshaft engine, derated to 550 shp. Fuel tank in fuselage center-section, with capacity of 151.3 U. S. gallons (useable) (573 litres).

Accomodation: Glazed cabin seats pilot and passenger side by side in front and three passengers behind. Provision for external sling for loads of up to 2,204 lbs. (1,000 kg). Can be equipped for rescue (hoist capacity 265 lb.; 120 kg), liaison, observation, training, agricultural, photographic, ambulance and other duties. As an ambulance, can accommodate two stretchers and a medical attendant internally.

| | | |
|---|---|---|
| Dimensions, External: | Main rotor diameter | 36 ft., 1-3/4 in |
| | Tail rotor diameter | 6 ft., 3-1/4 in |
| | Main rotor blade chord (constant) | 13.8 in |
| | Length overall, both rotors turning | 42 ft., 4-3/4 in |
| | Length of fuselage | 33 ft., 8 in |
| | Height overall | 10 ft., 1-3/4 in |
| | Skid track | 7 ft., 9-3/4 in |

Performance (Sea Level Standard Conditions)

| | | Internal | | External | |
|---|---|---|---|---|---|
| | | Average | Maximum | Average | Maximum |
| At Gross Weight | lb | 3,310 | 4,300 | 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 | 118 | 55-75 | 55-75 |
| Top Speed, Vne | mph | 130 | 130 | - | - |
| Useable Fuel US | gal | 146 | 146 | 46 | 46 |
| Service Ceiling | ft | (23,000)* | 17,710 | 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 |
| Rate of Climb Sl | fpm | 1,580 | 1,080 | 1,120 | 730 |
| Max. Range, SL | mi | 308 | 308 | 31** | 31** |

() Maximum certified altitude - 23,000 ft.

** Mission radius - includes: 10 minutes fuel reserve
3 minutes SL Hover
Return with no load

Present geophysical Configuration

| | |
|---|---|
| Lama Weight Empty | 2,193 lbs. |
| Maximum Fuel | 900 lbs. |
| Geophysical Electronics | 850 lbs. |
| Pilot | 165 lbs. |
| Navigator | 175 lbs. |
| Total | 4,458 lbs. |

## Electronics

The major components of the airborne data collection system are summarized below (shown pictorially in Figure 6 and schematically in Figure 7:

1. Gamma Ray Spectrometer, geoMetrics GR-800, utilizing a dual 256 channel capability to provide spectral data in the 0.4 to 3.0 MeV range for both the downward looking and the upward looking crystal packages and coverage in the 3.0 to 6.0 MeV range for cosmic background.

2. Crystal Detector, geoMetrics Model NaI-100/CS consisting of 2048 cubic inches in the downward looking configuration and 256 cubic inches appropriately shielded in an upward looking configuration.

3. A geoMetrics Digital Data Acquisition System, Model G-714 with "read-after-write" data verification, recording the following on magnetic tape:

   a. 512 channels of gamma ray spectrometer data

   b. Total magnetic intensity

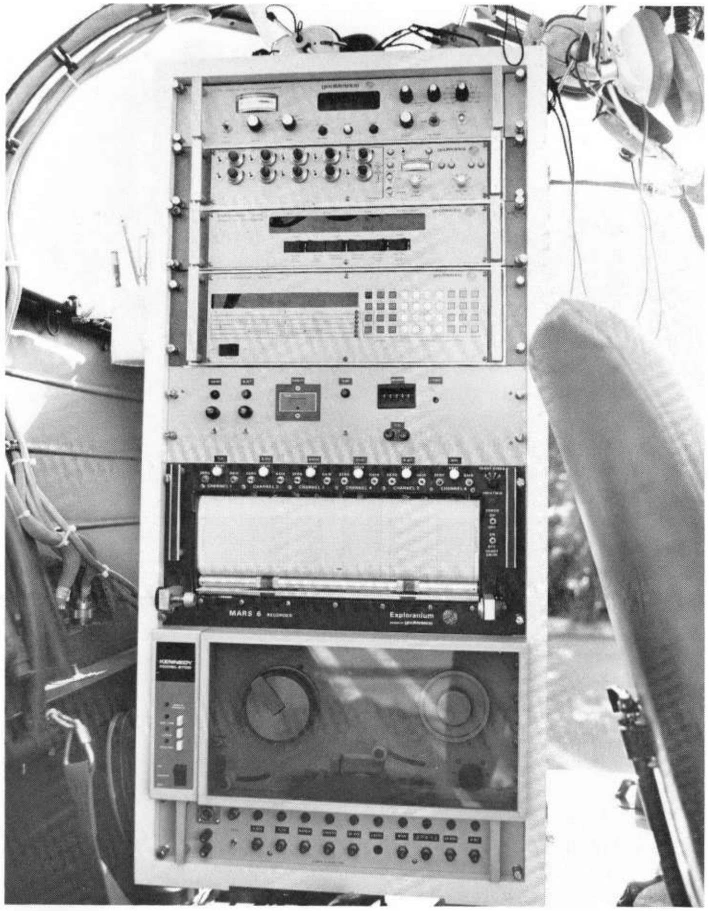
   c. Fiducial number from data system/camera

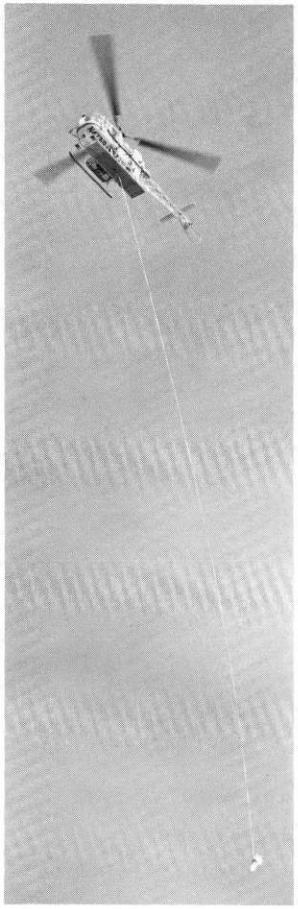
   d. Manually inserted information, i.e. date, survey area, and flight line number

   e. Altitude from radar altimeter and barometric altimeter (by analog-to-digital conversion)

   f. Time in days, hours, minutes and seconds

   g. Outside air temperature





## Figure 6

### HELICOPTER GEOPHYSICAL SURVEY SYSTEM
(Aerospatiale SA315B Lama)

Ideally suited to contour flying, this exploration platform is employed on a Midwest E.R.D.A. survey along the front range of the Rocky Mountains in central Colorado. [Far left]: A single shock-mounted instrument rack includes GeoMetrics Model G-803 Proton Magnetometer (top of rack), Model GR-900-2 Detector Interface console, Model GR-800D Multichannel Gamma Ray Spectrometer and G-714 Digital Data Acquisition System. A specially designed Intervalometer console is located above the Exploranium MARS-6 six-channel Analog Recorder and the Kennedy Model 9700 Magnetic Tape Deck. A fused Power Distribution Panel is shown at the bottom of the rack. Operator's seat is folded up to the left of the instrument rack. [Left]: Magnetometer "bird" sensor is towed from a 100 ft. nylon sleeved signal cable. [Bottom left]: The Lama was outfitted at GeoMetrics manufacturing facilities in Sunnyvale, California. [Below]: A center platform, held secure by the cargo hook, contains both a Model DET-1024 and DET-1024/256R exSquare™ detector for a total volume of 2,048 cu. in. downward-looking and 256 cu. in. upward-looking. A Bonzer altimeter and Automax flight-path recovery camera are also included on the center platform. The entire instrumentation system, including detectors and hardware weighs approximately 700 lbs. (318 kg) installed.

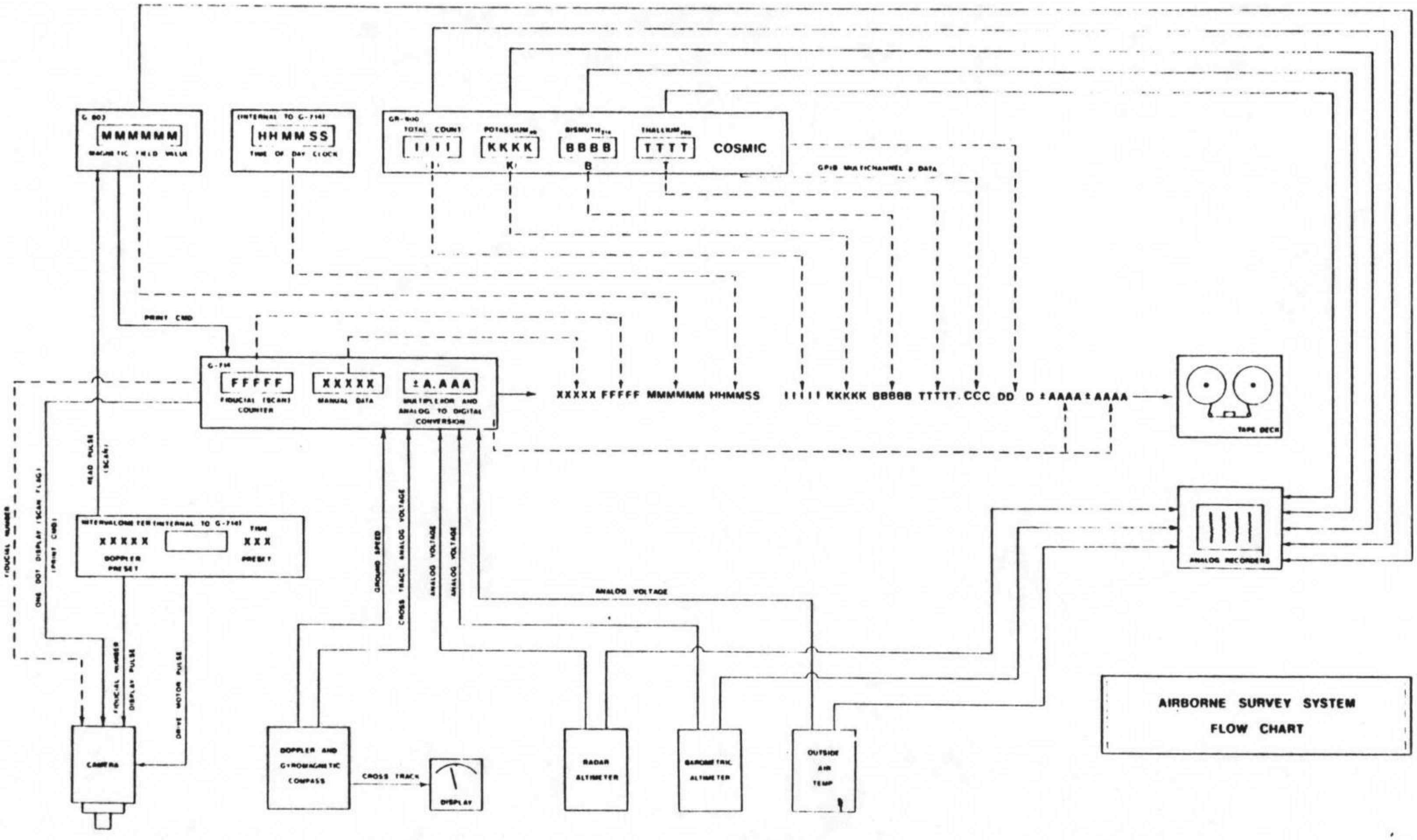

G 803
MMMMMM
MAGNETIC FIELD VALUE
(INTERNAL TO G-714)
HHMMSS
TIME OF DAY CLOCK
GR-800
TOTAL COUNT
POTASSIUM
BISMUTH
THALLIUM
IIII
KKKK
BBBB
TTTT
COSMIC
K
B
T
GPIB MULTICHANNEL & DATA
PRINT CMD
G-714
FFFFF
FIDUCIAL (SCAN) COUNTER
XXXXX
MANUAL DATA
± A.AAA
MULTIPLEXOR AND ANALOG TO DIGITAL CONVERSION
XXXXX FFFFF MMMMMM HHMMSS IIIII KKKKK BBBBB TTTTT. CCC DD D ± AAAA ± AAAA
TAPE DECK
ANALOG RECORDERS
READ PULSE (SCAN)
FIDUCIAL NUMBER
ONE DOT DISPLAY (SCAN FLAG) (PRINT CMD)
INTERVALOMETER (INTERNAL TO G-714)
XXXXX
DOPPLER PRESET
TIME
XXX
PRESET
FIDUCIAL NUMBER
DISPLAY PULSE
DRIVE MOTOR PULSE
GROUND SPEED
CROSS TRACK ANALOG VOLTAGE
ANALOG VOLTAGE
ANALOG VOLTAGE
ANALOG VOLTAGE
CAMERA
DOPPLER AND GYROMAGNETIC COMPASS
CROSS TRACK
DISPLAY
RADAR ALTIMETER
BAROMETRIC ALTIMETER
OUTSIDE AIR TEMP
AIRBORNE SURVEY SYSTEM
FLOW CHART

FIGURE 7

4. Magnetometer, geoMetrics Airborne Model G-803, capable of 0.125 gamma sensitivity, but operated at 0.25 gamma sensitivity.

5. Radar Altimeter, Sperry Model AA200 with recording output and display and minimum altitude range of 0 to 2,500 feet.

6. Rosemont Barometric Altimeter with recording output and display.

7. Recording Thermometer for monitoring outside air temperature.

8. Tracking Camera. Automax 35 mm framing camera with wide angle lens to provide flight path recovery data.

9. Analog Recorder geoMetrics (MARS 6)to record the following data:

   a. Bi214 using a window about the 1.76 MeV peak from the downward looking system. b. Bi air background using a window about the 1.76 MeV peak from the upward looking system.

   b. Magnetometer

   d. Radar Altitude

   e. Total count for downward looking system (0.4 to 3.0 MeV)

   f. Outside air temperature

   g. Event and time markers

10. HP 7155 single channel analog recorder during pre and post flight calibrations, this recorder is used to plot a full analog spectra for both the down and up crystal systems via the GR-800. Thus, a hard copy record of the data used for resolution, drift, etc., checks are available at all times. This approach provides instant verification of system parameters (refer to Figure 9 later in this report).

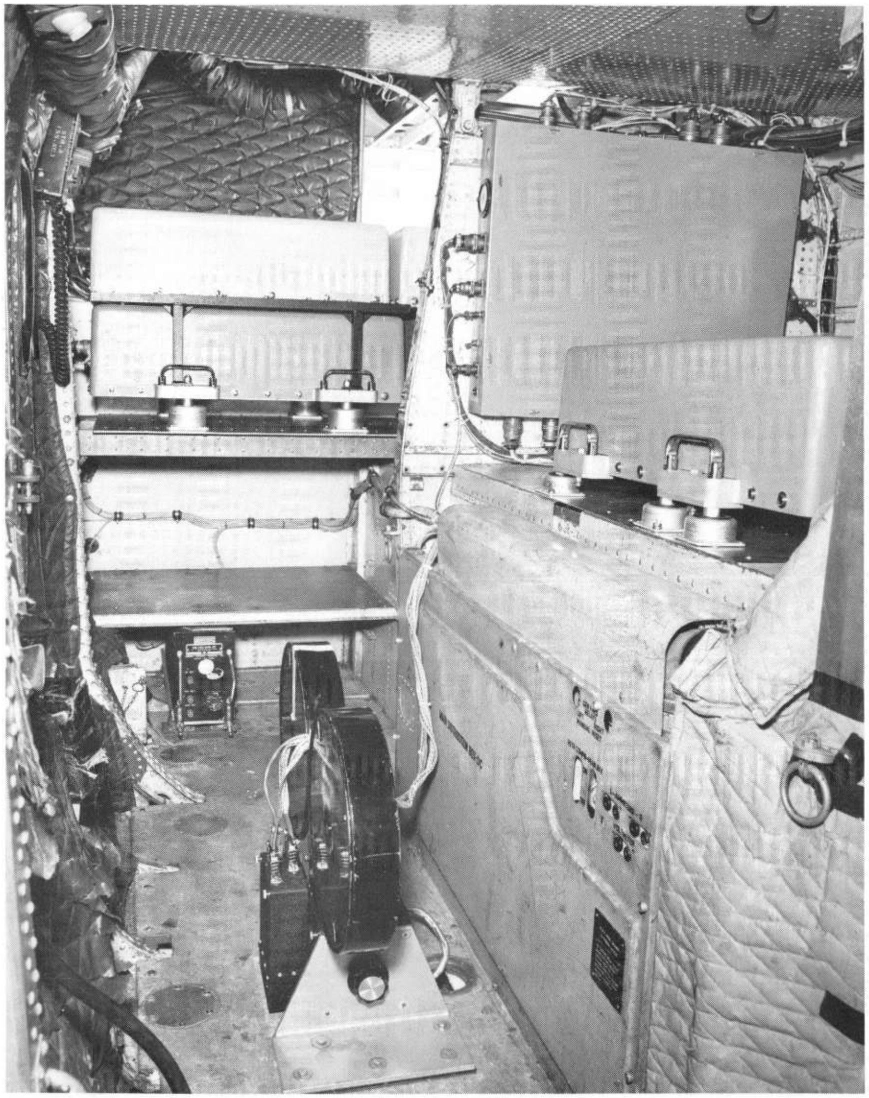
## FIXED WING AIRCRAFT

The fixed wing aircraft was a Grumman G-89, S2F Tracker, serial number 3, U.S. Registration N9AG, System code No. 04 (see Figure 8). This aircraft was originally designed and built by Grumman Aircraft Corporation for the U.S. Navy as a highly stable platform for carrying electronic instrumentatin in search of submarienes from carrier bases and/or short landing fields. Since it was designed for magnetic surveillance, it is a "magnetically clean" aircraft and thus ideal for collecting magnetic data. Overall, the aircraft's performance and safety features make it ideal for low level, fixed-wing airborne geophysical survey work. There is virtually no other fixed-wing aircraft which can carry the adequate payload at the necessary constant low airspeeds and tight terrain clearances and still maintain a wide envelope of safety. Performance data for the S2F in its present geophysical survey configuration are given below:

| | | |
|---|---|---|
| Aircraft empty | | 15,123 lbs |
| Electronic equipment | | 1,600 lbs |
| Main fuel usable | | 3,108 lbs |
| Auxiliary fuel usable | | 900 lbs |
| Pilot | | 175 lbs |
| Electronic operator | | 175 lbs |
| Maximum gross weight for geophysical survey operation | | 21,081 lbs |
| Maximum allowable aircraft gross weight | | 24,500 lbs |
| Minimum control speed | 85 KIAS at | 24,500 lbs |
| Safe single engine speed | 100 KIAS at | 24,500 lbs |
| Single engine rate of climb at | 120 KIAS<br>390 FPM at | 23,000 lbs |
| Rate of climb (two engines) | 2,000 FPM at | 5,000 ft |
| 120 KIAS at 23,000 lbs. | 1,200 FPM at | 10,000 ft |

(KIAS = Knots Indicated Air Speed)

Cruise Configuration Stalling Speed at Gross Weight 21,000 lbs
0° Bank - 80 KIAS 45° Bank - 96 KIAS



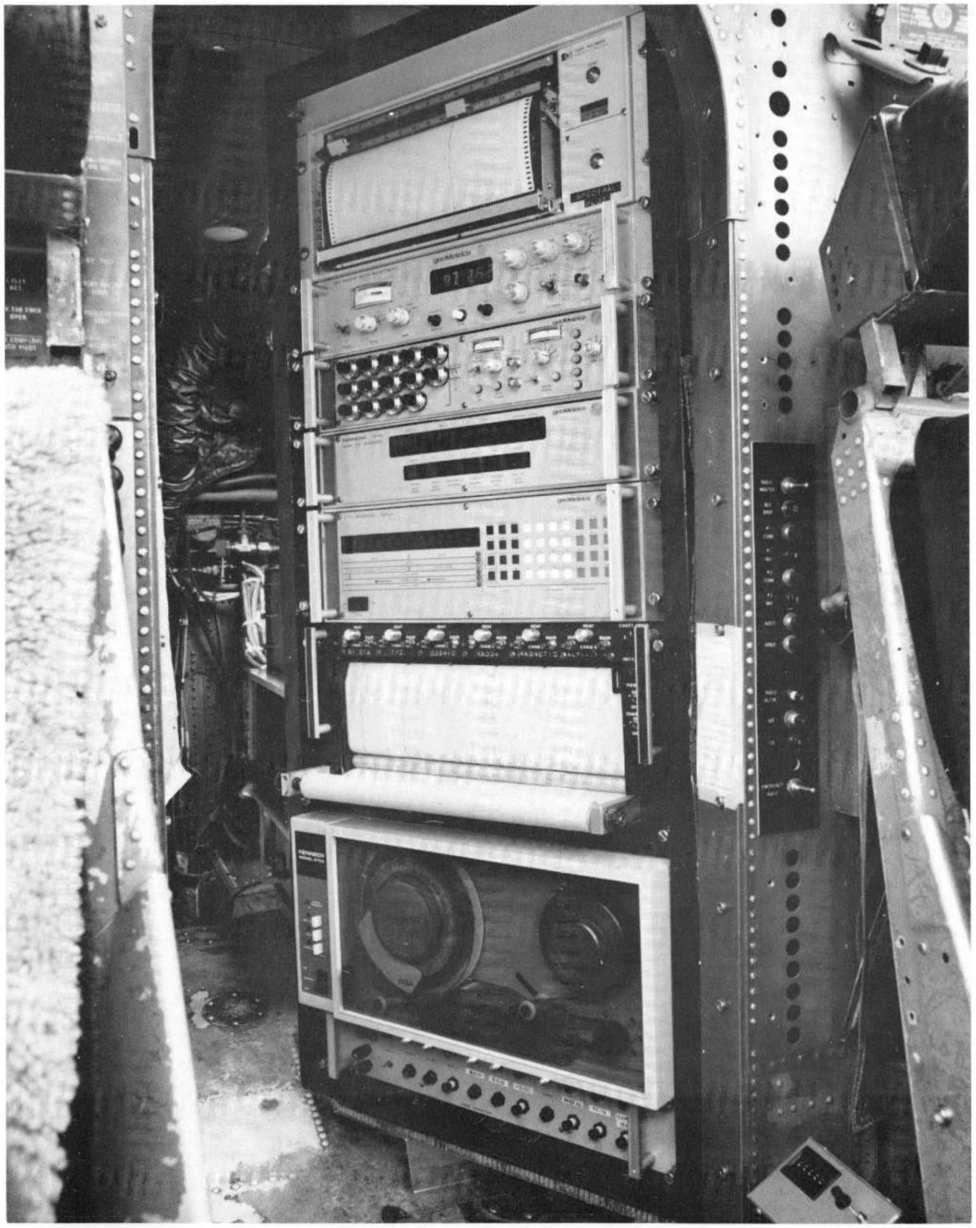


Figure 8

Left: Grumman S2F Survey Aircraft. Upper right: Geophysical instruments: G-803 Magnetometer, GR-800 Spectrometer, G-714 Data System & Recorders. Upper left: NaI exSquare™ Crystal detectors—3,072 cu.in. (50.4 l) down, 512 cu.in. (8.4 l) up. Camera: Automax G2.

|  |  |  |
|---|---|---|
| Usable Fuel | 518 U.S. Gallons | 3180 lbs Mains |
|  | 150 U.S. Gallons | 900 lbs Auxiliary |

400 lbs per hour at 1000 feet altitude and 120 KIAS at 23,000 lbs. gross weight duration 10 hours plus, due to burn off and lower gross gross weight.

Electronics

The major components of the airborne data collection system are summarized below (shown pictorially in Figure 8 and schematically in Figure 7):

1. Gamma Ray Spectrometer, geoMetrics GR-800, utilizing a dual 256 channel capability to provide spectral data in the 0.4 to 3.0 MeV range for both the downward looking and the upward looking crystal packages and coverage in the 3.0 to 6.0 MeV range for cosmic background.

2. Crystal Detector, geoMetrics model NaI-1000/CS consisting of 3584 cubic inches in the downward looking configuration and 512 cubic inches appropriately shielded in an upward looking configuration.

3. A geoMetrics digital Data Acquisition System, model G-714 with "read-after-write" data verification, recording the following on magnetic tape:

   a. 512 channels of gamma ray spectrometer data

   b. Total magnetic intensity

   c. Fiducial number from data system/camera

   d. Manually inserted information, i.e., data, survey area, and flight number

   e. Altitude from radar and barometric altimeters (by analog-to-digital conversion)

   f. Time in days, hours, minutes and seconds

   g. Outside air temperature

4. Magnetometer, geoMetrics Airborne model G-803, capable of 0.125 gamma sensitivity, but operated at 0.25 gamma sensitivity.

5. Radar Altimeter, Bonzer with a linear recording output, displaying an altitude range of 0 to 2500 feet.

6. Rosemont Barometric Altimeter with recording output and display.

7. Recording Thermometer for monitoring outside air temperature.

8. Tracking Camera, Automax 35 mm framing camera with wide angle lens to provide flight path recovery data

9. Analog Recorder geoMetrics MARS 6 to record the following data:
   a. $Bi_{214}$ using a window about the 1.76 MeV peak from the downward looking system.
   b. BiAir background using a window about the 1.76 MeV peak from upward looking system.
   c. Magnetometer
   d. Total count for downward looking system (0.4 to 3.0 MeV)
   e. Event and time markers

10. HP 7128, two channel analog recorder to record the following data:
    a. Outside air temperature
    b. Barometric altimeter
    c. Event and time markers
    d. During system calibrations, this recorder is used to plot full analog spectra for both the down and up crystal systems via the Gr-800. Thus, a hard copy of the data used for resolutions, drift, and other checks is available at all times (refer to Figure 9). This approach provides instant verification of system parameters.

Figure 9

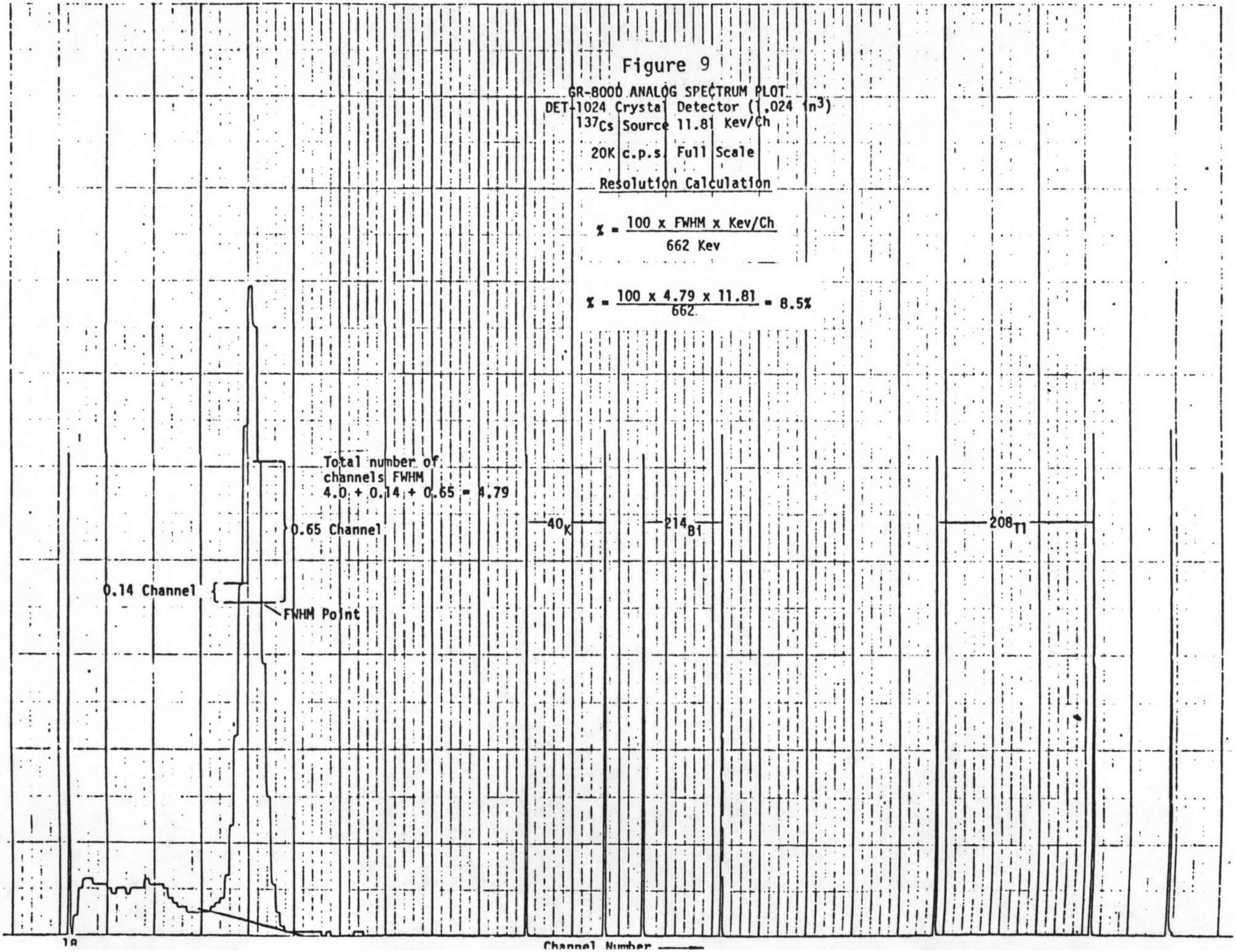
GR-8000 ANALOG SPECTRUM PLOT
DET-1024 Crystal Detector (1,024 in$^3$)
$^{137}$Cs Source 11.81 Kev/Ch

20K c.p.s. Full Scale

Resolution Calculation

$$\% = \frac{100 \times \text{FWHM} \times \text{Kev/Ch}}{662 \text{ Kev}}$$

$$\% = \frac{100 \times 4.79 \times 11.81}{662} = 8.5\%$$



## SYSTEM CALIBRATION

### AIRCRAFT AND COSMIC BACKGROUND

Full spectral data are collected at five (5) altitudes over water (14,000 feet, 12,000 feet; 10,000 feet; 8,000 feet and 6,000 feet) in an area where the existence of no airborne Bi214 can be assured (off shore over the Pacific Ocean). This results in separate spectra as shown schematically in Figure 10. We define S(12,000) to be the spectra at 12,000 feet from 0.4 MeV to 3.0 MeV with S(8,000) the same spectra at a lower altitude (8,000) and $C_i(h)$ the total count between 3.0 and 6.0 MeV at respective altitudes. Since the aircraft background is constant, the difference between any two altitudes separated sufficiently - typically, 2,000 feet - yields the cosmic spectral curve shape as shown schematically in Figure 10. Thus

$$S(12{,}000) - S(8{,}000) = \Delta S$$

and

$$\Sigma C_{12}(h_i) - \Sigma C_8(h_i) = \Delta C$$

This cosmic spectral curve is scaled back to 12,000 feet as follows:

$$\frac{C_{12}(h_i)}{\Delta C} \times \Delta S = \Delta C\,(12{,}000) \text{ the Cosmic Spectrum (shape and magnitude at 12,000 feet)}$$

The aircraft background is derived as follows:

$$S(12{,}000) - C(12{,}000) = \text{A/C Background}$$

Since data were collected at five altitudes, this procedure was repeated for each combination of altitudes and results averaged. Typical aircraft and cosmic spectra are shown in Figure 11 and 12 respectively.

### SYSTEM CONSTANTS

System constants were determined by occupation of the DoE Walker Field Test Pads. (See Ward, 1978, and Stromswold, 1978, for complete descriptions of the building and monitoring of the pads). The five test pads contained varying concentrations of K, U, and T as presented by BFEC:

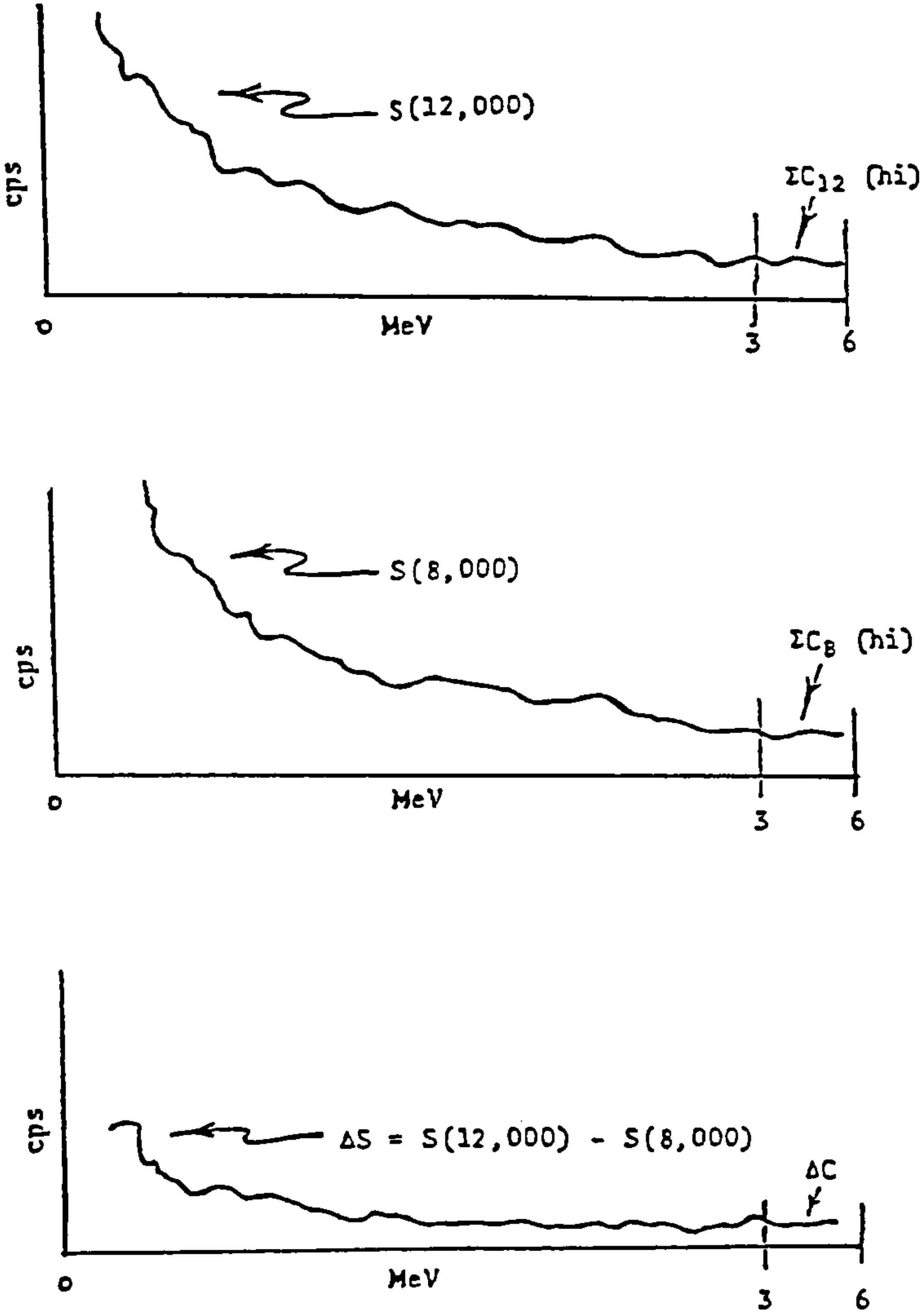


Figure 10 - Multiple altitude spectra schematic

AIRCRAFT BACKGROUND
ROTARY WING AIRCRAFT
DOWNWARD LOOKING CRYSTAL
2048 CUBIC INCHES
DATE: 25 JULY 1977

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DERIVED AIRCRAFT BACKGROUND SPECTRUM FROM PACIFIC OCEAN DATA

DOWNWARD-LOOKING CRYSTAL SPECTRUM FOR LINE AC BGD, DATED 072577

TC (0-6 MEV)  184.07 TC (0.4-3.0 MEV)  141.17 COSMIC (3-6 MEV)     0.00
U (1.12 MEV)     9.91 K (1.46 MEV)    14.54 U (1.76 MEV)     4.36 T (2.62 MEV)     4.29

CH   0 (0.000 MEV)   0.000 CPS *
CH   1 (0.012 MEV)   0.000 CPS *
CH   2 (0.024 MEV)   0.000 CPS *
CH   3 (0.035 MEV)   0.000 CPS *
CH   4 (0.047 MEV)   0.000 CPS *
CH   5 (0.059 MEV)   0.000 CPS *
CH   6 (0.071 MEV)   0.000 CPS *
CH   7 (0.083 MEV)   0.000 CPS *
CH   8 (0.095 MEV)   0.000 CPS *
CH   9 (0.106 MEV)   0.000 CPS *
CH  10 (0.118 MEV)   0.000 CPS *
CH  11 (0.130 MEV)   0.000 CPS *
CH  12 (0.142 MEV)   0.000 CPS *
CH  13 (0.154 MEV)   0.000 CPS *
CH  14 (0.165 MEV)   0.000 CPS *
CH  15 (0.177 MEV)   0.000 CPS *
CH  16 (0.189 MEV)   0.000 CPS *
CH  17 (0.201 MEV)   0.000 CPS *
CH  18 (0.213 MEV)  -0.025 CPS *
CH  19 (0.225 MEV)  -0.020 CPS *
CH  20 (0.236 MEV)   0.080 CPS *
CH  21 (0.248 MEV)   1.401 CPS *****
CH  22 (0.260 MEV)   3.792 CPS ************
CH  23 (0.272 MEV)   4.280 CPS **************
CH  24 (0.284 MEV)   4.334 CPS **************
CH  25 (0.295 MEV)   3.748 CPS ************
CH  26 (0.307 MEV)   3.897 CPS *************
CH  27 (0.319 MEV)   3.818 CPS ************
CH  28 (0.331 MEV)   4.236 CPS **************
CH  29 (0.343 MEV)   3.433 CPS ***********
CH  30 (0.355 MEV)   2.996 CPS **********
CH  31 (0.366 MEV)   2.559 CPS *********
CH  32 (0.378 MEV)   2.269 CPS ********
CH  33 (0.390 MEV)   2.102 CPS *******
CH  34 (0.402 MEV)   2.081 CPS ******* TOTAL COUNT
CH  35 (0.414 MEV)   2.121 CPS *******
CH  36 (0.426 MEV)   2.114 CPS *******
CH  37 (0.437 MEV)   1.976 CPS *******
CH  38 (0.449 MEV)   2.290 CPS ********
CH  39 (0.461 MEV)   2.188 CPS ********
CH  40 (0.473 MEV)   2.226 CPS ********
CH  41 (0.485 MEV)   1.983 CPS *******
CH  42 (0.496 MEV)   2.165 CPS *******
CH  43 (0.508 MEV)   2.158 CPS *******
CH  44 (0.520 MEV)   2.267 CPS ********
CH  45 (0.532 MEV)   2.217 CPS ********
CH  46 (0.544 MEV)   1.997 CPS *******
CH  47 (0.556 MEV)   2.447 CPS ********
CH  48 (0.567 MEV)   2.540 CPS *********
CH  49 (0.579 MEV)   2.586 CPS *********
CH  50 (0.591 MEV)   2.708 CPS *********
CH  51 (0.603 MEV)   2.481 CPS ********
CH  52 (0.615 MEV)   2.372 CPS ********
CH  53 (0.626 MEV)   1.866 CPS *******
CH  54 (0.638 MEV)   1.682 CPS ******
CH  55 (0.650 MEV)   1.661 CPS ******
CH  56 (0.662 MEV)   1.480 CPS *****
CH  57 (0.674 MEV)   1.474 CPS *****
CH  58 (0.686 MEV)   1.447 CPS *****
CH  59 (0.697 MEV)   1.431 CPS *****
CH  60 (0.709 MEV)   1.476 CPS *****
CH  61 (0.721 MEV)   1.453 CPS *****
CH  62 (0.733 MEV)   1.467 CPS *****
CH  63 (0.745 MEV)   1.579 CPS ******
CH  64 (0.756 MEV)   1.497 CPS *****
CH  65 (0.768 MEV)   1.548 CPS ******
CH  66 (0.780 MEV)   1.421 CPS *****
CH  67 (0.792 MEV)   1.282 CPS *****
CH  68 (0.804 MEV)   1.155 CPS ****
CH  69 (0.816 MEV)   1.246 CPS *****
CH  70 (0.827 MEV)   1.245 CPS *****
CH  71 (0.839 MEV)   1.161 CPS ****
CH  72 (0.851 MEV)   1.253 CPS *****
CH  73 (0.863 MEV)   1.231 CPS *****
CH  74 (0.875 MEV)   1.425 CPS *****
CH  75 (0.887 MEV)   1.452 CPS *****
CH  76 (0.898 MEV)   1.543 CPS ******
CH  77 (0.910 MEV)   1.444 CPS *****
CH  78 (0.922 MEV)   1.364 CPS *****
CH  79 (0.934 MEV)   1.289 CPS *****
CH  80 (0.946 MEV)   1.150 CPS ****
CH  81 (0.957 MEV)   1.144 CPS ****
CH  82 (0.969 MEV)   1.085 CPS ****
CH  83 (0.981 MEV)   1.061 CPS ****
CH  84 (0.993 MEV)   0.941 CPS ****
CH  85 (1.005 MEV)   0.919 CPS ****
CH  86 (1.017 MEV)   0.822 CPS ***
CH  87 (1.028 MEV)   0.816 CPS ***
CH  88 (1.040 MEV)   0.853 CPS ****
CH  89 (1.052 MEV)   0.901 CPS **** BISMUTH 214
CH  90 (1.064 MEV)   0.822 CPS ***
CH  91 (1.076 MEV)   0.867 CPS ****
CH  92 (1.087 MEV)   0.968 CPS ****
CH  93 (1.099 MEV)   0.851 CPS ****
CH  94 (1.111 MEV)   0.905 CPS ****
CH  95 (1.123 MEV)   0.847 CPS ****
CH  96 (1.135 MEV)   0.861 CPS ****
CH  97 (1.147 MEV)   0.800 CPS ***
CH  98 (1.158 MEV)   0.727 CPS ***
CH  99 (1.170 MEV)   0.751 CPS ***
CH 100 (1.182 MEV)   0.607 CPS *** BISMUTH 214
CH 101 (1.194 MEV)   0.663 CPS ***
CH 102 (1.206 MEV)   0.657 CPS ***
CH 103 (1.217 MEV)   0.633 CPS ***
CH 104 (1.229 MEV)   0.719 CPS ***
CH 105 (1.241 MEV)   0.671 CPS ***
CH 106 (1.253 MEV)   0.475 CPS **
CH 107 (1.265 MEV)   0.601 CPS ***
CH 108 (1.277 MEV)   0.661 CPS ***
CH 109 (1.288 MEV)   0.669 CPS ***
CH 110 (1.300 MEV)   0.606 CPS ***
CH 111 (1.312 MEV)   0.630 CPS ***
CH 112 (1.324 MEV)   0.652 CPS ***
CH 113 (1.336 MEV)   0.644 CPS ***
CH 114 (1.347 MEV)   0.652 CPS ***
CH 115 (1.359 MEV)   0.791 CPS ***
CH 116 (1.371 MEV)   0.787 CPS *** POTASSIUM 40
CH 117 (1.383 MEV)   0.834 CPS ****
CH 118 (1.395 MEV)   0.984 CPS ****
CH 119 (1.407 MEV)   1.072 CPS ****
CH 120 (1.418 MEV)   1.124 CPS ****
CH 121 (1.430 MEV)   1.088 CPS ****
CH 122 (1.442 MEV)   1.210 CPS *****
CH 123 (1.454 MEV)   1.231 CPS *****
CH 124 (1.466 MEV)   1.207 CPS *****
CH 125 (1.477 MEV)   0.995 CPS ****
CH 126 (1.489 MEV)   0.967 CPS ****
CH 127 (1.501 MEV)   0.624 CPS ***
CH 128 (1.513 MEV)   0.635 CPS ***
CH 129 (1.525 MEV)   0.512 CPS ***
CH 130 (1.537 MEV)   0.488 CPS **
CH 131 (1.548 MEV)   0.409 CPS **
CH 132 (1.560 MEV)   0.369 CPS ** POTASSIUM 40
CH 133 (1.572 MEV)   0.339 CPS **
CH 134 (1.584 MEV)   0.438 CPS **
CH 135 (1.596 MEV)   0.310 CPS **
CH 136 (1.608 MEV)   0.259 CPS **
CH 137 (1.619 MEV)   0.250 CPS **
CH 138 (1.631 MEV)   0.353 CPS **
CH 139 (1.643 MEV)   0.323 CPS **
CH 140 (1.655 MEV)   0.332 CPS **
CH 141 (1.667 MEV)   0.326 CPS ** BISMUTH 214
CH 142 (1.678 MEV)   0.267 CPS **
CH 143 (1.690 MEV)   0.275 CPS **
CH 144 (1.702 MEV)   0.245 CPS **
CH 145 (1.714 MEV)   0.347 CPS **
CH 146 (1.726 MEV)   0.352 CPS **
CH 147 (1.738 MEV)   0.293 CPS **
CH 148 (1.749 MEV)   0.359 CPS **
CH 149 (1.761 MEV)   0.270 CPS **
CH 150 (1.773 MEV)   0.334 CPS **
CH 151 (1.785 MEV)   0.245 CPS **
CH 152 (1.797 MEV)   0.255 CPS **
CH 153 (1.808 MEV)   0.174 CPS **
CH 154 (1.820 MEV)   0.228 CPS **
CH 155 (1.832 MEV)   0.188 CPS **
CH 156 (1.844 MEV)   0.115 CPS *
CH 157 (1.856 MEV)   0.084 CPS * BISMUTH 214
CH 158 (1.868 MEV)   0.147 CPS *
CH 159 (1.879 MEV)   0.147 CPS *
CH 160 (1.891 MEV)   0.139 CPS *
CH 161 (1.903 MEV)   0.109 CPS *
CH 162 (1.915 MEV)   0.091 CPS *
CH 163 (1.927 MEV)   0.151 CPS *
CH 164 (1.938 MEV)   0.088 CPS *
CH 165 (1.950 MEV)   0.136 CPS *
CH 166 (1.962 MEV)   0.157 CPS *
CH 167 (1.974 MEV)   0.119 CPS *
CH 168 (1.986 MEV)   0.109 CPS *
CH 169 (1.998 MEV)   0.113 CPS *
CH 170 (2.009 MEV)   0.106 CPS *
CH 171 (2.021 MEV)   0.147 CPS *
CH 172 (2.033 MEV)   0.137 CPS *
CH 173 (2.045 MEV)   0.171 CPS **
CH 174 (2.057 MEV)   0.154 CPS *
CH 175 (2.068 MEV)   0.108 CPS *
CH 176 (2.080 MEV)   0.162 CPS *
CH 177 (2.092 MEV)   0.104 CPS *
CH 178 (2.104 MEV)   0.138 CPS *
CH 179 (2.116 MEV)   0.137 CPS *
CH 180 (2.128 MEV)   0.119 CPS *
CH 181 (2.139 MEV)   0.169 CPS **
CH 182 (2.151 MEV)   0.148 CPS *
CH 183 (2.163 MEV)   0.101 CPS *
CH 184 (2.175 MEV)   0.114 CPS *
CH 185 (2.187 MEV)   0.088 CPS *
CH 186 (2.199 MEV)   0.101 CPS *
CH 187 (2.210 MEV)   0.085 CPS *
CH 188 (2.222 MEV)   0.130 CPS *
CH 189 (2.234 MEV)   0.117 CPS *
CH 190 (2.246 MEV)   0.113 CPS *
CH 191 (2.258 MEV)   0.116 CPS *
CH 192 (2.269 MEV)   0.088 CPS *
CH 193 (2.281 MEV)   0.097 CPS *
CH 194 (2.293 MEV)   0.095 CPS *
CH 195 (2.305 MEV)   0.087 CPS *
CH 196 (2.317 MEV)   0.059 CPS *
CH 197 (2.329 MEV)   0.015 CPS *
CH 198 (2.340 MEV)   0.041 CPS *
CH 199 (2.352 MEV)   0.070 CPS *
CH 200 (2.364 MEV)   0.087 CPS *
CH 201 (2.376 MEV)   0.085 CPS *
CH 202 (2.388 MEV)   0.084 CPS *
CH 203 (2.399 MEV)   0.064 CPS *
CH 204 (2.411 MEV)   0.123 CPS * THALLIUM 208
CH 205 (2.423 MEV)   0.076 CPS *
CH 206 (2.435 MEV)   0.116 CPS *
CH 207 (2.447 MEV)   0.147 CPS *
CH 208 (2.459 MEV)   0.108 CPS *
CH 209 (2.470 MEV)   0.120 CPS *
CH 210 (2.482 MEV)   0.092 CPS *
CH 211 (2.494 MEV)   0.127 CPS *
CH 212 (2.506 MEV)   0.169 CPS **
CH 213 (2.518 MEV)   0.206 CPS **
CH 214 (2.529 MEV)   0.262 CPS **
CH 215 (2.541 MEV)   0.184 CPS **
CH 216 (2.553 MEV)   0.206 CPS **
CH 217 (2.565 MEV)   0.195 CPS **
CH 218 (2.577 MEV)   0.173 CPS **
CH 219 (2.589 MEV)   0.201 CPS **
CH 220 (2.600 MEV)   0.329 CPS **
CH 221 (2.612 MEV)   0.232 CPS **
CH 222 (2.624 MEV)   0.187 CPS **
CH 223 (2.636 MEV)   0.171 CPS **
CH 224 (2.648 MEV)   0.177 CPS **
CH 225 (2.660 MEV)   0.089 CPS *
CH 226 (2.671 MEV)   0.122 CPS *
CH 227 (2.683 MEV)   0.124 CPS *
CH 228 (2.695 MEV)   0.131 CPS *
CH 229 (2.707 MEV)   0.090 CPS *
CH 230 (2.719 MEV)   0.027 CPS *
CH 231 (2.730 MEV)   0.012 CPS *
CH 232 (2.742 MEV)  -0.026 CPS *
CH 233 (2.754 MEV)  -0.024 CPS *
CH 234 (2.766 MEV)   0.038 CPS *
CH 235 (2.778 MEV)   0.003 CPS *
CH 236 (2.790 MEV)   0.060 CPS *
CH 237 (2.801 MEV)   0.038 CPS * THALLIUM 208
CH 238 (2.813 MEV)   0.023 CPS *
CH 239 (2.825 MEV)   0.008 CPS *
CH 240 (2.837 MEV)   0.078 CPS *
CH 241 (2.849 MEV)   0.027 CPS *
CH 242 (2.860 MEV)   0.047 CPS *
CH 243 (2.872 MEV)   0.039 CPS *
CH 244 (2.884 MEV)   0.084 CPS *
CH 245 (2.896 MEV)   0.025 CPS *
CH 246 (2.908 MEV)   0.025 CPS *
CH 247 (2.920 MEV)  -0.015 CPS *
CH 248 (2.931 MEV)   0.037 CPS *
CH 249 (2.943 MEV)  -0.005 CPS *
CH 250 (2.955 MEV)   0.042 CPS *
CH 251 (2.967 MEV)   0.002 CPS *
CH 252 (2.979 MEV)  -0.018 CPS *
CH 253 (2.990 MEV)   0.031 CPS *
CH 254 (3.002 MEV)  -0.106 CPS * TOTAL COUNT
CH 255 (3.014 MEV)   0.000 CPS *
```

Figure

COSMIC SPECTRUM
ROTARY WING AIRCRAFT
DOWNWARD LOOKING CRYSTAL
2048 CUBIC INCHES
DATE: 25 JULY 1977

```
DERIVED COSMIC SPECTRUM FROM PACIFIC OCEAN DATA

DOWNWARD-LOOKING CRYSTAL SPECTRUM FOR LINE COSMIC, DATED 072577

TC (0-6 MEV) 5275.09 TC (0.4-3.0 MEV) 3245.27 COSMIC (3-6 MEV) 1000.00
U (1.12 MEV)  165.91 K (1.46 MEV)  181.83 U (1.76 MEV)  157.56 T (2.62 MEV)  213.66

CH   0 (0.000 MEV)   0.000 CPS *
CH   1 (0.012 MEV)   0.000 CPS *
CH   2 (0.024 MEV)   0.000 CPS *
CH   3 (0.035 MEV)   0.000 CPS *
CH   4 (0.047 MEV)   0.000 CPS *
CH   5 (0.059 MEV)   0.000 CPS *
CH   6 (0.071 MEV)   0.000 CPS *
CH   7 (0.083 MEV)   0.000 CPS *
CH   8 (0.095 MEV)   0.000 CPS *
CH   9 (0.106 MEV)   0.000 CPS *
CH  10 (0.118 MEV)   0.000 CPS *
CH  11 (0.130 MEV)   0.000 CPS *
CH  12 (0.142 MEV)   0.000 CPS *
CH  13 (0.154 MEV)   0.000 CPS *
CH  14 (0.165 MEV)   0.000 CPS *
CH  15 (0.177 MEV)   0.000 CPS *
CH  16 (0.189 MEV)   0.000 CPS *
CH  17 (0.201 MEV)   0.000 CPS *
CH  18 (0.213 MEV)   1.091 CPS **
CH  19 (0.225 MEV)   1.313 CPS **
CH  20 (0.236 MEV)   2.226 CPS ***
CH  21 (0.248 MEV)  26.345 CPS ***************************
CH  22 (0.260 MEV)  89.243 CPS ******************************************************************************************
CH  23 (0.272 MEV) 100.516 CPS *****************************************************************************************************
CH  24 (0.284 MEV) 103.036 CPS *****************************************************************************************************
CH  25 (0.295 MEV)  94.423 CPS ***********************************************************************************************
CH  26 (0.307 MEV)  88.893 CPS ******************************************************************************************
CH  27 (0.319 MEV)  85.032 CPS **************************************************************************************
CH  28 (0.331 MEV)  80.528 CPS **********************************************************************************
CH  29 (0.343 MEV)  78.271 CPS *******************************************************************************
CH  30 (0.355 MEV)  72.498 CPS *************************************************************************
CH  31 (0.366 MEV)  74.934 CPS ****************************************************************************
CH  32 (0.378 MEV)  65.560 CPS *******************************************************************
CH  33 (0.390 MEV)  65.966 CPS *******************************************************************
CH  34 (0.402 MEV)  63.189 CPS **************************************************************** TOTAL COUNT
CH  35 (0.414 MEV)  62.880 CPS ****************************************************************
CH  36 (0.426 MEV)  64.078 CPS *****************************************************************
CH  37 (0.437 MEV)  67.602 CPS *********************************************************************
CH  38 (0.449 MEV)  69.116 CPS **********************************************************************
CH  39 (0.461 MEV)  76.972 CPS ******************************************************************************
CH  40 (0.473 MEV)  84.879 CPS **************************************************************************************
CH  41 (0.485 MEV)  96.049 CPS *************************************************************************************************
CH  42 (0.496 MEV)  94.167 CPS ***********************************************************************************************
CH  43 (0.508 MEV)  86.706 CPS ****************************************************************************************
CH  44 (0.520 MEV)  68.016 CPS *********************************************************************
CH  45 (0.532 MEV)  48.444 CPS *************************************************
CH  46 (0.544 MEV)  40.965 CPS ******************************************
CH  47 (0.556 MEV)  30.512 CPS ********************************
CH  48 (0.567 MEV)  33.160 CPS **********************************
CH  49 (0.579 MEV)  31.892 CPS *********************************
CH  50 (0.591 MEV)  25.907 CPS ***************************
CH  51 (0.603 MEV)  30.781 CPS ********************************
CH  52 (0.615 MEV)  27.055 CPS ****************************
CH  53 (0.626 MEV)  27.982 CPS *****************************
CH  54 (0.638 MEV)  25.776 CPS ***************************
CH  55 (0.650 MEV)  22.988 CPS ************************
CH  56 (0.662 MEV)  27.787 CPS *****************************
CH  57 (0.674 MEV)  25.274 CPS **************************
CH  58 (0.686 MEV)  25.240 CPS **************************
CH  59 (0.697 MEV)  23.489 CPS ************************
CH  60 (0.709 MEV)  24.769 CPS **************************
CH  61 (0.721 MEV)  22.350 CPS ***********************
CH  62 (0.733 MEV)  22.242 CPS ***********************
CH  63 (0.745 MEV)  22.424 CPS ***********************
CH  64 (0.756 MEV)  22.234 CPS ***********************
CH  65 (0.768 MEV)  20.332 CPS *********************
CH  66 (0.780 MEV)  18.821 CPS ********************
CH  67 (0.792 MEV)  20.493 CPS *********************
CH  68 (0.804 MEV)  19.339 CPS ********************
CH  69 (0.816 MEV)  19.021 CPS ********************
CH  70 (0.827 MEV)  17.949 CPS *******************
CH  71 (0.839 MEV)  20.235 CPS *********************
CH  72 (0.851 MEV)  17.491 CPS ******************
CH  73 (0.863 MEV)  18.370 CPS *******************
CH  74 (0.875 MEV)  16.244 CPS *****************
CH  75 (0.887 MEV)  16.331 CPS *****************
CH  76 (0.898 MEV)  17.519 CPS *******************
CH  77 (0.910 MEV)  16.689 CPS ******************
CH  78 (0.922 MEV)  17.150 CPS ******************
CH  79 (0.934 MEV)  19.230 CPS ********************
CH  80 (0.946 MEV)  17.111 CPS ******************
CH  81 (0.957 MEV)  16.248 CPS *****************
CH  82 (0.969 MEV)  14.954 CPS ****************
CH  83 (0.981 MEV)  17.324 CPS ******************
CH  84 (0.993 MEV)  16.276 CPS *****************
CH  85 (1.005 MEV)  14.813 CPS ****************
CH  86 (1.017 MEV)  15.703 CPS *****************
CH  87 (1.028 MEV)  13.767 CPS ***************
CH  88 (1.040 MEV)  16.414 CPS *****************
CH  89 (1.052 MEV)  13.642 CPS *************** BISMUTH 214
CH  90 (1.064 MEV)  13.624 CPS ***************
CH  91 (1.076 MEV)  13.517 CPS ***************
CH  92 (1.087 MEV)  13.700 CPS ***************
CH  93 (1.099 MEV)  14.633 CPS ****************
CH  94 (1.111 MEV)  14.303 CPS ***************
CH  95 (1.123 MEV)  13.766 CPS ***************
CH  96 (1.135 MEV)  14.949 CPS ****************
CH  97 (1.147 MEV)  13.503 CPS ***************
CH  98 (1.158 MEV)  13.481 CPS **************
CH  99 (1.170 MEV)  13.189 CPS **************
CH 100 (1.182 MEV)  13.602 CPS *************** BISMUTH 214
CH 101 (1.194 MEV)  12.965 CPS **************
CH 102 (1.206 MEV)  12.538 CPS **************
CH 103 (1.217 MEV)  14.001 CPS ***************
CH 104 (1.229 MEV)  11.346 CPS ************
CH 105 (1.241 MEV)  11.113 CPS ************
CH 106 (1.253 MEV)  13.669 CPS ***************
CH 107 (1.265 MEV)  11.910 CPS *************
CH 108 (1.277 MEV)  12.345 CPS *************
CH 109 (1.288 MEV)  10.736 CPS ************
CH 110 (1.300 MEV)  11.444 CPS ************
CH 111 (1.312 MEV)  11.433 CPS ************
CH 112 (1.324 MEV)  11.927 CPS *************
CH 113 (1.336 MEV)  11.846 CPS *************
CH 114 (1.347 MEV)  11.896 CPS *************
CH 115 (1.359 MEV)  11.470 CPS ************
CH 116 (1.371 MEV)  11.864 CPS ************* POTASSIUM 40
CH 117 (1.383 MEV)  10.286 CPS ***********
CH 118 (1.395 MEV)  10.084 CPS ***********
CH 119 (1.407 MEV)   9.642 CPS ***********
CH 120 (1.418 MEV)  11.778 CPS *************
CH 121 (1.430 MEV)  12.635 CPS **************
CH 122 (1.442 MEV)  10.601 CPS ************
CH 123 (1.454 MEV)   9.140 CPS **********
CH 124 (1.466 MEV)  11.144 CPS ************
CH 125 (1.477 MEV)  10.766 CPS ************
CH 126 (1.489 MEV)   9.250 CPS **********
CH 127 (1.501 MEV)  11.961 CPS *************
CH 128 (1.513 MEV)  10.296 CPS ***********
CH 129 (1.525 MEV)  10.900 CPS ************
CH 130 (1.537 MEV)   9.022 CPS **********
CH 131 (1.548 MEV)  10.311 CPS ***********
CH 132 (1.560 MEV)  10.151 CPS *********** POTASSIUM 40
CH 133 (1.572 MEV)   9.361 CPS **********
CH 134 (1.584 MEV)   8.753 CPS **********
CH 135 (1.596 MEV)  11.176 CPS ************
CH 136 (1.608 MEV)  10.130 CPS ***********
CH 137 (1.619 MEV)  10.551 CPS ************
CH 138 (1.631 MEV)   9.204 CPS **********
CH 139 (1.643 MEV)   9.159 CPS **********
CH 140 (1.655 MEV)   8.738 CPS **********
CH 141 (1.667 MEV)   8.679 CPS ********** BISMUTH 214
CH 142 (1.678 MEV)  10.154 CPS ***********
CH 143 (1.690 MEV)   9.743 CPS ***********
CH 144 (1.702 MEV)   9.453 CPS **********
CH 145 (1.714 MEV)   9.418 CPS **********
CH 146 (1.726 MEV)   8.425 CPS *********
CH 147 (1.738 MEV)   9.263 CPS **********
CH 148 (1.749 MEV)   9.653 CPS ***********
CH 149 (1.761 MEV)   9.412 CPS **********
CH 150 (1.773 MEV)   9.019 CPS **********
CH 151 (1.785 MEV)   9.329 CPS **********
CH 152 (1.797 MEV)  10.232 CPS ***********
CH 153 (1.808 MEV)   9.686 CPS ***********
CH 154 (1.820 MEV)   7.911 CPS *********
CH 155 (1.832 MEV)   8.104 CPS *********
CH 156 (1.844 MEV)   9.602 CPS ***********
CH 157 (1.856 MEV)   9.473 CPS ********** BISMUTH 214
CH 158 (1.868 MEV)   8.568 CPS **********
CH 159 (1.879 MEV)   8.105 CPS *********
CH 160 (1.891 MEV)   8.014 CPS *********
CH 161 (1.903 MEV)   8.365 CPS *********
CH 162 (1.915 MEV)   8.759 CPS **********
CH 163 (1.927 MEV)   6.994 CPS ********
CH 164 (1.938 MEV)   8.477 CPS *********
CH 165 (1.950 MEV)   8.144 CPS *********
CH 166 (1.962 MEV)   7.798 CPS *********
CH 167 (1.974 MEV)   8.214 CPS *********
CH 168 (1.986 MEV)   9.240 CPS **********
CH 169 (1.998 MEV)   7.945 CPS *********
CH 170 (2.009 MEV)   7.615 CPS *********
CH 171 (2.021 MEV)   6.816 CPS ********
CH 172 (2.033 MEV)   8.408 CPS *********
CH 173 (2.045 MEV)   7.196 CPS ********
CH 174 (2.057 MEV)   7.231 CPS ********
CH 175 (2.068 MEV)   7.473 CPS ********
CH 176 (2.080 MEV)   9.062 CPS **********
CH 177 (2.092 MEV)   8.116 CPS *********
CH 178 (2.104 MEV)   8.235 CPS *********
CH 179 (2.116 MEV)   7.653 CPS *********
CH 180 (2.128 MEV)   8.338 CPS *********
CH 181 (2.139 MEV)   7.237 CPS ********
CH 182 (2.151 MEV)   7.528 CPS *********
CH 183 (2.163 MEV)   8.039 CPS *********
CH 184 (2.175 MEV)   8.536 CPS **********
CH 185 (2.187 MEV)   8.888 CPS **********
CH 186 (2.199 MEV)   7.485 CPS ********
CH 187 (2.210 MEV)   8.211 CPS *********
CH 188 (2.222 MEV)   8.233 CPS *********
CH 189 (2.234 MEV)   8.055 CPS *********
CH 190 (2.246 MEV)   7.825 CPS *********
CH 191 (2.258 MEV)   7.062 CPS ********
CH 192 (2.269 MEV)   8.435 CPS *********
CH 193 (2.281 MEV)   7.440 CPS ********
CH 194 (2.293 MEV)   7.686 CPS *********
CH 195 (2.305 MEV)   7.110 CPS ********
CH 196 (2.317 MEV)   7.329 CPS ********
CH 197 (2.329 MEV)   7.890 CPS *********
CH 198 (2.340 MEV)   7.771 CPS *********
CH 199 (2.352 MEV)   7.147 CPS ********
CH 200 (2.364 MEV)   6.729 CPS ********
CH 201 (2.376 MEV)   6.264 CPS *******
CH 202 (2.388 MEV)   6.318 CPS *******
CH 203 (2.399 MEV)   7.050 CPS ********
CH 204 (2.411 MEV)   6.506 CPS ******** THALLIUM 208
CH 205 (2.423 MEV)   6.486 CPS *******
CH 206 (2.435 MEV)   6.589 CPS ********
CH 207 (2.447 MEV)   7.033 CPS ********
CH 208 (2.459 MEV)   6.515 CPS ********
CH 209 (2.470 MEV)   6.852 CPS ********
CH 210 (2.482 MEV)   6.871 CPS ********
CH 211 (2.494 MEV)   6.573 CPS ********
CH 212 (2.506 MEV)   6.417 CPS *******
CH 213 (2.518 MEV)   5.845 CPS *******
CH 214 (2.529 MEV)   6.127 CPS *******
CH 215 (2.541 MEV)   6.355 CPS *******
CH 216 (2.553 MEV)   6.964 CPS ********
CH 217 (2.565 MEV)   6.820 CPS ********
CH 218 (2.577 MEV)   6.670 CPS ********
CH 219 (2.589 MEV)   6.808 CPS ********
CH 220 (2.600 MEV)   5.940 CPS *******
CH 221 (2.612 MEV)   6.177 CPS *******
CH 222 (2.624 MEV)   6.176 CPS *******
CH 223 (2.636 MEV)   6.109 CPS *******
CH 224 (2.648 MEV)   6.347 CPS *******
CH 225 (2.660 MEV)   7.049 CPS ********
CH 226 (2.671 MEV)   5.757 CPS *******
CH 227 (2.683 MEV)   5.645 CPS *******
CH 228 (2.695 MEV)   5.229 CPS ******
CH 229 (2.707 MEV)   5.415 CPS ******
CH 230 (2.719 MEV)   6.190 CPS *******
CH 231 (2.730 MEV)   6.092 CPS *******
CH 232 (2.742 MEV)   6.466 CPS *******
CH 233 (2.754 MEV)   7.032 CPS ********
CH 234 (2.766 MEV)   5.533 CPS *******
CH 235 (2.778 MEV)   6.309 CPS *******
CH 236 (2.790 MEV)   5.559 CPS *******
CH 237 (2.801 MEV)   5.206 CPS ****** THALLIUM 208
CH 238 (2.813 MEV)   6.045 CPS *******
CH 239 (2.825 MEV)   5.257 CPS ******
CH 240 (2.837 MEV)   5.640 CPS *******
CH 241 (2.849 MEV)   5.835 CPS *******
CH 242 (2.860 MEV)   5.348 CPS ******
CH 243 (2.872 MEV)   4.804 CPS ******
CH 244 (2.884 MEV)   4.742 CPS ******
CH 245 (2.896 MEV)   5.304 CPS ******
CH 246 (2.908 MEV)   5.248 CPS ******
CH 247 (2.920 MEV)   6.036 CPS *******
CH 248 (2.931 MEV)   5.711 CPS *******
CH 249 (2.943 MEV)   5.513 CPS *******
CH 250 (2.955 MEV)   5.010 CPS ******
CH 251 (2.967 MEV)   5.579 CPS *******
CH 252 (2.979 MEV)   6.256 CPS *******
CH 253 (2.990 MEV)   5.207 CPS ******
CH 254 (3.002 MEV)   9.302 CPS ********** TOTAL COUNT
CH 255 (3.014 MEV)1000.000 CPS ****************************************************************************************************
```

Figure

| PAD | K | U | T |
|---|---|---|---|
| Matrix | 1.45% | 2.19 ppm | 6.26 ppm |
| K | 5.14% | 5.09 ppm | 8.48 ppm |
| U | 2.03% | 30.29 ppm | 9.19 ppm |
| T | 2.01% | 5.14 ppm | 45.33 ppm |
| Mixed | 4.11% | 20.39 ppm | 17.52 ppm |

Since the measurements were taken over a relatively short time period (a few hours), it was assumed that the matrix pad measurements contain not only the effects of the matrix pad itself, but also aircraft background (which is a constant), cosmic background (constant over the time period of interest), and all other local background (e.g. BiAir, etc.) effects. (The matrix pad is constructed with only the basic concrete mix without the additional elemental minerals). Thus, by subtracting the matrix pad count rates from the count rates in the four pads, we have eliminated aircraft and cosmic background and BiAir effects for the four pads. The pad concentrations are then modified in a similar fashion by the subtraction of the matrix pad concentrations. The differential concentrations in the pads are given in the table below.

| PAD | K | U | T |
|---|---|---|---|
| K-Matrix | 3.7% | 2.9 ppm | 2.2 ppm |
| U-Matrix | 0.6% | 28.5 ppm | 2.9 ppm |
| T-Matrix | 0.6% | 3.0 ppm | 39.0 ppm |
| Mixed-Matrix | 2.7% | 18.8 ppm | 11.3 ppm |

Considering the above, we can define a functional relationship between the differential concentrations and the residual count rates which will provide a method of determining the calibration constants for the spectrometer system. These calibration constants are the six (6) stripping coefficients which account for the interactions occuring between the elemental channels in the system (Compton scatter coefficients, etc.).

On the basis of an ideal situation, one would anticipate that some of these interactions should be negligible. This is not totally the case, since we are dealing with a system which has less than infinite resolving power (i.e. the energies are smeared to some extent).

Thus, energy peaks within a spectrum of a given element are Gaussian shaped rather than pure line spectra. Additionally, we are dealing with finite spectral windows, multiple peaked spectra, and pulse pileup; all tend to couple each window's response to the other.

Keeping in mind that we are dealing with the count rates corresponding to the concentrations presented in the last table, we define the following:

$KC_i$ = uncorrected system count rate for the K channel

$UC_i$ = uncorrected system count rate for the U channel

$TC_i$ = uncorrected system count rate for the T channel

$K_i$ = the percent differential concentration of potassium

$U_i$ = ppm differential concentration of uranium

$T_i$ = ppm differential concentration of thorium

where "i" refers to the ith pad.

We also define the following:

$\zeta_{kk}$ = sensitivity of $KC_i$ to concentrations of $K_i$

$\zeta_{ku}$ = sensitivity of $KC_i$ to concentrations of $U_i$

$\zeta_{kt}$ = sensitivity of $KC_i$ to concentrations of $T_i$

$\zeta_{uk}$ = sensitivity of $UC_i$ to concentrations of $K_i$

$\zeta_{uu}$ = sensitivity of $UC_i$ to concentrations of $U_i$

$\zeta_{ut}$ = sensitivity of $UC_i$ to concentrations of $T_i$

$\zeta_{tk}$ = sensitivity of $TC_i$ to concentrations of $K_i$

$\zeta_{tu}$ = sensitivity of $TC_i$ to concentrations of $U_i$

$\zeta_{tt}$ = sensitivity of $TC_i$ to concentrations of $T_i$

Using the above definitions, we now construct the functional relationship by means of the following nine (9) equations in sets of three (3) per pad.

K pad $KC_k = \zeta kk^{K} + \zeta ku^{U} + \zeta kt^{T}$

$UC_k = \zeta uk^{K} + \zeta uu^{U} + \zeta ut^{T}$

$TC_k = \zeta tk^{K} + \zeta tu^{U} + \zeta tt^{T}$

U pad $KC_u = \zeta kk^{K} + \zeta ku^{U} + \zeta kt^{T}$

$UC_u = \zeta uk^{K} + \zeta uu^{U} + \zeta ut^{T}$

$TC_u = \zeta tk^{K} + \zeta tu^{U} + \zeta tt^{T}$

T pad $KC_t = \zeta kk^{K} + \zeta ku^{U} + \zeta kt^{T}$

$UC_t = \zeta uk^{K} + \zeta uu^{U} + \zeta ut^{T}$

$TC_t = \zeta tk^{K} + \zeta tu^{U} + \zeta tt^{T}$

Separating these equation into consistent groups, we get for the uncorrected count rates in the K channel

(K pad) $KC_k = \zeta kk^{K}k + \zeta ku^{U}k + \zeta kt^{T}k$

(U pad) $KC_u = \zeta kk^{K}u + \zeta ku^{U}u + \zeta kt^{T}u$

(T pad) $KC_t = \zeta kk^{K}t + \zeta ku^{U}t + \zeta kt^{T}t$

The equations can be expressed in matrix notation

$$\begin{bmatrix} KC_k \\ KC_u \\ KC_t \end{bmatrix} = \begin{bmatrix} K_k & U_k & T_k \\ K_u & U_u & T_u \\ K_t & U_t & T_t \end{bmatrix} \cdot \begin{bmatrix} \zeta kk \\ \zeta ku \\ \zeta kt \end{bmatrix}$$

Where the k, u and t subscripts represent the K, U and T pads.

In a similar manner we can write two other matrix equations for $UC_i$ and $TC_i$ respectively.

$$\begin{bmatrix} UC_k \\ UC_u \\ UC_t \end{bmatrix} = \begin{bmatrix} K_k & U_k & T_k \\ K_u & U_u & T_u \\ K_t & U_t & T_t \end{bmatrix} \cdot \begin{bmatrix} \zeta uk \\ \zeta uu \\ \zeta ut \end{bmatrix}$$

$$\begin{bmatrix} TC_k \\ TC_u \\ TC_t \end{bmatrix} = \begin{bmatrix} K_k & U_k & T_k \\ K_u & U_u & T_u \\ K_t & U_t & T_t \end{bmatrix} \cdot \begin{bmatrix} \zeta_{tk} \\ \zeta_{tu} \\ \zeta_{tt} \end{bmatrix}$$

Collecting the above, these equations can be expressed in matrix form as

$$\begin{bmatrix} KC_k & UC_k & TC_k \\ KC_u & UC_u & TC_u \\ KC_t & UC_t & TC_t \end{bmatrix} = \begin{bmatrix} K_t & U_k & T_k \\ K_u & U_u & T_u \\ K_t & U_t & T_t \end{bmatrix} \cdot \begin{bmatrix} \zeta_{kk} & \zeta_{uk} & \zeta_{tk} \\ \zeta_{ku} & \zeta_{uu} & \zeta_{tu} \\ \zeta_{kt} & \zeta_{ut} & \zeta_{tt} \end{bmatrix}$$

or

$$\bar{A} = \bar{B} \cdot \bar{\zeta}$$

where $\bar{A}$ is the residual count rate matrix, $\bar{B}$ is the matrix of the known differential concentrations and $\bar{\zeta}$ the sensitivity matrix.

Rearranging the above equations we have

$$\bar{B} = \bar{A} \cdot \bar{\zeta}^{-1}$$

We now define

$$\bar{\zeta}^{-1} = \bar{\Delta}$$

Eliminating $\bar{\zeta}$, we get

$$\bar{B} = \bar{A} \cdot \bar{\Delta}$$

We can now solve for $\bar{\Delta}$ by matrix inversion.

Therefore, the differential concentrations in the mixed pad can be derived from the k,u,t pads to check the computed $\bar{\Delta}$.

$$\begin{bmatrix} K_m \\ U_m \\ T_m \end{bmatrix} = \begin{bmatrix} \Delta_{kk} & \Delta_{ku} & \Delta_{kt} \\ \Delta_{uk} & \Delta_{uu} & \Delta_{ut} \\ \Delta_{tk} & \Delta_{tu} & \Delta_{tt} \end{bmatrix} \cdot \begin{bmatrix} KC_m \\ UC_m \\ TC_m \end{bmatrix}$$

where the subscript m refers to the mixed pad. Expanding this in algebraic form we obtain the following set of equations:

$$K_m = \Delta_{kk}(KC_m + \frac{\Delta_{ku}}{\Delta_{kk}}UC_m + \frac{\Delta_{kt}}{\Delta_{kk}}TC_m)$$

$$U_m = \Delta_{uu}(UC_m + \frac{\Delta_{ut}}{\Delta_{kk}}TC_m + \frac{\Delta_{uk}}{\Delta_{uu}}KC_m)$$

$$T_m = \Delta_{tt}(TC_m + \frac{\Delta_{tu}}{\Delta_{tt}}UC_m + \frac{\Delta_{tk}}{\Delta_{tt}}KC^m)$$

The terms in parentheses in the above 3 equations are the "corrected stripped count rates" for the system, and the stripping coefficients are as follows:

$S_{ku} = \frac{\Delta_{ku}}{\Delta_{kk}}$ (effect of uranium on potassium)

$S_{kt} = \frac{\Delta_{kt}}{\Delta_{kk}}$ (effect of thorium on potassium)

$S_{ut} = \frac{\Delta_{ut}}{\Delta_{uu}}$ (effect of thorium on uranium)

$S_{uk} = \frac{\Delta_{uk}}{\Delta_{uu}}$ (effect of potassium on uranium)

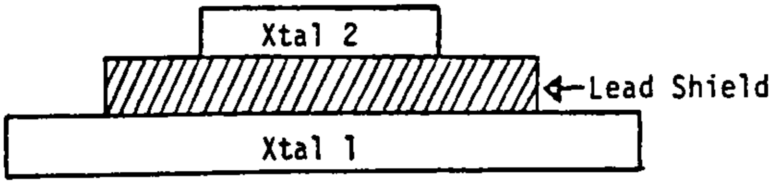
$S_{tu} = \frac{\Delta_{tu}}{\Delta_{tt}}$ (effect of uranium on thorium)

$S_{tk} = \frac{\Delta_{tk}}{\Delta_{tt}}$ (effect of potassium on thorium)

These stripping coefficients are defined in terms of $S_{ij}$ in order to eliminate confusion with $\alpha$, $\beta$, and $\gamma$, which are sometimes defined slightly differently.

## ATMOSPHERIC RADON CORRECTION

Consider the crystal configuration shown below:



Let 1 and 2 designate the down and up crystal respectively. The down crystal sees radiation rates of $I_1$ composed of the air signal $I_a$ and the ground signal $I_g$ plus aircraft and cosmic background.

Therefore $$I_1 = I_g + I_a + A_1 + C_1$$

Similarly, the up crystal sees the air signal and ground signal (both somewhat attenuated) plus an aircraft and cosmic background.

Therefore $$I_2 = \ell I_g + mI_a + A_2 + C_2$$

Where m is the response to the air signal and $\ell$ is the % of the ground signal getting through to the up detector.

Using the test pad data, the factor $\ell$ can be determined. Consider the two previous equations. When we subtract the matrix pad data from the K, U, and T pad data, we have essentially set $A_1$, $A_2$, $C_1$, and $C_2$ and $I_a$ equal to zero.

Therefore $$I_1 = I_g$$

$$I_2 = \ell I_g$$

$$\ell = \left(\frac{I_2}{I_1}\right)$$

Instead of using the count rates we can use the resultant sensitivities $1/\Delta_{uu}$ to determine $\ell$ for the elemental channel U.

$$\ell_u = \frac{1/\Delta uu \quad (\text{up})}{1/\Delta uu \quad (\text{down})}$$

It should be noted that due to "shine around" (since the shielding is not an infinite plane, the upward looking crystal responds to the surrounding terrain) on the test pads, as altitude increases, should decrease, thus $\ell = f(h)$.

Only the factor m remains to be determined. This unfortunately cannot be determined from test pad data. It can however be determined by flying over water (e.g. use of the Lake Mead over-water data).

Consider the equations for $I_1$ and $I_2$ again

$$I_1 = I_g + I_a + A_1 + C_1$$

$$I_2 = \ell I_g + mI_a + A_2 + C_2$$

Over water $I_g = 0$

We have $A_1$, $A_2$, $C_1$, and $C_2$ defined.

Removing the aircraft and cosmic background from the over water data and we are left with

$$I_1 = I_a$$

$$I_2 = mI_a$$

Since m is the shielding factor response to the air signal, we should have an air signal to "shield". Thus m is best determined if there is radon present.

Both up and down counting rates are corrected for aircraft and cosmic background and so we can solve the following two equations for $I_a$.

$$I_1 = I_g + I_a$$

$$I_2 = \ell I_g + mI_a$$

$$mI_a = I_2 - \ell I_g$$

but $I_g = I_1 - I_a$

then $I_a (m-\ell) = I_2 - \ell I_1$

or $I_a = \dfrac{I_2 - \ell I_1}{m - \ell}$ = Bi Air

and $I_a$ is then the Bi Air contribution from the surrounding air. This is then subtracted from the down looking U count resulting in corrected data.

## FIXED WING/ROTARY WING DATA NORMALIZATION

As required in the Raton Basin Project, the rotary wing data were normalized to the fixed wing data to provide continuity within NTMS data sets. Normalization was accomplished by multiplying the rotary wing reduced averaged record K, U, T, and total count values by an appropriate constant derived from data obtained on the Walker Field Calibration Pads, Lake Mead Dynamic Test Range, and flight line overlaps/intersections in the adjoining project area.

To obtain the normalization constant the following technique was implemented:

1. The fixed wing/rotary wing ratio of K, U, T, and total count cps for the Walker Field Calibration Pads were calculated and tabulated.

2. The fixed wing/rotary wing ratio of K, U, T, and total count cps for quasi-coincident fixed wing/rotary wing samples (spatially within 50 ± feet) were calculated for all four flights at each of the eight altitudes flown over the land portion of the Lake Mead Dynamic Test Range. Tabulation of these results included the plotting of histograms, scatter plots and associated statistical parameters.

3. Flight line overlaps/intersections occurring within individual NTMS sheets were subjected to the same procedure as in 2 above.

From results of the above, the proper normalization constant was selected and input to the processing scheme. In the case of all portions of the Raton Basin Project a multiplicative factor of 1.3 was applied to the rotary wing average record data (K, U, T, and total count) to normalize it to the fixed wing data.

# DATA PROCESSING

## DATA PREPARATION

The following sections summarize the techniques used for reduction and processing of the airborne data.

### Field Tape Verification and Edit

The field data tapes containing the airborne data are read into the computer to verify the recording and data quality. Data recovery is essentially 100% from the field tapes. During this phase, statistics are generated summarizing the altitude (radar and barometric), ground speed and air temperature for each flight line. Simultaneously, the spectral peaks are evaluated for shifts using a centroid calculation and the particular window's peak channel. The data are also checked for correct scan lengths and proper justification of data fields within each scan and and live time calculations are made. During this process, the desired window data fields are extracted from each spectrum and rewritten as a reformatted copy tape.

The reformatted tape data are then edited, checked and corrected. The data for each flight line are then read (with aborted or unnecessary flight line data edited out) and each data variable is checked for consistency, data spikes, gradients, etc. Every correction suggested by the computer is evaluated by the data processing personnel prior to actual correction. Upon completion of the phase, the data on the output tape are "clean" and ready for subsequent correction of the radiometrics and tieing of the magnetics.

### Flight Line Location

A single frame 35 mm camera is used for obtaining position recovery information. The photo locations are spotted or transferred to a suitable base map and are digitized. The fiducial numbers of the spotted points along each line are entered during the digitying process. A computer program is used to check the consistency of these data using calculated intersections from tie line to tie line and from traverse to traverse. This program allows easy detection of entry errors as well as potential flight path recovery errors.

A computer program then calculates the map location for each intersection and the beginning and end of each line based on the fiducial numbers and the control line/tie grid. A computer plot is made of these locations to check against the field plot and correct editing information. These flight lines are then overlain on the geologic base map and each map unit is digitized such that each sample falls within a single unit. This resulting location information is then merged with the geophysicial data using the fiducial numbers as common reference.

## RADIOMETRIC DATA REDUCTION

Reduction of these data was carried out utilizing system calibration constants as derived from high altitude over water flights, Lake Mead Dynamic Test Range, and the Walker Field Test Pads. The data reduction sequence used is summarized in the flow diagram in Figure 13.

Processing of the data was performed using the window energies given below:

Total count - 0.4 to 3.0 MeV

K - 1.37 to 1.57 MeV

U - 1.66 to 1.87 MeV (downward and upward looking system)

T - 2.41 to 2.81 MeV

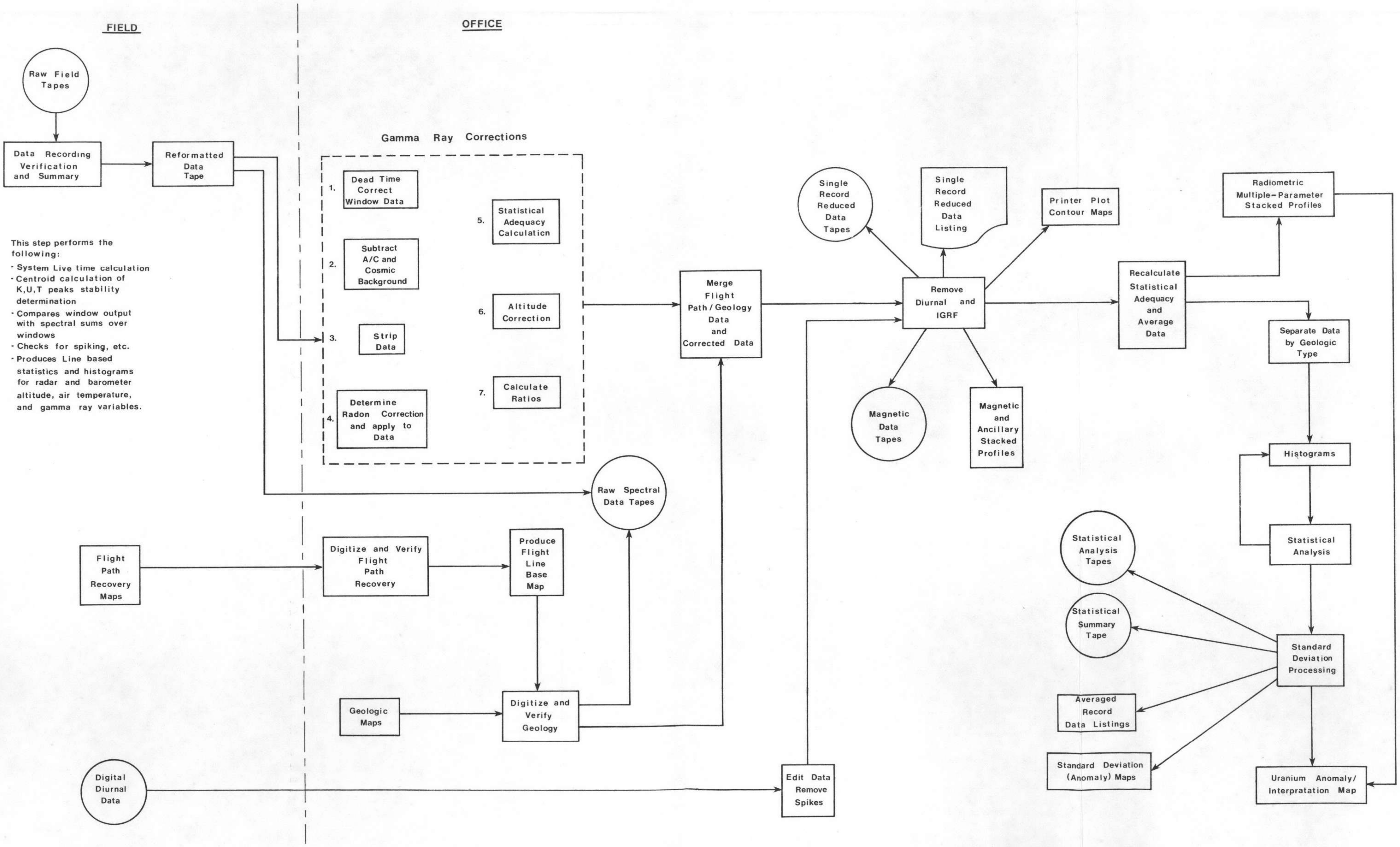
Cosmic - 3 to 6 MeV (downward and upward looking system)

Aircraft and Cosmic background for both Lama and the Tracker over these windows described above are summarized below:

| | | S2F | | LAMA I | |
|---|---|---|---|---|---|
| | | Aircraft | Cosmic* | Aircraft | Cosmic* |
| TC | (cps) | 212.04 | 3.115 | 150.83 | 3.022 |
| K | (cps) | 22.83 | 0.177 | 19.10 | 0.1650 |
| $U_{dn}$ | (cps) | 8.90 | 0.145 | 5.06 | 0.1417 |
| $U_{up}$ | (cps) | 1.75 | 0.152 | 0.36 | 0.1145 |
| T | (cps) | 7.76 | 0.189 | 4.25 | 0.1919 |

*Cosmic background values are in cps per 1.0 cps in the 3-6 MeV window.

# DATA PROCESSING FLOW DIAGRAM



This step performs the following:
- System Live time calculation
- Centroid calculation of K,U,T peaks stability determination
- Compares window output with spectral sums over windows
- Checks for spiking, etc.
- Produces Line based statistics and histograms for radar and barometer altitude, air temperature, and gamma ray variables.

Compton corrections to the down data were made using the following constants:

| Sij | S2F | LAMA I |
|---|---|---|
| $S_{ku}$ | 0.8613 | 0.8195 |
| $S_{kt}$ | 0.1588 | 0.1815 |
| $S_{ut}$ | 0.2986 | 0.2838 |
| $S_{uk}$ | 0.0 | 0.0 |
| $S_{tu}$ | 0.05312 | 0.06926 |
| $S_{tk}$ | 0.0 | 0.0 |

The ij subscripts represent the influence of the $j^{th}$ window on the $i^{th}$ window.

All parameters except for $S_{ut}$ are considered constants. $S_{ut}$ was considered an altitude dependent paramenter utilizing the following expression (after Grasty, 1975).

$S_{ut} = S_{ut_o} + 0.000076h$, where h is the altitude in hundreds of feet.

Altitude attenuation coefficients used are defined as follows:

ALTITUDE ATTENUATION COEFFICIENTS

| | | S2F | LAMA I |
|---|---|---|---|
| TC | (per foot) | .0022065 | .002129 |
| K | (per foot) | .003001 | .002897 |
| U | (per foot) | .002710 | .002240 |
| T | (per foot) | .002274 | .002198 |

All radiometric data presented in the strip charts have been normalized to 400 feet mean terrain clearance at STP using the expression

$$\exp\ u_i \left[\frac{273.15}{760} \times \frac{P}{T}\right] (h - 400)$$

where h is the height in feet, $u_i$ is the appropriate altitude attenuation coefficient, P is in mm of Hg, and T is in degrees Kelvin. In cases where the altitude exceeds 1,000 feet, the correction coefficients were limited to the 1,000 foot value.

Bi Air calculations are made using the following expressions:

$$Bi_{Air} = \frac{U_{up} - (R_{us} + \frac{C'uk}{C'uu} R_{ks} + \frac{C'ut}{C'uu} R_{ts})}{m - \ell}$$

Where $U_{up}$ = count rate from upward detectors

$\ell$ = crystal coupling constant

m = crystal geometric factor

$C'_{uk}$, $C'_{ut}$, $C'_{uu}$, = stripping coefficients relating down data to up data

$R_{us}$ = stripped uranium count rate - down system

$R_{ks}$ = stripped potassium count rate - down system

$R_{ts}$ = stripped thorium count rate - down system

The numerical values for the constant $\ell$ , m, $C'_{uk}$, and $C'_{uu}$ are given below:

| | S2F | LAMA I |
|---|---|---|
| $\ell$ | 0.0488 | 0.0686 |
| m | 0.189 | 0.168 |
| $C'_{uk}$ | 0.0 | 0.0 |
| $C'_{uu}$ | 0.03586 | 0.06078 |
| $C'_{ut}$ | 0.01687 | 0.02081 |
| $\mu\ell$ | -0.000233 | -0.000233 |
| $\mu m$ | -0.000034 | -0.000034 |

m and $\ell$ are altitude dependent as follows:

$\ell = \ell - \mu\ell$ x h, where h is in feet

$m = m - \mu m$ x h, where h is in feet

These Bi Air data are filtered and the filtered results are then removed, on a point by point basis, from the corrected uranium window data.

The window data are then evaluated for statistical adequacy prior to altitude correction to ensure that they are significant within the context of the anticipated errors in count statistics.

### Statistical Adequacy Test

The statistical adequacy test is made to determine whether the corrected data sample is sufficiently greater than the "noise" to represent the "signal" of interest.

We can define three separate criteria for detection thresholds (ref. Currie, Analytical Chemistry, Volume 40, No. 3, March 1968) of which only one is directly applicable to our case; this is the "critical level". This is the level at which the decision is made that a signal is "detected". We thus define this critical level as that level at which the data are statistically adequate.

Setting the actual levels in counts per second, "a priori" for each elemental window is difficult at best since the full effect of all parameters affecting the counts is not known to a sufficient degree of certainty. If the corrections to the data are a significant portion of the count rate, most of the error (exclusive of systematic errors due to electronics, etc.) in the corrected data can be ascribed to random errors within the applied corrections. The corrections are basically the results of counting radioactive decay products (gamma rays) and are therefore assumed to follow the classical Poisson distribution. The following assumptions concerning these corrections are:

1. In the best case, the error in each correction is additive.

2. The sum of these corrections also follows a Poisson distribution.

3. The uncertainty in the correction itself, is equal to the square root of the correction applied.

4. This uncertainty is directly reflected in the corrected single record count rate.

With these assumptions in mind, the criterion for determining the statistical adequacy of a given data sample may be defined as follows:

> If a corrected single record data sample exceeds 1.5 times the square root of the summed correction applied to that data sample, then that data sample is statistically adequate.

Since any calculation using statistically inadequate data (such as ratios) is also inadequate, the adequacy of each element of the single sample record data is tested prior to the calculation. This is done during the course of the processing by retaining all corrections applied to each data sample and determining its adequacy as explained above.

Not only are the results of this statistical adequacy test used to insure that calculated ratios will be meaningful but they are also utilized to determine the optimum interval over which the data should be averaged (e.g. 5 seconds or 7 seconds, etc.) to improve the overall data statistical adequacy. In the case of this project, the resulting averaging sample interval was 7 seconds. This resulted in 95% or better of the uranium data to be statistically adequate, exclusive of those data which were outside of altitude specifications (the overall altitude specification was maintained at the 98% level) and excluding the known water saturated map units and water bodies.

## MAGNETIC DATA REDUCTION

The magnetic data reduction processes are: correction for diurnal variation, tieing to a common magnetic datum, and subtraction of the regional magnetic field as defined by the International Geomagnetic Reference Field (IGRF). During data acquisition, the magnetic field is monitored by a ground-based diurnal magnetometer that samples every four seconds at a sensitivity of one-quarter gamma. These data are recorded on magnetic tape along with the time for synchronization with the airborne data.

The diurnal data are edited to keep only those readings taken during flight time and then remove spikes and man-made magnetic events. After editing, these data are displayed in profile form to ensure that all corrections necessary have been made. Next, the data are synchronized in time with the airborne data, interpolated, and subtracted from the airborne magnetic data.

The diurnally corrected magnetic data are then processed by a tieing program that compares the magnetic differences at intersections of flight lines and tie lines. This program calculates individual magnetic field biases for each flight tie line based on tie line intersections. This allows miss-ties to be minimized throughout the survey. These biases usually represent, after diurnal correction, changes in location of the ground-based magnetometer, or changes in the airborne equipment. The biases are manually evaluated and selectively applied.

# DATA PRESENTATION

## GENERAL

The majority of the actual presented data are contained in Volume II. These include the uranium anomaly/interpretation maps and pseudo-contour maps of potassium, uranium, thorium, and magnetic data and are integrated as part of the text in the interpretation section. In addition to these data, Volume II contains data presented in the form of radiometric profiles, flight path recovery maps, standard deviation maps, and histograms. Microfiche data are contained in Appendix C of this volume. Data tapes are available separately.

## RADIOMETRIC PROFILES

Stacked profiles were prepared from the averaged data for each traverse and tie line. These stacked profiles, plotted at a linear scale of 1:250,000, contain the following parameters: corrected Total Count, corrected Potassium, corrected Uranium, corrected Thorium, U/TH, U/K, and TH/K ratios, Bi Air, radar altimeter, and magnetometer data. Each of the stacked profile sheets contains a plot of the flight path superimposed on a geologic strip map. Included along these profiles are the fiducial numbers which correspond to flight path position as displayed on the flight path recovery maps. Each of the stacked profiles represents the data contained on the specific flight line within the boundaries of the specified NTMS Quadrangle sheet.

Radiometric traces on the stacked profiles contain an indicator showing those data which are statistically inadequate. These statistically inadequate data are marked by a small vertical tick at the sample location. The altitude profile has been limited in display to 1,000 feet. A dashed line at the 700 foot level is presented to show those data which do not meet the altitude specifications. The vertical scale of each variable remains constant on all stacked profiles. When overranging occurs, the trace is stepped and the step labeled showing the actual value. A pictorial representation of such a stepping profile is shown in Figure 14. At the end of each stacked profile, a statistical summary of the minimum value, maximum value, mean, and standard deviation for that variable is presented.

Contained in Volume II of this report is an equivalent set of stacked profiles for each quadrangle, photographically reduced to an approximate scale of 1:500,000.

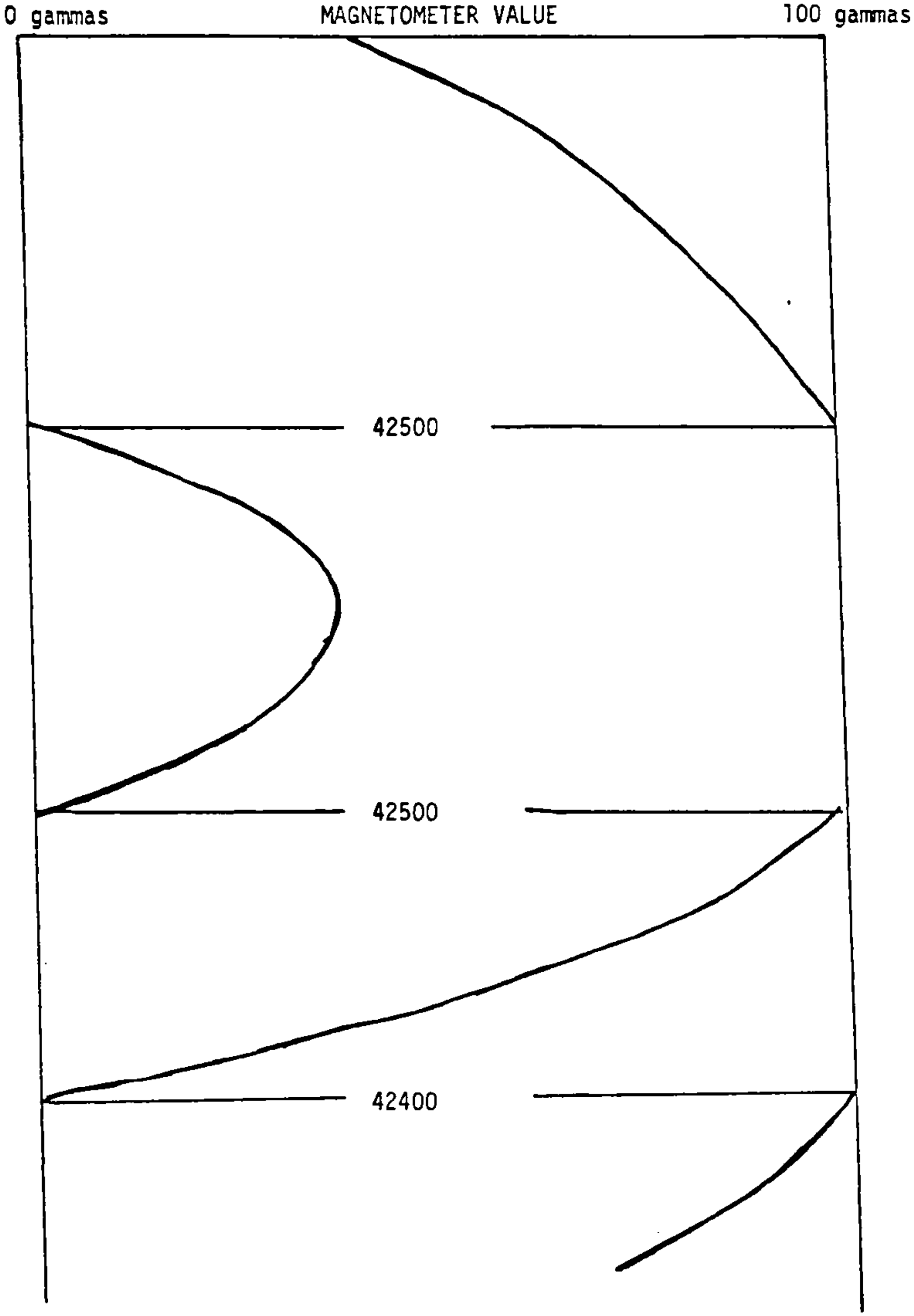


Figure 14 Plotter Step Value Labeling

## MAGNETIC PROFILES

A set of profiles containing the magnetic data (corrected, with IGRF removed), barometric altimeter data, radar altimeter data, diurnal monitor data, and temperature data are available at a linear scale of 1:250,000. Each of the stacked profiles contains a plot of the flight path superimposed on the geology over which the aircraft flew. Reduced scale, 1:500,000 copies of these are presented in Volume II of this report.

## FLIGHT PATH MAPS

For each of the NTMS quadrangle sheets covered by this survey, a flight path position map is available at a scale of 1:250,000. The actual flight path has been superimposed on the geologic quadrangle maps. Flight lines and tie lines are annotated along with fiducial numbers of located positions. Reduced scale, 1:500,000 copies of these can be found in Volume II of this report.

## STANDARD DEVIATION MAPS

Gamma ray standard deviation maps have been prepared for each NTMS quadrangle included in this survey. The six maps generated represent the following parameters: potassium, uranium, thorium, and U/TH, U/K and TH/K ratios. The data contained in each map represent only those data which are considered statistically adequate. This automatically excludes all data collected over water or data which falls outside of altitude specifications (i.e. altitude greater than 700 and less than 200 feet). The symbolism of each of the six maps is identical. The center of each circle represents the central averaged sample since the data had been averaged over a 7 second interval. The small boxes adjacent to each of the circles represents one standard deviation from the mean for that specific data sample. In order to determine whether the data shown are represented by positive or negative standard deviations, consider each map with north pointing away from the viewer. For east/west lines (traverse lines) positive standard deviations lie above or to the north of the traverse line with negative standard deviation below or to the south. On the north/ south lines (tie lines) positive standard deviations are to the left of the viewer (west) with negative standard deviations to the right (east).

These maps were generated at a scale of 1:250,000 for each NTMS sheet. In addition, these anomaly maps are presented in Volume II of this report at a reduced scale of approximately 1:500,000.

## HISTOGRAMS

Computer generated histograms, showing the count rate distribution for each of the six gamma ray parameters measured and calculated as a function of computer map unit are presented in Volume II of this report (see Figure 15). Information contained on these histograms includes the mean, the median, the standard deviation as calculated about the mean, and the total number of samples from which the statistics were derived.

## DATA LISTINGS

Single record reduced and averaged record (statistical analysis) data listings have been prepared on microfiche. The microfiche are contained in Volume I of this report as Appendix C. Each of the single record and averaged record data listings are presented for the data contained in a single quadrangle. The data contained in the single record data listings are summarized below:

1. Fiducial number

2. System/Quality (SAKUT) - The first digit identifies the system used to collect the sample. The remaining digits define the results of statistical adequacy testing for altitude, potassium, uranium, and thorium. A value of 0 indicated that the data are statistically adequate. A value of 1 indicates that the data are statistically inadequate. All data collected in excess of 700 feet and less than 200 feet are considered statistically inadequate.

3. Time - time presented in hours, minutes, and seconds

4. Altitude - altitude presented in feet above terrain

5. LAT/LONG - Latitude and Longitude presented in terms of decimal degrees

6. Magnetic field expressed in residual gammas

7. Geology - code representing geologic units

8. K, U, T - count rate of corrected K, U, T data

9. U/TH, U/K, TH/K - calculated ratios of the three parameters

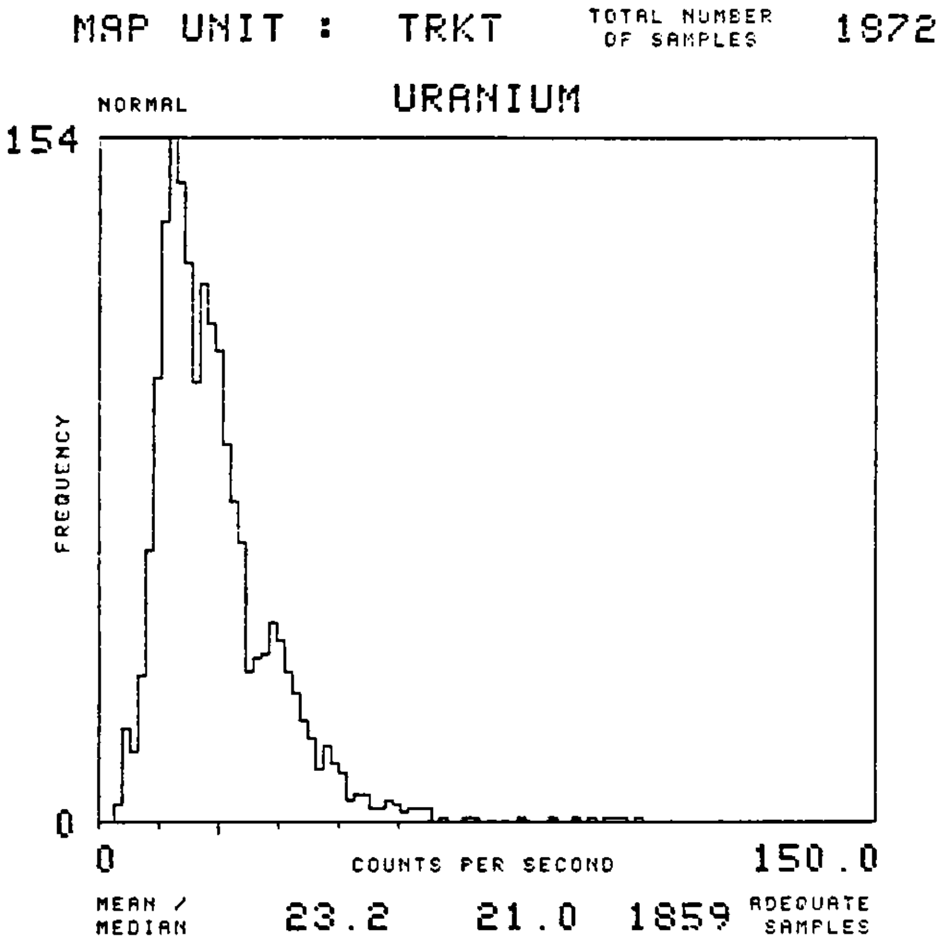


Figure 15 Sample Computer Map Unit Histogram

10. Total count - corrected total count data (0.4 to 3.0 MeV)

11. COS - downward looking cosmic count rate in the 3-6 MeV channel

12. Uair - atmospheric Bi-214 count rate

13. Temperature - outside air temperature in degrees centigrade

14. Press - barometric pressure in inches of mercury

The averaged record (statistical analysis) data listings are summarized below:

11. Fiducial number

2. System/Quality (SAKUT) - The first digit identifies the system used to collect the sample. The remaining digits define the results of statistical adequacy testing for altitude, potassium, uranium, and thorium. A value of 0 indicated that the data are statistically adequate. A value of 1 indicates that the data are statistically inadequate. All data collected in excess of 700 feet and less than 200 feet are considered statistically inadequate.

3. LAT/LONG - Latitude and longitude presented in terms of decimal degrees

4. Magnetic field expressed in residual gammas

5. Geology - code representing geologic formations

6. K, U, T - count rate of corrected K, U, T data and the number of (+) standard deviations from the mean

7. U/TH, U/K, Th/K - calculated ratios of the three parameters, and the number of (+) standard deviations from the mean

8. Total count - corrected total count data (0.4 to 3.0 MeV)

9. COS - downward looking cosmic count rate in the 3-6 MeV channel

10. Uair - atmospheric Bi-214 count rate

## DATA TAPES

Data tape files have been generated for each of the 1:250,000 NTMS quadrangle sheets. The tapes are IBM compatible and recorded on 9 track EBCDIC at 800 bpi. Four separate sets of data tapes are presented: raw spectral data tapes, single record reduced data tapes, statistical analysis tapes, and magnetic data tapes. All but the raw spectral data tapes were formatted according to the standards set forth in Bendix Field Engineering Corporation (BFEC)specification 1200-C (February, 1979). The raw spectral tapes were processed according to BFEC specification 1200-B. Detailed descriptions of the data tape formats are presented in Appendix A.

# DATA INTERPRETATION METHODS

## GENERAL

The stated objective of the NURE Program is the evaluation of the uranium potential of the United States. In support of this goal, high sensitivity airborne radiometric and magnetic surveys have been implemented to obtain reconnaissance information pertaining to regional distribution of uraniferous materials. Within this context, data interpretation has been oriented toward regional detection and description of anomalously high concentrations of uranium.

By far the most significant natural sources of gamma radiation in the geologic environment are the radioactive decay series of potassium 40 (K40), thorium 232 (Th232) and uranium 238 (U238) of which 0.7% is uranium 235. Potassium 40 is the largest contributor to natural radioactivity, accounting for nearly 98%, as it is the most abundant gamma ray emitter-.012% of all potassium in nature. (Refer to GSA Memoir 97 for abundances of uranium, thorium, and potassium).

Potassium 40 is directly identified by the airborne spectrometer from a single clear peak at 1.46 mev (million electron volts) in its gamma ray spectrum. However, thorium 232 and uranium 238 do not have any clear, distinct peaks at sufficiently high energies to allow direct detection from airborne systems. Instead, daughter products which do have distinct peaks are measured as representing the abundance of the parent element. For thorium 232, the daughter nuclide thallium 208 (T1208) has a distinct peak at 2.62 meV while uranium 238 has a daughter, bismuth 214 (Bi214) possessing a clear peak at 1.76 meV (see Figure 8 for a composite decay series spectrum). Consequently the fundamental assumption implicit to airborne uranium and thorium measurements is that the measured daughter products are in radioactive equilibrium - the number of atoms of disintegrating daughter nuclides are equal to the number being formed (see Adams and Gasparini, 1970).

An airborne gamma ray measurement is the sum of photons counted during a specified time interval from a multitude of gamma ray sources which include the three geologic emitters that are being sought plus other interfering sources. These others include, but are not limited to higher energy cosmic rays, aircraft and instruments, contributions from overlapping decay series and airborne radon 222. (See Burson, 1974 and McSharry, 1973 for a more complete discussion of airborne radiometric measurements, and Radiometric Data Reduction in this volume for a complete description of data correction procedures).

When correlating ground data (geochemical, geological, etc.) with the corrected data derived from raw airborne measurements, the interpreter must remember what an individual airborne gamma ray sample physically measures. First, the terrestrial component of the gamma radiation measured by the airborne detector emanated primarily from the upper 18 inches of material on the earth's surface (Gregory and Horwood, 1963). The airborne measurement cannot "see" any deeper into the underlying rock material and is essentially a measurement of the soil's or exposed (weathered) rock's radioactivity. Secondly, since each airborne sample is an accumulation of gamma rays measured on a moving platform over a fixed period of time, the individual sample represents a large areal extent of surficial material. For this survey, with specifications of 400 feet mean terrain clearance and an average ground speed of 70 to 135 miles per hour, a one second sample corresponds to an oval approximately 700 to 1200 feet long by 600 feet wide (assuming an infinite, uniformly distributed source). Accordingly, averaged samples represent tremendous volumes of surficial materials.

## METHODOLOGY

As described previously, the gamma ray data were located by computer map units, histograms were produced and statistical analyses performed. The basic unit for interpretation then is the averaged sample and its attendant deviations about a particular map unit's mean.

The uranium anomaly/interpretation map displays each individual averaged sample that meets the following criteria:

1. The averaged uranium sample must be greater than or equal to 1 standard deviation above its map unit mean.

2. The sample must have a U/T ratio greater than or equal to 1 standard deviation above its unit mean.

3. Each U/T ratio defined in (2) must have a corresponding thorium value lying at least greater than minus one (-1) standard deviation below the mean. If the thorium sample is less than one standard deviation below the mean, the U/T ratio is considered questionable.

All the possible anomalies displayed on the map are then examined for clusters, trends, and comparisons with all other available data.

Minimum requirements in the subsequent interpretation discussions of each quadrangle for anomalies listed in the uranium anomaly summary are defined as follows:

> Two (2) consecutive averaged U samples lying two or more standard deviations above the mean or three (3) consecutive averaged U samples, two of which are one (1) or more standard deviations and the third of which is two (2) or more standard deviations above the mean.

Statistical anomalies which meet the above criteria can result from several factors or circumstances including: (1) true concentration of uraniferous minerals, (2) differential surface cover (soils and/or vegetation) within a lithologic unit, (3) local weather conditions such as rain and snow, (4) extreme facies variation within a mapped unit, and (5) differential weathering of rocks within mapped units. Obviously an averaged sample which lies on the boundary between two map units is not truly reflecting either one, but is rather an average of both. Thus, for two markedly different units, such a sample would be anomalous relative to one of the units and not be a true indication of radioactive differences within the unit.

The potassium, thorium, uranium, and residual magnetic data were plotted as separate pseudo-contour maps and overlain on the geologic base map and standard deviation maps. Regional trends of each variable and average counting rates could thus be easily and quickly determined and compared with the associated geological, magnetic, and statistical trends. Only the long wavelengths within each variable would show any line-to-line continuity on the pseudo-contour maps and thus, only regional trends will appear.

Each quadrangle's stacked profiles were also overlain on the corresponding geologic and standard deviation maps and anomaly map to further delineate trends and to allow a more detailed analysis of individual anomalies. Since the interpretation was concentrated on detection of anomalous uranium, subtle trends present in the potassium and thorium channels and ratios were only examined in a cursory manner. Even during such a brief examination of the profiles, it was evident that the spectrometer system was highly sensitive to changes in surface materials, even in areas of low counting rates such as glacial drift. Thus radiometrics have a real potential for performing general surficial mapping "geochemical analysis" on a geologic unit (or soils) basis in addition to merely radioactive mineral "anomaly hunting".

Mean values of percent potassium (%K), equivalent uranium (eU), and equivalent thorium (eT) incorporated into the text are based on the radiometric system's sensitivity as defined by calibrations on the DoE's Lake Mead Dynamic Test Range. Normalized * equivalent sensitivities at 400 feet altitude are:

| Radioelement | Equivalent Percent / PPM | Counts/Second |
|---|---|---|
| K | 1% K | 90.3 |
| U | 1 ppm eU | 10.0 |
| T | 1 ppm eT | 6.4 |

(*See section on Aircraft Data Normalization)

# BIBLIOGRAPHY

# BIBLIOGRAPHY

Adams, J. A. S., and Gasparini, P., 1970, *Gamma-Ray Spectrometry of Rocks*; Elsevier Publishing Co.

Burson, Z. G., 1974, *Airborne Surveys of Terrestrial Gamma Radiation in Environmental Research*; IEEE Trans. Nucl. Sci., NS-21, No. 1, p. 558-571.

Butler, A. P., Jr., Finch, W. I., and Twenhofel, W. S., 1962, *Epigenetic Uranium Deposits in the United States*; U. S. Geol. Survey Mineral Resources Map MR-21 (with text), scale 1:3,000,000.

Clark, S. P. Jr., Peterman, Z. E., and Heier, K. S., 1966, *Abundances of Uranium, Thorium, and Potassium in Handbook of Physical Constants*; Geol. Soc. of Am. Memoirs, 97, p. 521-540.

Cohee, G. V., 1962, *Tectonic Map of the United States*; U.S. Geol. Survey and Amer. Assoc. of Pet. Geol., special map (12,500,000).

Currie, L. A., 1968, *Limits for Qualitative Detection and Quantitative Determination*; Analytical Chemistry, Vol. 40, No. 3, p. 586-593.

Grasty, R. L., *Uranium Measurement by Airborne Gamma-Ray Spectrometry*; Geophysics, Vol. 40, No. 3, June 1975, p. 503-519.

Gregory, A. F., and Horwood, J. L., 1963, *A Spectrometric Study of the Attenuation in Air of Gamma Rays from Mineral Resources*; U.S. Atomic Energy Commission Report CEX-60-3, Washington, D.C.

Mallory, W. W. ed., 1972, *Geologic Atlas of the Rocky Mountain Region*; Rocky Mountain Association of Geologists, Hirshfeld Press, Denver.

McSharry, P. J. and Emerson, D. W., *The Collection and Processing of Gamma Ray Spectrometer Data*; 2nd International Conference on Geophysics of the Earth and Oceans, Sydney, Australia, January 1973.

Robertson, J.M., 1976, *Mining Districts of Northeastern New Mexico*: in Guidebook of Vermejo Park Northeastern New Mexico, New Mexico Geological Society 27th Field Conference, p. 257-262.

# APPENDIX A

# TAPE FORMATS

# RATON AND SANTE FE QUADRANGLES

# NEW MEXICO

# Appendix A

## SINGLE RECORD REDUCED DATA TAPE

## REFERENCE: PARAGRAPHS 4.7.6 AND 6.1.6, BFEC 1200-C

The Single Record Tape is an unlabeled, nine track, 800 BPI, NRZI. All data are recorded as EBCDIC characters. Each tape contains but one file of format, header, data, and trailer records for no more than one quadrangle. The tape is divided into 8000 character blocks containing the following information.

### Block 1 - Format Data

This block contains 6768 characters in 94 consecutive lines of 72 characters containing the following literal description.

02 0978 (DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODES)

SINGLE RECORD REDUCED DATA TAPE

FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK)

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | A40 | Quadrangle Name as Project Identification |
| 2 | A20 | Name of Subcontractor |
| 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 to 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 (99999) |
| 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 |

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 13 | I3 | Number of Channels (0-3 MEV) in 4PI System For First Aerial System |
| 14 | I3 | Number of Channels (0-3 MEV) 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 |

FORMAT FOR SINGLE RECORD REDUCED DATA RECORD (THIRD THRU LAST BLOCK)

| 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 |

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 16 | F4.1 | Uncertainty in Terrestrial Thorium to One Decimal Place in PPM Equivalent TH |
| 17 | F6.1 | Uranium-To-Thorium Ratio to One Decimal Place in PPM Equivalent U Per PPM EQuivalent 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 |

This description serves to identify the format of data on subsequent blocks on the tape. The remaining 132 characters on this block are blanks.

### Block 2 - Tape Identification Data

The second block contains the identifiers for the data contained in subsequent blocks. The identification information is written according to the format description in the first half of the first block. The remaining 4978 characters on this block are blanks.

### Block 3 (And Subsequent Blocks) - Single Record Data

These blocks contain data written according to the format description in the second half of the first block. There will be 50 logical records per physical block. As of August 1979, the uncertainties specified in the data blocks are undefined, and are hardwired to contain the value 99.9.

### Trailer Block

A trailer block follows the last data record for each flight line. This record is always 8000 characters long, all of which are the digit nine.

## STATISTICAL ANALYSIS TAPE

REFERENCE: Paragraphs 4.7.7 and 6.1.6, BFEC 1200-C

The statistical analysis data tape is an unlabeled, nine track, 800 BPI, NZRI. All data is recorded as EBCDIC characters. The block length is 8000 characters long. Each tape contains one file of data for no more than on quadrangle.

### Block 1 - Format Description Data

The first physical block on this tape contains a format description for data on subsequent blocks. The first 7560 characters on this block contains 105 lines of 72 characters exactly as written below:

03 0978 (DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODES)

STATISTICAL ANALYSIS DATA TAPE

FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK)

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | A40 | Quadrangle Name as Project Identification |
| 2 | A20 | Name of Subcontractor |
| 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 |
| 8 | F6.1 | Nominal Altitude System Sensitivity Relative to 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 (99999) |
| 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 (0-3 MEV) in 4PI System For First Aerial System |
| 14 | I3 | Number of Channels (0-3 MEV) in 2PI System For First Aerial System |

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 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 |

## FORMAT FOR STATISTICAL ANALYSIS DATA RECORD (THIRD THRU LAST BLOCK)

| 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 | F5.1 | Potassium Standard Deviation From the Mean to One Decimal Place and Algebraically Signed |
| 14 | F6.1 | Averaged Concentration of Terrestrial Uranium (BI-214) to One Decimal Place in PPM Equivalent U |
| 15 | F4.1 | Uncertainty in Terrestrial Uranium to One Decimal Place in PPM Equivalent U |
| 16 | F5.1 | Uranium Standard Deviation From the Mean to One Decimal Place and Algebraically Signed |
| 17 | F6.1 | Averaged Concentration of Terrestrial Thorium (TL-208) to One Decimal Place in PPM Equivalent TH |
| 18 | F4.1 | Uncertainty in Terrestrial Thorium to One Decimal Place in PPM Equivalent TH |

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 19 | F5.1 | Thorium Standard Deviation From the Mean to One Decimal Place and Algebraically Signed. |
| 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 | Averaged Uranium-To-Thorium Ratio to One Decimal Place in PPM Equivalent U Per PPM Equivalent TH |
| 25 | F5.1 | Uranium-To-Thorium Ratio Standard Deviation From the Mean to One Decimal Place and Algebraically Signed |
| 26 | F6.1 | Averaged Uranium-To-Potassium Ratio to One Decimal Place in PPM Equivalent U Per Percent K |
| 27 | F5.1 | Thorium-To-Potassium Ratio Standard Deviation From the Mean to One Decimal Place and Algebracially Signed |
| 28 | F6.1 | Averaged Thorium-To-Potassium Ratio to One Decimal Place in PPM Equivalent TH Per Percent K |
| 29 | F5.1 | Thorium-To-Potassium Ratio Standard Deviation From the Mean to One Decimal Place and Algebraically Signed |

The remaining 440 characters in this block are blanks.

## Block 2 - Statistical Analysis Identification Data

The second block contains the identifiers information for the data contained in subsequent blocks according to the format specification in the first part of Block 1. The final 6078 characters on this block are blanks.

## Block 3 - Statistical Analysis Data

The third and subsequent blocks contain statistical analysis data in the format specified by the second part of the Block 1. Fifty logical records are allowed per block. The uncertainty values shown are, as of August 1979, undefined. They are hardwired to the number 99.9.

## Trailer Block

A trailer block follows the last data record for the summary geologic information and the averaged record data for each flight line. This record is always 8000 characters long, all of which are the digit nine.

## MAGNETIC DATA TAPE

REFERENCE: Paragraphs 4.7.8 and 6.1.6, BFEC 1200-C

The Magentic Data Tape is an unlabeled, nine track, 800 BPI, NRZI. All data are recorded as EBCDIC characters. Each tape contains data for no more than one quadrangle and are divided into 8000 character blocks as described below.

### Block 1 - Tape Format Description

The first block contains 3384 characters of format information in exactly the following format:

04 0978 (DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODES)

MAGNETIC DATA TAPE

FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK)

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | A40 | Quadrangle Name as Project Identification |
| 2 | A20 | Name of Subcontractor |
| 3 | I4 | Approximate Date of Survey (Month, Year) |
| 4 | I3 | Number of Flight Lines on This Tape |
| 5 | I4 | First Flight Line on This Tape |
| 6 | I6 | First Record Number of First Flight Line |
| 7 | I3 | Julian Date (Day of Year) First Flight-Line Data Was Collected |
| 8 | F8.4 | Latitude of Ground Base Station to Four Decimal Places in Degrees For First Flight Line |
| 9 | F8.4 | Longitude of Ground Base Station to Four Decimal Places in Degrees For First Flight line |
| 10-14 | (SAME) | Repeat of Items 5-9 For Second Flight Line on This Tape |
| * | * | * |
| * | * | * |
| * | * | * |
| 495-499 | (SAME) | Repeat of Items 5-9 For 99th Flight Line on This Tape |

FORMAT FOR MAGNETIC DATA RECORD (THIRD THRU LAST BLOCK)

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 1 | I1 | Aerial System Identification Code |
| 2 | I4 | Flight Line Number |
| 3 | I6 | Record Identification Number |

| ITEM | FORMAT | DESCRIPTION |
|---|---|---|
| 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 | F5.1 | Outside Air Pressure to One Decimal Place in MMHG |
| 9 | A8 | Surface Geologic Map Unit Code |
| 10 | F7.1 | Total Magnetic Field Intensity to One Decimal Place In Gammas |
| 11 | F7.1 | Residual (IGRF Removed) Magnetic Field Intensity to One Decimal Place in Gammas |
| 12 | F7.1 | Diurnal Magnetic Intensity Variation to One Decimal Place in Gammas |
| 13 | F7.1 | Magnetic Depth-To-Basement to One Decimal Place in Meters (if Required) |

The remaining 4616 characters in this block are blanks.

### Block 2 - Tape Identification Data

This block contains information about the data in subsequent blocks organized according to the format specification in the first half of Block 1.

### Block 3 - Magnetic Data

This block and subsequent block contains magnetic data for the quadrangle organized according to the format specifications in the second half of Block 1.

### Trailer Block

Trailer block follows the last data record for each flight line. This record is always 8000 characters long, all of which are the digit nine.

# RAW SPECTRAL DATA TAPE

## REFERENCE: PARAGRAPHS 4.7.1 AND 6.1.5, BFEC 1200-B

The RAW SPECTRAL DATA is unlabeled nine track, 800 BPI, NRZI. All data are recorded as EBCDIC characters. Each tape contains but one file of header, data, and trailer records for no more than one NTMS quadrangle. The maximum record length is 5472 characters.

The tape is organized such that each flight line of data is preceded by a header record and followed by trailer record. If a flight line is not complete on a given physical tape, no trailer record follows its last data record on the first tape, nor does a header record precede its first data record on the second tape.

### Header Record

The header record is 144 characters long with seven defined data fields. These fields are:

1. Type of tape. A 32-character field with the text "RAW SPECTRAL DATA" left justified.
2. Project identification. A 32-character field with, for example, the text "NTMS NL 16-1,2 RAWLINS" left justified. With the exception of special projects, such as the Walker Field Test Pads and Lake Mead Dynamic Test Range, all project identification fields begin with "NTMS" followed by the sheet number. Additional information may be abbreviated.
3. Subcontractor name. A 10-character field with the text "GEO-METRICS."
4. System identification. A 6-character field with the aircraft registration number right justified.
5. Flight line number. A 6-character field with the flight line number right justified.
6. Data flown. A 6-character field with the date, expressed as YYJJJ, right justified. YY are the last two digits of the calendar year and JJJ is the Julian date.
7. Sample period. A 6-character field describing the spectrometer accumulation time. Examples are: 1.0 SEC, 0.5 SEC, etc.

The remaining 46 characters of the header record are blank filled. A length of 144 characters was chosen to allow to future expansion and because 144 is divisible by the number of characters per word of many popular computers.

## Data Record

Each data record may contain up to four data scans (logical records), with each scan 1368 characters long. Therefore, the minimum physical length of a data record is 1368 characters and the maximum physical length is 5472 characters.

The data scan has fifteen defined data fields.

| | | | |
|---|---|---|---|
| 1. | Record identification | F10.2 | 1- 10 |
| 2. | Latitude in degrees | F10.4 | 11- 20 |
| 3. | Longitude in degrees | F10.4 | 21- 30 |
| 4. | Time of day (HHMMSS) | 312 | 31- 36 |
| 5. | Total magnetic field in gammas | F 9.2 | 37- 45 |
| 6. | Terrain clearance in feet | F 5.0 | 46- 50 |
| 7. | Barometric pressure in inches mercury | F 5.2 | 51- 55 |
| 8. | Outside temperature in degreec C | F 5.1 | 56- 60 |
| 9. | Quality flag code (altitude) | I 4 | 61- 64 |
| 10. | Raw count data - 4 detector | 255I3 | 65- 829 |
| 11. | Live time - 4 detector-in seconds | F10.5 | 830- 839 |
| 12. | Raw count date - 2 detector | 255I2 | 840-1349 |
| 13. | Live time - 2 detector-in seconds | F10.5 | 1350-1359 |
| 14. | Cosmic - 4 detector | I 5 | 1360-1364 |
| 15. | Cosmic - 2 detector | I 4 | 1365-1368 |

If a scan is not within the recovered path locations, the latitude and longitude, data fields 2 and 3, set to 0.0000.

The quality flag code, data field 9, is made equal to 0000 if the radar altimeter is within specifications and equal to 1000 if the radar altimeter is not within specifications.

The raw count data, fields 10 and 12, are presented for channels 0 through 254, corresponding to energies from 0 to 3 MeV for both the downward looking (4 ) and upward looking (2 ) detector arrays. The accumulation periods for the 4 and 2 detectors are identical, so each scan has data for both detectors. The counts in each channel are observed, with no corrections for ADC dead time nor conversion to counts per second. Energy per channel is 11.82 KeV. Since the spectrometer does not respond to energies below 200 KeV, the counts in channels 0 through 17 (varies with system) will always be zero.

The live times, data field 11 and 13, are calculated by subtracting the product of the gross counts (0 to 6 MeV) and ADC dead time (8 sec) from the actual accumulation period for the data scan. This procedure is valid because the successive approximation ADC used has a fixed conversion time of 8 sec regardless of pulse amplitude.

The cosmic counts, data fields 14 and 15, are observed with no corrections for ADC dead time nor conversion to counts per second.

The data scan logical record length of 1368 characters was chosen to allow recording of all spectrometer channels for both 4 and 2 detectors with little chance of individual channel overflow given accumulation times of approximately one second. If overflow does occur, the overflow value is represented modulo 1000 (4 detector) or modulo 100 (2 detector) with leading zeros not suppressed. The specific value of 1368 characters was chosen because it is divisible by the number of characters per word of many popular computers.

## Trailer Record

Trailer record follows the last data record for each flight line. This record is always 5472 characters long, all of which are the digit nine.

# APPENDIX B

# PRODUCTION SUMMARY

# RATON AND SANTA FE QUADRANGLES

# NEW MEXICO

## APPENDIX B

## DAILY PRODUCTION SUMMARY OCTOBER - NOVEMBER 1978

## LAMA I N47319

Raton and Santa Fe Quadrangles

| | |
|---|---|
| 10-18-78 | 375 miles Raton |
| 10-19-78 | 294 miles Raton |
| 10-20-78 | 450 miles Raton |
| 10-27-78 | 275 miles Raton |
| 10-29-78 | 380 miles Santa Fe |
| 10-30-78 | 321 miles Santa Fe |
| 11-01-78 | 378 miles Santa Fe |
| 11-03-89 | 276 miles Santa Fe |

Total Miles Flown For Above Period - 2749 miles

# APPENDIX B

## DAILY PRODUCTION SUMMARY - OCTOBER - NOVEMBER 1978

## S2F TRACKER N9AG

## RATON BASIN PROJECT

| | |
|---|---|
| 10-16-78 | 674 miles Santa Fe |
| 10-17-78 | 674 miles Raton and Santa Fe |
| 10-18-78 | 678 miles Santa Fe |
| 10-19-78 | 226 miles Santa Fe |

Total Miles Flow For Above Period - 2252 miles

# APPENDIX C

# MICROFICHE OF DATA

# RATON AND SANTA FE QUADRANGLES

# NEW MEXICO