MASTER

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AERIAL RADIOMETRIC AND MAGNETIC SURVEY

BOZEMAN NATIONAL TOPOGRAPHIC MAP

MONTANA

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE
GRAND JUNCTION, COLORADO
UNDER SMALL BUSINESS ADMINISTRATION SUBCONTRACT NO. 78-178-M

HIGH LIFE HELICOPTERS, INC.
PUYALLUP, WASHINGTON
AND
GEODATA INTERNATIONAL, INC.
DALLAS, TEXAS

Geodata International, Inc.

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE
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UNDER BENDIX FIELD ENGINEERING CORPORATION SUBCONTRACT NO. 78-178-M

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SECTION I.

INTRODUCTION

A. GENERAL

1. Area Surveyed

High Life Helicopters, Inc., Puyallup, Washington, conducted an airborne gamma ray and total magnetic field survey during the Period August 3, 1978 to August 18, 1978. The survey covered a region of the state of Montana identified as the Bozeman National Topographic Map NL12-8. The specific area of this report as outlined on Figure 1 was surveyed from a rotary-wing aircraft using large-volume radiation detectors with associated airborne electronic equipment. Each map line was flown in an east-west direction with an average length of 98 miles, and each tie line was flown in a north-south direction with an average length of 69 miles. Map lines and tie lines were surveyed as shown in Figure 2 using a Lama helicopter.

All data reduction and reporting for this survey was sub-contracted to Geodata International, Inc. of Dallas, Texas. This report is separated into two volumes. Volume I gives the description of the program and results, and Volume II presents the flight line profile data and statistical analysis results.

2. Summary of the Location, Geology and Physiography of the Bozeman Sheet

The Bozeman National Topographic Map Sheet area is bounded by the latitudes 45°00' and 46°00' north and 110°00' and 112°00' west. The area is within the Rocky Mountain physiographic region, and consists of a series of elongated ranges and broad intermontane valleys. The geology, as shown on the Geology of the Bozeman Quadrangle (Intrasearch, 1979), is both stratigraphically and structurally complex. Rock units range from Archean to Recent in age, with two major orogenic disturbances deforming the strata during the Late Cretaceous and Tertiary times. Marine transgressions and retreats occurred periodically during Precambrian, Paleozoic and Mesozoic eras, interrupted with times of terrestrial deposition and erosion. An early period of igneous intrusion and mountain building is recorded in the Precambrian record. The Late Cretaceous time saw the end of marine submergence of the area and the occurrence of volcanism which recurred at intervals during the Cenozoic. Uranium and thorium mineralization is reported within the map area associated with veins, pegmatites and placer deposits.

Fig. 1. Index Map Showing Area Surveyed

Fig. 2. NTMS Indicating Flight Line Location

B. OPERATIONAL PROGRAM

The airborne data gathered were reduced using ground-based computer facilities to give the basic uranium, thorium and potassium equivalent gamma radiation intensities, ratios of these intensities, aircraft altitude above the earth's surface, total gamma ray and earth's magnetic field intensity, correlated as a function of geologic units indicated from the developed geologic map. Results of analyses of these field data are presented as profile plots of the gamma radiation and earth's magnetic field. The surveyed area of Figure 1, which indicates latitude/longitude position, has been based according to the National Topographic Map Series (NTMS) which covers the United States with 1° latitude/ 2° longitude sheets. The topographic maps have a scale of approximately 1 inch = 4 miles. Each final base map is an overlay of the NTMS base map from which certain geographic data have been transposed, and includes the available geologic data. Each final anomaly map has the surveyed flight lines superpositioned with the standard deviations of each fifth data point relative to the average value within each geologic unit as determined for each NTMS map. These anomaly maps are identified as National Gamma Ray Map Series Maps (NGRMS).

Computer profile plots of the gamma radiation and magnetic field data have been created for all surveyed map lines and tie lines. Each line has indicated on the profiled line the location of each geologic type as a function of record number. The distribution of data within each geologic unit has been calculated and is included. The scale of the profile data in this final report is 1:500,000 and the scale of the NGRMS is both 1:250,000 and 1:500,000. The bound final report containing the 1:500,000 profile data also contains the flight line map, geologic base of the pertinent NTMS and the NGRMS maps indicating the standard deviations at the scale of 1:500,000. Two sets of profiled data for each line flown are included with one set displaying magnetic field, gamma radiation and other data. The second set includes only flight line magnetic field, temperature, pressure, and altitude data, plus magnetic field data as measured at a base station. Each set contains the flight line location relative to the geologic map. All data have been located giving latitude and longitude positions in fractional degrees as made possible from visual spotting, photographic recording of the aircraft location, and from VLF/OMEGA guidance of the aircraft and recording of location on magnetic tape. Data have been acquired and processed according to the data flow shown in Figure 3.

The magnetic data tapes containing (1) raw data, (2) the single record reduced data, (3) the statistical analysis data, and (4) the magnetic field data are converted to the EBCDIC format and retained for filing within the USDOE permanent data bank.

This final report includes a general geologic description of the area, including descriptions of the various geologic units and correlates the airborne data to the geologic units as provided by the geologic maps. Also included is a frequency distribution study of the data as a function of the geologic units encountered over the NTMS area including the tie line data.

This report also consists of a discussion of the area surveyed and includes all single record reduced data and averaged record data listings on MICROFICHE.

FIGURE 3. DATA FLOW DIAGRAM

SECTION II

THE GEODATA AIRBORNE SYSTEM

A. GENERAL

The Geodata Airborne System is mounted in an Aerospatiale Lama helicopter of the type shown in Figure 4. The functional block diagram is shown in Figure 5. Eight (8) 4" x 4" x 16" NaI(Tl) detectors are used to measure spectrally the surface-emitted gamma ray intensity at an aircraft elevation of about 400 feet above the earth's surface. Two (2) 4" x 4" x 10" NaI(Tl) detectors, which are largely shielded from the surface radiation, are used to measure the atmospheric ^{214}Bi radiation.

Two detector packages, each containing four of the eight 16" long detectors and each with 1,024 cu.in. of NaI(Tl), are used to measure gamma radiation from the surface. The total detector volume is 2,048 cu.in., and a $V/v > 20.0$ at an aircraft speed of 102.4 mph, (V = detector volume, in.³; v = aircraft speed, mph).

The system block diagram of Figure 5 shows the center of the system to be the Digital Equipment Corporation LSI-11 computer system. The 2,048 cu.in., 4π solid angle, detector data are accumulated for each one-second data integration period in a manner giving no readout dead time onto magnetic tape. A single magnetic tape is used to record total spectral data and all peripheral data. Analog presentation of the total gamma ray intensity, magnetic field and altitude data are plotted onto multi-track paper as data are gathered allowing immediate examination for data quality. A spectral presentation giving the sum of all one-second data sets is created by the ground-based computer for each flight line (EOFL) as quality control, Figure 6. Spectral data from the unshielded (4π) detector array are accumulated each 1.0 second, and spectral data from the shielded (2π) detector array are accumulated each 10.0 seconds. Data from the shielded detector are used to determine the concentration of atmospheric ^{214}Bi which allows calculation of the surface-emitted ^{214}Bi values before altitude corrections. All data are then corrected to a constant aircraft altitude above the surface of 400 feet. A highly accurate radar altimeter, the Collins ALT-50 system, makes a measurement during each second. Automatic digital gain calibration of the detector arrays is accomplished by stabilizing on the ^{208}Tl photopeak by placing the 2.615 MeV photopeak into channel 224.

A proton precession magnetometer, having a 0.25 gamma readout resolution and less than ± 2.0 gamma noise envelope, is also sampled once each second, giving a measurement of the total intensity of the earth's magnetic field. The sensor is carried as a "bird" on a 100-foot cable to minimize the magnetic effects of the helicopter. A permanent record of flight location is also made using 35mm film which records

Figure 4. Aerospatiale Lama Helicopter

Fig. 5. Functional Block Diagram

Figure 6. Typical End-of-Flight Line Spectral Plot

a continuous recoverable track with 20% frame overlap at an elevation of 400 feet. Position data from the Global Navigation encoding of latitude and longitude is placed onto magnetic tape each second. The record number-of-the-day along the flight line is displayed during flight and key aircraft positions are marked on the flight map with their appropriate record number.

The attenuation of gamma radiation is calculated using equations accounting for air density and uses experimentally determined values for linear attenuation coefficients. The energy region 3 MeV to 6 MeV is used to allow cosmic events to be removed from the data in the energy range 0-3 MeV. The average energy resolution of the 4π detector array related to the ^{137}Cs energy line at 662 keV did not exceed 10.9%, where the resolution for each detector was 9.5% or better.

The airborne equipment has three basic operating modes: (1) CALIBRATE, which allows proper gain calibrations of the radiation detectors to be set; (2) OPERATE, which allows data to be received, reduced and recorded, and (3) PLAYBACK, which allows the operator to examine the newly acquired data.

B. FLIGHT RECOVERY METHODS

Visually recorded data and photographically recorded data have been used to locate the flight line position. The Global Navigation GNS-500A is used to maintain the aircraft on flight line with the latitude and longitude data being recorded on magnetic tape to assist in flight line location. These lines have been positioned by many locations as a function of record numbers. These data are computer plotted giving the flight path as a line of dots, each "dot" representing every fifth record location, and each "circle" representing every 50th record location. Figure 7 indicates the computer plot of a typical map line. These data are then transferred to form the flight line base shown in Figure 2. Location points used to position the flight line at least every 10 miles are shown on the flight line map as an "X".

C. DATA REDUCTION

The processing flow chart representative of the work performed for this survey is shown in Figure 3. The original field data tapes contain the various tag words, 4π spectrum and 2π spectral data for each one second along the flight line. The REFORM program sums the proper energy intervals of the spectra for each second and produces a trailer record for each line which contains the accumulated 4π and 2π spectra for the line. The CDTCRT is a data certification program which is run immediately upon receipt of the field data tapes and produces the EOFL spectral plots, Figure 6. The program identification and function are given as:

PROGRAM

FUNCTION

REFORM
FIXMOD

Produce energy group sums and EOFL spectra.
Primary processing for matrix reduction, BIAIR
computation, live times, background and altitude
correction.

Figure 7. Computer presentation of Typical Map Line

Figure 8. Typical Map Line Showing Statistical Deviations

STACK	Flight path recovery to produce plots of actual paths at a scale of 1:250,000.
DOPTAP	Single record processing with latitude/longitude, IGRF and single point statistical adequacy computation. Produces microfiche.
MMPLT	Averaged record processing with averaged statistical adequacy computation. Produces radiometric stacked profiles plot tapes.
GNDMRG	Merges aircraft magnetometer and ground magnetometer in proper time sequence and transfers temperature, pressure and altitude information.
RMPLT	Produces tapes for magnetometer stacked profile plots.
GEOLOG	Produces averaged value microfiche with geology and plot tape for standard deviation "dot plots" related to geologic type.
HISTO, MERGE	Programs preliminary to obtaining the histograms as a function of geologic type for the entire area.
DMPLT	Produces plot tape for the area histograms.

As stated in the above list of program functions, the FIXMOD program performs the primary processes for determining the reported eTh, eU and K counting rate associated with the earth's surface as corrected to 400 feet above the surface. For this reason, the analytical work of this program is described in more detail below.

Each one second of 4π spectral data is summed by the REFORM program according to the following energy intervals:

Cosmic:	3.0	to	6.0 MeV
^{208}Tl photopeak	2.410	to	2.796 MeV
^{214}Bi photopeak	1.660	to	1.860 MeV
^{40}K photopeak	1.357	to	1.556 MeV

In general, these raw sums contain counts not only from ground sources, but also from aircraft background and atmospheric radioactivity. To determine the counts in the energy intervals which are caused only by the isotope associated with the interval, a 4×4 matrix method is used. This matrix may be formed through the use of a standard cosmic spectrum, plus the Walker Field Pad determinations of α , β , γ , and f, or from four standard spectra representing respectively cosmic, thorium, uranium, and potassium pure spectra at a 400 foot altitude.

This matrix multiplication is represented by:

$$\begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} \\ A_{21} & A_{22} & A_{23} & A_{24} \\ A_{31} & A_{32} & A_{33} & A_{34} \\ A_{41} & A_{42} & A_{43} & A_{44} \end{bmatrix} \cdot \begin{bmatrix} \text{COS} \\ \text{TL} \\ \text{BI} \\ \text{K} \end{bmatrix} = \begin{bmatrix} \text{MCOS} \\ \text{MTL} \\ \text{MBI} \\ \text{MK} \end{bmatrix}$$

where the A_{ij} are the elements of the 4 x 4 matrix; the column matrix on the left represents the four raw data sums and the column matrix on the right is the counts in each energy interval caused only by the indicated isotope. The total count (TC) from 0.4 to 3.0 MeV does not require matrix multiplication. These matrix results counts are for the measured live time. To obtain the counts per second, it is necessary to divide by the live time, LTC1, thus:

$$\begin{aligned} \text{MCOS/LTC1} &= \text{COS1} \\ \text{MTL/LTC1} &= \text{TL1} \\ \text{MBI/LTC1} &= \text{BI1} \\ \text{MK/LTC1} &= \text{K1} \\ \text{TC/LTC1} &= \text{TC1} \end{aligned}$$

The TL1, BI1, K1, and TX1 counts per second contain the aircraft associated backgrounds caused by thorium, uranium and ^4OK . Geodata has determined these backgrounds for the Lama N49537 installation to be 4.26 counts per second in the ^{208}Tl energy interval due to background ^{208}Tl , 6.29 counts per second in the ^{214}Bi energy interval due to background ^{214}Bi , 4.28 counts per second in the ^4OK interval due to background ^4OK , and 147.4 counts per second in the range of .4 MeV to 3.0 MeV. For this work, the background counting rates were determined by high altitude flights free from atmospheric ^{214}Bi . The backgrounds are checked during the survey by observing counting rates over large water bodies under the flight path.

The backgrounds are subtracted from the above determined count rate values

$$\overline{\text{TL1}} = \text{TL1} - 4.26$$

$$\overline{\text{BI1}} = \text{BI1} - 6.29$$

$$\overline{\text{K1}} = \text{K1} - 4.28$$

$$\overline{\text{TC}} = \text{TC1} - 147.4$$

The $\overline{\text{BI1}}$ and $\overline{\text{TC}}$ values contain counts caused by atmospheric ^{214}Bi which must be subtracted before altitude correction is applied. The 2π crystal data are used to determine the magnitude of the count to be subtracted. Since the predominant variable source affecting the 2π crystal is the atmospheric ^{214}Bi , it is possible to utilize most of the spectrum in the BIAIR determination and thereby produce some improvement in the statistical error. The energy range used for the 2π crystal is from 1.05 to 2.79 MeV. Within this range, the aircraft background has been determined as 8.51 counts per second, and the 4π cosmic count greater than 3.0 MeV must be multiplied by .445 to determine the 2π cosmic count in the 1.05 to 2.79 MeV range.

The atmospheric ^{214}Bi (BIAIR) associated with the unshielded detector array is determined using the shielded detector by the relation:

$$\text{BIAIR} = \frac{G(X) \cdot \text{VA} - .445\text{COS1} - 8.51 - (k_1\overline{\text{TL1}} + k_2\overline{\text{BI1}} + k_3\overline{\text{K1}})}{1 - k_2G(X)}$$

where: $G(X)$ is the relationship between the 4π and 2π detector measurement solid angle and the volume change of the detector arrays.

VA is the total count, 2π , ch (91-239), c/s; COS1 is the 4π cosmic count 3.0-6.0 MeV, c/s; k_1 , k_2 , k_3 are constant correction factors for the penetration/spill of the surface-emanated radiation, and are respectively .181, .048, .039.

$\overline{TLI}$, $\overline{BII}$, $\overline{KI}$ are results of data reduction, 4π , c/s

The final ^{214}Bi and total count counting rates caused by surface sources are then

$$\text{BISUR} = \overline{BII} - \text{BIAIR}$$

$$\text{TCSUR} = \overline{TC} - 17.0 \text{ BIAIR}$$

where: 17.0 is the ratio using Bi spectral data of the count rate in the .4 to 3.0 MeV range to the count rate in the 1.66 to 1.86 MeV range.

The quantities $\overline{TLI}$, BISUR , $\overline{KI}$, and TCSUR are then corrected to an equivalent counting rate at 400 feet through the equations indicated below:

$$\text{TLS} = \overline{TLI} \cdot e^{-\mu_1 \left(400 - \frac{\rho}{\rho_0} x \right)}$$

$$\text{BIS} = \text{BISUR} \cdot e^{-\mu_2 \left(400 - \frac{\rho}{\rho_0} x \right)}$$

$$\text{KS} = \overline{KI} \cdot e^{-\mu_3 \left(400 - \frac{\rho}{\rho_0} x \right)}$$

$$\text{TCS} = \text{TCSUR} \cdot e^{-\mu_4 \left(400 - \frac{\rho}{\rho_0} x \right)}$$

where: TLS, BIS, KS, TCS = respective counting rates at 400 feet by surface sources

ρ = air density

ρ_0 = .001293 gm/cc, air density

$\mu_1, \mu_2, \mu_3, \mu_4$ = respective linear attenuation coefficients

x = aircraft height above the surface in feet

Following data reduction, average values for each radiation variable and variable ratio are plotted for each flight line to demonstrate the consistency of average values and that a smooth flow of results continue from day to day and from start to finish of each day. Quality control on the eU (BIAIR) in the atmosphere is also monitored through examination of data acquired over water with the requirement being that near-zero intensities for BIS should exist.

Magnetic field data are determined at the crossings of the tie line and map line data, and the corrections for the diurnal variations are determined. Any heading errors have previously been removed from all data. The magnetic field data are then IGRF corrected to give the residual magnetic field.

D. DATA PRESENTATION

The surveyed area was positioned geographically to completely cover the specific National Topographic Map. The topographic map has been used as the flight base and sufficient geographical and 15' location information have been shown. The flight line pattern has been super-positioned onto these created base maps where the standard deviation levels for each independent variable and each ratio of these variables have been plotted (NGRMS) based on the data contained within the total map area. Every fifth data point along each map line has its standard deviation value shown at the location of that value. Therefore, there are six NGRMS sheets which indicate the location and magnitude of anomalous data, Volume II.

The radiometric multi-variable map line profile, which represents all variables as a function of their latitude or longitude location, depending on line direction, for each line, is presented at a scale of 1:500,000. Each profile presents:

1. Aircraft altitude above the surface
2. eTh (^{208}Tl from ^{232}Th decay series)
3. eU (^{214}Bi from ^{238}U decay series)
4. K (^{40}K from natural potassium)
5. BiAir (atmospheric ^{214}Bi)
6. Residual magnetic field
7. Gross count (greater than 400 keV)
8. eU/cTh ($^{214}\text{Bi}/^{208}\text{Tl}$) ratio
9. eU/K ($^{214}\text{Bi}/^{40}\text{K}$) ratio
10. eTh/K ($^{208}\text{Tl}/^{40}\text{K}$) ratio
11. Geologic data including aircraft flight path

The magnetic multi-variable map line profile, which represents five variables as a function of their latitude or longitude location, depending on line direction, for each line, plus geologic data at a scale of 1:500,000, is presented as:

1. Aircraft altitude
2. Atmospheric temperature
3. Atmospheric pressure
4. Magnetic field base line station data
5. Residual magnetic field data
6. Geological data including aircraft flight path

The output of these various computations supplies, beyond the two profile sets, the following data:

- * Histograms of the radiation data distribution within each geologic unit.
- * Histograms of the average velocity distribution for each one-second record for each map and tie line.
- * Histograms of the average altitude distribution for each one-second record for each map and tie line.

- * Tables giving the average radiation concentration of each geologic unit for each flight line.
- * Set of maps showing the standard deviation data as a function of location and radiation variable.

These types of presentation will be explained in this report.

SECTION III

GEOLOGY OF THE SURVEYED AREA

A. LOCATION AND GENERAL PHYSIOGRAPHY

The radiometric and magnetic survey was conducted over an area in southcentral Montana. The Bozeman National Topographic Map Sheet (N.T.M.S., 1958) is bounded by the latitudes 45°00' and 46°00' north and 110°00' and 112°00' west. Included within the map area are the counties of Broadwater, Gallatin, Jefferson, Madison, Park, Stillwater and Sweetgrass.

Montana may be divided into three physiographic regions (Perry, 1962). The western division consists of high, rugged mountain ranges with broad, fertile valleys; the eastern section consists of rolling, grass-covered plains, trenched by major rivers; the central region is mainly plains, but in places, isolated mountains rise several thousand feet above the plains. The Bozeman National Topographic Map Sheet area is located in the southernmost part of the western division. The western mountains, known collectively as the Rocky Mountains, are in reality a series of 40 or more individual ranges. Within the Bozeman Map Sheet area, the major ranges or mountains are from west to east: the Greenhorn Range, the Gravelly Range, the Tobacco Root Mountains, the Madison Range, the Gallatin Range, the Bridger Range, the Snow Mountains, the Crazy Mountains, and the Absaroka Range. The Absaroka Range in the southeastern corner of the map sheet has several plateaux, termed the Buffalo Plateau, the Lake Plateau and the East and West Boulder plateaux. Many of the ranges rise a mile or more above the valleys to elevations in excess of 9,000 feet. Most ranges lie subparallel, trending in a northnorthwesterly direction. The ranges can be as much as 20 miles wide, and more than 50 miles long (Perry, 1962). Between each range is an intermontane valley; generally, these are 5 to 20 miles wide and 25 to 75 miles long. The Gallatin and Bridger ranges form a major drainage divide between the Yellowstone River System, in the eastern part of the map sheet area, and the Gallatin-Madison-Missouri River System, which drains the western half of the area. Both major drainage systems flow to the north or north-northeast. Many small tributary rivers have headwaters in the summit areas of the local ranges. The width of the major river valleys varies considerably from one location to another; in some places, the rivers flow through narrow gorges, in others, they have a braided pattern over wide valley floors. Evidence for mountain and valley glaciation is common, with cirques, U-shaped valleys, morainal ridges and other glacial geomorphological features. Ennis Lake in the central Madison River Valley is the only large water body, man-made or otherwise, to occur in the area.

B. GEOLOGY

Precambrian

Precambrian rocks crop-out in the Tobacco Root Mountains, the Gravelly Range and the London Hills in the western part of the area; in

the Madison Range and northward in the central part of the map sheet area; and in the Absaroka Range and Snow Mountains in the east. The oldest of the Precambrian rocks belong to a complex of metamorphosed sediments, which have been altered into gneiss, schist, quartzite and marble. In the Tobacco Root Mountains and in the Gravelly Range, uplift of four miles, or more, and removal of younger strata has exposed hundreds of square miles of the "Basal Complex". The "Basal Complex" has been divided into the Pony Series, essentially gneiss, and the Cherry Creek Series, which contains marble (Perry, 1962). It is possible, however, that the Pony and Cherry Creek series may be one immense series of metamorphic rocks, which vary greatly between distant exposures. The easternmost limit of exposed Cherry Creek Marble is in the western foothills of the Bridger Range (Perry, 1962). In their type locality, the Cherry Creek rocks are estimated to have a total thickness of 9,000 feet. The marble units form the thickest and most persistent layers. A layer of schistose rock with up to 50 percent magnetite can be traced in the Gravelly Range. Gneisses and schists of many different types are the most abundant lithologies of the series. The Cherry Series may be divided into a lower section of dominantly feldspar gneiss, a middle part of dominantly schist, with some quartzite, and an upper part containing marble, along with other metamorphics. The Pony Series in its type locality is mainly gneisses, with mica schist and thin quartzite layers.

Precambrian intrusions of igneous rock happened before or during the time of Early Precambrian mountain building. Commonly the igneous rocks have been converted to gneiss and schist. Many of the early igneous rocks were granitic. Other non-granitic types occurred; e.g., the chromium-bearing norite in the Absaroka Range.

Above the "Basal Complex", in the study area, is a considerable thickness of water-formed sediments known as the Belt Series. These rocks are mainly quartzite and argillite with impure limestones. The Belt Series, which is Late Precambrian in age (600 million years), is some one or two miles thick. It was originally composed of sands and clays deposited in a Precambrian sea, which extended westward across Montana. Most of the sediments were shallow water deposits, as indicated by mud-cracks, ripple-marks, cross-bedding and casts of salt crystals (Perry, 1962).

Paleozoic

During the latest Precambrian and Lower Cambrian times, erosional bevelling of the Precambrian rocks occurred. In the Middle Cambrian time, shallow seas spread eastward over the Precambrian basement. The Cambrian System is comprised of a thickness of Middle and Late Cambrian strata, which is greater than 2,000 feet. The system consists of an alternating sequence of shale and limestone, with a transgressive quartzite at the base (Hanson, 1957).

The basal formation is the Flathead Quartzite, which rests unconformably upon the Precambrian strata. It varies in thickness from a feather-edge to over 300 feet, and is mainly composed of quartz sand, but may contain hematite and glauconite in its upper part. The Flathead Quartzite is intergradational with the Wolsey Shale (Hanson, 1957).

The Wolsey Shale is green-gray to purple-gray, fissile and micaceous shale. Thin layers of glauconitic and argillaceous sandstone and siltstone occur in its lower section. The unit ranges from 70 to over 400 feet thick, and is intergradational with the superimposed Meagher Limestone (Hanson, 1957).

The Meagher Limestone is a carbonate unit which thins eastward. The limestone is micro-grained and becomes increasingly distinctly bedded eastward. Thin limestone conglomerate beds are present and glauconite is a common constituent of the fragmental and oolitic limestones (Hanson, 1957).

The Park Shale is lithologically similar to the Wolsey. Generally, it has less sandstone and locally contains limestone conglomerate beds. It varies from 50 to 500 feet thick. Overlying the Park Shale is the Pilgrim Limestone which thins eastward and undergoes a facies change from dolomite through massive limestone to thin-bedded, shaly limestone and limestone conglomerate (Hanson, 1957).

The Snowy Range Formation consists of interbedded shales and limestones. The formation has a high amount of shale and limestone conglomerates and has beds of columnar limestone. The Grove Creek Formation overlies the Snowy Range in the map area. It is the uppermost unit of the Cambrian System. A Lower Ordovician fauna has been located in the uppermost part of the Grove Creek, in the northern Bighorn Mountains to the east of the map area (Shaw, 1954, p.33). The Grove Creek is mainly limestone.

At the close of the Cambrian Period, the seas withdrew and much, if not all, of the map area became a low-lying terrestrial surface; an environment which persisted into Ordovician times. The seas returned in the Middle Ordovician, approaching from the east and northeast rather than from the west as did the Cambrian seas. In western Montana, limy sediments were deposited known as the Bighorn Dolomite. Maximum thickness of the Bighorn is to the east of the map area, and it thins westward; the thinning is due, in part, to erosion which took place prior to the deposition of the Devonian rocks. The dolomite is divided into two main units. The basal three quarters of the lower unit is a massive dolomite; the upper quarter is a thin-bedded dolomite. The upper unit is a repetition, or series of repetitions, of the lower unit. At the base of the upper unit, a brecciated dolomite, argillaceous and cherty, is exposed (Richards and Nieschmidt, 1957).

The lower part of the Bighorn Formation is either Middle or Upper Ordovician; whereas, the upper part is Upper Ordovician. An unconformity exists where it is overlain by Devonian strata. All of western and central Montana was a land surface during the Silurian and the early part of the Devonian periods. In Middle Devonian time, the area was once more submerged. Approximately, a thousand feet of strata, first limestone and dolomite, then marine evaporites, and finally shales were deposited (Perry, 1962). The Devonian strata of the area consists of the Three Forks Formation resting conformably on the Jefferson Formation, which is gradational downward with the Maywood Formation. The

Three Forks is a shale, with minor beds of sandstone, limestone and dolomite. The Jefferson consists of dark-colored carbonates varying from massive to thin-bedded. It is mainly limestone in the basal half, and dolomite in the upper half. The basal formation is the Maywood, consisting of poorly exposed yellow, orange and red calcareous clastics, which grade into, and are locally interbedded with, light-colored limestone (Robinson and Barnett, 1963, p.24). The unit's contacts with the underlying strata are erosional unconformities; whereas, the contacts with the superimposed Jefferson appear to be conformable.

The Mississippian Period began with the Bozeman Map Sheet area submerged beneath marine water. A thousand feet of limestone, of the Madison Group, were deposited (Perry, 1962). In the latter part of the Mississippian Period, the Madison Sea was restricted and a long tongue of marine water extended east-west across Montana. Into this tongue-shaped gulf were deposited shales and sediments of the Big Snowy Group.

The Madison Group is divisible into two formations. In ascending order, these are the Lodgepole and Mission Canyon formations. The Lodgepole Formation is a gray limestone and dolomite with a basal unit of chert. The Mission Canyon includes all of the Madison-carbonates overlying the Lodgepole Formation: it is progressively more dolomitized toward the east.

The overlying Big Snowy Group consists of shale, shaly limestone and cherty limestone, a sandstone unit which includes sandy siltstones, calcarenites, sandy dolomite and red siltstones. A basal unit contains dolomitic siltstone, calcareous sandstone, dolomite and brecciated dolomite and limestone. The clastic rocks of the Big Snowy Formation are mostly near-shore marine deposits; possible exceptions are the basal siltstones which could be floodplain deposits (Robinson and Barnett, 1963, p. 47).

Overlying the Big Snowy Group is the Amsden Formation. It is some 150-200 feet thick and consists of cherty carbonates underlain by red shales, siltstones and sandstones. The Amsden is mainly a transgressive, shallow water, marine formation; many of the clastics were derived from erosion of local carboniferous rocks (Robinson and Barnett, 1963, p. 49). The sea of Amsden time persisted on into the beginning of the Pennsylvanian Period, when the Quadrant Formation was deposited.

The Triassic-Permian-Pennsylvanian sequence of the northern Rockies disconformably overlies the Mississippian marine strata. In turn, it is disconformably overlain by the Jurassic sediments (Munyan, 1957). Sloss (1950) has termed the Triassic-Permian-Pennsylvanian sequence the Absaroka Depositional Cycle. There are no regional unconformities, nor major interruptions of tectonic behavior recorded above the Amsden or below the pre-Middle Jurassic unconformity.

In Pennsylvanian time, there was a widespread influx of clean, light-colored sand which formed the Quadrant Formation of southwestern Montana. The cementation of the Quadrant is largely from quartz overgrowths; however, a little carbonatic cement is present in nearly every stratum.

In some strata, carbonate is the principle cement (Robinson and Barnett, 1963, p. 50). Thickness of the unit ranges from 200 to 400 feet, and increases westward where limestone beds appear within it.

Permian seas existed throughout southern Montana and in these seas limestone, shale and sandstone accumulated. In southwestern Montana, the seas contained an abundance of lime phosphate in solution. The occasional precipitation of the lime phosphate resulted in two to six foot beds of natural rock phosphate interlayered with sandstone and shale of the Phosphoria Formation. Thick beds of oil shale are also present in southwestern Montana. The Permian Phosphoria Formation grades upward into the Triassic strata of the Dinwoody Shale.

Mesozoic

Triassic time saw most of the map area, and the rest of Montana, as a land area undergoing erosion. In the southern part of the state, desert conditions existed. Brilliant red sandstone and gypsum-bearing rocks of the Chugwater Formation were deposited (Perry, 1962).

A marine sea invasion covered most of Montana during Middle Jurassic time. Into the sea, sandy, shaly and limestone sediments of the Ellis Group were deposited. To the east of the map area, the lowest unit of the Ellis, the Piper Formation, ranges in thickness from 115 to 190 feet (Imlay, 1954). The Piper is divisible into a lower red-bed and gypsum member, a middle limestone member, and an upper red-bed member. The contact of the Piper with the overlying Rierdan Formation is sharp, and is marked by an abrupt change in claystone characteristics. The Rierdan varies in thickness from 115 to 170 feet, to the east of the map area (Imlay, 1954), where it consists of three members: the Canyon Springs Sandstone, the Stockade Beaver Shale, and the Hulett Sandstone. The contact of the Rierdan with the younger Swift Formation is sharp, and marked by a change from oolitic sandstone or limestone to greenish-gray glauconitic siltstone and claystone. The contact between the Rierdan and the Swift formations is interpreted as a disconformity. The Swift is comprised of two units, which grade vertically and laterally into each other. The lower member is claystone, with interbedded silty to sandy greenish-gray layers. The upper member consists of a glauconitic sandstone, which thins eastward.

Before Jurassic-time ended, marine waters receded from Montana; however, beds of sand and mud continued to be laid down by rivers flowing across a broad coastal plain. These fluvial deposits are known as the Morrison Formation. The contact of the Swift Formation with the overlying Morrison is marked by an abrupt change from compact fossiliferous, sandy limestone, or glauconitic sandstone, to a soft, reddish or greenish-gray, silty claystone with interbeds of sandstone and silty limestone. The Morrison Formation, of Late Jurassic-age, is composed of 50 to 300 feet of extremely variegated shale and siltstone, thin nodular limestone, white and brown sandstone, black shale with a bed of coal, or carbonaceous shale near the top.

Jurassic time merged with Early Cretaceous time without any major environmental changes. A slow buildup of terrestrial deposits continued. Near the beginning of the Cretaceous, a layer of sand with black flint fragments was deposited. The deposition of several hundred feet of the Kootenai Formation followed. A basal sandstone, known as the Lakota Sand, is recorded. The Kootenai Formation averages several hundred feet of red shale and brown to gray sandstone. In the latest Kootenai time, a large freshwater lake existed, limy muds and limestone being deposited in this lake (Perry, 1962).

The final marine invasion of the Montana area began during Late Cretaceous time. An inland sea, which extended from the Gulf of Mexico to the Arctic Ocean covered the area. The Late Cretaceous marine shoreline migrated eastward and westward across the Montana area. Major transgressions occurred during Colorado, Claggett and Bearpaw time (Perry, 1962). In the first and greatest marine transgression, some 2,000 feet of muds and local sands accumulated. They are known as the Colorado Group, and are remarkable for their uniform characteristics over extensive areas. The Group is comprised of the Thermopolis Shale, the Mowry Shale, the Frontier Formation, a sandy shale with local benthic layers, and the Cody Shale.

The Telegraph Creek Formation, of Late Cretaceous age, is composed of 160 feet of dark-gray to dark-brown shale and sandy shale beds. The formation is transitional between the underlying marine sediments of the Colorado Group and the overlying Virgelle Sandstone and Eagle Sandstone.

The Virgelle Sandstone, Eagle Sandstone and Miner Creek Formation, formed when the sea had receded from the map area; whereas, the Cokedale Formation and the Billman Creek Formation formed during subsequent advances of the Upper Cretaceous seas.

The Eagle Sandstone is composed of some 250 feet of massive, friable, brown and white sandstone beds. The Cokedale Formation consists of andesitic siltstone and sandstone, claystone, tuff, bentonite and coal; the Cokedale Formation is roughly the equivalent of the Claggett Shale, which is mapped in the Beartooth Mountain area; the Claggett Shale consists principally of gray and brown shale. The Cokedale is overlain by the sandstone and shale of the transitional Everts Formation. The Miner Creek Formation is composed of andesitic siltstone and sandstone, tuff and bentonite. The Miner Creek Formation is roughly equivalent to the Judith River Formation of the Beartooth Mountains. The Judith River consists of lenticular, soft, friable, gray sandstone and shale beds; some lignite beds occur within the Judith River Formation. The Billman Creek Formation consists of gray claystone with interbedded sandstone, siltstone and conglomerate. It is roughly the equivalent of the Bearpaw Formation of the Beartooth Mountains. The Bearpaw is mainly shale formed during the final transgression of the Late Cretaceous seas.

The final episode of the Late Cretaceous was the deposition of the Hell Creek Formation. The Hell Creek is some 700 feet thick, and consists of terrestrial sediments deposited after the final retreat of the Cretaceous seas. The sediments, gray sandstone, greenish shale and mudstone, with local coal and lignite, were formed on a coastal plain

from sediments derived from the rising Rocky Mountains.

Near the end of the Cretaceous in western Montana, a series of large volcanoes came into existence. In places, the flows piled up to a thickness of 4,000 to 5,000 feet (Perry, 1962). The beds of lava lie almost parallel to, and above, the strata of the Colorado Group and Eagle Sandstone. The outflow of lavas was part of the intense mountain-making deformation of the Laramide Orogeny. It is probable that flows from neighboring volcanoes merged forming a more or less continuous sheet of volcanic material (Perry, 1962). Many of the dikes and sills are the residual feeders of volcanoes long since eroded and washed away. The chemical and mineralogical composition of the Cretaceous lavas is different from the igneous material of later ages. The lithologies are those of andesite and basalt; generally, dark reddish-brown, but in places, they may be gray to black (Perry, 1962). The Elkhorn Mountains Volcanics are mapped in the northwestern corner of the Three Forks Quadrangle (Robinson and Barnett, 1963), and in the vicinity of the Jefferson Canyon Thrust. The total thickness of the Elkhorn Mountains Volcanics is several thousand feet in this area. They are mainly porphyritic andesite flows with rare latite layers. In the northwest, the volcanics include breccia in units as much as 500 feet thick (Robinson and Barnett, 1963). Debris from these flows were transported eastward toward the Cretaceous seas, or were deposited into the Cretaceous seas. Sediments composed of lava boulders and cobbles, sands and muds formed the Livingston Formation, which is mapped to the east of the surveyed area.

Cenozoic

Succeeding the development of the Cretaceous volcanoes, the Rocky Mountains were formed by folding and faulting of the existing strata and Cretaceous lavas (Perry, 1962). In Late Cretaceous and Early Tertiary times, compressive forces deformed the area of western Montana. The strata were bent into huge folds. In places, horizontal strata were forced into vertical positions. In other places, shales were crumpled. Many of the folds are 50 to 100 miles long, and 10 to 25 miles wide. Large pieces of the earth's crust broke and moved along slipping planes. Some plates were thrust upward and over younger rocks. The compressive forces appear to have been from the southwest with the strata deforming and breaking in a northwesterly direction. A major exception to this trend occurs in the vicinity of the Tobacco Root Mountains, where the trend-line for the major folds is radial. Igneous activity during the Laramide Orogeny is believed to have been minimal. After the large mountain-building folds developed, deep-seated igneous activity occurred. A major batholith is exposed in the Tobacco Root Mountains, where it overlies a major anticlinal structure. Nearly all the intrusions were granitic (Perry, 1962), and formed during the early part of the Tertiary. A few small intrusions of non-granitic composition developed. In many places, peripheral to the batholiths, the aureole rock was subjected to contact metamorphism. Mineral veins, with the more soluble constituents, were squeezed through the solidifying rock, and are numerous in western Montana.

The Paleocene encompassed the erosion of the first Rocky Mountains. The debris was transported eastward to form the terrestrial deposits of the Fort Union Formation. The Fort Union-Hell Creek contact

is based on a color change from the light-greenish cast of the underlying Cretaceous formation to the black, impure coal beds of the Tulloch Member of the Fort Union (Schulte, 1962). The Fort Union is comprised of three members; the Tulloch, the Lebo and the Tongue River. The Paleocene sediments were deposited in intermontane basins, at the base of low mountains. Nine thousand feet of the Fort Union sediments were laid down in the Bighorn Basin to the east of the map area. The sediments include clay, shale, siltstone and sandstone, with local lignite beds.

The Early Tertiary erosion exposed the batholiths in western Montana. Renewed igneous activity occurred. Rhyolitic and dacitic lavas poured from vents and covered large areas. Many Mid-Tertiary dikes developed. Part of the volcanism occurred before and during the development of large Tertiary lakes. Volcanic dust and ash is found interbedded with the lacustrine sediments.

The Tertiary rocks of the northwestern part of the area were designated the Bozeman Lake Beds by Peale (1893; 1896). These rocks have since been subdivided into three gradational map units (Robinson and Barnett, 1963, p. 61). They are, in ascending order, the Milligan Creek Formation, the Climbing Arrow Formation and the Dunbar Creek Formation. They are sometimes referred to as the Bozeman Group. A basal limestone conglomerate, included within the Bozeman Group, is known as the Sphinx Conglomerate. The Bozeman Group overlies an erosional surface formed during, or soon after, the Laramide Orogeny. The youngest rocks which they overlie are the Elkhorn Mountains Volcanics. Superimposed on the Bozeman Group are Upper Tertiary gravels, which unconformably overlie the Climbing Arrow Formation (Robinson and Barnett, 1963).

The Sphinx Conglomerate is a limestone conglomerate with a reddish-orange calcareous matrix. The conglomerate may have formed an extensive apron at the base of the Laramide Mountains.

The Milligan Creek Formation consists of limestone and marlstone beds, alternating with limestone beds, and has a thickness of some 300 feet in the Three Forks Quadrangle. It is considered to be of Eocene-age, and formed in a lacustrine environment (Robinson, 1963).

The Climbing Arrow Formation is composed of olive, thick-bedded, sandy, bentonitic clay and coarse sand beds with subordinate light-colored sandstone, siltstone, conglomerate and limestone (Robinson and Barnett, 1963, p.69). It may have a thickness in excess of 1,500 feet. It is of Late Eocene to Early Oligocene-age. The Climbing Arrow Formation is largely the product of an aggrading stream system.

The Dunbar Creek Formation is mainly white to grayish, thick-bedded, tuffaceous siltstone, partly lacustrine and partly eolian, with interbedded sandstone and conglomerate. Rare components are bentonitic clay and white limestone. Similar rocks to the Dunbar Creek Formation are found in the Townsend and Clarkston valleys (Robinson and Barnett, 1963). The Dunbar Creek may be in excess of 1,000 feet thick in places. In part, the Dunbar Creek is early Oligocene in age, and is probably wholly Oligocene. The rock types of the Dunbar Creek are very similar

to those of the Climbing Arrow, and are presumably of similar mixed origin; some are fluviatile, some eolian, some lacustrine. In Dunbar Creek time, the drainage was mainly interior (Robinson and Barnett, 1963). The well-sorted, thick-bedded, white sandstone and siltstone, formed from rhyolitic ash, are lacustrine or bolson deposits.

After the compressive deformation of the map area and the subsequent denudation, a second orogenic disturbance occurred. Large blocks of the crust were moved vertically, some upward, some downward relative to themselves. Some areas were domed or arched; in other places, the crust was ruptured and long faults formed (Perry, 1968). This process, which began during Oligocene-time or later,, continued throughout much of the rest of the Tertiary. The faults generally lie at the base of the mountain ranges; e.g., along the west side of the Tobacco Root Range and the west side of the Madison Range. The orientation of many of the faults is northerly or northwesterly (Perry, 1962).

When the Early Tertiary erosion surface was uplifted to form the second Rocky Mountain complex, a series of long ridges and valleys formed. Large lakes collected in the intermontane valleys. Lacustrine sediments accumulated, composed of sands and muds from the neighboring mountains. Interbedded with the sands and muds are the volcanic ashes. Sediment thicknesses of 1,000 feet plus filled the valleys and formed sedimentary plains. Some of the sediments were outwash materials spread over valley floors. Subsequent fluvial downcutting produced Late Tertiary terraces.

The latest period of igneous activity in western Montana was during the Middle and Late Tertiary (Miocene through Pliocene times). It followed the draining of the Middle Tertiary lake beds. Basaltic lavas flowed from vents, in some places covering the lacustrine and valley-fill sediments. The lavas were very fluid, and spread rapidly and extensively over the land surface; high volcanic peaks did not form.

A great variety of Pliocene and Pleistocene sediments occur in the Bozeman National Topographic Map Sheet area. The most extensive of these surficial deposits are the alluvia of the river valleys. In the mountain valleys, the various alpine glaciations modified the bedrock configuration, and left poorly sorted till debris and morainal complexes. Glacial outwash deposits occur over and beyond the limits of the glacial till. Travertine, colluvium, fan deposits, landslide debris, eolian sands and silts, terrace deposits, pediment veneers and older lacustrine sediments are mapped within the surveyed area. These are usually thin deposits and are generally poorly consolidated.

C. BRIEF DESCRIPTION OF THE GEOLOGIC UNITS

Cenozoic

Quaternary

Qtr: Travertine Deposits

Qal, Qc, Qac: Alluvium and Colluvium

Alluvial deposits (Qal) and colluvial deposits (Qc), where

undifferentiated, are designated Qac.

Qf: Fan Deposits

Qls: Landslide Deposits

Qs: Windblown Silt and Sand Deposits

Qt: Terrace Deposits

Qp: Pediment Veneer

Qg: Glacial Debris

Q: Quaternary Undivided

Surficial deposits of unspecified character are designated Q.

Qv: Quaternary Volcanics

This category includes the Yellowstone tuff.

Quaternary-Tertiary

QTs: Sediments

Sediments of this group include alluvial deposits, pyroclastics, landslides, glacial material, and late Tertiary lake beds.

Tertiary

Pliocene-Miocene

Tls: Freshwater Limestone

This formation is composed of limestone of freshwater origin.

Tg: Gravel

Tertiary gravel deposits include sand, silts, and clay.

Oligocene

Td: Dunbar Creek Formation

The Dunbar Creek unit consists primarily of a light-colored, tuffaceous siltstone.

Tc: Climbing Arrow Formation

Olive clay and yellow sand characterize the Climbing Arrow Formation.

Oligocene-Eocene

Tb: Bozeman Group

The Bozeman grouping includes the Dunbar Creek (Td) and Climbing Arrow (Tc) formations, both of Oligocene origin, as well as the Milligan Creek Formation (Tm) and Sphinx Conglomerate (Ts), which belong to the Eocene.

Eocene

Tm: Milligan Creek

Light-colored limestone, sandstone, and conglomerate comprise the Milligan Creek Formation.

Ts: Sphinx Conglomerate

The Sphinx unit is a calcareous pebble conglomerate.

Tla: Langford Formation

This formation consists of a pebble-boulder conglomerate.

Tl: Lacustrine Deposits

Tu: Tertiary Undivided

Tertiary units of undifferentiated characteristics are mapped by this designation.

Tvb: Basalt

Tv: Volcanics

Deposits of volcanic origin include flows and associated pyroclastic deposits consisting of andesite, basalt, rhyolite, dacite, and other extrusive rocks.

Ti: Intrusives

Tvs: Volcanics and Sediments

This category includes andesite and basalt flows, breccias, tuffs, and channel-fill deposits of sand and gravel.

Cenozoic-Mesozoic

Tertiary-Cretaceous

TKi: Intrusives

These Tertiary-Cretaceous intrusive formations are composed of andesite, dacite, latite, quartz monzonite, and related rocks.

TKl: Livingston Formation

The Livingston Formation is a depositional unit which is the equivalent of the Fort Union Formation (FKf), as well as Cretaceous volcanic deposits (Kv), the Hoppers Formation (Kh), Billman Creek Formation (Kbc), Miner Creek Formation (Kmc), and Cokedale Formation (Kcd). In the Yellowstone Park area, the Livingston unit is equivalent to the Landslide Creek Formation (Kla) and the Everts Formation (Kev). In the Beartooth Mountains, the Hill Creek Formation (Khc), Lennep Sandstone (Kle), Bearpaw Shale (Kbp), Judith River Formation (Kjr), and Claggett Shale (Kcl) are the equivalent of the Livingston.

TKf: Fort Union Formation

This Paleocene unit is formed of conglomerate, sandstone and siltstone.

Mesozoic

Cretaceous

Kv: Volcanics

Andesitic flows and breccia constitute these units.

Khc: Hell Creek Formation

Gray sandstone, greenish clay and mudstone are the main components of the Hell Creek Formation. There are a few thin coal beds. The unit is specific to the Beartooth Mountains.

Kh, Kle: Hoppers Formation and Lennep Sandstone

Both the Hoppers Formation and the Lennep Sandstone are composed andesitic sandstone, claystone, and siltstone. The Lennep unit is found only in the Beartooth Mountains.

Kla: Landslide Creek Formation

The Landslide Creek unit consists of sandstone and shale. It is found only in the Yellowstone Park area.

Kbc, Kbp: Billman Creek Formation and Bearpaw Shale

The Billman Creek Formation (Kbc) is primarily a gray claystone, with interbedded sandstone, siltstone, and conglomerate. It is roughly equivalent to the Bearpaw Shale (Kbp), a unit found in the Beartooth Mountains.

Kmc, Kjr: Miner Creek and Judith River formations

Andesitic siltstone and sandstone, tuff, and bentonite comprise the Miner Creek unit (Kmc). Its rough equivalent in the Beartooth

Mountains is the Judith River Formation (Kjr).

Kev: Everts Formation

The sandstone and shale of the Everts Formation is found only in the Yellowstone Park area.

Kcd, Kcl: Cokedale Formation and Claggett Shale

The Cokedale Formation (Kcd) contains andesitic siltstone and sandstone, claystone, tuff, bentonite and coal. Its approximate equivalent in the Beartooth Mts. is the Claggett Shale (Kcl).

Ke, Kvi, Kvu: Eagle and Virgelle Sandstones

The Eagle unit (Ke) is composed of sandstone and siltstone with lignite beds in the upper part. The Virgelle unit (Kv), which is sometimes mapped as the basal part of the Eagle Formation, is a gray to tuff massive sandstone. Where the Virgelle Formation is undifferentiated from younger strata of the Eagle unit, the designation Kvu is used.

Ktc, Ketc: Telegraph Creek Formation

Siltstone, sandy shale, and concretionary sandstone are the components of the Telegraph Creek unit. Where this formation is not differentiated from the Virgelle & Eagle units (Kvi, Ke), the map designation is Ketc.

Kc, Kf, Kcf, Kmcf: Cody Shale and Frontier Formation

The Cody unit (Kc) is a gray and brown shale with a basal sandstone member. Where this formation is undifferentiated from the alternating beds of sandstone and carbonaceous shale of the Frontier unit (Kf), the map shows the designation Kcf. A lack of differentiation between these units and the Telegraph Creek, Eagle, Virgelle (Ketc), or other younger formations (Kcd, Kcl; Kev; Kmc, Kjr), the designation is Kmcf.

Kco: Colorado Shale

This unit entails the Telegraph Creek Formation (Ktc), Cody Shale (Kc), Frontier Formation (Kf), Mowry Shale (Km), and Thermopolis Shale (Kt).

Km, Kt, Kk, Kmtk: Mowry and Thermopolis Shales and Kootenai Formation

The Mowry unit (Km) is a brown to gray shale and sandstone. The Thermopolis Shale (Kt) is dark, with some sandstone. The Kootenai Formation consists of a red and green sandstone, mudstone, limestone and a basal pebble conglomerate. Where the three units are undivided, the occurrence is labeled Kmtk.

Kl: Lower Cretaceous, Undivided

Ku: Cretaceous, Undivided

Jurassic

Jm: Morrison Formation

The Morrison unit consists of vari-colored shale, siltstone, mudstone, limestone, and sandstone.

Je: Ellis Group

There are three members of the Ellis Group: the Swift Formation (Js), Rierdon Formation (Jr) and Piper Formation (Jp).

Js: Swift Formation

Calcareous sandstone is the major component of the Swift Formation in its upper portions. At base, the unit has a pebble conglomerate.

Jr: Rierdon Formation

The Rierdon unit is composed of gray shale and limestone.

Jp: Piper Formation

The Piper Formation contains gray shale, argillaceous limestone, and multi-colored siltstone.

Ju: Jurassic Undivided

Jurassic-Triassic

JTru: Jurassic-Triassic Undivided

Triassic

Trc: Chugwater Formation

The Chugwater Formation, found in the Beartooth Mountains, is made up of red shale and shaly limestone.

Trd: Dinwoody Formation

The Dinwoody unit contains shale, sandstone, and limestone or dolomite.

Mes: Mesozoic, Undivided

Paleozoic

Permian

Pp: Phosphoria Formation

The Phosphoria Formation is composed of limestone, shale,

phosphatic sandstone and chert. It interfingers with the Shedhorn Sandstone (Ps).

Ps: Shedhorn Sandstone

The sandstone, dolomite, and chert of the Shedhorn unit are found interfingered with the Phosphoria Formation.

Permian-Pennsylvanian-Mississippian

PlPMp, PlPMu: Permian-Pennsylvanian-Mississippian, Undivided

The PlPMp grouping includes the Phosphoria Formation (Pp), Shedhorn Sandstone (Ps), Quadrant Sandstone (lPq), Amsden Formation (lPMa) and the Big Snowy Formation (Mb). Where the Mission Canyon Limestone (Mmi) and Lodgepole Limestone (Ml) are also subsumed, the designation is PlPMu.

Pennsylvanian

lPq: Quadrant Sandstone

The light-colored sandstone of the Quadrant unit is found along with some limestone.

Pennsylvanian-Mississippian

lPMa, lPMqa: Amsden Formation

Dolomite, calcareous sandstone, siltstone, and limestone comprise the Amsden Formation. Where this unit is not differentiated from the Quadrant Sandstone (lPq), the map designation is lPMqa.

lPMu: Pennsylvanian-Mississippian, Undivided

Undivided units of Pennsylvanian or Mississippian age are designated lPMu.

Pennsylvanian-Mississippian-Devonian-Ordovician

lPMDOu: Middle Paleozoic, Undivided

Formations of unspecified middle Paleozoic origins are labeled lPMDOu in mapping.

Mississippian

Mb: Big Snowy Formation

The Big Snowy Formation consists of variegated shale, limestone and sandstone.

Mm, (Mmi, Ml): Madison Group

Two members of the Madison Group (Mm) are identified in this region. The Mission Canyon Limestone (Mmi) is a massive, cliff-

forming, gray limestone and dolomite with some siltstone. The Lodgepole Limestone (Ml) is also cliff-forming, gray in color, and is associated with dolomite. It includes a basal chert.

Mu: Mississippian, Undivided

Mississippian-Devonian

MDt: Three Forks Shale

In addition to shale, the Three Forks unit contains limestone, dolomite and siltstone.

MDmt,MDtj,MDtjm: Mississippian-Devonian, Undivided

Where the Madison Group (Mm) is undifferentiated from the Three Forks Shale (MDt), the map shows the designation MDmt. Undivided units pertaining to the Three Forks (MDt) and Jefferson (Dj) formations are designated MDtj; inclusion of the Maywood Formation requires the designation MDtjm.

Mississippian-Devonian-Ordovician

MDOt: Mississippian-Devonian-Ordovician, Undivided

Where the Bighorn Dolomite (Ob) is not differentiated from the units subsumed within MDtjm, the map shows the label MDOt.

Mississippian-Devonian-Ordovician-Cambrian

Devonian

Dj,Dm,Djm: Jefferson and Maywood Formations

The Jefferson Formation (Dj) consists of gray dolomite and limestone. The Maywood unit (Dm) is formed of an orange siltstone, grading upward into gray limestone. Where the two formations are not differentiated, the map is labeled Djm.

Ordovician

Ob: Bighorn Dolomite

Gray dolomite and limestone comprise the Bighorn unit.

Cambrian

Gg,6s,6r,6gs: Grove Creek and Snowy Range formations

The Grove Creek unit (Gg) is a gray conglomeratic limestone and shale. The Snowy Range Formation (6s) consists of green shale, gray limestone and a pebble conglomerate. The Snowy Range equivalent in the Greenhorn Range is the Red Lion Formation (6r). Undifferentiated occurrences of these formations are labeled (6gs).

6p,6sp: Pilgrim Limestone

The Pilgrim Limestone (6p) is a dolomitic limestone with pebble conglomerate, shale and siltstone. Where it is not divided from the Snowy Range unit (6s), the map shows 6sp.

6ps: Park Shale

The multi-colored shale of this unit contains thin beds of limestone, siltstone and sandstone.

6m,6w,6f: Meagher Limestone, Wolsey Shale and Flathead Quartz

The Meagher unit (6m) is composed of gray limestone and dolomite. The Wolsey (6w) is a greenish to brown shale with interbeds of sandstone and limestone. The Flathead unit (6f) is a formation of sandstone and quartzite. Undifferentiated occurrences pertaining to these units are noted as 6mwf.

6m: Middle Cambrian, Undivided

This generalized designation subsumes the Park Shale (6ps), Meagher Limestone (6m), Wolsey Shale (6w), and Flathead Quartzite (6f).

6u: Cambrian, Undivided

This designation entails all formations of Cambrian origin.

Pal: Paleozoic, Undivided

Precambrian

p6n: North Boulder Formation

The North Boulder Formation is composed of coarse arkose and conglomerate.

p6g,p6gn,p6d: Metamorphic Rocks

These Precambrian metamorphic rocks include granite (p6g), gneissic rocks (p6gn), and dolomite marble (p6d).

p6u: Undifferentiated Rocks

These undivided units include gneiss, schist, and granite with locally occurring pegmatite, limestone, and quartzite. The designation includes pu-Belt, Belt series, and Stillwater complex rocks.

D. RADIOACTIVE MINERAL OCCURRENCES

Uranium

An area lying along the Boulder River, south of Big Timber, in Park and Sweetgrass counties, has above average radioactivity (Jarrard,

1957). The rocks are part of the Precambrian core of the Absaroka Range. The mineral tyuyamunite, a calcium-uranium-vanadate, has been identified. The anomalies and tyuyamunite minerals are believed to have originated in granitic rocks or pegmatite; however, ore concentrations are thought to be minimal.

A second prospect is in the vicinity of Shoddy Creek in the Three Forks Quadrangle, Jefferson County. The prospect (Jarrard, 1957) probably occurs in the Climbing Arrow Formation of the Bozeman Group (Robinson and Barnett, 1963). The deposit may have been derived from pyroclastic and volcanic debris contained within the Climbing Arrow.

Thorium

Four thorium occurrences are mapped by Weis (1963, Figure 43). Three occur in Madison County, one in Park County. The most northerly occurrence in Madison County is associated with a pegmatite, to the south of Jefferson River, in the London Hills area. A second occurrence appears to be located between the town of Red Bluff and the Willow Creek Reservoir. It is associated with a non-sedimentary rock type (Weis, 1963). The most southerly occurrence in Madison County is located in the Madison Range to the east of Ennis Lake. Weis (1963) maps it as an ancient placer deposit. The Thorium occurrence in Park County is in the same general location as the uranium mineralization and anomalous radioactivity discussed earlier. It is in granitic or pegmatite rocks of the Absaroka Range, immediately to the west of the Boulder River.

SECTION IV

RESULTS OF DATA ANALYSIS

A. GEOLOGIC BASE MAPS

The Bozeman geologic base map is created to the scale of the NTMS with geologic data and includes latitude, longitude and major geological features. The geologic base map is shown without the super-positioned flight lines at the scale of 1:250,000 and 1:500,000.

B. NATIONAL GAMMA RAY MAP SERIES (NGRMS)

The geologic base has been photographically screened to allow emphasizing of the flight line locations and information regarding data analyses. These maps are the base to which the statistical information for six variables has been added for every fifth data point and are identified as the National Gamma Ray Map Series which are presented at the scale of 1:250,000 and 1:500,000. The detail data for each of these map lines are presented as profile information for six variables and location of geologic information with statistical data included along each map line as discussed in Section IV (F).

C. RADIOMETRIC STACKED PROFILES

The profiles of Map Lines 1 - 23 and Tie Lines 1 - 9 are presented within this report at the scale of 1:500,000. The same vertical scale is used for a given variable for all map lines, but the vertical scale changes to fit the specific variable plotted. The scales used for each variable are:

1. Altitude

100 feet/division, aircraft altitude above the surface;
no averaging.

2. Tl (^{208}Tl)

10 counts/second/division (C/S/div.). Seven seconds of data are averaged with weighting of 1:2:3:4:3:2:1 and the average value plotted at the center of the group of 7.
5.5 c/s = 1 ppm eTh.

3. Bi (^{214}Bi)

5 C/S/div; 7-second weighted average as for Tl.
8.0 c/s = 1 ppm eU.

4. K (^4OK)
30 C/S/div; 7-second weighted average as for T_l.
85.0 c/s = 1%K.
5. BiAir
5 C/S/div; 50-second average.
6. Residual Magnetic Field (RMAG)
50 gammas/division; the residual magnetic field is the total magnetic field as measured by a proton precession magnetometer from which has been subtracted the International Geomagnetic Reference Field (Stassinapoulos; NSSDC-72-12).
7. Total Count, 400 keV to 2.80 MeV (GC)
500 C/S/div; no averaging
8. $^{214}\text{Bi}/^{208}\text{Tl}$ Ratio (Bi/T_l)
.08/div; 7-second weighted averaging as for T_l.
9. $^{214}\text{Bi}/^4\text{OK}$ Ratio (Bi/K)
.04 /div; 7-second weighted averaging as for T_l.
10. $^{208}\text{Tl}/^4\text{OK}$ Ratio (T_l/K)
.06 /div; 7-second weighted averaging as for T_l.
11. Geology
The surface geology along the flight line, with a width of about six miles, is displayed above the profiles and the flight path is superimposed.

D. MAGNETIC STACKED PROFILE DATA

For each Map Line and Tie Line, a magnetic multiple-parameter stacked profile is produced at a scale of 1:500,000 in Volume II of this report, and at a scale of 1:250,000 as separate sheets. The same vertical scale is used for a given variable for all Map Lines, but the vertical scale varies to fit the specific variable plotted. The scales used for each variable are:

1. Altitude
100 feet/division; aircraft altitude above the surface;
no averaging.

2. Temperature

2 degree celsius/division; no averaging.

3. Barometric Pressure

0.25 inches mercury/division; no averaging.

4. Base Station - Magnetic Field

5 gammas/div; no averaging

5. Residual Magnetic Field

50 gammas/division; no averaging.

E. MAGNETIC TAPES AND LISTINGS

The description of the magnetic tapes and their listings is presented in Appendix II.

F. STATISTICAL AND GEOLOGICALLY-CREATED DEVIATIONS IN RESULTANT DATA

A set of tables are included; see Tables 1-6. These list the average value for each geologic unit encountered on each flight line as a function of flight line for each of the radiation variables.

Standard deviations of the data have been calculated assuming the data to have a normal distribution within the geologic type. When geochemical anomalies modify the normal distribution, then the frequency distribution of the data will be distorted about the mean. Geologic unit data have been analyzed to determine the variance.

$$\sigma^2 = \frac{1}{N-1} \left\{ \sum_{i=1}^N x_i^2 - N\bar{x}^2 \right\}$$

where the standard deviation is σ , N is the number of samples, x_i is the value at the sample number i , and $\bar{x}$ is the mean value for the geologic type. The listing for averaged record data output gives the mean value and magnitude of deviations, relative to the mean, with the $\pm 1\sigma$, $\pm 2\sigma$, and $\pm 3\sigma$ levels being placed on the NGRMS Sheets for the six variables as previously explained. The distribution of data within the geologic units encountered are included.

A statistical adequacy test is run on all data. If the test fails, the value of the displayed ratio variable is set to zero and not included in summary tables which gives the average value. The test is made on T_l(eTh), B₁(eU) and K where:

	CU	DJM	EMF	ESP	EU	IPMB	IPMD	IPAG	IPMU	JTRU	JU	KBC	KCD	KCF	KCL	KCU	KDC	KE	KETC	KEV	KF	KH	KK	KL
ML 1			33	11	36			15		32						41				63	41		33	
ML 2			19		20			20		30						45					51		44	
ML 3			67		90	26		52		34	50					35					33		31	
ML 4			52					25		27						30					24		29	28
ML 5										39						42							39	32
ML 6			32		24					33						42							38	
ML 7					32					12						36							31	
ML 8					23					28						36							25	
ML 9					12											39								
ML10					32																			
ML11					33											31								
ML12					21		27		77		40													
ML13	22				38		16	15	24		21				29					33			32	
ML14					28		15		19		24				39					32			21	
ML15					47		51		11		18			33	35	35				36			24	30
ML16												30	36					36						
ML17					32				19		24	32	30	33				34				32		
ML18					28		36		12		22	31	26						30			31		
ML19					21			36			22	25	25									30		23
ML20					33						22	27										29	18	20
ML21					32						22	27										23		28
ML22					41			34			42	30	28									26		23
ML23		39			47			25			29	31	27			45						26	50	
IL 1					46	38					22					44					46	31	42	
IL 2		27			40																		27	
IL 3					27					23	31					41							21	29
IL 4					23			49		37	44					45							34	
IL 5					37		17				24			43			25							
IL 6									20		26	31		35					33			31		
IL 7					26				25		20											36	27	
IL 8					29				25															
IL 9					23				15															

Table 1. Geologic Unit Average Value as a Function of Map Line for ^{208}Tl (counts/sec.)

	NDA	NDC	KPCF	KATR	K1	KU	KV	KVC	KVD	ADDE	MDPT	ADDEMDPT	RTUJ	NOTJRES	AE	AB	AO	DB	UG	PAL	PEO	PEG
AL 1	41			36	24					19		15	15		19							53
AL 2				32	24							30	16	24	39	24					25	101
AL 3					43								27		32							154
AL 4					20					32			21		21							
AL 5										16					9							
AL 6										17	32				12							
AL 7										21	30				21					35		
AL 8													14		19	22	20		13			
AL 9														11								
AL 10													20		26							
AL 11														38	31	30						
AL 12				30										27	17	38						
AL 13				33		20						9		30								
AL 14				29		52			29			22		55								
AL 15		29		25		30			30												46	
AL 16		34	38						34													
AL 17		35		26					38					41		18						
AL 18		26												12	29							
AL 19														16	26							
AL 20		24												11								
AL 21		26								25				38	27							
AL 22		35					55							34	35	44						
AL 23		32					38			20				32	29	20						
AL 1					36					41					17	43						
AL 2							38				30									20		
AL 3										8				24		35					49	
AL 4										31			14	29	20							
AL 5														29								
AL 6	30	20													61							
AL 7			43							25												
AL 8									37			47	27									
AL 9						42							19		19							

	PECH	PER	PEO	FIP	FFIP	PP	PS	Q	QAC	QAL	QC	QF	QG	QDS	QS	QT	QIR	QIS	QV	TR	TC	TD	TE	TF
80 1	47		54	43	11			42		45		67		37		73								
80 2			43	64	7		25	41		46		62	82			81								40
80 3			41	19	35	46	24	37		53	34	77	69			102								43
80 4			40	22			26	53		67		92				115								
80 5			52	23				37	25	68		47		38		41								
80 6			47	29						40		47	32			20								53
80 7			50	13				28		46		50	48											46
80 8			67	21	23			196		41		48	36											56
80 9			66							41		51	56											45
8010			61					35		49		54												44
8011			52		46			46		47			58											38
8012			43					37	33	39			41											
8013			46					8	42	41			42	28	30			51						
8014			45					44		39		45	51	20				61						
8015	107		55					40	20	37		45		37	28			54						
8016			50					34		40		43				36		51		43				
8017			32					30		36		47						49						45
8018			33	24				36		40		44						46				47		43
8019			23	18	9					36		46			49			48			50			32
8020		31	24		19					34				25	40			48			46			34
8021		59	43		10					41		43	15		57			47			40			51
8022					10					39	34	40	18					52			64			42
8023			56	38	12	35				36		45			52			49						45
80 1		49	57	20						39														41
80 2		41	47	40				59		55		49			59			50			62			67
80 3	50		53		15					37														
80 4	116		31	23						38				27				54						
80 5			37		16			29		42		34						45	40	46				
80 6			40					37		40							57							55
80 7			38					54	16	35		28	39			36								36
80 8			65					32		40														
80 9			46					27		37														

	11	18F	181	18D	1E	18A	18S	18	1S	10	1V	1V8	1VS
AL 1	41								34		33		
AL 2	29					43					45		
AL 3	38										46		
AL 4	33								27		43		
AL 5	36						38				36	25	
AL 6	53										33	31	
AL 7	40										37		
AL 8	37										36		
AL 9											34		
AL10											35		
AL11											33		
AL12	15		67								30		40
AL13			59										
AL14			46	26							51		
AL15			15	32	47								
AL16		29		32	54						42		
AL17		30		33	57								
AL18	36	29		32	52								
AL19		27		32	43								
AL20	32	27		35	48		44						
AL21		28		35					43				
AL22		28		35									
AL23	59	32	40	37	45								
IL 1			52										
IL 2			66										
IL 3	41				49			21					
IL 4	26										26		
IL 5	36										35		30
IL 6	46	28									41		
IL 7	25	34		37							46		
IL 8	26			36							25		
IL 9	25			29							19		

	CU	DDM	EW	ESP	EU	IPNB	IPNDU	IPNGA	IPND	DIRU	DU	KBC	KCD	KCF	KCL	KCO	KDC	KE	KEFC	KEV	KF	KH	KA	KL
AL 1			10	6	10			14		14						16				18	17		14	
AL 2			11		9			15		15						18					22		19	
AL 3			14		28	12		19		17	16					16					15		17	
AL 4			16					22		13						16					14		16	12
AL 5										17						18							18	11
AL 6			12		13					20						18							22	
AL 7					14					14						15							14	
AL 8					10					14						19							15	
AL 9					9											15								
AL 10					10																			
AL 11					12											17								
AL 12					9		10			16	17													
AL 13	10				13		11	12		14	12			13		15			11				17	
AL 14					13		13			16	15			17		15			20				10	
AL 15					15		17			15	14		14	17	10			16	15				15	15
AL 16												18	13					16				17		
AL 17					12					15	18	16	18	15				16				17		
AL 18					18		19		9		17	13	11						16			11		16
AL 19					20			19			24	18	18									12	20	18
AL 20					15						16	15										9		14
AL 21					15							13	13									10		13
AL 22					16			16			18	14				16						12	19	
AL 23		18			19			20			17	13	12			19						12	15	
AL 1					13	20					18										20		16	
AL 2		13			15																			
AL 3					11					18	19					19							17	15
AL 4					11			20		17	18					19							16	
AL 5					11		8				12			13			11							
AL 6										14	15	12		14					12			10		
AL 7					13					12	11											15	13	
AL 8					5					10														
AL 9					10					11														

Table 2. Geologic Unit Average Value as a Function of Map Line for ^{214}Bi (COUNTS/SECOND)

	KLA	KAC	KACE	KATA	KT	KU	KV	KVC	KVD	KDEU	KDMI	KDEUMDUT	KDID	KDJRSES	KH	KU	KV	KW	KX	KY	KZ	PAG	PED	PAG
KL 1	16			16	19					9		8	5		9									
KL 2				13	17							10	9	10	10							11		
KL 3					19								9		11									
KL 4					12					11			10		14									
KL 5										9					8									
KL 6										10		15			9									
KL 7										12		12		17	14						26			
KL 8													9		16	8		16			11			
KL 9														11										
KL10													17		10									
KL11															12	15								
KL12				13										14										
KL13				15		13						3		14										
KL14				15		16			11			11		13										
KL15		13		13		13			13					14										10
KL16		14	12						14															
KL17		16		14					11															
KL18		12												16		17								
KL19														10										
KL20		12												11										
KL21		14									16			12		16								
KL22		16					26							13		15	17							
KL23		14					17				14			10		12	13							
KL 1					19					16						16	14							
KL 2							15				15													
KL 3										6				8										
KL 4										12			8	14		12								
KL 5														7										
KL 6	12	14													12									
KL 7			18										13											
KL 8									13			14	7											
KL 9						10							10											

	PEGS	PEN	PRU	PIPM	PIPP	PIPP	PIPP	PS	U	SAC	CAL	NC	QF	QG	QDS	QS	QT	QTR	QTS	QV	TS	TC	TD	TE	TF
AL 1	13		16	17	7				15		17		21		14		15								
AL 2			15	24	9			20	15		16		19	17			23								18
AL 3			14	11	16	15		19	14		16	12	21	16			21								12
AL 4			14	13				17	16		21		25				26								
AL 5			13	11					13	7	20		17		14		16								
AL 6			14	15							15		18	9			11								17
AL 7			17	12					8		16		17	17											16
AL 8			18	13	5				34		18		19	19											16
AL 9			19								19		20	15											17
AL 10			17						16		16		17												16
AL 11			15		15				11		17			16											17
AL 12			13						13	13	15			13											
AL 13			12						9	16	15			14	15	14			14						
AL 14			13						15		16		18	14	13				19						
AL 15	20		16						13	12	14		18		13	14			16						
AL 16			20						12		16		18				12		21		17				
AL 17			17						9		17		21						23						21
AL 18			18	18					10		18		12						23				22		21
AL 19			7	20	8						18		16						23			22			17
AL 20		15	15		13						16				17	19			20			19			16
AL 21		25	19		13						18		17	15		23			18			22			19
AL 22					5						16	15	16	10					18			25			18
AL 23			19	18	7	15					14		19				20		20						16
AL 1		19	17	14							17														17
AL 2		17	17	20					16		20		18			24			21			41			40
AL 3	17		16		15						17														
AL 4	20		10	14							16				13				18						
AL 5			11		9				10		14		13						13	14	16				
AL 6			14						12		15						12								17
AL 7			14						20	10	14		13	11			12								14
AL 8			18						12		15					12									
AL 9			17						11		13														

	11	TAF	TKI	TKL	TL	TLA	TLS	TM	TS	TU	TV	TVB	TVS
ML 1	18								16		13		
ML 2	10					20					16		
ML 3	14										14		
ML 4	14								12		14		
ML 5	10						16				12	10	
ML 6	21										13	9	
ML 7	16										12		
ML 8	15										15		
ML 9											13		
ML 10											16		
ML 11											13		
ML 12	6		19								12		14
ML 13			20										
ML 14			16	12							19		
ML 15			25	11	17								
ML 16		15		12	22						20		
ML 17		15		11	32								
ML 18	15	15		13	27								
ML 19		14		13	24								
ML 20	11	13		14	20			19					
ML 21		13		13						17			
ML 22		12		13									
ML 23	11	11	17	13	18								
FL 1			22										
FL 2			19										
FL 3	19				20			16					
FL 4	10										10		
FL 5	14										12		12
FL 6	15	12									14		
FL 7	12	15		14							16		
FL 8	4			14							10		
FL 9	12			11							9		

	CU	UUM	EMWF	ESP	EU	IFAB	IPMDU	IPMGA	IPMD	JTRU	JU	KBC	KCD	KCF	KCL	KCU	KDC	KE	KETC	KEV	KF	KH	KK	KL
ML 1			114	50	151			53		96						103				104	105		95	
ML 2			88		102			66		85						126					126		111	
ML 3			214		237	50		155		96	174					100					91		86	
ML 4			160					62		78						72					61		84	110
ML 5										95						119							87	141
ML 6			145		126					72						117							87	
ML 7					145					31						118							85	
ML 8					102					91						92							103	
ML 9					84											122								
ML10					125																			
ML11					124											105								
ML12					98		124		156		149													
ML13	99				109		69	50	66		61			101		110			121				67	
ML14					98		48		64		69			117		103			82				45	
ML15					147		127		36		52		119	107	105			109	103				60	81
ML16												121	171					118				141		
ML17					108				60		70	134	120	103					110			143		
ML18					109		117		45		68	133	93									151		65
ML19					93			118			60	121	92									138	59	67
ML20					163						67	106										123		80
ML21					116							112	128									139		88
ML22					130			88			106	130				118						154	128	
ML23		167			143			63			76	120	96			118						150	98	
TL 1					156	97					61									97			76	
TL 2		90			125																			
TL 3					98					78	85					104							55	115
TL 4					91			127		103	113					118							95	
TL 5					129		68				76			147			103							
TL 6									75		82	136		116					119			154		
TL 7					107				68		59											156	78	
TL 8					71				71															
TL 9					125				136															

Table 3. Geologic Unit Average Value as a Function of Map Line for ^{40}K (COUNTS/SECOND)

	NLA	KNC	KMCF	KRTK	KT	KU	KV	KVC	KVO	KDEU	KDRT	KDEURDUT	KDTJ	KDTJMMES	KK	KU	KU	UG	UG	PAL	FED	PEG
ML 1	141			130	86					91		48	60		62							145
ML 2				102	67							92	80	79	115	61					82	231
ML 3					138								96		101							231
ML 4					59					120			85		59							
ML 5										70					27							
ML 6										99		140			52							
ML 7										78		162			65					96		
ML 8													44		95	76		79		55		
ML 9														45								
ML10																						
ML11													70		133							
ML12				105										125	110	76						
ML13				103		94						45		76	58	85						
ML14				65		133			127			71		103								
ML15		123		60		137			112					195								128
ML16		126	144						106													
ML17		138		39					134					123		54						
ML18		107												62	89							
ML19														73	72							
ML20		101												62								
ML21		110									62			140	81							
ML22		127					208							126	90	122						
ML23		140					170							95	86	52						
TL 1					92					160					59	139						
TL 2							155				86										58	
TL 3									41					77		105						129
TL 4									113				49	86	66							
TL 5														132								
TL 6	138	125													187							
TL 7			157																			
TL 8									112			171	81									
TL 9						121							70		110							
													93									

	PEGR	PER	PEO	PIP	PPP	PIPP	PP	PS	U	JAC	QAL	GC	QF	CG	QLS	CS	QI	QTR	QTS	QV	TA	TC	TD	TG	TG
ML 1	115		149	121	45				141		138		204		144		194								
ML 2			145	154	15			67	144		149		183	171			194								137
ML 3			122	69	106	177		66	135		152	79	162	141			195								126
ML 4			124	64				61	183		180		194				202								
ML 5			140	71					133	98	157		137		140		122								
ML 6			144	87							129		142	96			80								141
ML 7			159	30					108		124		148	105											129
ML 8			155	60	104				231		134		148	120											168
ML 9			158								135		148	141											157
ML10			149						99		157		150												171
ML11			134		102				118		142			156											151
ML12			108						129	108	125			109											
ML13			122						27	109	124			111	91	90			140						
ML14			129						129		116		129	130	82				138						
ML15	165		155						114	61	116		124		114	91			146						
ML16			129						120		130		124				135		147		153				
ML17			109						161		126		133						132						129
ML18			104	83					134		135		134						128				140		138
ML19			78	46	38						130		129						139			146			116
ML20		117	87		77						110				71	138			148			146			149
ML21		148	112		39						129		138	48		171			130			99			177
ML22					41						135	137	126	67					151			168			145
ML23			168	103	43	88					132		120				155		133						161
TL 1		174	150	69							122														156
TL 2		146	139	105					171		149		141				161		150			221			211
TL 3	148		141		52						117														
TL 4	190		117	70							116				136				139						
TL 5			126		60				100		140		114						124	99	141				
TL 6			130						133		151						158								184
TL 7			109						191	54	127		74	105			133								151
TL 8			149						110		131						132								
TL 9			143						110		138														

	TI	TKF	TKI	TKL	TL	TLA	FLS	TM	TS	TU	TV	TVB	TVS
ML 1	141								91		132		
ML 2	126					154					163		
ML 3	154										141		
ML 4	130								101		148		
ML 5	170						139				144	101	
ML 6	199										133	95	
ML 7	147										145		
ML 8	124										135		
ML 9											140		
ML10											144		
ML11											139		
ML12	125		175								121		157
ML13			200										
ML14			184	130							154		
ML15			210	124	125								
ML16		136		123	151						132		
ML17		145		150	155								
ML18	157	140		133	162								
ML19		142		135	164								
ML20	149	136		143	181			132					
ML21		154		145						121			
ML22		160		147									
ML23	188	157	122	150	125								
TL 1			170										
TL 2			207										
TL 3	120				159				59				
TL 4	127										134		
TL 5	138										139		130
TL 6	168	149									150		
TL 7	109	148		149							173		
TL 8	121			137							111		
TL 9	104			128							97

	CU	DS	EMF	ESP	EO	IPFB	IPROU	IPFGA	IPRO	UPRO	UO	KAC	KCU	KCF	KCL	KCO	KOC	KE	KETC	KEV	KF	KH	KA	KU
EL 1			31	56	29			97		50						42				32	43		45	
EL 2			56		48			58		56						42					44		45	
EL 3			22		32	53		48		66	32					56					47		65	
EL 4			32					91		53						56					61		57	45
EL 5										43						44							44	36
EL 6			41		57					60						45							60	
EL 7					44					118						44							53	
EL 8					47					52						57							60	
EL 9					80											42								
EL10					33																			
EL11					39											61								
EL12					47		37		22		43													
EL13	44				42		66	81	63		67			47		39			34				55	
EL14					50		86		87		67			44		51			65				34	
EL15					32		34		142		80		43	50	29			45	48				65	51
EL16												63	38					49				54		
EL17					41				83		78	51	58	47					55			58		
EL18					70		54		87		80	42	46									38		75
EL19					99			55			124	74	71									41	115	89
EL20					50						76	54										41		54
EL21					48							55	46									40		60
EL22					41			50		47		48				37						45	41	
EL23		47			42			90		62	44	46				47						40	56	
EL 1					24	57				83											44		60	
EL 2		49			40																			
EL 3					41					51	63					49							61	50
EL 4					53			42		51	41					44							50	
EL 5					32		51			52				30			46							
EL 6									77	58		41		40					39			35		
EL 7					52				54	60												42	51	
EL 8					17				44															
EL 9					51				72															

Table 4. Geologic Unit Average Value as a Function of Map Line for $^{214}\text{Bi}/^{210}\text{Pb}$ (Times 100)

	ALA	KMC	KMCF	KMK	K1	KU	KV	KVC	KVU	KDEU	KDPT	KDDEU	KDPT	KDTU	KDTUMES	KM	KU	KU	UB	UG	KAL	KED	KEG
PL 1	39			45	67					55		58	35			53							26
PL 2				43	71							35	50	43	26	76						45	25
PL 3					45									35		36							17
PL 4					47					38				49		80							
PL 5										59						98							
PL 6										63		53				83							
PL 7										56		43			165	67				85			
PL 8													63			86	41		54	52			
PL 9															108								
PL10														93		36							
PL11																42	50						
PL12				45										37		75	41						
PL13				50		55						43		56									
PL14				52		31			40			52		44									
PL15		46		57		46			38					27									39
PL16		44	31						43														
PL17		53		49					31						42		94						
PL18		45													84	78							
PL19															67	78							
PL20		50													126								
PL21		54									65			35		66							
PL22		44					47							40		44	39						
PL23		44					45						69	35		43	63						
TL 1					53					49						108	33						
TL 2							39				53										65		
TL 3										93					34		48						40
TL 4										39				69	48	70							
TL 5															26								
TL 6	43	52														20							
TL 7			42									55											
TL 8									37			34		27									
TL 9						26								57		41							

	PEGN	PEN	PEU	PIPM	PIPM	PIPM	PS	U	QAC	QAL	QC	QF	QG	QLS	QS	GT	QTR	QTS	QV	Tb	TC	TD	TG	1G
ML 1	30		32	47	74			37		39		32		39		21								
ML 2			37	39	128		83	37		35		33	22			28								46
ML 3			37	66	49	33	82	39		30	37	30	28			21								29
ML 4			38	68			63	35		31		30				24								
ML 5			29	47				38	29	31		37		39		39								
ML 6			33	51						39		39	29			61								31
ML 7			36	88				31		43		35	36											36
ML 8			39	63	25			17		45		42	52											33
ML 9			35							49		41	29											38
ML10			33					50		38		33												36
ML11			33		33			35		36			28											45
ML12			37					41	41	44			32											
ML13			32					126	39	39			34	57	47			29						
ML14			33					36		44		41	28	68				33						
ML15	22		30					34	63	42		40		37	50			31						
ML16			41					36		47		42				35		41		41				
ML17			56					30		46		45						49						48
ML18			58	88				29		47		29						49				46		49
ML19			35	123	101					47		34			56			48			45			57
ML20		52	65		71					49				70	46			41			41			47
ML21		42	86		131					44		40	102		41			40			57			38
ML22					53					42	43	40	56					35			40			45
ML23			34	49	65	44				38		43			40			43						43
TL 1		39	33	68						45														43
TL 2		42	38	51				32		37		39			40			43			69			59
TL 3	33		34		115					47														
TL 4	18		36	67						45				54				35						
TL 5			31		50			36		34		38						30	36	35				32
TL 6			36					34		39							24							41
TL 7			39					38	65	41		48	27			35								
TL 8			34					40		39					35									
TL 9			44					47		37														

	TL	TAF	TRI	TKL	TL	TLA	TLS	TM	IS	TU	TV	TVB	TVS
ML 1	44								49		40		
ML 2	35					46					37		
ML 3	39										36		
ML 4	44								48		35		
ML 5	30						42				34	42	
ML 6	42										42	29	
ML 7	40										35		
ML 8	42										44		
ML 9											39		
ML10											46		
ML11											41		
ML12	47		32								43		37
ML13			36										
ML14			41	47							37		
ML15			33	36	38								
ML16		54		40	41						48		
ML17		51		34	56								
ML18	42	52		40	53								
ML19		53		43	57								
ML20	36	50		41	41		45						
ML21		48		40					40				
ML22		45		40									
ML23	19	37	43	37	41								
TL 1			44										
TL 2			29										
TL 3	48				41				40				
TL 4	41										43		
TL 5	37										37		42
TL 6	34	44									34		
TL 7	51	46		39							37		
TL 8	17			40							45		
TL 9	65			41							50		

	CU	DJA	EMF	ESP	EU	IPAB	IPNDU	IPMGA	IPMU	JTRU	JU	KBC	KCD	KCF	KCU	KDC	KE	KETC	KEV	KF	KH	KA	KL
ML 1			93	130	66			296		181					173				116	164		161	
ML 2			160		97			246		216					150					174		178	
ML 3			69		121	184		152		228	93				192					171		259	
ML 4			101					366		192					257					246		204	113
ML 5										180					156							227	83
ML 6			104		109					280					170							262	
ML 7					106					486					138							215	
ML 8					107					162					215							166	
ML 9					115										136								
ML10					87																		
ML11					106										171								
ML12					105		83		104		118												
ML13	101				142		166	245	222		232			140	146			94				217	
ML14					152		292		260		241			148	165			256				228	
ML15					104		139		428		296		122	166	97		150	157				272	205
ML16												157	80				140				120		
ML17					121				257		260	122	148	153				155			126		
ML18					172		167		215		257	103	127								77		264
ML19					219			166			430	154	200								87	356	272
ML20					121						254	149									80		192
ML21					137							119	106								78		200
ML22					128			198			167	111			145						78	156	
ML23		175			140			352			243	117	137		178						83	196	
TL 1					86	240					300									216		217	
TL 2		152			126																		
TL 3					115					244	234				195							318	142
TL 4					148			162		177	163				175							167	
TL 5					91		132				172			91		118							
TL 6									199		190	96		127				112			71		
TL 7					129				198		202										97	178	
TL 8					72				161														
TL 9					91				85														

Table 5. Geologic Unit Average Value as a Function of Map Line $^{214}\text{Bi}/^{40}\text{K}$ (Times 1000)

	KLA	KMC	KMCF	KATK	KT	KU	KV	KVC	KVU	KDEU	KDHT	KDOE	KDUT	KDTJ	KDTJMMES	KH	KU	KU	OR	UG	PAL	PED	PEG
ML 1	118			127	215					112			178	89		190							
ML 2				137	257							118	108	135	88	316					142	110	
ML 3					140									102		117						112	
ML 4					210					108				126		305							
ML 5										167						332							
ML 6										110		114				274							
ML 7										159		80			492	218					282		
ML 8													205		183	129		139		208			
ML 9															267								
ML10																							
ML11													256			78							
ML12				135										111		122	205						
ML13				156		155						110		201		220	188						
ML14				183		123			95			163		133									
ML15		114		234		100			123					75								142	
ML16		118	82						140														
ML17		138		156					88						136		323						
ML18		121													168	266							
ML19															151	302							
ML20		123													252								
ML21		135									267				93	233							
ML22		127					130								120	176	145						
ML23		107					106					234			117	148	255						
FL 1					216					135						344	102						
FL 2							97				192										227		
FL 3										265					109		163					129	
FL 4										108				240	165	214							
FL 5														55									
FL 6	85	115													66								
FL 7			116										172										
FL 8									125			83	107										
FL 9						89							130			70							

	PEGN	PEN	PEU	PIP	PPP	PIPM	OPP	PS	U	QAC	QAL	QC	QF	QG	QLS	QS	QT	QTR	QTS	QV	TB	TC	TD	TG	TG
ML 1	124		114	159	207				110		132		107		101		42								
ML 2			112	167	580			347	104		112		113	104			117							136	
ML 3			120	200	162	87		303	107		117	158	134	131			111							102	
ML 4			119	249				243	105		117		133				132								
ML 5			98	156					105	72	135		126		106		133								
ML 6			103	172							126		131	99			152							120	
ML 7			113	397					73		136		119	165										130	
ML 8			132	168	55				147		141		136	156										108	
ML 9			124								148		144	114										112	
ML10			124						167		122		122											96	
ML11			125		153				126		124			104										115	
ML12			142						108	125	134			137											
ML13			114						362	147	127			130	172	158			108						
ML14			113						124		143		143	110	165				142						
ML15	110		106						121	204	134		149		123	163			114						
ML16			160						102		147		146				94		145		115				
ML17			167						56		137		161						160					170	
ML18			180	233					78		144		96						164				159	155	
ML19			110	495	272						141		124			202			169			156		156	
ML20		136	176		180						154				243	136			139			131		108	
ML21		174	176		357						141		127	336		141			148			235		111	
ML22					141						123	109	131	158					123			138		136	
ML23			116	180	182	175					107		163			132			158					127	
TL 1		112	119	227							152													113	
TL 2		123	128	191					110		139		136			150			145			186		191	
TL 3	117		119		387						149														
TL 4	108		96	242							144				101				137						
TL 5			92		158				109		104		111						110	147	116				
TL 6			111						93		104							82						95	
TL 7			136						114	198	113		195	105			95							98	
TL 8			123						113		120														
TL 9			130						125		101														

	TI	TAF	TKI	TKL	TL	TLA	TLB	TM	TS	TU	TV	TVB	TVS
ML 1	126								181		101		
ML 2	81					130					102		
ML 3	94										102		
ML 4	113								133		99		
ML 5	65						115				89	108	
ML 6	116										99	93	
ML 7	115										88		
ML 8	146										117		
ML 9											92		
ML10											113		
ML11											97		
ML12	56		118								109		94
ML13			104										
ML14			101	92							125		
ML15			120	94	143						155		
ML16		117		106	148								
ML17		107		79	208								
ML18	97	108		98	172								
ML19		105		102	150								
ML20	77	99		100	110		151						
ML21		86		97						143			
ML22		81		95									
ML23	59	76	150	92	150								
IL 1			139										
IL 2			92										
IL 3	162				128				281				
IL 4	88										84		
IL 5	104										93		100
IL 6	94	86									95		
IL 7	117	104		97							97		
IL 8	35			105							98		
IL 9	150			95							98		

	CU	DQA	ENRF	ESP	EU	IPMB	IPMDU	IPMGA	IPMD	JTRU	JU	KBC	KCD	KCF	KCL	KCU	KDC	KE	KETC	KEV	KF	KH	KA	KL
ML 1			293	232	234			300		355						408				375	369		355	
ML 2			288		209			423		376						357					397		394	
ML 3			314		374	336		321		352	290					347					366		396	
ML 4			323					402		361						453					403		360	249
ML 5										415						355							471	233
ML 6			241		192					464						368							436	
ML 7					221					412						316							377	
ML 8					227					311						393							245	
ML 9					145											323								
ML 10					262																			
ML 11					273											301								
ML 12					230		224		468		274													
ML 13	213				343		246	309	374		350			297		368			278				386	
ML 14					301		343		299		364			336		330							468	
ML 15					326		403		309		366		282	334	332				333	321			413	398
ML 16												251	212					288				228		
ML 17					298				319		345	239	255	325					279				219	
ML 18					263		310		266		324	239	284									200		360
ML 19					229			306			356	210	281									212	310	304
ML 20					240						339	265										192		357
ML 21					288							216	220									192		336
ML 22					323				394		405	235				386						173	390	
ML 23					335				391		380	265	296			375						207	336	
TL 1		371			298	383					362									486				
TL 2		311			324																			
TL 3					280					303	368					396							401	256
TL 4					265			384		357	400					392							373	
TL 5					286		261				337			299			256							
TL 6									273		328	234		311					285				294	
TL 7					256				373		338											230	357	
TL 8					407				362															
TL 9					189				117															

Table 6. Geologic Unit Average Value as a Function of Map Line $^{208}\text{Tl}/^{232}\text{Th}$ (Times 1000)

	ALA	KMC	KNC	KTK	KT	KU	KV	KVC	KVO	KOE	KMT	KDOE	KDOT	KDTJ	KMTJAMES	KM	KU	KU	OB	UG	PAL	PEO	PEG
ML 1	297			282	320					215			317	262		347							366
ML 2				322	362							339	215	308	341	410					314	440	
ML 3					311									288		322						657	
ML 4					450					278				258		375							
ML 5										278						349							
ML 6										175		234				306							
ML 7										276		192			321	332				365			
ML 8														332		219	311	260		257			
ML 9															247								
ML10																							
ML11														283		214							
ML12				297											300	290	403						
ML13				318		292							230		363	293	459						
ML14				352		392			237				316		288								
ML15		245		425		219			323						282							365	
ML16		273	264						326														
ML17		259		316					289														
ML18		263													329		338						
ML19															198	345							
ML20		246													223	383							
ML21		248									407				274	349							
ML22		283				267								303	394	364							
ML23		242				231					335			338	340	402							
TL 1					402					269						318	310						
TL 2							252				357										352	375	
TL 3										238					319		331						
TL 4										273				323	340	316							
TL 5															220								
TL 6	223	222														331							
TL 7			277																				
TL 8									334			278	314										
TL 9						347							388			175							
													228										

	PEGN	PEN	PEU	PIPH	PIPH	PIPH	PS	Q	QAC	QAL	QC	QF	QG	QLS	QS	QT	QTR	QTS	QV	TB	TC	TD	TG	TG
ML 1	414		358	347	265			305		332		331		259		379								
ML 2			301	419	450		399	286		316		345	481			412							291	
ML 3			337	316	330	265	363	275		384	435	456	466			524							351	
ML 4			317	358			375	292		371		463				559								
ML 5			372	337				277	264	437		346		271		338								
ML 6			328	339						324		334	343			259							376	
ML 7			322	450				256		323		342	454										375	
ML 8			396	261	220			646		317		323	302										347	
ML 9			396							306		345	405										292	
ML10			401					344		322		371											264	
ML11			394		459			384		350			369										255	
ML12			406					290	310	321			414											
ML13			366					312	384	334			378	311	340			367						
ML14			349					346		333		357	395	243				435						
ML15	546		354					349	335	321		369		331	320			371						
ML16			390					292		312		350				267		355		282				
ML17			302					191		300		355						373					352	
ML18			315	290				270		305		330						377				344	318	
ML19			309	401	260					299		355			361			350			346		278	
ML20		263	277		253					311				355	293			334			317		230	
ML21		408	348		284					316		317	331		342			367			414		290	
ML22					279					291	252	326	283					350			347		303	
ML23			337	364	286	396				281		377			338			369					295	
TL 1		287	376	317						328													268	
TL 2		286	341	382				348		370		349			367			336			281		321	
TL 3	341		366		326					322														
TL 4	608		268	349						326				203				392						
TL 5			298		308			298		302		293						362	404	328				
TL 6			313					278		269							346						299	
TL 7			368					296	304	276		404	379			272							238	
TL 8			395					296		307					277									
TL 9			326					270		272														

	TI	TAF	TAI	TKL	TL	TLA	TLS	TM	TS	TU	TV	TVB	TVS
ML 1	288								373		254		
ML 2	229					279					279		
ML 3	246										286		
ML 4	252								274		289		
ML 5	215						275				266	256	
ML 6	277										247	326	
ML 7	262										258		
ML 8	329										268		
ML 9											234		
ML10											247		
ML11											240		
ML12	121		385								253		254
ML13			295										
ML14			262	201							334		
ML15			358	265	375								
ML16		217		266	357						324		
ML17		212		229	373								
ML18	231	209		247	328								
ML19		196		240	266								
ML20	214	200		247	269			333					
ML21		183		244						357			
ML22		178		240									
ML23	315	205	341	250	360								
TL 1			315										
TL 2			317										
TL 3	343				314				359				
TL 4	210										194		
TL 5	279										256		240
TL 6	278	194									278		
TL 7	233	232		252							264		
TL 8	220			266							223		
TL 9	238			236							199		

THE PROGRAMME GEOLST COMPLETED NORMALLY...

- (1) $\sigma_{T\ell} = \sqrt{T\ell_{\Sigma} - \overline{T\ell}_1}$; Test does not fail if $\overline{T\ell}_1 \geq 1.5 \sigma_{T\ell}$
- (2) $\sigma_{Bi} = \sqrt{Bi_{\Sigma} - \overline{Bi}_{SUR}}$; Test does not fail if $\overline{Bi}_1 \geq 1.5 \sigma_{Bi}$
- (3) $\sigma_K = \sqrt{K_{\Sigma} - \overline{K}_1}$; Test does not fail if $\overline{K}_1 \geq 1.5 \sigma_K$

Where Σ represents the total raw count in the energy interval, and subscript (1) represents results of 4π data analysis. A column set is placed onto the microfiche for the single point listings of reduced data which lists A-K-U-T as altitude (A), potassium (K), uranium (U) and thorium (T). If the statistical adequacy test does not fail; a zero (0) is inserted. If it fails, a one (1) is inserted for the K-U-T. However, for altitude (A), 0 represents data from 0-700 feet. 1 represents data from 701-1000 feet, and 2 represents data from 1001 and greater feet.

G. FREQUENCY DISTRIBUTIONS OF DATA FOR EACH GEOLOGIC TYPE

The geologic units have been the basis for separation of the six radiation variables. Frequency distribution plots, which display the number of occurrences at a specific magnitude as a function of the magnitude for each of the six radiation variables, are included for each geologic unit. Data from all map line and tie lines have been included to determine these frequency distributions in Appendix I. Table A1-1 gives a summary of the average and standard deviation values for all geologic units, (also included on all histograms in Appendix I).

H. MICROFICHE REPRODUCTION OF THE SINGLE RECORD REDUCED AND AVERAGED RECORD DATA

The output listings of the single record non-averaged reduced data and averaged record data have been reproduced on MICROFICHE and are included with the report where up to 208 computer listings may be placed on a projectable 4" x 5-3/4" transparency.

I. TEST LINES

Flight lines within the map sheet area were chosen having a length of about five miles, and were surveyed prior to and following each day's operation, conditions allowing such flights. The results of these test line surveys over the same morning and evening surface location are summarized in Appendix III.

J. ALTITUDE AND GROUND SPEED HISTOGRAMS

A histogram of the ground speed of the helicopter and its altitude are included for each map and tie line in Appendix III.

K. ANOMALOUS DATA DETERMINED FROM EXAMINATION OF PROFILE LINE DATA

An evaluation of the results of all data from flight line profiles and statistical deviation maps (NGRMS maps) is made for each line. Particular attention should be given to the eU/eTh ratio in the profile data and in the NGRMS map to detect regions of anomalous eU.

1. Analysis of Histograms

The radioactivity data is shown in histogram form with counts per second (c/s) plotted against number of events (Appendix I). The histograms for ^{208}Tl and ^{40}K were examined for conformity to a Gaussian curve. It is generally assumed that a geologic map unit, which encompasses a fairly homogeneous lithology, would have a unimodal distribution. Where map units vary significantly from a unimodal distribution, a further subdivision into more homogeneous lithologic types may be recommended. Table 7 shows the map units which vary from a unimodal model, and for which separation of two or more distributions is feasible. Only units with excess of 200 events are considered.

2. Interpretation of Radioactivity Data

Introduction

The ^{208}Tl , ^{214}Bi , and $^{214}\text{Bi}/^{208}\text{Tl}$ (ratio) data were examined for anomalous values. An anomaly is defined by a minimum of two adjacent, two-standard deviation values, or a single, three-standard deviation value. The anomalies were listed by flight line in Table 8; by geologic map unit in Table 9; Table 9 is statistically summarized in Table 10. Only positive anomalies were examined for ^{208}Tl and ^{214}Bi , but both positive and negative values were studied for the ratio anomaly.

The Relationship of The Radioactivity Anomalies to the Geologic Map Units

Quaternary and Quaternary-Tertiary Geologic Map Units: Qal;Qc;Qf;Qls;Qs;Qt;Qg;Q;Qv;QTs

^{208}Tl

Five Quaternary-aged units and one Quaternary-Tertiary-aged unit contain almost 20% of the ^{208}Tl anomalies. The Qal, Q and QTs units have most of these anomalies. It appears that the ^{208}Tl anomalies are almost exclusively in sedimentary rocks which are either poorly consolidated or unconsolidated. Very few of the ^{208}Tl anomalies coincide with ^{214}Bi anomalies, and none coincide with "negative" $^{214}\text{Bi}/^{208}\text{Tl}$ anomalies. Most of the anomalies are the result of changes of lithotypes within the geologic map units. It is possible that some are monazite-bearing placer deposits. Very large ^{208}Tl anomalies are recorded for Quaternary units at ML3W, stations 6820-6925 (Qf); ML4W, stations 15,100-15,145 (Qal); ML4W, stations 15,180-15,315 (Qf); ML5W, stations 11,375-11,500 (Qal); ML5W, stations 13,855-13,900 (Qal); and TL2S, stations 7,145-7,170 (Qal).

^{214}Bi and $^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

Seven Quaternary-aged units and one Quaternary-Tertiary-aged unit have approximately 22% of the ^{214}Bi and 18% of the $^{214}\text{Bi}/^{208}\text{Tl}$ anomalies. Most of the two sets of anomalies are in the Qal, Qf, Q and QTs units. The Qal and Qf units have particularly high numbers of ratio

TABLE 7. GEOLOGIC UNITS WITH SIGNIFICANT VARIATIONS FROM UNIMODAL DISTRIBUTIONS, BASED ON THE ANALYSIS OF THE ^{208}Tl HISTOGRAMS

<u>Map Unit -</u>	<u>No. Events</u>	<u>Recommended Split ^{208}Tlc/s</u>
<u>Quaternary</u>		
Qac	314	30
Qls	307	no
Qs	357	45
Qt	359	no
Qg	805	no
<u>Tertiary</u>		
Tg	2,192	no
Tc	457	no
Tl	850	no
Tv	11,358	no
Ti	2,210	no
<u>Tertiary-Mesozoic</u>		
TKi	2,050	no
<u>Mesozoic</u>		
Kbc	463	no
Kmc	601	no
Kvu	494	no
Ketc	470	no
Kf	368	no
Kco	2,852	no
Kl	421	no
Ju	994	no
JTru	1,011	no
<u>Paleozoic</u>		
P1PMp	542	no
P1PMu	230	no
1PMqa	246	no
1PMu	823	no
1PMDOu	211	40
Mm	1,187	no
Mu	355	22
MDtjm	618	no
MDOt	293	no
MDGu	234	no
Gu	1,918	no
<u>Precambrian</u>		
P6n	291	no
P6g	363	no
P6gn	272	no
P6u	19,332	no

TABLE 8. Summary of Anomalies

	^{208}Tl	^{214}Bi	$^{214}\text{Bi}/^{208}\text{Tl}$
ML1E	p6u,3895-3900,3920;Q, 3905-3910;	Q,3910-3915;	Tv,3470-3475;
ML1W	P1PMp,11835-11850;JTru, 11875-11885;Ts,13625- 13635;	Qf,13165-13170;	Kco,11730-11740,11750; p6gn,12880;
ML2E	Tv,14490-14495,14715- 14735,14820-14835,14930- 14940;	p6u,14535-14540;Qv, 14490-14505;	Tv,15280;
ML2W	Kf,7990-8005;*Qg,8750- 8780;Kco,9310,9315-9325, 9360-9375;Kk,9350-9360; JTru,9420-9430;	Kf,7990-8010;p6g,8975- 8985;Kco,9320-9325;JTru, 9425;Mm,9440-9445;	Qf,8450;JTru,9055-9060;
ML3E	Tv,17080-17040,17150- 17160;		Tv,16640;p6u,17710-17715, 17730;
ML3W	Mu,4540-4550;Pp,4580- 4590;JTru,5870-5890;Kco, 6070-6090;*Tv,6130-6165; Qg,6685-6690;p6g,6720- 6755;*Qf,6820-6925;6mwf, 7230-7235;	Mu,4545-4555;JTru,5885- 5890;Kco,6025-6035;Tv, 6155-6165;Kk,6540-6545; Qg,6690;Qf,6815-6820, 6835-6845,6860,6900;	JTru,5820-5825,5840;Kco, 6460,6560-6575;Kk,6545-6555; [Qc,7375-7380;]
ML4E	*Tv,3015-3050,3180-3205, *3230-3265,3320-3355;	Tv,3025-3030;Q,3050- 3055,3105-3110,3200- 3205,3220-3225;Tv,3240- 3250,3340-3345,3375- 3390;	Q,3740-3750;
ML4W	*Qa1,15100-15145;*Qf, 15180-15315;Tv,16385- 16390;	Qf,15265-15275,15290- 15300,15310-15315;	P1PMp,15950,16010;
ML5E		Qa1,6535-6545;	p6u,5040;Tv,5100-5110; [Tv,6020-6025;]
ML5W	*Qa1,11375-11500;*Tv, 11500-11680;*Qa1,13855- 13900;Tvb,14210;Kk,13285- 13300;		Qa1,11395-11400;
ML6E	Tv,6690-6710;Ti,7030, 7060-7065,7100-7140, 7160-7170;	Ti,7040-7065,7080,7185- 7195;	Tv,7565,7720-7725;MD06u, 7870;

(Table 8 Cont'd.)

	^{208}Tl	^{214}Bi	$^{214}\text{Bi}/^{208}\text{Tl}$
ML6W	Kco, 10510-10515; Ti, 10525-10550, 10555-10570;	pGu, 9340-9345; Ti, 10535-10545, 10550-10555;	pGu, 10725; Pa1, 9925-9945;
ML7E	Tv, 9400-9410, *10230-10260, 10305-10310, 10550-10575;	pGu, 9075-9085, 9180-9190 Tv, 10250-10290, 10355, 10385;	Tv, 9645-9655, 9680; Gu, 9815-9820; pGu, 10035-10070;
ML7W	Tv, 8845-8855;		pGu, 7350; JTru, 7510-7520; Mes, 8305-8320;
ML8E	Tg, 10810-10835; pGu, 11920-11940, 11955-12060, 12160-12180; Q, 11945-11955;	Q, 11945-11950; pGu, 11970-11990, 12010-12040, 12055-12075, 12125-12130, 12155-12160, 12260-12265, 12300-12305;	pGu, 11215-11220, 11235-11245, 11265, 11280-11305; MDtj, 11385; Tv, 11645-11650;
ML8W		Tv, 3700, 5860;	Kco, 4400-4405, 4420, 4430, 4645; pGu, 4830-4840, 5070, 5130, 5260-5290; Tv, 5230-5240, 5540-5550, 5585, 5730;
ML9E	pGu, 13070-13180, *13205-13280;	pGu, 13065, *13075-13145, *13150-13190, *13210-13245, 13670-13675;	
ML9W	pGu, 3255-3260, 3375-3380;	Tv, 585-590; Qa1, 2890-2895;	Tv, 580-590, 1350; pGu, 1680-1700, 1760, 1900, 2315-2320, 2335; Qa1, 2820-2830;
ML10E	Q, 5645-5660; Qa1, 6435-6440;	pGu, 5650-5660, 5745-5750, 6155-6160;	pGu, 5130-5135, 5150-5160, 5230, 6240; Q, 5310, 5490;
ML10W	*pGu, 20760-20815, *21270-21315, 21420-21425, 21680-21700;	pGu, 21890, 21950; Tv, 22870-22885, 22915;	Qa1, 21125-21130; Mm, 22260-22270; Tv, 22530, 22790-22795;
ML11E	pGu, 4150-4155;	pGu, 4110; Qa1, 3665-3670;	Q, 4575, 4610, 4670-4675, 4800; pGu, 4640, 4735, 4770, 4815-4820, 4920, 4945;
ML11W	pGu, 19370-19375; Q, 19775-19780;	Tv, 18150, 18210;	Tv, 17530-17545, 18120, 18150, 18210;
ML12E	1PMu, 2635-2660;		Mm, 2115; pGu, 2175-2195, 2225-2250, 2260-2270, 2310, 2345-2350, 2415-2435, 2510-2515, 2530;
ML12W			Tki, 14650, 14675; Qa1, 14730-14745, 14795-14800; pGu, 16095-16100, 16115-16120; Tv, 16820-16835, 16955;

(Table 8 Cont'd.)

^{208}Tl	^{214}Bi	$^{214}\text{Bi}/^{208}\text{Tl}$
ML13E Kk,1275-1280;		1PMu,1030,1490,1540;Ku, 1755-1780;
ML13W pGu,13080-13105;QTs, 13835-13845;		Ju,11835,12230-12240;1PMDOu, 12325-12345;MDtjm,13365;Tki, 14130-14135;
ML14E		
ML14C	Ketc,11395-11400	
ML14CE		Q1s,23315-23320;
ML14CW		Ju,11185-11200;1PMDOu,11115; Qt,10820-10840;
ML14W pGgn,10410-10430;pGu, 10355-10360;		pGgn,10415-10420;TKi,9115- 9120,9130-9135,9145-9150;
ML15E K1,16340-16350;		
ML15W QTs,7595-7615,8080-8095; TKi,8725-8740;		Q1s,6055-6060;1Pmu,6820-6835; Kmtk,6905; QTs,7585-7590;
ML16E		TK1,17180-17185,17470-17475;
ML16W	pGu,3645-3650;T1, 4545-4550;Qa1,3735- 3750;Tkf,5720-5725, 5790;	Tkf,5605,5710-5715,5735, 5775;Qa1,3745-3750,4855;
ML17E	TK1,18230-18235;	
ML17W Kh,480-490,500;Qa1, 2460-2480;	TKf,545-555,620-625, 1050;Kh,1270-1275;Kmc, 1345-1360;T1,2410-2420 2430-2435;Qa1,2450- 2460,2475-2495;QTs, 2525-2530,2690-2700;	Tkf,1050-1060;Kh,1265-1280; Kcd,1350-1355;QTs,2225-2235, 2690-2700;pGu,2800-2820, 2865,3360-3365;Mu,3060-3065, 3085;Qa1,3350;
ML18E		TK1,18940-18945;
ML18W	TKf,405-410;Qc,1245; QTs,2210;T1,2300-2305; 1PMDOu,3015-3020;	Tkf,405-410,785;K1,1230-1240; 1PMu,1350,1360-1375;MDtjm, 1400;Gu,1410-1415,2760-2765; pGu,1425,2790-2800;Qf,1485, 1495;Mm,3190-3195;Qa1,3200;
ML19E		

(Table 8 Cont'd.)

	^{208}Tl	^{214}Bi	$^{214}\text{Bi}/^{208}\text{Tl}$
ML19W		Gu, 3320-3325; Mm, 3380-3385, 3670-3680; Qa1, 3905-3915; TK1, 5855-5860;	Mm, 3350-3360; Kv, 3420-3425; P1PMp, 3625-3640, 3655-3670; QTs, 3805-3810; Qa1, 3820-3825, 3885-3890; Qs, 4030-4035; [Qf, 5050-5055]; K1, 5280-5290; Tkf, 5530; TK1, 5745, 5850-5855, 5895, 5905-5910;
ML20E		TK1, 6800-6805;	TK1, 7450;
ML20W		Qa1, 8130-8135;	Ju, 6830; Gu, 6910-6925; pGu, 6940-6950; Qa1, 7330, 7375-7380; pGn, 8605;
ML21E		TK1, 8825;	
ML21W	Tg, 9185-9195;	pGn, 9000-9010;	MDtjm, 10805-10810; P1PMu, 10830-10835; Qg, 10850-10895; Tkf, 11095-11100; [Tkf, 11055-11060;] TK1, 11395-11400, 11410;
ML22E			
ML22W	Kbc, 12085-12095; Mm, 12790-12795; Kk, 12880-12885, 13025-13045; Kv, 14175-14190;	Kk, 12910-12915; Tc, 13525; Kv, 13780-13795;	Qg, 12305-12325; Kv, 13790-13795;
ML23E	TK1, 10805, 11335-11365;	TK1, 10665;	[TK1, 11110-11120, 11345-11350;]
ML23W	Q1s, 14805; Gu, 15255-15260, 15405-15420;	Ju, 14545-14550; Q1s, 14800-14805; Gu, 15240-15250, 15260-15265; Tg, 15325;	Tg, 14265-14275, 14530-14535; Kk, 14560-14565; Qf, 14870-14875; Gu, 15955;
TL1	Kf, 11420-11425;		Tg, 8305-8310; [pGu, 9160-9165;] pGu, 9230, MDGu, 10865-10875; Mm, 11000-11015, 11235-11255; 1PMb, 11270, 11280-11290; Tki, 9955-9975; 10060;
TL2N	MDmt, 3870-3875;	QTs, 3485-3500; Tg, 3510-3530;	Tc, 3500-3505; Tg, 3510-3515; Gu, 3690; Mmi, 3835; QTs, 3895-3900;
TL2S	Qa1, 7145-7170;		pGd, 7020;
TL3N	Ju, 3155-3160;	T1, 2490-2495; Ju, 3155-3160;	Qa1, 3045;

(Table 8 Cont'd.)

	^{208}Tl	^{214}Bi	$^{214}\text{Bi}/^{208}\text{Tl}$
TL3S	p6u, 5400-5420; 5500;		Kco, 5535; Ts, 6160; Kk, 6310-6340; P1PMu, 6410-6415, 6450; MD6u, 6450, 6460, 6470; p6g, 6500-6525, 6535;
TL4N			Qa1, 1620-1630, 1715-1720;
TL4S	JTru, 2775-2780, 2800-2805; QTs, 4365, 4405;	JTru, 2780-2785;	p6u, 3750; [Qa1, 4250-4255;]
TL5N			
TL5S	Tv, 2055-2070		P1PMu, 890-895, 900, 920-930; Tv, 1305; [Tv, 2280-2300;]
TL6N			
TL6S	Tv, 18360-18365;	Tv, 18440-18445;	
TL7N	TK1, 13240-13245;	TK1, 12870-12875;	
TL7S	Tv, 2105-2115, 2130-2135, 2215-2220, 2305-2310; Q, 2350-2355;	Tv, 2105-2120, 2215, 2255-2260, 2280-2290, 2345-2350;	Q1s, 465-470, 520-525; Ti, 1565-1570; Tv, 1835, 1895;
TL8N		TK1, 11840;	TK1, 11835;
TL8S	Q, 770; p6u, 1735-1750, 1760-1765; MD06u, 1920-1930;	TK1, 475-485; p6u, 1585-1595, 1745-1750, 1760;	[TK1, 385-400;]TK1, 475-480, 495; [1PMu, 935-950;]Tv, 2255, 2360; Q, 2615, 2725;
TL9E		p6u, 11450-11460, 12145-12150;	MD0t, 10900-10905; Q, 10935, 10990-10995, 12240-12245, 12280-12290; Tv, 11355-11360; p6u, 12145-12165, 12270-12275, 12300-12350; Q, 12360-12370; Mm, 12465-12500; TK1, 12745, 12825, 12940-12945;

* denotes large anomalies

[....] denotes negative ratio anomaly.

TABLE 9. Radioactivity Anomalies Per Geologic Map Unit

<u>Unit</u>	<u>^{208}Tl</u>	<u>^{214}Bi</u>	<u>$^{214}\text{Bi}/^{208}\text{Tl}$</u>	
<u>Quaternary</u>				
Qa1	6	8	16	[1]
Qc		1		[1]
Qf	2	8	4	[1]
Qls	1	1	4	
Qs			1	
Qt			1	
Qg	2	1	2	
Q	6	6	14	
Qv		1		
<u>Quaternary-Tertiary</u>				
QTs	5	4	4	[1]
<u>Tertiary</u>				
Tg	2	2	4	
Tc		1	1	
Ts	1		1	
Tl		5		
Tvb	1			
Tv	25	21	28	[2]
Ti	6	7	2	
<u>Tertiary-Cretaceous</u>				
TKi		1	7	
TKl	3	8	16	[3]
TKf		6	9	[1]
<u>Mesozoic-Cretaceous</u>				
Kv	1	1	2	
Kh	2	1	1	
Kbe	1			
Kmc		1		
Kcd			1	
Ketc		1		
Kf	3			
Kco	5	2	9	
Kk	5	2	3	
Kmtk			1	
Kl	1		2	
Ku			1	
<u>Jurassic</u>				
Ju	1	2	4	
<u>Jurassic-Triassic</u>				
JTru	5	3	4	

(Table 9. Cont'd.)

	<u>^{208}Tl</u>	<u>^{214}Bi</u>	<u>$^{214}\text{Bi}/^{208}\text{Tl}$</u>	
<u>Undivided</u>				
Mes			1	
<u>Paleozoic</u>				
Pp	1			
P1Pmp	1		4	
P1Pmu			6	
1PMu	1		6	[1]
1PMDOu		1	2	
Mm	1	3	7	
Mu	1	1	2	
Mmi			1	
MDmt	1			
MDtj			1	
MDtjm			1	
MDOt			1	
MDtu			4	
MDOGu	1		1	
Gmwf	1			
Gu	2	3	6	
Pal			1	
<u>Precambrian</u>				
pGn		1	1	
pGg	1	1	2	
pGgn	1		1	[1]
pGd			1	
pGu	21	28	51	[1]

[.....] Denotes negative ratio anomaly

TABLE 10. Statistical Summary of Radioactivity Anomalies by Geologic Unit

	<u>^{208}Tl</u>	<u>^{214}Bi</u>	<u>$^{214}\text{Bi}/^{208}\text{Tl}$</u>	
<u>Quaternary</u>				
No. of Units w/Anomalies	5	7	7	3
No. of Anomalies	17	26	42	3
<u>Quaternary-Tertiary</u>				
No. of Units w/Anomalies	1	1	1	1
No. of Anomalies	5	4	4	1
<u>Tertiary</u>				
No. of Units w/Anomalies	5	5	5	1
No. of Anomalies	35	36	36	2
<u>Tertiary-Mesozoic(Cretaceous)</u>				
No. of Units w/Anomalies	1	3	3	2
No. of Anomalies	3	15	32	4
<u>Mesozoic</u>				
No. of Units w/Anomalies	9	8	11	
No. of Anomalies	24	13	29	
<u>Paleozoic</u>				
No. of Units w/Anomalies	9	4	14	1
No. of anomalies	10	8	45	1
<u>Precambrian</u>				
No. of Units w/Anomalies	3	3	5	2
No. of Anomalies	23	30	56	2
<u>Total Sample</u>				
No. of Units w/Anomalies	33	32	47	10
No. of Anomalies	117	132	246	13

anomalies. ^{214}Bi anomalies coincide with ratio anomalies at the following locations: ML16W, stations 3735-3750 (Qa1) ML17W, stations 2690-2700 (Qts). These are the most likely loci for uranium concentration through uranyl ions precipitating from either ground or near-surface aqueous solutions. Carbonaceous material can produce the necessary "reducing" environment to facilitate precipitation and/or adsorption of the ions. A relatively large ^{214}Bi anomaly occurs on TL2S, stations 7145-7170, but no ratio anomaly coincides with this location.

Tertiary Geologic Map Units: Tg;Tc;Ts;Tl;Tvb;Tv;Ti;

^{208}Tl Anomalies

Five Tertiary-aged units have approximately 30% of the total ^{208}Tl anomalies. Most of the 30% is in the Tv and Ti units. The Tv unit includes volcanic flows and associated pyroclastic rocks consisting of andesite, basalt, rhyolite, dacite and other extrusive lithologies. The Ti rocks are mainly granitic, but other lithologies were also intruded. Many hydrothermal veins were formed in or peripheral to the igneous rocks. Many of the ^{208}Tl anomalies coincide with ^{214}Bi anomalies and are thought to reflect intra-unit changes in background radioactivity, due to lithology changes within a map unit. Some of the ^{208}Tl anomalies may be related to vein formations. The ^{208}Tl anomalies on ML3W, stations 6130-6165; ML4E, stations 3015-3050, 3230-3265; ML5W, stations 11,500-11,680; ML7E, stations 10,230-10,260 are large anomalies.

^{214}Bi and $^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

Five Tertiary-aged units have approximately 27% of the ^{214}Bi anomalies and 14% of the ratio anomalies. Most of the ^{214}Bi anomalies occur in the Tv unit, with minor concentrations in the Tl and Ti; most of the ratio anomalies occur in the Tv unit, with a minor concentration in the Tg unit. Four ^{214}Bi anomalies coincide with ratio anomalies on: ML9W, stations 585-590 (Tv); ML11W, station 18,150 (Tv) and 18,210 (Tv); and TL2N, stations 3510-3530 (Tg). These locations are potential areas for uranium concentration. Many of the other anomalies reflect changes in lithology, within a particular unit. The anomalies associated with the igneous rocks may be formed by hydrothermal vein solutions in the vicinity of fractures and faults of the host rock.

Tertiary-Mesozoic Geologic Map Units: TKi,TKl;TKf

^{208}Tl Anomalies

Only one Tertiary-Mesozoic unit has ^{208}Tl anomalies; this is the unit TKl. It is such a conglomerate of varied formations that the ^{208}Tl anomalies are not easily interpreted.

^{214}Bi and $^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

Three Tertiary-Mesozoic units have approximately 11% of the ^{214}Bi anomalies and 15% of the ratio anomalies. The TKl unit has the greatest number of anomalies, but they are not easily interpreted. Only one of the TKf ^{214}Bi anomalies coincides with a ratio anomaly. This occurs on ML18W, stations 405-410, and may be significant, as much of the material in the Fort Union Formation is derived from volcanic sources.

Mesozoic Geologic Map Units: Kv;Kh;Kbc;Kmc;Kcd;Ketc;Kf;Kco;Kk;Kmtk;Kl;Ku;Ju;JTru;Mes

^{208}Tl Anomalies

Nine Mesozoic units contain approximately 20% of the total ^{208}Tl anomalies. Most of the anomalies are in the units Kf, Kco, Kk and JTru. Many of these anomalies, particularly those of the Kco and JTru units, are associated with intra-unit changes in lithology.

^{214}Bi and $^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

The Mesozoic-aged units have 10% and 11%, respectively, of the ^{214}Bi and ratio anomalies. Most of the anomalies are in the Kco, Kk, Ju and JTru units and many of these anomalies reflect the effect of litho-changes within these map units. The better prospects for uranium ore concentration are where the ^{214}Bi anomalies coincide with the ratio anomalies. These coincidences occur on ML3W, station 6545 (Kk); ML17W, stations 1265-1280 (Kh); ML17W, stations 1350-1355 (Kcd); ML22W, stations 13,790-13,795 (Kv).

Paleozoic Geologic Map Units: Pp;PlPmp;PlPmu;lPmu;lPMDOu;Mm;Mu;Mmi;MDmt;MDtj;MDtjm;MDOt;MDGu;MDOGu;Gmwf;Gu;PaI

^{208}Tl Anomalies

Table 10 shows that nine Paleozoic-aged units have approximately eight percent of the total ^{208}Tl anomalies. Many of the units contain more than one geological formation and all have several litho-changes contained within their areas. The possibility of ancient placer deposits, which are rich in monazite, or vein-deposits intruded into the Paleozoic host rocks, cannot be discounted as potential explanations for some of these anomalies.

^{214}Bi and $^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

Only four of the Paleozoic units have ^{214}Bi anomalies. These are lPMDOu, Mm, Mu and Gu. All of these units are comprised of more than one formation and a number of lithologies. None of the ^{214}Bi anomalies coincide with ratio anomalies, and are not considered to be important.

On the other hand, 14 of the Paleozoic units have approximately 18 percent of the ratio anomalies. The anomalies are mainly concentrated in the units PlPmp; PlPmu, lPmu, Mm, MDGu and Gu; all of these units contain more than one formation and many changes of lithology. Most of the ratio anomalies are considered to be due to changes of lithology within a particular geologic map unit. However, supergenic or epigenic concentration and precipitation of uranyl ions might be the reason for some of the anomalies.

Precambrian Geologic Map Units: PEn,PGg,PGgn,PGd,PGu

^{208}Tl Anomalies

The great majority of the ^{208}Tl anomalies in the Precambrian rocks occur in unit pGu which has approximately 18 percent of the total ^{208}Tl anomalies. The pGu unit contains many different lithologies, which might account for most of the radiometric anomalies; on the other hand, many veins, some pegmatites and possibly some old placer deposits, occur within the pGu rock types and could be potential thorium concentrations.

^{214}Bi and $^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

Approximately 22 percent of both the ^{214}Bi and ratio anomalies occur in the Precambrian units, mostly in the pGu unit. Uranium deposits are known to occur within some of the Precambrian rocks in the Absaroka Range. However, only the ^{214}Bi anomaly on TL9, stations 12,145-12,150 coincides with a ratio anomaly. Many of the anomalies are the result of litho-changes within the pGu unit, which is a "catch-all" unit for the Precambrian.

Relationship of Radioactivity Anomalies to Known Uranium Occurrences

^{208}Tl Anomalies

The large ^{208}Tl anomaly on ML10W, stations 21,265-21,315 is very near the location of a known thorium deposit in the Madison Range, to the east of Ennis Lake. Weis (1963) mapped the thorium concentration as occurring in an ancient placer deposit. The ^{208}Tl anomaly occurs in a pGu unit. The other known locations of thorium deposits within the Bozeman Map area do not coincide with the locations of ^{208}Tl anomalies.

^{214}Bi and $^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

Two ratio anomalies on ML5E, station 5040 (pGu) and ML5E, stations 5100-5110 (Tv) are in the general vicinity of known uranium mineralization in the Absaroka Range (Jarrard, 1957). Jarrard (1957) reported that the uranium concentrations were associated with pegmatite exposures in granitic host rocks. However, none of ^{214}Bi anomalies coincide with ratio anomalies in this part of the Absaroka Range.

A ^{214}Bi anomaly on TL2N, stations 3430-3450 is close to a uranium prospect in the Shoddy Creek area (Jarrard, 1957). The ^{214}Bi anomaly does not coincide with a ratio anomaly, and is mapped in a QTs unit; however, the uranium prospect is believed to occur in the Climbing Arrow Formation of the Bozeman Group. There are several ^{214}Bi and ratio anomalies in this general area which are worthy of further, more detailed, investigation.

Relationship of Radioactivity Anomalies to Cultural Features

^{208}Tl Anomalies

There does not appear to be any significant relationship between the sparsely scattered cultural features, such as ranches,

towns, roads, railroads and mine tailings, and the locations of ^{208}Tl anomalies.

^{214}Bi Anomalies

Very few coincidences of ^{214}Bi anomalies with cultural features exist for the Bozeman Map Sheet area. Where anomalies are close to mapped cultural features (NTMS, 1958), the anomalies are small; e.g., ML6E, stations 7120-7165, which are in the vicinity of mine tailings.

$^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

Several small ratio anomalies lie close to mines or mine tailings; otherwise, there appears to be little or no relationship between cultural features and $^{214}\text{Bi}/^{208}\text{Tl}$ anomalies.

Trends

^{208}Tl Anomalies

The ^{208}Tl anomalies are not evenly distributed throughout the map sheet area. They form clusters, which are confined to the central, southwestern and southeastern portions of the area. In the southwest two clusters occur; one is in the Madison River Valley, where some extensive anomalies occur in the Quaternary units. The other cluster is in the southern part of the Gallatin Range, where a variety of Paleozoic, Mesozoic, and Tertiary units crop-out. Two clusters occur in the southeast; both are in the Absaroka Range, where the dominant unit is p6u. In the central part of the map sheet area, two clusters exist. One is in the Ruby Mountain area, where Precambrian, Cambrian, Tertiary and Quaternary rocks crop-out; the second is on the northeastern-flanks of the Madison Range; here, the predominant unit is p6u.

^{214}Bi Anomalies

The ^{214}Bi anomalies have an uneven distribution throughout the map sheet area. Several clusters exist. Two small clusters occur in the southwest, one in the eastern part of the Madison River Valley and the neighboring Madison Range; the other is in the southernmost part of the Gallatin Range, in the vicinity of the Lincoln and Cinnamon mountains. In the southeast, two groups occur in the Absaroka Range. The first is in, and to the south of, the Snow Mountains, where many Tertiary-aged volcanic and intrusive rocks occur; the second is in the vicinity of the West Boulder Plateau and is mainly in the p6u unit. In the northeast, a small cluster occurs in the Quaternary sediments of Madison River Valley, and another exists in the Cretaceous to Quaternary units to the northwest of the town of Three Forks.

$^{214}\text{Bi}/^{208}\text{Tl}$ Anomalies

The ratio anomalies are more plentiful and more evenly distributed throughout the map sheet region than are the ^{208}Tl or ^{214}Bi anomalies. However, three areas of greater than average concentration of anomalies do occur. One is in the East Boulder Plateau area of the Absaroka

Range; the second is in the Bridger Range; the third is in the northwestern corner of the map sheet, in the London Hills and Jefferson River area. Each of the three areas have a variety of lithologies and chronological units.

3. Summary and Recommendations

The ratio anomalies are approximately twice as abundant as the ^{208}Tl and ^{214}Bi anomalies. The majority of the anomalies occur in the Quaternary, Tertiary and Precambrian geologic map units. The units Qal, Q, Tv, TKl, and pGu have the greatest aggregates; these units, with the exception of Qal, have a number of formations and/or lithologic types contained within them. Many of the anomalies are thought to be associated with changes in background radiation due to lithology changes. On the other hand, many hydrothermal veins transect the Tv and pGu units; thorium and uranium concentrations, in some places, may be related to the hydrothermal veins.

The ^{208}Tl data has a number of extensive anomalies. Many of these occur in the Quaternary sediments and in the Precambrian metasedimentaries and Belt Series. The large anomalies in the sedimentary rocks are of interest, in view of the fact that placer deposits rich in monazite are prime sources of thorium concentration. Ancient placer deposits are known to occur in the Precambrian units. An ancient placer deposit in the Madison Range to the east of Lake Ennis is very close to a ^{208}Tl anomaly on ML10W, stations 21,265-21,315.

With the exception of several ^{214}Bi anomalies on ML9E, the ^{214}Bi anomalies tend not to be as large as the more extensive of the ^{208}Tl anomalies. Many of the ^{214}Bi anomalies coincide geographically with ^{208}Tl anomalies. This suggests that these anomalies reflect the changes in background radioactivity due to changes in lithology within a map unit. Relatively few ^{214}Bi anomalies coincide with ratio anomalies. However, it is the loci where ^{214}Bi anomalies do coincide with $^{214}\text{Bi}/^{208}\text{Tl}$ anomalies that are the most likely locations of uranium ion concentration and precipitation. The two ratio anomalies which are in the general vicinity of an area of known uranium mineralization in the Absaroka Range do not coincide with ^{214}Bi anomalies.

APPENDIX I

FREQUENCY DISTRIBUTION OF RADIATION DATA

AS A FUNCTION OF GEOLOGIC UNIT

TA		BI		K		BI/TA		BI/K		TA/K		NO. EVENTS	GEOL. UNIT
σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$		
9.0676	22.0	6.3254	10.7	17.1775	99.8	0.1745	0.4480	0.0545	0.1010	0.0661	0.2130	10.0	.CU
7.7947	35.3	3.6602	16.6	20.7303	101.7	0.0817	0.4803	0.0347	0.1668	0.0513	0.3492	63.0	.DJM
17.5753	40.5	3.3280	12.6	54.8630	140.2	0.1416	0.3523	0.0399	0.1006	0.0487	0.2897	87.0	.EMHF
1.0073	11.8	1.2910	6.5	6.9940	50.8	0.0772	0.5625	0.0153	0.1300	0.0450	0.2325	4.0	.ESP
13.4689	34.1	5.3889	14.8	50.2137	126.2	0.2076	0.4752	0.0535	0.1281	0.0767	0.2801	1918.0	.EU
13.6218	34.1	6.2340	17.8	31.6080	91.9	0.4960	0.6263	0.1349	0.2212	0.0574	0.3676	263.0	.IPHM
16.2792	39.5	4.9275	15.0	31.5565	109.1	0.1751	0.4316	0.0513	0.1445	0.0849	0.3518	211.0	.IPMDU
17.3644	28.5	5.2673	16.1	44.8355	79.2	0.2992	0.6767	0.0972	0.2345	0.0685	0.3569	246.0	.IPMGA
12.6722	22.2	3.9171	14.7	29.5614	72.7	0.2895	0.7602	0.0851	0.2253	0.0901	0.3109	823.0	.IPMU
12.3101	32.2	4.2248	15.8	35.1975	91.7	0.2702	0.5599	0.0998	0.1998	0.0735	0.3602	1011.0	.JTRU
10.5710	25.8	5.0950	15.3	29.9325	74.0	0.3014	0.6603	0.1049	0.2301	0.0672	0.3531	994.0	.JU
4.6444	30.3	3.9332	15.0	19.3677	127.0	0.1639	0.5098	0.0421	0.1223	0.0407	0.2419	541.0	.KMC
5.3113	30.5	3.1254	13.8	23.2359	114.7	0.1215	0.4652	0.0347	0.1249	0.0536	0.2722	326.0	.KCU
6.3536	34.0	3.5574	15.2	19.3890	109.2	0.1218	0.4587	0.0428	0.1438	0.0434	0.3136	492.0	.KCF
5.2620	35.1	1.6330	10.2	6.0324	105.0	0.0487	0.2942	0.0143	0.0971	0.0324	0.3329	24.0	.KCL
12.0443	40.1	4.9468	17.8	30.8131	111.0	0.2181	0.4749	0.0771	0.1732	0.0800	0.3683	2982.0	.KCU
4.9678	25.1	1.9954	11.4	23.7217	103.6	0.0957	0.4659	0.0441	0.1181	0.0824	0.2567	27.0	.KUC
3.4136	35.1	3.4663	16.5	12.8284	113.4	0.0951	0.4724	0.0266	0.1459	0.0352	0.3124	34.0	.KE
5.6980	32.3	3.6973	14.7	25.9804	108.5	0.1419	0.4701	0.0568	0.1458	0.0532	0.3062	470.0	.KETC
23.5997	63.5	3.2358	18.4	44.2242	164.8	0.0995	0.3218	0.0240	0.1161	0.0526	0.3752	33.0	.KEV
14.4058	40.7	6.4762	18.4	30.5677	104.2	0.1228	0.4654	0.0445	0.1783	0.0573	0.3889	368.0	.KF
4.3915	30.3	4.1571	14.4	17.4826	145.4	0.1549	0.4837	0.0330	0.1008	0.0288	0.2098	411.0	.KH
11.5073	35.7	4.7356	17.7	30.6593	90.8	0.2213	0.5344	0.0916	0.2148	0.0980	0.4073	1558.0	.KK
5.5043	28.4	3.5346	14.5	32.7416	99.2	0.1839	0.5302	0.0760	0.1650	0.0868	0.3079	421.0	.KL
7.8522	36.2	4.0328	15.2	15.1470	140.3	0.1238	0.4083	0.0411	0.1112	0.0576	0.2736	146.0	.KLA
5.9345	31.4	3.4792	14.4	28.5892	128.9	0.1089	0.4660	0.0327	0.1157	0.0523	0.2508	601.0	.KMC
4.9307	41.3	3.4726	15.8	12.2930	152.1	0.0689	0.3809	0.0239	0.1030	0.0276	0.2722	23.0	.KMCF
6.5976	31.3	3.2467	14.8	25.0685	98.1	0.1305	0.4891	0.0517	0.1600	0.0610	0.3281	494.0	.KMTK
8.3974	34.6	3.9022	18.7	29.8122	94.3	0.1220	0.5579	0.0559	0.2101	0.0524	0.3763	68.0	.KT
12.9759	32.1	3.5979	13.6	33.3094	112.9	0.1779	0.4791	0.0505	0.1330	0.0998	0.2932	174.0	.KU
13.6730	43.5	8.8074	19.5	40.9808	178.7	0.1427	0.4518	0.0520	0.1118	0.0637	0.2456	362.0	.KV
4.9952	35.9	2.6980	13.8	12.8620	113.6	0.0838	0.3895	0.0274	0.1230	0.0424	0.3185	494.0	.KVV
16.1065	30.1	4.4683	15.7	60.9866	119.2	0.3106	0.5529	0.1099	0.1444	0.0703	0.2593	234.0	.MDEU
9.6167	26.8	3.9264	15.3	24.4856	73.1	0.1763	0.6159	0.0720	0.2268	0.0573	0.3689	116.0	.MDMT
16.6162	34.0	4.3771	13.4	42.7453	158.1	0.1394	0.3970	0.0307	0.0878	0.0984	0.2466	174.0	.MDUEU
7.6690	21.4	3.4363	10.8	30.3980	79.0	0.1645	0.5336	0.0532	0.1484	0.0736	0.2845	293.0	.MDUT
7.0432	19.7	4.1089	9.9	25.1232	67.9	0.2531	0.5520	0.0890	0.1669	0.0578	0.2989	132.0	.MDTJ
12.0635	35.7	4.0226	13.3	44.1807	120.7	0.2150	0.4169	0.0549	0.1216	0.0646	0.3016	618.0	.MDTJH
22.5506	40.7	4.1854	12.7	64.9985	142.6	0.6059	0.5164	0.1651	0.1524	0.0569	0.3208	100.0	.MES
10.4723	25.0	5.4523	15.3	33.6063	75.2	0.3592	0.7079	0.1350	0.2438	0.0825	0.3458	1187.0	.MM
11.2558	32.7	4.8009	15.1	31.7147	69.4	0.2033	0.5025	0.0771	0.1864	0.0732	0.3721	355.0	.MU
5.8913	20.5	2.6248	10.2	19.2736	79.1	0.1970	0.5420	0.0568	0.1397	0.0384	0.2607	30.0	.UH
13.7537	23.7	6.5427	18.4	23.0981	73.9	0.2733	0.8397	0.0655	0.2423	0.0923	0.3061	31.0	.PAL
7.8490	21.6	3.0080	11.7	26.1028	65.1	0.2293	0.6002	0.0798	0.2033	0.0540	0.3412	80.0	.PEU
50.9267	82.0	6.2037	19.0	59.7910	172.7	0.1919	0.3058	0.0410	0.1176	0.1462	0.4452	363.0	.PEG
47.1245	92.9	5.7843	19.0	44.8809	173.4	0.1078	0.2472	0.0314	0.1125	0.1556	0.5052	272.0	.PEGN
13.6957	44.3	6.1249	19.5	27.9096	140.5	0.1314	0.4581	0.0457	0.1425	0.0795	0.3151	291.0	.PEN
32.4916	51.8	6.9522	16.2	48.1936	138.6	0.1666	0.3618	0.0490	0.1231	0.1192	0.3635	19636.0	.PEU
14.5053	26.7	5.6629	16.3	37.6958	77.7	0.3690	0.7182	0.1649	0.2567	0.0761	0.3513	542.0	.PIPMF
13.9353	24.6	5.2120	14.0	33.9058	75.6	0.4242	0.7277	0.1533	0.2277	0.0870	0.3220	230.0	.PIPMU
7.4486	36.7	2.4692	15.5	42.8132	116.1	0.0901	0.4128	0.0454	0.1485	0.0729	0.3562	39.0	.PP
6.0328	26.0	4.2000	19.1	26.0044	73.2	0.2394	0.7547	0.1309	0.2980	0.0747	0.3826	91.0	.PS
20.9502	42.0	5.1920	15.0	46.1858	138.7	0.1333	0.3843	0.0402	0.1126	0.0860	0.3034	3013.0	.PU
12.4502	31.4	3.6066	14.0	27.0000	87.5	0.1984	0.4993	0.0503	0.1689	0.0672	0.3535	314.0	.QAC
12.1843	41.7	5.0375	17.5	29.4240	130.8	0.1361	0.4390	0.0443	0.1382	0.0636	0.3201	8150.0	.QAL
4.6029	34.7	2.6681	14.4	28.7713	121.5	0.0846	0.4215	0.0283	0.1231	0.0929	0.3031	61.0	.UC
20.2626	52.8	5.1291	18.9	38.7486	145.3	0.1061	0.3807	0.0369	0.1346	0.0679	0.3602	3726.0	.WF
22.7716	47.4	4.4080	14.7	41.8113	118.6	0.2236	0.3795	0.0679	0.1387	0.0851	0.3685	805.0	.UG
8.5001	33.4	3.7142	14.7	27.4944	117.0	0.1716	0.4695	0.0485	0.1333	0.0644	0.2912	307.0	.ULS
11.9417	49.4	6.3635	21.1	32.4890	147.9	0.1154	0.4349	0.0443	0.1459	0.0528	0.3358	357.0	.US
36.6425	66.4	7.6914	19.1	47.0949	165.6	0.1277	0.3246	0.0329	0.1165	0.1241	0.3884	359.0	.UT
25.7699	57.3	3.4512	12.4	52.7966	158.6	0.0887	0.2473	0.0235	0.0825	0.0553	0.3465	60.0	.GTK
10.7035	50.8	5.9229	20.4	22.4440	139.4	0.1230	0.4129	0.0428	0.1486	0.0564	0.3651	4723.0	.UTS
6.0704	40.4	1.5245	14.4	17.2643	99.8	0.0787	0.3650	0.0311	0.1471	0.0303	0.4043	14.0	.UV
6.2086	45.3	2.8184	16.6	17.9773	145.7	0.0983	0.3771	0.0256	0.1160	0.0506	0.3139	189.0	.TE
12.0872	38.9	12.0479	26.5	43.1621	175.4	0.2192	0.4652	0.0630	0.1575	0.0556	0.3444	457.0	.TC
5.7461	47.9	5.0974	22.2	19.6587	140.3	0.0697	0.4625	0.0367	0.1595	0.0456	0.3448	99.0	.TU
13.0518	46.9	6.4000	18.6	41.1791	158.8	0.1279	0.4132	0.0436	0.1226	0.0678	0.3012	2214.0	.TG
15.0766	41.2	6.7783	16.6	57.8419	152.0	0.1056	0.4239	0.0505	0.1166	0.0711	0.2763	2188.0	.FI
4.6429	29.4	3.4143	14.4	17.2718	144.7	0.1349	0.4982	0.0267	0.1009	0.0282	0.2045	3246.0	.TAF
17.1955	56.6	5.7740	20.4	41.6248	186.0	0.1484	0.3882	0.0395	0.1143	0.0698	0.3057	2084.0	.TKI
5.9286	34.0	3.1067	13.5	18.9302	141.3	0.1033	0.3997	0.0255	0.0973	0.0443	0.2470	9109.0	.TAL
8.0637	50.5	5.2004	21.9	18.2069	154.1	0.1042	0.4395	0.0354	0.1435	0.0650	0.3325	850.0	.TL
3.7146	43.0	4.1249	20.0	11.1050	154.4	0.0821	0.4653	0.0253	0.1300	0.0201	0.2791	45.0	.FLA
3.0536	38.2	2.6720	16.2	14.8113	139.3	0.0595	0.4237	0.0124	0.1158	0.0244	0.2753	38.0	.TFS
4.4019	44.1	2.8282	20.0	9.1805	132.7	0.0877	0.4579	0.0255	0.1514	0.0363	0.3331	29.0	.TSM
6.0211	26.9	3.2022	14.4	25.6282	89.4	0.1969	0.5655	0.0754	0.1786	0.0686	0.3133	168.0	.TS
6.3776	43.6	2.8817	17.4	13.8446	121.4	0.0437	0.4017	0.0185	0.1439	0.0272	0.3578	18.0	.TU
13.2697	37.7	5.0911	13.6	39.1527	143.1	0.1336	0.3846	0.0320	0.0987	0.0578	0.2636	11410.0	.TV
3.4228	25.9	2.5941	10.8	8.9018	100.9	0.1278	0.4256	0.0285	0.1078	0.0357	0.2581	144.0	.TVH
6.1345	37.4	3.0397

GEOLOGIC UNIT IPMGR

GEOLOGIC UNIT KBC

TOTAL EVENTS 314

GEOLOGIC UNIT QAL TOTAL EVENTS 7000

GEOLOGIC UNIT QV

TOTAL EVENTS 14

APPENDIX II

DESCRIPTION OF MAGNETIC TAPES AND LISTINGS

A. DESCRIPTION OF DATA TAPES

A1. General

All data tapes are 9-track, 800 BPI (NRZI), odd parity, EBCDIC code. Each tape contains a gum label giving the survey project name, month and year of survey, tape type, subcontractor name, date tape created, tape reel count, tape recording characteristics, block size in Bytes and location of tape format information.

The general description for each of the tape types is as follows:

<u>Block Number</u>	<u>Description</u>
1	Format Description
2	Tape Identification
3	First Data Block
4	Second Data Block
.	.
.	.
.	Last Data Block
EOF	

A2. Raw Spectral Data Tapes

Block Size (Physical Record): 6600 characters
 Logical Record, Data : 1100 characters

1. Format Description Block (Block 1)

The Format Description utilizes 4248 characters. The remaining 2352 characters of this block are blanks.

Line Number	Character Number											
	12345678901234567890123456789012345678901234567890123456789012											
1	01 0978 (DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODES)											
2												
3	RAW SPECTRAL DATA TAPE											
4												
5	FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK ON TAPE)											
6												
7	ITEM	FORMAT	DESCRIPTION									
8	1	A40	QUADRANGLE NAME AS PROJECT IDENTIFICATION									
9	2	A20	NAME OF SUBCONTRACTOR									
10	3	I4	APPROXIMATE DATE OF SURVEY (MONTH, YEAR)									

Line Number	12345678901234567890123456789012345678901234567890123456789012	Character Number	
11	4	I1	AERIAL SYSTEM IDENTIFICATION CODE
12	5	A20	AIRCRAFT IDENTIFICATION BY TYPE AND FAA NUMBER
13	6	I3	BFEC CALIBRATION REPORT NUMBER
14	7	F6.3	4PI SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL PLACES IN SECONDS
15			
16	8	F6.3	2PI SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL PLACES IN SECONDS
17			
18	9	I3	NUMBER OF CHANNELS (0-3 MEV) FOR 4PI SYSTEM
19	10	I3	NUMBER OF CHANNELS (0-3 MEV) FOR 2PI SYSTEM
20	11	I3	NUMBER OF FLIGHT LINES ON THIS TAPE
21	12	I4	FIRST FLIGHT LINE NUMBER ON THIS TAPE
22	13	I6	FIRST RECORD NUMBER OF FIRST FLIGHT LINE
23	14	I3	JULIAN DATE (DAY OF YEAR) FIRST FLIGHT LINE WAS COLLECTED
24			
25	15-17	I4,I6,I3	REPEAT OF ITEMS 12-14 FOR SECOND FLIGHT LINE ON THIS TAPE
26			
27	*	*	*
28	*	*	*
29	*	*	*
30	306-308	I4,I6,I3	REPEAT OF ITEMS 12-14 FOR 99TH FLIGHT LINE ON THIS TAPE
31			
32			
33			FORMAT FOR RAW SPECTRAL DATA RECORD (THIRD THRU LAST BLOCK ON TAPE)
34			
35	ITEM	FORMAT	DESCRIPTION
36	1	I1	AERIAL SYSTEM IDENTIFICATION CODE
37	2	I4	FLIGHT LINE NUMBER
38	3	I6	RECORD IDENTIFICATION NUMBER
39	4	I6	GMT TIME OF DAY (HHMMSS)
40	5	F8.4	LATITUDE TO FOUR DECIMAL PLACES IN DEGREES
41	6	F8.4	LONGITUDE TO FOUR DECIMAL PLACES IN DEGREES
42	7	F6.1	TERRAIN CLEARANCE TO ONE DECIMAL PLACE IN METERS
43	8	F7.1	TOTAL MAGNETIC FIELD INTENSITY TO ONE DECIMAL PLACE IN GAMMAS
44			
45	9	A8	SURFACE GEOLOGIC MAP UNIT CODE
46	10	I4	QUALITY FLAG CODES
47	11	F4.1	OUTSIDE AIR TEMPERATURE TO ONE DECIMAL PLACE IN DEGREES CELSIUS
48			
49	12	F5.1	OUTSIDE AIR PRESSURE TO ONE DECIMAL PLACE IN MMHG
50	13	F5.3	LIVE TIME COUNTING PERIOD TO THREE DECIMAL PLACES IN SECONDS
51			
52	14	I4	SUMMED RAW OUTPUT FROM COSMIC CHANNELS (3-6 MEV) IN COUNTS
53			
54	15	I4	RAW OUTPUT FROM CHANNEL 1 IN COUNTS
55	16	I4	RAW OUTPUT FROM CHANNEL 2 IN COUNTS
56	*	*	*
57	*	*	*
58	*	*	*
59	270	I4	RAW OUTPUT FROM CHANNEL 256 IN COUNTS
-	-	-	2352 BLANK CHARACTERS

2. Tape Identification Block (Block 2)

The information and format for this block are indicated in lines 8 through 30 of the Format Description Block A2.1, and 1396 characters are produced. The remaining 5204 characters in this block are blanks.

If fewer than 99 flight lines exist, the unused flight line information, 13 characters per flight line, is filled with 9's through the 99th flight line.

3. Raw Spectral Data Blocks

The information and format for the logical records in these blocks are indicated in lines 36 through 59 of the Format Description Block A2.1. One logical record contains 1100 characters. There are six such logical records per 6600 character physical record or block.

The 2π data logical record is recorded after the corresponding 4π data collection intervals at a frequency dependent on the 2π system data collection interval. For example, if the 4π data collection interval is 1 second and the 2π data collection interval is 10 seconds, then 10 records of 4π data are recorded followed by 1 record of the 2π data which was collected during the preceding 10 seconds. The format for the 2π data is identical to that of the 4π data, except for lines 40 through 49 of the Format Description Block given above. These variables are expressed in the 2π record as all nines in the format specified for I and F fields, and all zeros for A fields.

A3. Single Record Reduced Data Tapes

Block Size (Physical Record): 6900 characters
Logical Record, Data : 138 characters

1. Format Description Block (Block 1)

The Format Description utilizes 6768 characters. The remaining 132 characters of this block are blanks.

Line Number	Character Number
1	02 0978 (DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODES)
2	
3	SINGLE RECORD REDUCED DATA TAPE
4	
5	FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK)
6	

Line Number	Character Number											
	12345678901234567890123456789012345678901234567890123456789012											

Line	ITEM	FORMAT	DESCRIPTION
7			
8	1	A40	QUADRANGLE NAME AS PROJECT IDENTIFICATION
9	2	A20	NAME OF SUBCONTRACTOR
10	3	I4	APPROXIMATE DATE OF SURVEY (MONTH, YEAR)
11	4	I1	NUMBER OF AERIAL SYSTEMS USED TO COLLECT DATA FOR
12			THIS QUADRANGLE
13	5	I1	AERIAL SYSTEM IDENTIFICATION CODE FOR FIRST SYSTEM
14	6	A20	AIRCRAFT IDENTIFICATION BY TYPE AND FAA NUMBER FOR
15			FIRST SYSTEM
16	7	F6.1	NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO
17			TERRESTRIAL POTASSIUM (K-40) TO ONE DECIMAL PLACE
18			IN CPS PER PERCENT K FOR FIRST SYSTEM
19	8	F6.1	NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO
20			TERRESTRIAL URANIUM (BI-214) TO ONE DECIMAL PLACE
21			IN CPS PER PPM EQUIVALENT U
22	9	F6.1	NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO
23			TERRESTRIAL THORIUM (TL-208) TO ONE DECIMAL PLACE
24			IN CPS PER PPM EQUIVALENT TH
25	10	I6	BLANK FIELD (999999)
26	11	F6.3	4PI-SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL
27			PLACES IN SECONDS FOR FIRST SYSTEM
28	12	F6.3	2PI-SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL
29			PLACES IN SECONDS FOR FIRST SYSTEM
30	13	I3	NUMBER OF CHANNELS (0-3 MEV) IN 4PI SYSTEM FOR FIRST
31			AERIAL SYSTEM
32	14	I3	NUMBER OF CHANNELS (0-3 MEV) IN 2PI SYSTEM FOR FIRST
33			AERIAL SYSTEM
34	15-24	(SAME)	REPEAT OF ITEMS 5-14 FOR SECOND AERIAL SYSTEM
35	*	*	*
36	*	*	*
37	*	*	*
38	85-94	(SAME)	REPEAT OF ITEMS 5-14 FOR NINTH AERIAL SYSTEM
39	95	I3	NUMBER OF FLIGHT LINES ON THIS TAPE
40	96	I4	FIRST FLIGHT LINE NUMBER ON THIS TAPE
41	97	I6	FIRST RECORD NUMBER OF FIRST FLIGHT LINE
42	98	I3	JULIAN DATE (DAY OF YEAR) FIRST FLIGHT-LINE DATA WAS
43			COLLECTED
44	99-101	I4,I6,I3	REPEAT OF ITEMS 96-98 FOR SECOND FLIGHT LINE ON THIS
45			TAPE
46	*	*	*
47	*	*	*
48	*	*	*
49	390-392	I4,I6,I3	REPEAT OF ITEMS 96-98 FOR 99TH FLIGHT LINE ON THIS
50			TAPE
51			
52	FORMAT FOR SINGLE RECORD REDUCED DATA RECORD (THIRD THRU LAST BLOCK)		
53			
54	ITEM	FORMAT	DESCRIPTION
55	1	I1	AERIAL SYSTEM IDENTIFICATION CODE
56	2	I4	FLIGHT LINE NUMBER
57	3	I6	RECORD IDENTIFICATION NUMBER
58	4	I6	GMT TIME OF DAY (HHMMSS)
59	5	F8.4	LATITUDE TO FOUR DECIMAL PLACES IN DEGREES

Line	Character Number											
Number	12345678901234567890123456789012345678901234567890123456789012											
60	6	F8.4	LONGITUDE TO FOUR DECIMAL PLACES IN DEGREES									
61	7	F6.1	TERRAIN CLEARANCE TO ONE DECIMAL PLACE IN METERS									
62	8	F7.1	RESIDUAL (IGRF REMOVED) MAGNETIC FIELD INTENSITY									
63			TO ONE DECIMAL PLACE IN GAMMAS									
64	9	A8	SURFACE GEOLOGIC MAP UNIT CODE									
65	10	I4	QUALITY FLAG CODES									
66	11	F6.1	APPARENT CONCENTRATION OF TERRESTRIAL POTASSIUM									
67			(K-40) TO ONE DECIMAL PLACE IN PERCENT K									
68	12	F4.1	UNCERTAINTY IN TERRESTRIAL POTASSIUM TO ONE DECIMAL									
69			PLACE IN PERCENT K									
70	13	F6.1	APPARENT CONCENTRATION OF TERRESTRIAL URANIUM									
71			(BI-214) TO ONE DECIMAL PLACE IN PPM EQUIVALENT U									
72	14	F4.1	UNCERTAINTY IN TERRESTRIAL URANIUM TO ONE DECIMAL									
73			PLACE IN PPM EQUIVALENT U									
74	15	F6.1	APPARENT CONCENTRATION OF TERRESTRIAL THORIUM									
75			(TL-208) TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH									
76	16	F4.1	UNCERTAINTY IN TERRESTRIAL THORIUM TO ONE DECIMAL									
77			PLACE IN PPM EQUIVALENT TH									
78	17	F6.1	URANIUM-TO-THORIUM RATIO TO ONE DECIMAL PLACE IN									
79			PPM EQUIVALENT U PER PPM EQUIVALENT TH									
80	18	F6.1	URANIUM-TO-POTASSIUM RATIO TO ONE DECIMAL PLACE IN									
81			PPM EQUIVALENT U PER PERCENT K									
82	19	F6.1	THORIUM-TO-POTASSIUM RATIO TO ONE DECIMAL PLACE IN									
83			PPM EQUIVALENT TH PER PERCENT K									
84	20	F8.1	GROSS GAMMA (0.4-3.0 MEV) COUNT RATE TO ONE DECIMAL									
85			PLACE IN COUNTS PER SECOND									
86	21	F6.1	UNCERTAINTY IN GROSS GAMMA COUNT RATE TO ONE DECIMAL									
87			PLACE IN COUNTS PER SECOND									
88	22	F5.1	ATMOSPHERIC BI-214 4PI CORRECTION TO ONE DECIMAL									
89			PLACE IN PPM EQUIVALENT U									
90	23	F4.1	UNCERTAINTY IN ATMOSPHERIC BI-214 4PI CORRECTION									
91			TO ONE DECIMAL PLACE IN PPM EQUIVALENT U									
92	24	F4.1	OUTSIDE AIR TEMPERATURE TO ONE DECIMAL PLACE IN									
93			DEGREES CELSIUS									
94	25	F5.1	OUTSIDE AIR PRESSURE TO ONE DECIMAL PLACE IN MMHG									

2. Tape Identification Block (Block 2)

The information and format for this block are indicated in lines 8 through 49 of the Format Description Block A3.1, and 1922 characters are produced. The remaining 4978 characters of this block are blanks.

If less than nine aerial systems are used, the space allocated for additional systems is filled with 9's in the format specified for each item using I and F fields, and with zeros for A fields.

Similarly, if fewer than 99 flight lines exist, the unused flight line information, 13 characters per flight line, is filled with 9's through the 99th flight line.

3. Single Record Reduced Data Blocks

The information and format for the logical records in these blocks are indicated in lines 55 through 94 of the Format Description Block A3.1. One logical record contains 138 characters. There are 50 such logical records per 6900 character physical record or block.

The data appearing in locations specified by lines 68, 72, 76, 86 and 90 of the Format Description Block A3.1 are 9's in the format specified in each case.

A4. Statistical Analysis Data Tapes

Block Size (Physical Record): 8000 characters
Logical Record, Data : 160 characters

1. Format Description Block (Block 1)

The Format Description utilizes 7560 characters. The remaining 440 characters are blanks.

Line Number	Character Number
1	03 0978 (DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODES)
2	
3	STATISTICAL ANALYSIS DATA TAPE
4	
5	FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK)
6	
7	ITEM FORMAT DESCRIPTION
8	1 A40 QUADRANGLE NAME AS PROJECT IDENTIFICATION
9	2 A20 NAME OF SUBCONTRACTOR
10	3 I4 APPROXIMATE DATE OF SURVEY (MONTH, YEAR)
11	4 I1 NUMBER OF AERIAL SYSTEMS USED TO COLLECT DATA FOR
12	THIS QUADRANGLE
13	5 I1 AERIAL SYSTEM IDENTIFICATION CODE FOR FIRST SYSTEM
14	6 A20 AIRCRAFT IDENTIFICATION BY TYPE AND FAA NUMBER FOR
15	FIRST SYSTEM
16	7 F6.1 NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO
17	TERRESTRIAL POTASSIUM (K-40) TO ONE DECIMAL PLACE
18	IN CPS PER PERCENT K
19	8 F6.1 NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO
20	TERRESTRIAL URANIUM (BI-214) TO ONE DECIMAL PLACE
21	IN CPS PER PPM EQUIVALENT U
22	9 F6.1 NOMINAL ALTITUDE SYSTEM SENSITIVITY RELATIVE TO
23	TERRESTRIAL THORIUM (TL-208) TO ONE DECIMAL PLACE
24	IN CPS PER PPM EQUIVALENT TH
25	10 I6 BLANK FIELD (999999)
26	11 F6.3 4PI-SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL
27	PLACES IN SECONDS FOR FIRST SYSTEM
28	12 F6.3 2PI-SYSTEM DATA COLLECTION INTERVAL TO THREE DECIMAL
29	PLACES IN SECONDS FOR FIRST SYSTEM

Line Number	1234567890123456789012345678901234567890123456789012345678901234567890123456789012	Character Number	
30	13	I3	NUMBER OF CHANNELS (0-3 MEV) IN 4PI SYSTEM FOR FIRST
31			AERIAL SYSTEM
32	14	I3	NUMBER OF CHANNELS (0-3 MEV) IN 2PI SYSTEM FOR FIRST
33			AERIAL SYSTEM
34	15-24	(SAME)	REPEAT OF ITEMS 5-14 FOR SECOND AERIAL SYSTEM
35	*	*	*
36	*	*	*
37	*	*	*
38	85-94	(SAME)	REPEAT OF ITEMS 5-14 FOR NINTH AERIAL SYSTEM
39	95	I3	NUMBER OF FLIGHT LINES ON THIS TAPE
40	96	I4	FIRST FLIGHT LINE NUMBER ON THIS TAPE
41	97	I6	FIRST RECORD NUMBER OF FIRST FLIGHT LINE
42	98	I3	JULIAN DATE (DAY OF YEAR) FIRST FLIGHT LINE DATA WAS
43			COLLECTED
44	99-101	I4,I6,I3	REPEAT OF ITEMS 96-98 FOR SECOND FLIGHT LINE ON THIS
45			TAPE
46	*	*	*
47	*	*	*
48	*	*	*
49	390-392	I4,I6,I3	REPEAT OF ITEMS 96-98 FOR 99TH FLIGHT LINE ON THIS
50			TAPE
51			
52			FORMAT FOR STATISTICAL ANALYSIS DATA RECORD (THIRD THRU LAST BLOCK)
53			
54	ITEM	FORMAT	DESCRIPTION
55	1	I1	AERIAL SYSTEM IDENTIFICATION CODE
56	2	I4	FLIGHT LINE NUMBER
57	3	I6	RECORD IDENTIFICATION NUMBER
58	4	I6	GMT TIME OF DAY (HHMMSS)
59	5	F8.4	LATITUDE TO FOUR DECIMAL PLACES IN DEGREES
60	6	F8.4	LONGITUDE TO FOUR DECIMAL PLACES IN DEGREES
61	7	F6.1	TERRAIN CLEARANCE TO ONE DECIMAL PLACE IN METERS
62	8	F7.1	RESIDUAL (IGRF REMOVED) MAGNETIC FIELD INTENSITY
63			TO ONE DECIMAL PLACE IN GAMMAS
64	9	A8	SURFACE GEOLOGIC MAP UNIT CODE
65	10	I5	QUALITY FLAG CODES
66	11	F6.1	AVERAGED CONCENTRATION OF TERRESTRIAL POTASSIUM
67			(K-40) TO ONE DECIMAL PLACE IN PERCENT K
68	12	F4.1	UNCERTAINTY IN TERRESTRIAL POTASSIUM TO ONE DECIMAL
69			PLACE IN PERCENT K
70	13	F5.1	POTASSIUM STANDARD DEVIATION FROM THE MEAN TO ONE
71			DECIMAL PLACE AND ALGEBRAICALLY SIGNED
72	14	F6.1	AVERAGED CONCENTRATION OF TERRESTRIAL URANIUM
73			(BI-214) TO ONE DECIMAL PLACE IN PPM EQUIVALENT U
74	15	F4.1	UNCERTAINTY IN TERRESTRIAL URANIUM TO ONE DECIMAL
75			PLACE IN PPM EQUIVALENT U
76	16	F5.1	URANIUM STANDARD DEVIATION FROM THE MEAN TO ONE
77			DECIMAL PLACE AND ALGEBRAICALLY SIGNED
78	17	F6.1	AVERAGED CONCENTRATION OF TERRESTRIAL THORIUM
79			(TL-208) TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH
80	18	F4.1	UNCERTAINTY IN TERRESTRIAL THORIUM TO ONE DECIMAL
81			PLACE IN PPM EQUIVALENT TH

Line	Character Number											
Number	12345678901234567890123456789012345678901234567890123456789012											
82	19	F5.1	THORIUM STANDARD DEVIATION FROM THE MEAN TO ONE									
83			DECIMAL PLACE AND ALGEBRAICALLY SIGNED									
84	20	F8.1	GROSS GAMMA (0.4-3.0 MEV) COUNT RATE TO ONE DECIMAL									
85			PLACE IN COUNTS PER SECOND									
86	21	F6.1	UNCERTAINTY IN GROSS GAMMA COUNT RATE TO ONE DECIMAL									
87			PLACE IN COUNTS PER SECOND									
88	22	F5.1	ATMOSPHERIC BI-214 4PI CORRECTION TO ONE DECIMAL									
89			PLACE IN PPM EQUIVALENT U									
90	23	F4.1	UNCERTAINTY IN ATMOSPHERIC BI-214 4PI CORRECTION									
91			TO ONE DECIMAL PLACE IN PPM EQUIVALENT U									
92	24	F6.1	AVERAGED URANIUM-TO-THORIUM RATIO TO ONE DECIMAL									
93			PLACE IN PPM EQUIVALENT U PER PPM EQUIVALENT TH									
94	25	F5.1	URANIUM-TO-THORIUM RATIO STANDARD DEVIATION FROM THE									
95			MEAN TO ONE DECIMAL PLACE AND ALGEBRAICALLY SIGNED									
96	26	F6.1	AVERAGED URANIUM-TO-POTASSIUM RATIO TO ONE DECIMAL									
97			PLACE IN PPM EQUIVALENT U PER PERCENT K									
98	27	F5.1	URANIUM-TO-POTASSIUM RATIO STANDARD DEVIATION FROM									
99			THE MEAN TO ONE DECIMAL PLACE AND ALGEBRAICALLY SIGNED									
100			SIGNED									
101	28	F6.1	AVERAGED THORIUM-TO-POTASSIUM RATIO TO ONE DECIMAL									
102			PLACE IN PPM EQUIVALENT TH PER PERCENT K									
103	29	F5.1	THORIUM-TO-POTASSIUM RATIO STANDARD DEVIATION FROM									
104			THE MEAN TO ONE DECIMAL PLACE AND ALGEBRAICALLY									
105			SIGNED									

2. Tape Identification Block (Block 2)

The information and format for this block are indicated in lines 8 through 49 of the Format Description Block A4.1, and 1922 characters are produced. The remaining 6078 characters of this block are blanks.

If less than nine aerial systems are used, the space allocated for additional systems is filled with 9's in the format specified for each item using I and F fields, and with zeros for A fields.

Similarly, if fewer than 99 flight lines exist, the unused flight line information, 13 characters per flight line, is filled with 9's through the 99th flight line.

3. Statistical Analysis Data Blocks

The information and format for the logical records in these blocks are indicated in lines 55 through 103 of the Format Description Block A4.1. One logical record contains 160 characters. There are 50 such logical records per 8000 character physical record or block.

The data appearing in locations specified by lines 68, 74, 80, 86 and 90 of the Format Description Block A4.1 are 9's in the format specified in each case.

A5. Magnetic Data Tapes

Block Size (Physical Record): 8000 characters
 Logical Record (Data) : 80 characters

1. Format Description Block (Block 1)

The Format Description utilizes 3384 characters. The remaining 4616 characters are blanks.

Line Number	Character Number											
1	04 0978 (DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODES)											
2												
3	MAGNETIC DATA TAPE											
4												
5	FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK)											
6												
7	ITEM	FORMAT	DESCRIPTION									
8	1	A40	QUADRANGLE NAME AS PROJECT IDENTIFICATION									
9	2	A20	NAME OF SUBCONTRACTOR									
10	3	I4	APPROXIMATE DATE OF SURVEY (MONTH, YEAR)									
11	4	I3	NUMBER OF FLIGHT LINES ON THIS TAPE									
12	5	I4	FIRST FLIGHT LINE ON THIS TAPE									
13	6	I6	FIRST RECORD NUMBER OF FIRST FLIGHT LINE									
14	7	I3	JULIAN DATE (DAY OF YEAR) FIRST FLIGHT LINE DATA WAS									
15			COLLECTED									
16	8	F8.4	LATITUDE OF GROUND BASE STATION TO FOUR DECIMAL									
17			PLACES IN DEGREES FOR FIRST FLIGHT LINE									
18	9	F8.4	LONGITUDE OF GROUND BASE STATION TO FOUR DECIMAL									
19			PLACES IN DEGREES FOR FIRST FLIGHT LINE									
20	10-14	(SAME)	REPEAT OF ITEMS 5-9 FOR SECOND FLIGHT LINE ON THIS									
21			TAPE									
22	*	*							*			
23	*	*							*			
24	*	*							*			
25	495-499	(SAME)	REPEAT OF ITEMS 5-9 FOR 99TH FLIGHT LINE ON THIS									
26			TAPE									
27												
28	FORMAT FOR MAGNETIC DATA RECORD (THIRD THRU LAST BLOCK)											
29												
30	ITEM	FORMAT	DESCRIPTION									
31	1	I1	AERIAL SYSTEM IDENTIFICATION CODE									
32	2	I4	FLIGHT LINE NUMBER									
33	3	I6	RECORD IDENTIFICATION NUMBER									
34	4	I6	GMT TIME OF DAY (HHMMSS)									
35	5	F8.4	LATITUDE TO FOUR DECIMAL PLACES IN DEGREES									
36	6	F8.4	LONGITUDE TO FOUR DECIMAL PLACES IN DEGREES									
37	7	F6.1	TERRAIN CLEARANCE TO ONE DECIMAL PLACE IN METERS									
38	8	F5.1	OUTSIDE AIR PRESSURE TO ONE DECIMAL PLACE IN MMHG									
39	9	A8	SURFACE GEOLOGIC MAP UNIT CODE									
40	10	F7.1	TOTAL MAGNETIC FIELD INTENSITY TO ONE DECIMAL PLACE									
41			IN GAMMAS									
42	11	F7.1	RESIDUAL (IGRF REMOVED) MAGNETIC FIELD INTENSITY									

Line Number	Character Number											
	12345678901	23456789012	34567890123	45678901234	56789012345	67890123456	78901234567	89012345678	90123456789	01234567890	12345678901	23456789012

44	12	F7.1	DIURNAL MAGNETIC INTENSITY VARIATION TO ONE DECIMAL
45			PLACE IN GAMMAS
46	13	F7.1	MAGNETIC DEPTH-TO-BASEMENT TO ONE DECIMAL PLACE
47			IN METERS (IF REQUIRED)

2. Tape Identification Block (Block 2)

The information and format for this block are indicated in lines 8 through 25 of the Format Description Block A5.1, and 2938 characters are produced. The remaining 5062 characters of this block are blanks.

If fewer than 99 flight lines exist, the unused flight line information, 29 characters per flight line, is filled with 9's through the 99th flight line in the format indicated.

3. Magnetic Data Blocks

The information and format for the logical records in these blocks are indicated in lines 31 through 46 of the Format Description Block A5.1. One logical record contains 80 characters. There are 100 such logical records per 8000 character physical record or block.

If the magnetic depth-to-basement is not required, this item is expressed as 99999.9.

A6. Statistical Analysis Summary Tapes

Block Size (Physical Record): 7000 characters
 Logical Record (Data) : 140 characters

1. Format Description Block (Block 1)

The Format Description utilizes 4320 characters. The remaining 2680 characters are blanks.

Line Number	Character Number											
	12345678901	23456789012	34567890123	45678901234	56789012345	67890123456	78901234567	89012345678	90123456789	01234567890	12345678901	23456789012

1	05	0978	(DATA TAPE TYPE AND FORMAT SPECIFICATION DATE CODE)
2			
3			STATISTICAL ANALYSIS SUMMARY TAPE (OR FILE)
4			
5			FORMAT FOR TAPE IDENTIFICATION BLOCK (SECOND BLOCK)
6			
7	ITEM	FORMAT	DESCRIPTION
8	1	A40	QUADRANGLE NAME AS PROJECT IDENTIFICATION
9	2	A20	NAME OF SUBCONTRACTOR
10	3	I4	APPROXIMATE DATE OF SURVEY (MONTH, YEAR)
11	4	I6	NUMBER OF GEOLOGIC MAP UNITS USED FOR THIS

Line Number	Character Number
12	12345678901234567890123456789012345678901234567890123456789012

12 QUADRANGLE

13

14 FORMAT FOR STATISTICAL ANALYSIS SUMMARY DATA RECORD (THIRD THRU LAST
15 BLOCK)

16

ITEM	FORMAT	DESCRIPTION
1	A8	SURFACE GEOLOGIC MAP UNIT IDENTIFYING CODE
2	I6	TOTAL RECORDS FOR GEOLOGIC MAP UNIT
3	I6	NUMBER OF POTASSIUM RECORDS COMPUTED FOR GEOLOGIC UNIT
4	F6.1	POTASSIUM CONCENTRATION MEAN TO ONE DECIMAL PLACE IN PERCENT K
5	F6.1	POTASSIUM CONCENTRATION STANDARD DEVIATION TO ONE DECIMAL PLACE IN PERCENT K
6	A3	POTASSIUM CONCENTRATION DISTRIBUTION CODE
7	I6	NUMBER OF URANIUM RECORDS COMPUTED FOR GEOLOGIC UNIT
8	F6.1	URANIUM CONCENTRATION MEAN TO ONE DECIMAL PLACE IN PPM EQUIVALENT U
9	F6.1	URANIUM CONCENTRATION STANDARD DEVIATION TO ONE DECIMAL PLACE IN PPM EQUIVALENT U
10	A3	URANIUM CONCENTRATION DISTRIBUTION CODE
11	I6	NUMBER OF THORIUM RECORDS COMPUTED FOR GEOLOGIC UNIT
12	F6.1	THORIUM CONCENTRATION MEAN TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH
13	F6.1	THORIUM CONCENTRATION STANDARD DEVIATION TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH
14	A3	THORIUM CONCENTRATION DISTRIBUTION CODE
15	I6	NUMBER OF URANIUM-TO-THORIUM RATIO RECORDS COMPUTED FOR GEOLOGIC UNIT
16	F6.1	URANIUM-TO-THORIUM RATIO MEAN TO ONE DECIMAL PLACE IN PPM EQUIVALENT U PER PPM EQUIVALENT TH
17	F6.1	URANIUM-TO-THORIUM RATIO STANDARD DEVIATION TO ONE DECIMAL PLACE IN PPM EQUIVALENT U PER PPM EQUIVALENT TH
18	A3	URANIUM-TO-THORIUM RATIO DISTRIBUTION CODE
19	I6	NUMBER OF URANIUM-TO-POTASSIUM RATIO RECORDS COMPUTED FOR GEOLOGIC UNIT
20	F6.1	URANIUM-TO-POTASSIUM RATIO MEAN TO ONE DECIMAL PLACE IN PPM EQUIVALENT U PER PERCENT K
21	F6.1	URANIUM-TO-POTASSIUM RATIO STANDARD DEVIATION TO ONE DECIMAL PLACE IN PPM EQUIVALENT U PER PERCENT K
22	A3	URANIUM-TO-POTASSIUM RATIO DISTRIBUTION CODE
23	I6	NUMBER OF THORIUM-TO-POTASSIUM RATIO RECORDS COMPUTED FOR GEOLOGIC UNIT
24	F6.1	THORIUM-TO-POTASSIUM RATIO MEAN TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH PER PERCENT K
25	F6.1	THORIUM-TO-POTASSIUM RATIO STANDARD DEVIATION TO ONE DECIMAL PLACE IN PPM EQUIVALENT TH PER PERCENT K
26	A3	THORIUM-TO-POTASSIUM RATIO DISTRIBUTION CODE

2. Tape Identification Block (Block 2)

The information and format for this block are indicated in lines 8 through 11 of the Format Description Block A6.1, and 70 characters are produced. The remaining 6930 characters of this block are blanks.

3. Statistical Analysis Summary Data Blocks

The information and format for the logical records in these blocks are indicated in lines 18 through 60 of the Format Description Block A6.1. One logical record contains 140 characters. There are 50 such logical records per 7000 character physical record or block.

B. DESCRIPTION OF LISTINGS

B1. Single record reduced data listings: include the following information on Microfiche:

<u>ITEM</u>	<u>DESCRIPTION</u>
REC	Sequential record number
Lat	Location Y in latitude
Long	Location X in longitude
RMag	Residual magnetic field, gammas
Alt	Surface altitude
GEO UNIT	Geologic Type
AKUT	A=Altitude; K=Potassium; U=Uranium T=Thorium - Results of statistical adequacy test
COS	Cosmic c/s
BiAir	Airborne ^{214}Bi , 4π data
GC	Gross count, .4 MeV - 2.8 MeV
T _l	^{208}Tl c/s
Bi	^{214}Bi c/s
K	^{40}K c/s
BI:T _l	Ratio
BI:k	Ratio
T _l :K	Ratio
TEMP	Outside Air Temperature ($^{\circ}\text{C}$)
BP	Atmospheric Pressure (In. Hg)

B2. Averaged record data listings: include the following information on Microfiche:

<u>ITEM</u>	<u>DESCRIPTION</u>
REC	Sequential Record number
GEO UNIT	Geologic type
AKUT	A=Altitude; K=Potassium; U=Uranium; T=Thorium - Results of statistical adequacy test
Long	Longitude of X location of geologic type
Lat	latitude of Y location of geologic type
RMag	Residual magnetic field, gammas
COS	Cosmic, 4π
BiAir	Atmospheric Bi, 4π
GC	Gross count, c/s

ITEMDESCRIPTION

T_l	T_l value, c/s
Rank	T_l standard deviation rank
B_i	B_i value, c/s
Rank	B_i standard deviation rank
K	K value, c/s
Rank	K standard deviation rank
B_i/T_l	Ratio value
Rank	B_i/T_l standard deviation rank
B_i/K	Ratio value
Rank	B_i/K standard deviation rank
T_l/K	Ratio value
Rank	T_l/K standard deviation rank

APPENDIX III

PRODUCTION SUMMARY

APPENDIX III

PRODUCTION SUMMARY - Survey Time Period

Data reduction began with daily tape verification by quality control of tapes by creation of a listing of the processed field data tape the day following each flight day. The flight location map was completed in August prior to final data reduction in March, 1979.

<u>ML/TL</u>	<u>DATE</u>	<u>SURVEYED LINE MILES</u>	<u>AVERAGE SPEED/DAY</u>	<u>AVERAGE ALT/DAY</u>
TL9	August 3, 1978	69	77	517
ML(18,23)W	4	360	77	405
ML(10,17)W	5	480	76	445
TL6S	6	409	70	460
ML(4-9)W				
ML(1-3)W	7	340	62	506
ML(1-3)E, TL85				
ML(4-9)E	14	493	72	437
TL7S				
ML(14-19)E				
ML(10-13)E	15	259	72	505
ML(20-23)E				
TL(6-8)N				
TL(2-5)N	16	80	86	384
TL1	18	265	80	405
TL(2-5)S				

TABLE AIII-1. TEST LINE RESULTS

The histograms indicating aircraft speed and surface altitude distributions as a function of map and tie lines discussed under Section IV (I) are included in Appendix III. The results of the Test Lines studies are listed in Table AIII-1 below:

UNIT	A U G U S T								
	3	4	5	6	7	14	15	16	18
PRE COS	24.49	30.42	30.88	30.67	30.58	30.96	31.51	34.13	31.46
POS COS	30.84	32.79	34.25	32.094	37.41	33.03	34.56	35.30	35.20
T1	36.49	38.49	40.64	41.86	41.90	38.66	40.09	40.51	39.06
T1	41.82	41.36	41.67	42.47	42.02	41.10	40.69	42.42	39.48
Bi	17.25	20.95	18.92	20.14	15.14	19.40	17.57	16.89	16.03
Bi	16.94	17.14	16.95	17.29	17.27	16.36	18.54	17.77	16.38
K	123.92	131.64	140.89	142.38	141.76	133.16	138.16	129.17	125.32
K	139.16	140.51	144.48	147.62	143.00	140.23	145.13	133.00	122.49
GC	1265.6	1387.6	1425.1	1422.8	1374.4	1299.8	1374.8	1291.0	1258.8
GC	1362.4	1333.7	1449.3	1334.0	1352.2	1283.41	1369.8	1347.3	1393.1
BIAIR	3.38	7.79	8.97	5.39	1.58	1.94	2.59	1.46	1.66
BIAIR	5.57	4.37	8.37	2.77	2.14	2.15	3.50	11.34	6.53
ALT	353.4	360.3	365.40	370.75	372.64	359.08	350.39	358.46	363.41
ALT	368.6	386.8	389.3	402.06	378.51	378.41	386.10	370.62	367.72

TABLE AIII-2. Average Lama II Speed and Altitude Determined from data of Appendix II.

<u>LINE NO.</u>	<u>~AVERAGE SPEED, MPH</u>	<u>~AVERAGE ALTITUDE, FEET</u>
1E, 1W	63,58	605,492
2E,2W	64,72	413,451
3E,3W	55,48	510,440
4E,4W	64,83	475,462
5E,5W	63,57	472,427
6E,6W	73,92	457,452
7E,7W	61,54	537,471
8E,8W	66,78	495,469
9E,9W	70,62	488,486
10E,10W	67,79	592,491
11E,11W	84,62	669,536
12E,12W	52,75	716,475
13E,13W	55,70	522,424
14E,14ME,14MW,14W	70,97,73,75	413,496,487,449
15E,15W	66,74	358,361
16E,16W	99,85	408,370
17E,17W	68,75	347,373
18E,18W	104,79	385,412
19E,19W	62,83	364,404
20E,20W	95,64	408,401
21E,21W	57,77	379,405
22E,22W	96,76	412,397
23E,23W	66,82	432,410
TL1	68	435
TL2N,TL2S	91,100	398,372
TL3N,TL3S	83,75	362,397
TL4N,TL4S	93,88	374,394
TL5N,TL5S	78,68	403,428
TL6N,TL6S	75,70	408,458
TL7N,TL7S	84,73	405,485
TL8N,TL8S	85,75	610,635
TL9	77	517

TABLE AIII-3. Diurnal Corrections to Map Line Data

<u>LINE NO.</u>	<u>DIURNAL CORRECTION, GAMMAS</u>	<u>LINE NO.</u>	<u>DIURNAL CORRECTION, GAMMAS</u>
ML1E	-10	ML1W	-6
ML2E	-6	ML2W	-2
ML3E	-8	ML3W	0
ML4E	13	ML4W	-2
ML5E	16	ML5W	-1
ML6E	-10	ML6W	-9
ML7E	-4	ML7W	15
ML8E	-1	ML8W	13
ML9E	-2	ML9W	8
ML10E	15	ML10W	-5
ML11E	12	ML11W	-4
ML12E	9	ML12W	0
ML13E	7	ML13W	-2
ML14E	1	ML14W	-11
ML15E	-5	ML15W	16
ML16E	-8	ML16W	11
ML17E	-7	ML17W	7
ML18E	-2	ML18W	2
ML19E	-3	ML19W	7
ML20E	14	ML20W	13
ML21E	-10	ML21W	16
ML22E	-8	ML22W	-6
ML23E	3	ML23W	0
TL1	-12	ML14ME	-7
TL2N,2S	-9,-3	ML14MW	-7
TL3N,3S	-11,-5		
TL4N,4S	15,1		
TL5N,5S	13,-2		
TL6N,5S	-2,0		
TL7N,7S	-2,7		
TL8N,8S	-1,15		
TL9N,9S	-5		

Magnetic heading corrections required are -3.56 gammas westerly correction, +3.56 gammas easterly correction, +1.0 gammas northerly correction, and -1.0 gammas southerly correction.

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