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Robert E. LeResche — Commissioner

Ross G. Schaff — State Geologist

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INVESTIGATION OF ALASKA'S URANIUM POTENTIAL

By G.R. Eakins, B.K. Jones and R.B. Forbes

INVESTIGATION OF ALASKA'S URANIUM POTENTIAL

Part 1 - Reconnaissance Program, West-Central Alaska and Copper River Basin
By Gilbert R. Eakins

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Two types of analyses for uranium in the stream-sediment samples are presented. One split of the stream-sediment samples was sent to Resource Associates of Alaska's laboratory, where they were analyzed for U by the fluormetric method after acid extraction. This is the method employed for U by most laboratories. The completeness of uranium extraction unavoidably varies with the particular type of uranium-bearing minerals present and possibly with the amount of iron, manganese, and carbonaceous material present, which can interfere with the extraction. Analyses by the method are shown in the text and appendix columns with the designation "RAA."

Splits of most of the stream-sediment samples were also analyzed by Los Almos Scientific Laboratory's (LASL) under their ERDA-sponsored Hydrochemical and Stream-sediment Reconnaissance Program. Analyses at LASL were performed by the delayed-neutron counting method, which gives total uranium. This method can be used only if a reactor is available. Samples analyzed by this method are prefaced by the designation "LASL."

To provide as much information as possible and to illustrate what can be expected by the two different analytical methods, results of both are tabulated in the tables of analyses. It should be emphasized that the chemical analyses were monitored and frequently checked. Differences such as those shown between the chemical-fluormetric method and delayed-neutron counting, according to LASL, are normal and to be expected.

ABSTRACT

The Alaska Division of Geological and Geophysical Surveys (DGGS), under ERDA contract AT(05-1)-1639, conducted a 6-week reconnaissance program in west-central Alaska and in the Copper River basin-Chitina River valley area to aid in determining the uranium potential of the state. Division personnel also submitted samples from the Healy, Eagle, and Charley River quadrangles.

DGGS personnel collected 916 stream-sediment samples and 427 bedrock samples for uranium, thorium, and potassium oxide determinations, and 565 water samples for uranium analyses. A statistical analysis of the determinations was made using a computer at the University of Alaska. The means, thresholds, anomalies, and U:Th ratios were calculated for eight separate regions. A complete tabulation of the analyses is found in appendix A; anomalous values are indicated on the maps and in the tables.

A set of maps was constructed combining sample locations, aerial radiometric survey data, and the general geology. Isorad maps showing radiometric values determined by hand-carried scintillometers on the ground are included for the areas investigated in west-central Alaska.

The alkaline plutonic rocks in the west-central part of the state contain unusual amounts of uranium and thorium and are believed to have a potential for commercial uranium deposits. Stream-sediment samples from this region contained up to 111 ppm uranium, 150 ppm thorium, and 7.3 percent potassium oxide. Bedrock samples contained as much as 258 ppm uranium, 290 ppm thorium, and 17.19 percent potassium oxide. The U content of stream sediments was often higher than that of the surrounding bedrock, indicating concentrating of U in the streams.

Water samples were found to generally be very low in uranium, but several anomalies were determined. The highest uranium content in the water samples was 3.95 ppb, obtained from a stream in the Zane Hills.

Analyses of sediments, bedrock, and water samples from the Copper River basin-Chitina River valley area, the Healy area, and the Eagle-Charley River area yielded disappointingly low values for U. The maximum U content of stream sediments was 10 ppm, rocks 2.5 ppm, and water 3.5 ppb. More detailed investigations in most of these areas, however, is recommended.

Petrographic studies of the plutonic rocks in west-central Alaska were performed by Dr. R.B. Forbes and B.K. Jones (part II of this report), who found a correlation of certain minerals with U and Th within individual plutons, but no mineralogic guides to U and Th that could be applied overall in the region. A limited number of calculations showed that nepheline syenite contained the most U (mean 12.83 ppm) of the seven most common igneous rock types. Granite was second (10.38 ppm U). The highest concentrations of U were found in alkalic dikes in the Darby Mountains and Selawik Hills, and in a broad zone in the Selawik Lake complex.

Radiometric readings taken with hand-carried scintillometers at most sample sites and other locations yielded impressive values in the plutonic rocks of west-central Alaska. Backgrounds were commonly 200 to 400 counts per second (cps). The maximum was 2,000 cps over a dike in the Selawik Hills. In contrast with the plutonic belt in the western part of the state, radiometric readings obtained in the Copper River basin-Chitina River valley area were very low. The maximum reading in a single point was 160 cps, and the usual values were under 60 cps.

Although specific targets for drilling were not defined, the DGGS party concluded that all the plutons of west-central Alaska warrant detailed examination for potential uranium deposits. The Cretaceous sediments in the upper part of the Chitina valley appear to deserve further investigation. Too little work was done in the Eagle-Charley River area to make any judgment, but the presence of a thick sequence of rocks ranging in age from Precambrian to Tertiary will no doubt be studied further by industry. Sampling results in the Healy D-1 quadrangle were not encouraging, but farther west the belt of Tertiary coal-bearing rocks and granite intrusives has produced uranium anomalies and is being explored by industry.

Anomalous values of the U, Th, and K_2O, and radiometric measurements are discussed for the separate areas, and suggestions are offered for exploration. A combination of all uranium exploration techniques is needed to locate potential uranium deposits in Alaska. For example, it was frequently found that only one type of sample (stream sediment, bedrock, or water) would show an anomally at a particular location, whereas the others did not. Also, correlations between aerial and ground radiometric surveys and geochemical surveys were often lacking, indicating that each method may or may not be effective, depending on local conditions.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of others who, in many cases, contributed a great amount of time and effort to certain phases of this study.

Cheri L. Carver, field assistant, performed the keypunching and computer work to obtain the statistical analyses of the sample determinations and assembled the data into useful form for the report. In addition, she was a dedicated assistant in the field, collecting and handling the samples.

Dr. Daniel B. Hawkins, professor and head of the Geology Department at the University of Alaska, generously gave his time in writing the computer program and arranging for use of the University computer.

Dr. Robert R. Sharp, Jr., head of the hydrogeochemical and stream-sediment project at the Los Alamos Scientific Laboratory, and his group performed uranium analyses of the water samples and splits of the stream-sediment samples.

Henry S. Potworowski, laboratory supervisor at the DGGS laboratory, and his staff made U, Th, and K_2O determinations, an essential part of this project. Numerous problems related to the analyses and equipment were worked out by these people. Namok Veach, assayer-chemist, performed some mineral analyses and identifications.

Ann Schell, cartographer for the DGGS, spent many hours drafting the maps and figures.

Other members of the DGGS who contributed samples or assisted in map compilation include geologists Wyatt G. Gilbert, Mitchell W. Henning, Robert M. Kline, Thomas K. Bundtzen, and Patrick L. Dobey; and geological assistants Jeffrey T. Kline and Jeffrey A. Morehouse.

Appreciation is due UV Industries and Jack Fisher, camp manager, for their hospitality at the Hogatza dredge mining camp.

INTRODUCTION

Reconnaissance sampling of stream sediments, water, and bedrock was conducted during 1975 in widespread areas of Alaska as a part of the National Uranium Resource Evaluation (NURE) program. The Alaska project was conducted by the Alaska State Division of Geological and Geophysical Surveys (DGGS) under a contract with the U.S. Energy Research and Development Administration (ERDA), who is the administrator of the NURE program. The sampling program is referred to as phase II by ERDA. Phase I consisted of a summary of published and unpublished geological data and uranium investigations within the state and construction of a 1:1,000,000-scale map of Alaska showing the distribution and classification of the alkaline intrusive rocks (Eakins and Forbes, 1975). The primary objective of phase II was to collect geochemical and radiometric data to aid industry in the search for new uranium deposits. Alaska is presently of particular interest because it is a large region that is still generally untested for uranium. The correlations between the U, Th, and K_2O contents of water, stream sediments, and bedrock and radiometric surveys will help determine the reliability of each with respect to uranium exploration in the state.

Personnel consisted of G.R. Eakins, principal investigator, Dr. R.B. Forbes with the University of Alaska Geophysical Institute, and C.L. Carver and B.K. Jones, graduate students at the University of Alaska who were geological assistants in the field and office. Jones performed much of the petrographic studies and Carver compiled the maps and geochemical data.

The field work was supported by a full-time helicopter during the 6 weeks in the field. Six separate base camps were occupied.

All the stream-sediment and bedrock samples were analyzed for Th and K_2O by the DGGS laboratory. Because of early problems with the analytical equipment, the DGGS contracted Resource Associates of Alaska (RAA) in Fairbanks to do the uranium analyses. Later in the program, however, the DGGS laboratory perfected the U method by purchasing new equipment and reanalyzed many of the samples.

The water samples were analyzed by the University of California Los Alamos Scientific Laboratory (LASL) in Los Alamos, New Mexico in conjunction with their geochemical survey of several western states and Alaska under another ERDA contract. The Los Alamos work is being directed by Dr. R.R. Sharp, Jr. Also, splits of most of the stream-sediment samples were analyzed by Los Alamos Laboratory. Therefore, two sets of U values---one marked "RAA" and one "LASL"---are reported for most stream-sediment samples. Values reported by Los Alamos are generally higher than those reported by RAA.

Alaska is about one-fifth the area of the entire U.S. and includes a large variety of geologic settings that suggest many targets for the prospector. A cross section between Anchorage and Point Barrow, Alaska, has been shown to be generally similar to a cross section between San Francisco and Denver. However, mineral exploration in Alaska is faced with numerous difficulties and high costs. Because of the general lack of roads, the rugged terrain, and the remoteness of most of the state, most programs require full-time helicopter support. Many questions are unanswered regarding the behavior of uranium in arctic and subarctic climates and in metamorphic terrains. Research programs are needed to determine the most effective methods of exploring this vast region. Field work on one such program was completed for ERDA during 1976. This was an on-the-ground follow up of the aerial radiometric survey of the Copper River basin concluded by Texas Instruments during 1975. Although uranium exploration in Alaska is far behind that of the conterminous states, the tempo is increasing and ERDA and industry have conducted radiometric and geochemical programs during the past 3 years (1974-76).

Uranium has been produced from only one locality in the state, the Ross-Adams mine on Prince of Wales Island in southeastern Alaska. About 120,000 tons of ore averaging approximately 1 percent U_3O_8 were produced from a small peralkaline granite stock of Late Triassic or Early Jurassic age (Lanphere and others, 1964). A number of radioactive prospects are present within a 70-square-mile area surrounding the stock (MacKevett, 1963; Stephens, 1971), but so far none of them has been found to be of commercial grade. Exploration in this area again is intense. Brief summaries of the history of uranium exploration in Alaska have been published (Eakins, 1969, 1975a, 1975b; Cobb, 1970).

No effort has been made in this report to define land status or ownerships. State land selections under the Alaska Statehood Act, selections by Native groups under the Alaska Native Claims Settlement Act, and Federal classifications are still pending. Present control and prior claims should be determined for each specific area of interest before any surface activities are undertaken. Because of the diversity of the geology among the several areas investigated, descriptions of the geology and results of the investigation of each area are included in separate sections.

AREAS OF INVESTIGATION

The two principal areas (fig. 1) investigated by the DGGS party during the 1975 field season were: (1) west-central Alaska, including the Darby Mountains, Granite Mountain-Clem Mountain area, Selawik Hills, and Zane Hills, and (2) the southwest part of the Copper River basin and parts of the Chitina River valley in the south-central part of the state.

These areas were chosen because the granitic rocks in west-central Alaska were known to be anomalously radioactive and to consist of alkaline rock types favorable for uranium associations, and because the Copper River basin contains nonmarine Tertiary sediments near granitic terrain which

Figure 1. Index map of areas investigated for uranium by DGGS, 1975. Numbers refer to plates (in pocket).

may be a setting similar to that of sandstone-type uranium districts in the western U.S. The Chitina River valley was included because it contains Mesozoic sandstones which have some of the characteristics of uranium-bearing sandstones and because it is near the Copper River basin. The investigation of one predominantly granitic area and one predominantly sedimentary area provided the opportunity of testing the sampling methods in both types of potential uranium provinces.

In addition to the two principal areas investigated, stream-sediment samples were collected by DGGS field parties in two other regions and analyzed for U, Th, and K. These areas are (1) the Healy D-1 quadrangle and vicinity in the Healy coal district and (2) parts of the Eagle and Charley River quadrangles along the Yukon River and near the Canadian border.

The north flank of the Alaska Range contains nonmarine coal-bearing Tertiary deposits and has been investigated for uranium by industry; it is still in an area of interest. The Kandik Basin has also been considered to have a potential for uranium in sediments of Precambrian, Paleozoic, and Tertiary ages.

Summaries of the general geology and previous investigations for uranium in these areas have been published previously (Eakins, 1975). Portions of that report are included in appendix E for reference.

The general areas that were investigated are covered by the following U.S. Geological Survey 1:250,000 (4 miles-to-the-inch) topographic quadrangle sheets:

General area	Quadrangles
West-central Alaska	
Darby Mountains	Solomon, Bendeleben
Granite Mt. and Hunter Creek plutons	Candle, Selawik
Selawik Hills	Candle, Selawik
Zane Hills and Purcell Mts.	Shungnak, Hughes
North flank Alaska Range	
Healy district	Healy
East-central Alaska	
Eagle-Charley River area	Eagle, Charley River
South-central Alaska	
Southern Copper River basin	Talkeetna Mountains, Gulkana, Valdez, Anchorage
Chitina River valley	Valdez, McCarthy

Greater detail is provided by the USGS 1:63,360 (1 inch-to-the-mile) scale topographic sheets, which are available for all areas except the Shungnak, the western part of Selawik, and most of the Hughes quadrangles. All sample locations and field data were posted on a 1:63,360 scale. Maps of the areas not covered by 1:63,360 scale were obtained by enlarging the 1:250,000 topographic sheets. The results of the field work and sampling by the DGGS in each of the eight above areas are discussed separately.

Aerial photos of a 1:20,000 scale were obtained for the areas sampled in west-central Alaska and these were examined for structural features. Photos were not purchased for the Copper River region.

FIELD METHODS EMPLOYED

Stream-Sediment Sampling

Silt-size sediments were collected from beneath the water of streams for U, Th, and K_2O analyses. Because of the large areas investigated during a relatively short time in the field, the sampling was of a broad reconnaissance nature. Most streams were in mountainous areas and were very swift, but some sediments were also collected in streams in the lowlands bordering the highlands. These areas were tundra- or muskeg-covered and the water was sluggish or stagnant. These samples consisted mostly of carbonaceous material because mud was generally scarce.

In addition to sediment sampling at each location, an effort was made to collect a water sample for uranium analysis, make a radiometric measurement with a hand-carried scintillometer, and note the type of bedrock and stream float.

Sampling was done by two people working out of the helicopter. The number of stream-sediment samples collected during a working day was not great---20 to 30---because of the long distances to and from work areas, time lost for refueling, difficulty in finding landing places, relocating other members of the field party, and frequent difficulty in finding fine material suitable for a sediment sample. Whenever possible, approximately 1 cup of material was taken and placed in a cloth sample bag. The DGGS lab handled their analyses for U, Th, and K_2O. Sample splits were shipped to the Los Alamos Scientific Laboratory for analysis to accompany the water samples. Unfortunately, mislabeling of some of the splits of stream sediments and water shipped to Los Alamos caused many of the Los Alamos samples to be discarded.

Water Sampling

Water samples were taken at most of the sediment-sample locations. Plastic bottles were provided by Los Alamos, and the samples were shipped to their laboratory for analysis by the neutron activation method. Generally, two water samples were collected at each sample site: a 25-ml vial and a 4-ounce vial. However, there were periods when the supply of vials became exhausted in the field and no water samples were taken.

The total number of water samples taken was 565. The samples were collected by simply dipping the vial into running water, avoiding carbonaceous and particulate matter as much as possible. Prior to taking the sample the vial was rinsed in the water to be sampled and the sample taken by moving it up and down in a clear part of the stream to obtain a "cross section" of the flow. No special treatment was used except for rinsing the vials in dilute HNO_3 before taking them to the field and adding 3 drops of concentrated HNO_2 to the sample collected. Much more sophisticated techniques such as filtering and measuring the Eh and pH of the waters are to be used in future water sampling by the Los Alamos Laboratory and others engaged in the NURE program throughout Alaska and the entire nation.

In general, reports of water sampling for uranium in Alaska by industry have been rather discouraging. The geology and topography in Alaska are considerably different than those of the Canadian Shield province, where some success with the method has been achieved. Research is needed to construct models providing for the possible movement of uranium in the arctic and subarctic basins. A paper by the Russian V.P. Borovitskii (1975) touched on the effectiveness of geochemical exploration of swamps and bogs in permafrost regions, but little information on the geology and topography was included. Publications by the USGS (Williams, 1970; Péwé, 1975) provide data on the ground water in the permafrost regions of Alaska, and may be useful in any such studies.

Bedrock Sampling

The extensive exposures of Cretaceous alkaline plutons in the southeastern Seward Peninsula and west-central Alaska have been described by Miller (1970, 1972) and Miller and Bunker (1975). The rocks are unusually potassic and subsilicic. The abnormally high uranium and thorium contents of the Darby Mountains and the Hogatza plutonic belt suggest that they may be favorable areas for economic concentrations of uranium and thorium.

Forbes and Jones conducted the sampling and petrographic study of the granitic rocks. Their report on the mineralogy and U and Th associations constitute a separate section of this report (part II) and should be referred to for descriptions of the rocks in each area.

Systematic sampling of bedrock along selected traverses across the plutons was done to collect samples for U, Th, and K_2O analysis and thin sectioning. The traverses were made along ridges where the exposures were best, and a sledge hammer was used to obtain samples as little weathered as possible. Forbes and Jones discuss the findings in the section on petrology, and tables and maps have been compiled to show the relations of the bedrock characteristics to the radiometric surveys and to the stream-sediment and water analyses. Of particular interest to a uranium potential study are determining the average U, Th, and K_2O contents of the various rock types, learning where the radioactive elements are contained within the rocks, and determining if leaching of the uranium has occurred.

For comparison of the U and Th values obtained from analyses of rock and water samples collected for this study with general averages, it will help to keep the following figures in mind.

Average uranium content of selected crustal rocks and major rock types (W.I. Finch, 1967, p. 2)

Rock	*Mean uranium (ppm)*
Crustal	*2.0*
Mafic igneous	*0.8*
Intermediate igneous	*1.8*
Felsic igneous	*3.5*
Volcanic glass	*5.6*
Clay and shale	*3.2*
Limestone	*1.3*
Sandstone	*2.2*

The value for felsic igneous rocks, around 4 ppm, is generally considered normal. Thorium concentrations of granitic rocks (> 70% SiO_2) average 18 ppm (Wedephol, 1969, p. 92-B-2), and about 2 ppm in plateau basalts. The U:Th ratio in igneous rocks normally is about 1:4. The ratios of U to Th and K_2O in bedrock are believed to be significant and an aid in defining potential uranium-enriched districts. When the U content approaches or exceeds the Th content, the ratio is anomalous and may indicate U enrichment even though the actual level is relatively low. However, U is more soluble than Th in the zone of weathering and oxidation, causing the two elements to become separated and the ratio to change.

Weathering processes in the subarctic environment of west-central Alaska rapidly produce an accumulation of talus and rubble at outcrops because of the extreme temperature variations. Chemical weathering in the region, however, is retarded by permanently frozen ground and low rainfall, so that the rubble buildup is preserved. Because of the accumulation of debris, there are few good outcrops where the bedrock is exposed in place. Chemical weathering is more active in the Copper River basin-Chitina River valley region, where the climate is warmer and wetter.

Studies of the granitic rocks by Jones and Forbes show that no general mineralogy guides can be applied to locate the most favorable uranium-rich localities in all areas, but each pluton has its own particular mineral assemblages associated with uranium and thorium.

Ground Radiometric Survey

Portable Mount Sopris single-channel scintillometers were carried by each member of the field party. Radioactivity measurements were made at most sample sites and are reported in the tables along with the analysis of each sample. All four instruments were calibrated to give the same responses under identical conditions. The meters indicated the radioactivity in counts per second (cps), which ranged from a low of 20 over tundra and some sediments to a maximum of 2,000 on a syenite dike in the Selawik Hills.

The measurements were generally made by placing the instruments directly on the ground or bedrock. The maximum reading obtained at each station was the one reported. The readings have been used to construct isorad maps of the areas examined in the southeastern part of the Seward Peninsula and west-central Alaska. The added bulk of this extra set of maps led to their reduction for inclusion within the text instead of printing them at the same scale as the sample location maps.

The Copper River basin radiometric surveys were not contoured, which, because of the consistently low values, would be of little use. The difference between the average radiometric measurements of the two regions is extreme. Whereas measurements of the bedrock in the Seward Peninsula—west-central region averaged 200-300 cps and occasionally reached 1200-2000 cps, those in the Copper River basin region seldom were as high as 100 cps and were usually less than 60 cps.

Because stream-sediment samples and corresponding radiometric measurements were often obtained where no bedrock was exposed, readings were taken on the stream gravels. In some low areas neither bedrock nor float were present and readings were taken on tundra. Although correlations between particular radiometric measurements and U or Th content of stream sediments and bedrock are often poor or nonexistent, they do exist for general areas. A discussion of the correlations between counts per second and U and Th contents of the igneous rocks is included in the section on igneous rocks by Forbes and Jones (p. 80).

Aerial Radiometric Survey Data

A highly sophisticated airborne radiometric and magnetic survey of the most of Copper River basin, the Seward Peninsula, and west-central Alaska was conducted by Texas Instruments, Inc. (1975) for ERDA during the summer of 1975. The aerial survey intentionally covered areas being investigated on the ground by the DGGS. A high-sensitivity multichannel gamma-ray system was flown at a 6.25-mile (10-km) spacing at an average altitude of 400 feet above the ground. The system scanned a 800-foot-wide strip at this altitude.

The anomalies presented on the Texas Instruments anomaly maps were determined statistically, and represent values in standard deviations above or below the mean value for each particular rock unit. This method depends on the accuracy of geologic mapping and rock classifications, which is still uncertain in some area. "Preferred" anomalies indicate U enrichment over Th or K (or both). The listings of the raw data, point by point, are needed for detailed study and interpretations, but these have not been made available in the Texas Instruments open-filed report (GJO-1653).

The flight lines and the anomalies as determined by Texas Instruments have been transferred to the sample location-geology maps accompanying this report in an effort to correlate as many of the available data as possible. For more information on these anomalies the reader is referred to GJO-1653.

The Texas Instruments report on the survey stated:

> *The principal problem encountered was low counting rates, especially in the basin areas caused by water-shielding by the saturated surface materials. This may have effectively prevented detection of any uraniferous provinces which might be present in those areas.*

Because of the nature of the intrusive rocks and relatively thin surficial cover, anomalies are much more numerous in the Seward Peninsula--west-central Alaska region than in the Copper River basin region.

Follow-up ground studies to determine the cause and significance of the aerial radiometric anomalies encountered in Alaska are being initiated by ERDA. Field parties will make detailed examinations of the anomalies with hand-carried multichannel spectrometers and by detailed mapping. The first follow-up project, conducted in the Copper River basin during the summer of 1976, will be an aid in interpreting the radiometric data and determining if leaching and migration of uranium has occurred, and will also be a general aid in uranium exploration of lowlands in Alaska. Similar follow-up studies are planned for other areas within the state.

SUMMARY OF RESULTS

Summaries of the results of the program are discussed by principal areas. Plates showing sample locations and the aerial radiometric anomalies discussed accompany the report. Sample analyses and statistics appear in appendixes A, B, and C. Correlation matrices are listed in appendix D. The general geologic setting of each area is summarized in appendix E.

Granite Mountain Area

The field party was based at the White Alice communications facility located on the top of Granite Mountain in the western part of the Candle quadrangle (pl. 1). Field work was possible only 5 of the 9 days at this location because of the weather. The areas sampled include the Granite Mountain pluton with its satellitic body on the northeast side, the Quartz Creek pluton, and the Hunter Creek pluton. General locations of the plutons of west-central Alaska are shown on figure 2.

Stream-Sediment Sampling

A total of 146 stream sediment samples were collected in this area. Results of the analyses are:

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0-88	6.4774	23.5104	3
Uppm (LASL)	0.14-91	13.8012	44.061	7
Th ppm	0-79	20.5366	51.404	7
K_2O%	0.64-4.67	1.9384	3.432	5

The highest U value reported, 88 ppm (sample B137), was from near the head of Doc Creek, a small north tributary to Sweepstakes Creek on the south flank of Granite Mountain. The Th value for this sample was 25.8 ppm, which results in a U:Th ratio of 3.41:1. However, the radiometric reading at this sample location was only 20 cps, and the bedrock is basalt or andesite. Another sediment sample (B140) collected about 1 mile downstream from B137 yielded only 2.2 ppm U and 5.59 ppm Th. Additional sampling is needed near the head of Doc Creek to determine the source of the uranium in sample B137.

Six other unusually high values range between 18.0 and 28.0 ppm. Three of these---B61, B62, and B71---were collected in the headwaters of the Peace River on the northeast flank of Granite Mountain. Panned concentrates from this area have previously been reported to contain anomalously high radioactivity, uranium-bearing minerals, and a variety of sulfides (Gault and others, 1953; Elliott and Miller, 1969; and Miller and Elliott, 1969). Bedrock exposures are almost entirely lacking, but four small pits dug in 1952 along the north fork of the northernmost part of the Peace River revealed weathered granitic rock. A small stock satellitic to Granite and consisting of monzonite, syenite, and nepheline syenite has been mapped in this area by Miller and Elliott (1969, figs. 1, 7). The area is covered by tundra and several feet of soil, but is well drained and completely free of brush so that further exploration would be relatively easy.

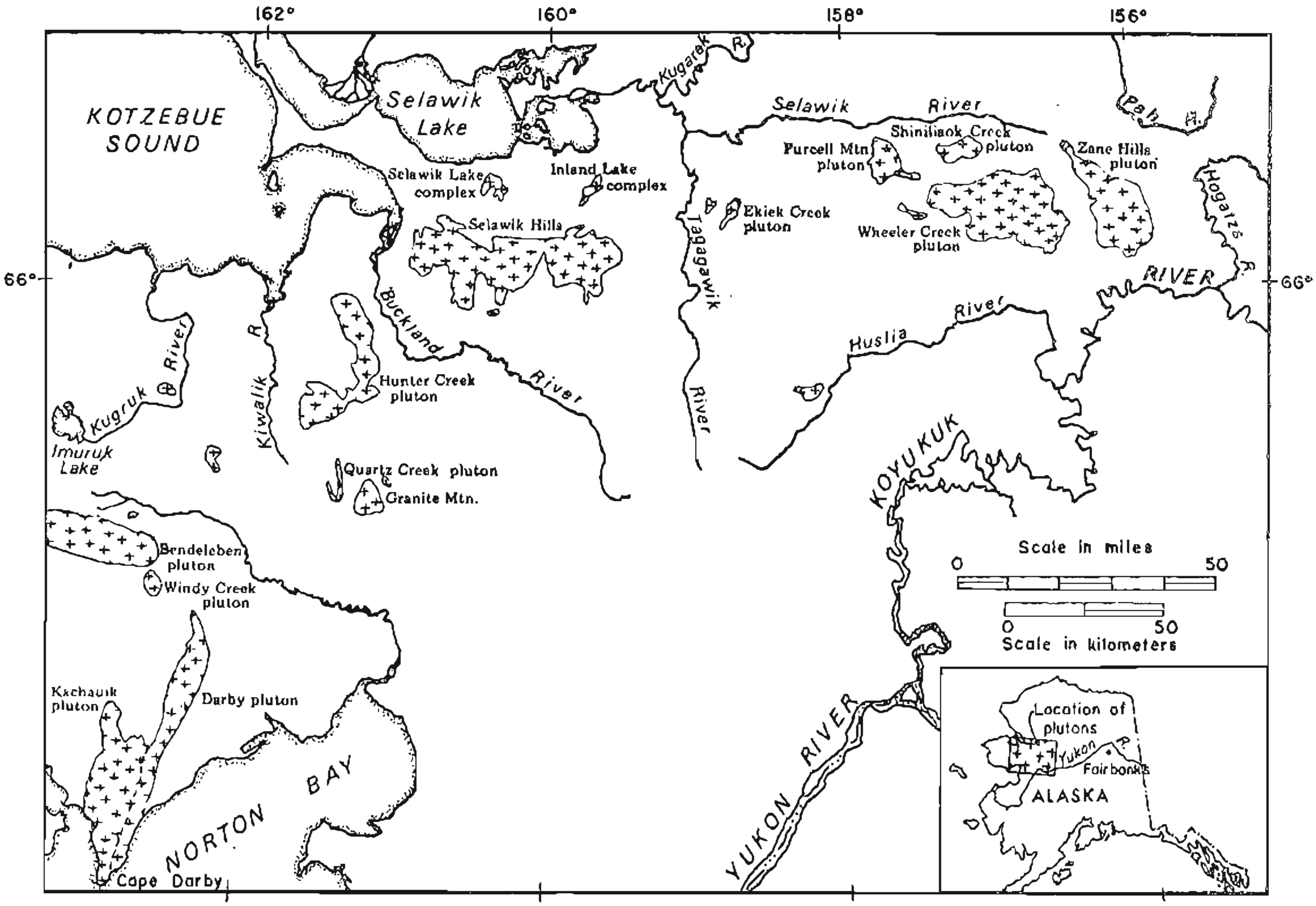

Figure 2. Plutons of west-central Alaska.

A sediment sample (B30) from a stream 4 miles south of Clem Mountain yielded 18.8 ppm U; sample B51, from near the south end of the Hunter Creek pluton, produced 20.3 ppm U. The latter sample was collected near or on a fault mapped by Patton (1967).

Numerous other sediment samples from the Granite Mountain-Hunter Creek pluton area, i.e., Anzac, Boulder, Connally Creeks, and others, contained above-average amounts of uranium (10-15 ppm). Most were from the Granite Mountain pluton. The west side of the Hunter Creek pluton is anomalously high in thorium---up to 78 ppm, and uranium up to 12.5 ppm. The highest Th and K_2O values usually were from the samples having the higher uranium values.

Water Sampling

A total of 134 water samples were taken in the Granite Mountain-Hunter Creek pluton area:

	Range	Mean	Threshold	Anomalies
H_2O (ppb)	0-2.15	0.7508	1.5936	8

Four of the water anomalies were in samples B25, B27, B31, and B44, collected over granitic rocks of the Hunter Creek pluton, between flight lines 62 and 63. Three more (B62, B65, and B72) were from the headwaters of Peace River on the northeast flank of Granite Mountain, and one (B118) was from Anzac Creek.

Bedrock Sampling

A total of 153 rock samples were collected in the Granite Mountain-Hunter Creek pluton area for analysis and thin sectioning. The highest uranium and thorium contents by chemical analysis and radiometric measurements were obtained from the syenites or nephline syenites of Granite Mountain. The ranges in the chemical analyses of the rock samples were:

	Range	Mean	Threshold	Anomalies
U* ppm	0-258	3.6898	10.1592	5
Th ppm	0-290	25.5889	67.8015	10
K_2O* %	0.10-9.15	4.0735	8.9503	3

*B149R and B151R not used in calculating threshold because of extremely high values.

The highest single U and Th values as shown above are highly anomalous, and the second highest values were 29 ppm U and 93 ppm Th. The sample containing 258 ppm U (B150R) was from nepheline syenite dikes on the southwest flank of Granite Mountain, just a few hundred yards west of the northern end of the landing field.

Most of the bedrock in the area has been reduced to rubble, but boulders of the radioactive nepheline syenite are up to 3 feet long and 1 foot thick. The syenite occurs as banded dikes cutting a highly fractured and veined diorite(?) porphyry. Scattered grains in the nepheline syenite fluoresce a bright orange. The Th content was 32.8 ppm.

The highest thorium value (289 ppm) was from a sample (B152R) of a radioactive boulder found near the head of Granite Creek. The U content was only 10.9 ppm, so the highest Th and highest U were not from the same sample but were from the same general locality.

Two bedrock samples collected at Granite Mountain which produced very high radiometric readings and anomalous U or Th values were submitted to the DGGS laboratory for mineralogical analyses. One sample (B149R) was from the nepheline syenite dikes which contains 258 ppm U. It was found a few hundred yards west of the northern end of the runway on Granite Mountain. The second sample (B151R) was from a boulder near the head of Granite Creek on the southwest flank of Granite Mountain. The analyses by size fractions and their radioactivity are given in tables 1 and 2.

Table 1. Mineral composition, 5EIR

Mesh size	Fraction number	Weight-percent	Net radiation count (60 sec)	Magnetic at (amps):	Specific gravity	Mineralogy: Major	Mineralogy: Minor
80-200	IR-1	1.48	14	0.0		Magnetite	Plagioclase, K-feldspar
80-200	IR-2	0.59	4	0.4		Biotite, plagio, clase, nepheline, K-feldspar	
80-200	IR-3	0.24	17	0.8		Biotite, plagio-clase, K-feldspar	Nepheline
80-200	IR-11	0.02	10	(15°)* 1.2	2.87	Sphene	Zircon
80-200	IR-12	0.14	8	(15°)* 1.2	2.87	Plagioclase, K-feldspar, nepheline	
80-200	IR-9	0.03	26	(5°)* 1.2	2.87	Zircon, sphene	
80-200	IR-10	0.61	12	(5°)* 1.2	2.87	K-feldspar, plagio-clase	Nepheline
80-200	IR-15	0.39	128	Nonmag.1.2	3.3	Zircon	
80-200	IR-16	0.05	35	Nonmag.1.2	2.87-3.3	Zircon	Plagioclase
80-200	IR-14	18.71	14	Nonmag.1.2	2.87	Plagioclase, K-feldspar, nephe-line	
40-80		50.95	10			K-feldspar, plagio-clase, nepheline	Biotite
+40		0.56	7				
-200		26.23	18				

*Side slope at Franz magnetic separator.

Table 2. Mineral composition, 5E4R

Mesh size	Fraction number	Weight-percent	Net radiation count (60 sec)	Magnetic at (amps):	Specific gravity	Mineralogy: Major	Mineralogy: Minor
80-200	4R-1	1.29	11	0.0		Magnetite	Plagioclase, mica
80-200	4R-2	1.72	4	0.4		Mica, plagioclase	Magnetite
80-200	4R-3	0.83	14	0.8		Plagioclase, mica, K-feldspar	
80-200	4R-12	0.12	213	(17^{o})* 1.2	3.3	Zircon	Uraninite-thorianite
80-200	4R-13	0.02	14	(17^{o})* 1.2	2.87-3.3	Zircon, plagioclase	
80-200	4R-11	0.47	2	(17^{o})* 1.2	2.87	Plagioclase, K-feldspar, mica	
80-200	4R-20	0.03	524	(5^{o})* 1.2	3.3	Uraninite-thorianite, zircon	
80-200	4R-21	0.01	72	(5^{o})* 1.2	2.87-3.3	Mica	Uraninite-thorianite
80-200	4R-7	1.63	0	(5^{o})* 1.2	2.87	Oligoclase, mica, K-feldspar	
80-200	4R-9	21.80	0	Nonmag.1.2	2.87	Oligoclase	
40-80	4R-14	3.01	7	0.0		Magnetite	Plagioclase
40-80	4R-15	4.94	4	0.8		Biotite, plagioclase, K-feldspar	
40-80	4R-18	0.36	340	0.8	3.3	Zircon	Uraninite-thorianite
40-80	4R-19	0.04	90	0.8	2.87-3.3	Plagioclase, mica	Zircon, uraninite-thorianite
40-80	4R-17	46.10	0	Nonmag.0.8		Plagioclase, K-feldspar	
-200		17.63	18				

*Side slope at Franz magnetic separator.

Aerial Radiometric Survey

The flight lines and radiometric anomalies from the Texas Instruments survey are indicated on the accompanying sample location maps. Flight-line 65 crosses 2 miles north of Granite Mountain summit in an east-west direction and, fortunately, crosses the headwaters of Peace River. A "suspect" anomaly is indicated at the Peace River locality, where stream-sediment samples and ground radiometric surveys also produced uranium and thorium anomalies. Another aerial anomaly along flight-line 65 was found 6 miles west of the Peace River anomaly, over a nepheline syenite zone on the western margin of the Granite Mountain pluton.

Two suspect anomalies appear on flight-line 62 in the Hunter Creek area of the Hunter Creek pluton, where anomalous Th values were obtained from stream-sediment samples. One suspect anomaly is along flight-line 60, 10 miles southwest of Buckland.

Aerial radiometric anomalies east of the area investigated by the DGGS suggest that the Cretaceous sediments should be investigated for their uranium potential. These occur near the center of the Candle quadrangle and contain some volcanic debris and plant remains (Patton, 1967).

Ground Radiometric Survey

Scintillometer readings in the Granite Mountain-Hunter Creek pluton area ranged from a low of 17 cps over basalt to a maximum of 1,200 cps on nepheline syenite dikes on the southwest side of Granite Mountain (figs. 3, 4, 5). Counts measured over lavas were generally less than 50 cps. Counts over monzonite and quartz monzonite varied between 100 and 250 cps. Syenites usually produced between 200 and 300 cps.

An area of about 1 square mile at the head of Peace River is particularly interesting because exceptionally high readings (up to 370 cps) were obtained over tundra and soil in the stream banks. Stream gravels also produced up to 300 cps. These levels of radioactivity are unusually high even for exposed granitic bedrock, and generally a thin cover soil and tundra will completely mask radiation. But in this area there are no bedrock exposures except in a few test pits along the stream channel, and soil and tundra are several feet thick. Radioactive material has been incorporated into the overburden. Thorium was found to be above average in the sediment samples (up to 35.3 ppm) and the uranium was as high as 28 ppm.

"Contouring" ground radiometric measurements produced a broad high over the central part of Granite Mountain. One pronounced anomaly appears on the west side of the landing strip, where the radioactive nepheline syenite dikes were found, and one centers in the headwaters of Peace River.

There was a general decrease in radiometric measurements northward from Granite Mountain along the Hunter Creek pluton, but another "high" appears at the head of Spruce Creek, a tributary to Hunter Creek.

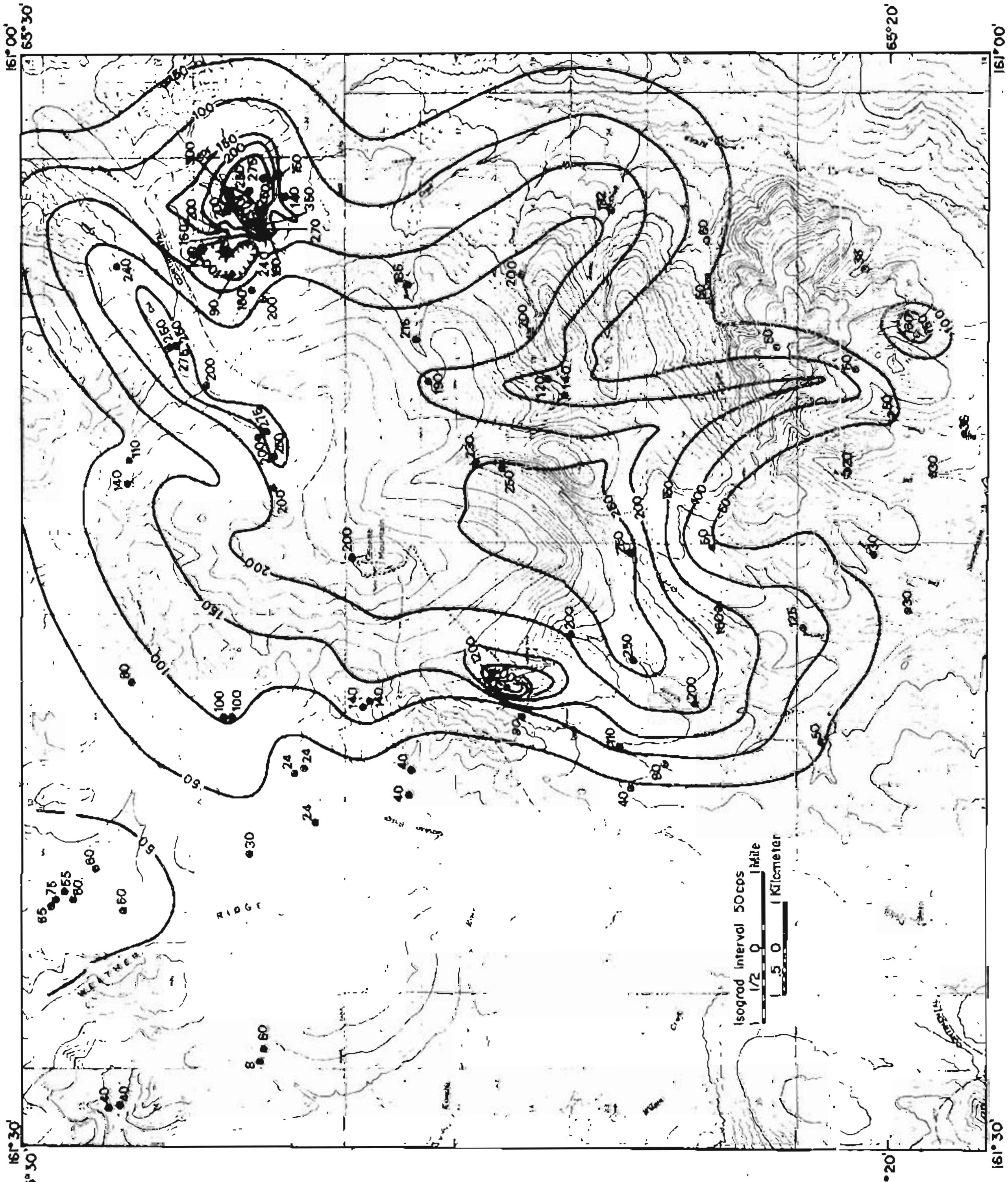

Figure 3. Ground radiometric survey, Granite Mountain area, Candle B-5 quadrangle; by G.R. Eakins and C.L. Carver, 1976.

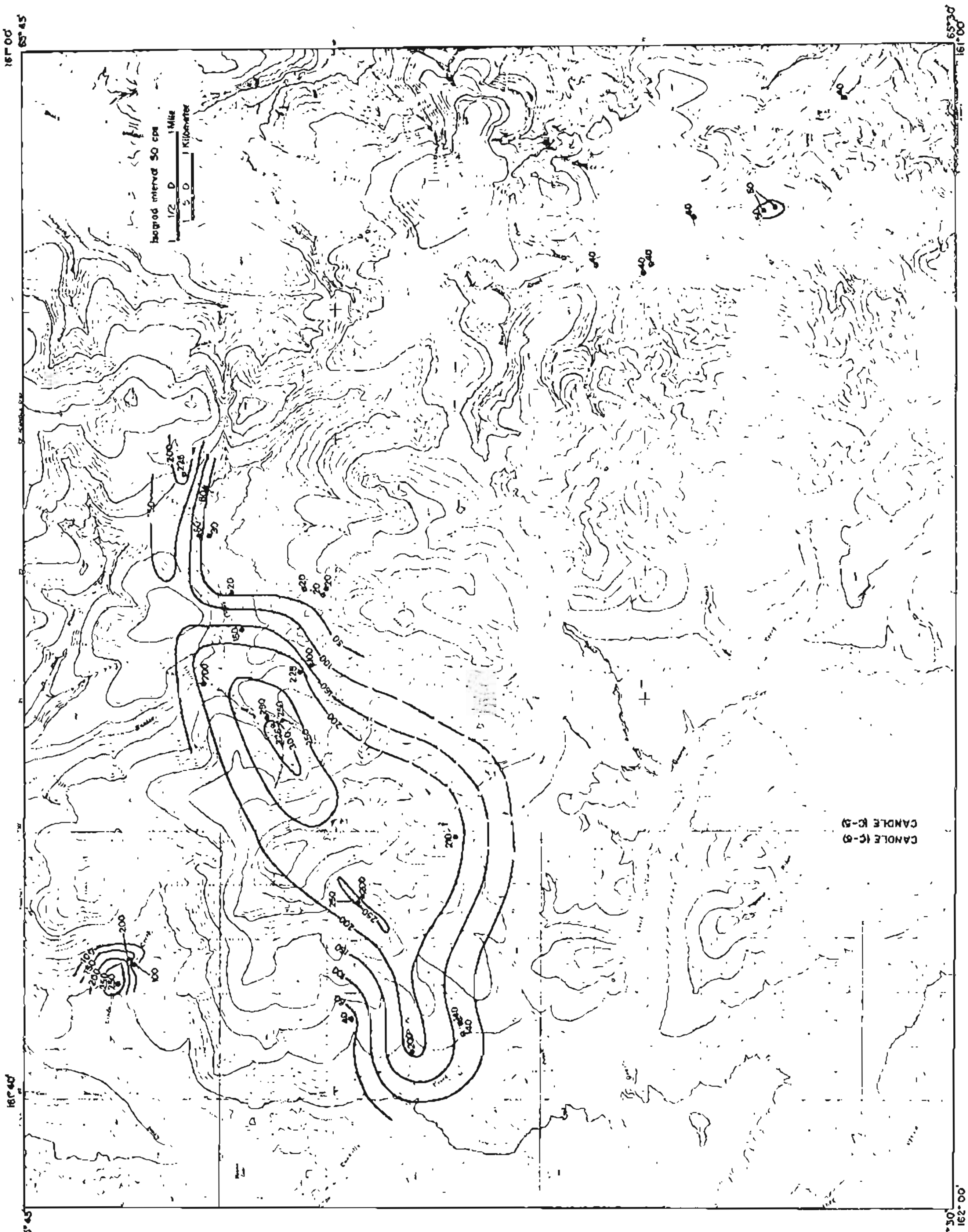

Figure 4. Ground radiometric survey, part of Hunter Creek pluton, Candle C-5 and C-6 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

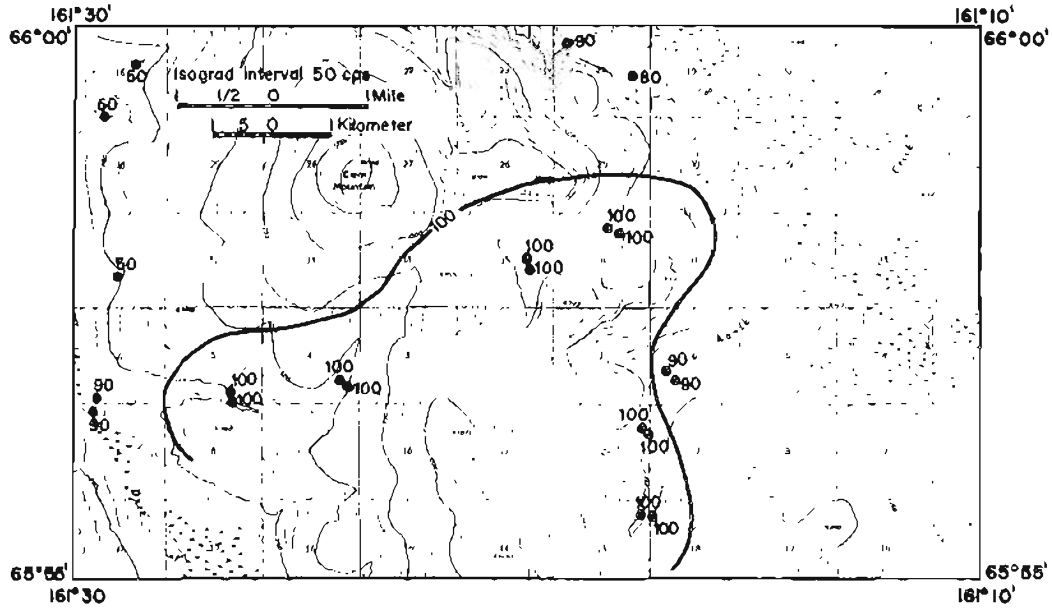

Figure 5. Ground radiometric survey, northern part of Hunter Creek pluton; Candle D-5 quadrangle, by G.R. Eakins and C.L. Carver, 1976.

Suggestions for Exploration

The headwaters of Peace River have been known for many years to contain radioactive material, and it still appears to the writer to be one of the most intriguing localities for exploration. Anomalous U and Th have been found in stream gravel concentrates and stream-sediment samples, and both ground and aerial radiometric surveys have shown the area to be anomalous. Mineralization is believed to be associated with a small monzonite-syenite stock. The area would be relatively easy to explore by drilling. Uraninite or thorianite (or both) were identified in a sample of a granitic boulder on the south side of Granite Mountain.

More detailed studies and sampling are needed to localize uranium prospects in the Granite Mountain-Hunter Creek pluton area. Radiometric and geochemical anomalies are rather widespread around the margins of Granite Mountain and along the western side of the Hunter Creek pluton. Forbes and Jones suggest that rocks of the Granite Mountain pluton most favorable for uranium associations are those containing abundant nepheline and garnet but little plagioclase and amphibole.

The Cretaceous sediments near the center of the Candle quadrangle probably warrant investigation. Compositions of the sediments and aerial radiometric anomalies indicate a favorable area for exploration.

The Darby Mountains

The field party was based at Moses Point, an abandoned FAA station on Norton Bay, while conducting sampling of the Darby Mountains area (pl. 2). The area is in the eastern Solomon quadrangle and the southeastern corner of the Bendeleben quadrangle. Plutonic rocks and streams were sampled from Cape Darby, on the southern end of the Darby Peninsula, northward 60 miles to Death Valley on the east side of the range. On the western side, the northernmost point reached was the Omilak mine on Omilak Mountain. The geologic setting is described in appendix E.

Stream-Sediment Sampling

A total of 163 stream-sediment samples were collected in the area. Results of the analyses are:

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0-81	14.8669	49.2515	15
Uppm (LASL)	6.8-111	20.7463	60.1325	7
Th ppm	4.4-150	33.7210	87.3388	8
K_2O%	0.76-5.5	2.6492	4.3178	7

Agreement between the U analyses reported by RAA and LASL is reasonably good for the sediment samples collected in the Darby Mountains area. Average values for both U and Th are high in the stream sediments. A group of sediment samples (J20-J65) from an area west of Vulcan and Clear Creeks in the Solomon D-1 quadrangle are almost all unusually high, up to 81 ppm U and 99 ppm Th.

Ground radiometric readings were consistently above average (200-600 cps) and the aerial radiometric survey also revealed an anomaly in the D-1 quadrangle (flight-line 71).

The Dry Canyon stock on the west flank of the Darby Mountains produced a highly anomalous stream-sediment sample (77 ppm) and the highest Th value produced in the Darby Mountain area (149.5 ppm).

Bedrock samples collected on the ridges in the same areas as the stream-sediment samples were much lower in uranium content than were the sediments. It appears that uranium has been weathered from the granitic rocks and concentrated in the fines in the streams (especially samples J20-J65), whereas thorium has not migrated significantly. Another possibility for the great disparity in uranium values to consider is that the U extraction from the bedrock by laboratory methods was much less than from the stream sediments. It may be that both the natural and laboratory processes are factors. Since the Los Alamos Laboratory did not do U analyses for bedrock samples, there are no delayed-neutron-activation analyses for comparison.

Water Sampling

A total of 126 water samples was collected in the Darby Mountains area, generally from stream-sediment sites. Results of the water analyses for U are:

	Range	Mean	Threshold	Anomalies
H_2O ppb	0.3-2.3	0.9352	1.984	7

Overall there is some correlation of high U values in the waters to those in corresponding sediment samples. Although the water values are mostly in a low range, the higher ones may relate to anomalous amounts of U in the bedrocks. Four of the anomalous values are 1 to 3 miles south of the aerial radiometric anomaly on flight-line 71.

Bedrock Sampling

A total of 117 bedrock samples were collected in the Darby Mountains area, mostly along an east-west traverse near Vulcan Creek. Bedrock analyses produced the following:

	Range	Mean	Threshold	Anomalies
U ppm	0-20.3	5.1074	12.496	5
Th ppm	0-85.6	32.6709	74.9435	4
K_2O%	0.02-11.18	5.4809	10.7727	8

The Darby Mountains are enriched in silica. Although the U content of some rock samples is unusually high for granitic rocks, the values are generally considerably lower than those of the stream sediments. Thorium, on the other hand, is rather consistently high. Above-average U was obtained from samples in the series J1R-J72R, from the northeast side of the Darby Mountains in the Solomon D-1 quadrangle. The area is underlain by quartz monzonite of the Darby pluton and is drained largely by Clear and Vulcan Creeks.

The corresponding Th content of this series of samples is anomalously high and in greater proportions than that normally found in igneous rocks; this results in a relatively low U:Th ratio, suggesting a Th province.

Two small outcrop areas on the west side of the Darby Mountains are exposures of the Dry Canyon Creek stock. It is predominantly a hornblende-biotite-nepheline syenite consistently high in Th (to 76.0 ppm) and slightly anomalous in U (up to 20.3 ppm). Forbes and Jones found that the samples containing abundant accessary minerals and little nepheline were the best hosts for uranium.

At the time of this writing, the U.S. Department of Interior issued a news release on a uranium-thorium-rare earth find by the USGS in the Kachauik pluton of the Darby Mountains. A 13-page USGS open-file report (Miller, Elliott, Finch, and Brooks, 1976) has been released to the public (Sept. 27, 1976). The DGGS field party did not reach the particular sites of the discoveries, but did conduct sampling within 4 miles of them.

The information in the USGS report is significant to this study and a considerable portion is reproduced here with location maps (figs. 6 and 7).

> *Uranium-, thorium, and rare-earth bearing rocks were found by a U.S. Geological Survey field party 15 miles northeast of Golovin, Alaska, in the southeastern Seward Peninsula (fig. 6) in June 1976. The mineralized areas occur in syenite and appear to be concentrated along the margins of alkaline dikes, with allanite tentatively identified as the principal mineral containing the uranium-, thorium-, and rare-earths. Samples contain as much as 0.15 percent U_3O_8 and 1.05 percent ThO_2, and over 2 percent rare-earth elements. These mineralized rocks are closely associated with alkaline dikes which are part of a dike swarm that crops out over at least 250 km^2 (100 mi^2). This large dike swarm is thus of considerable economic interest.*

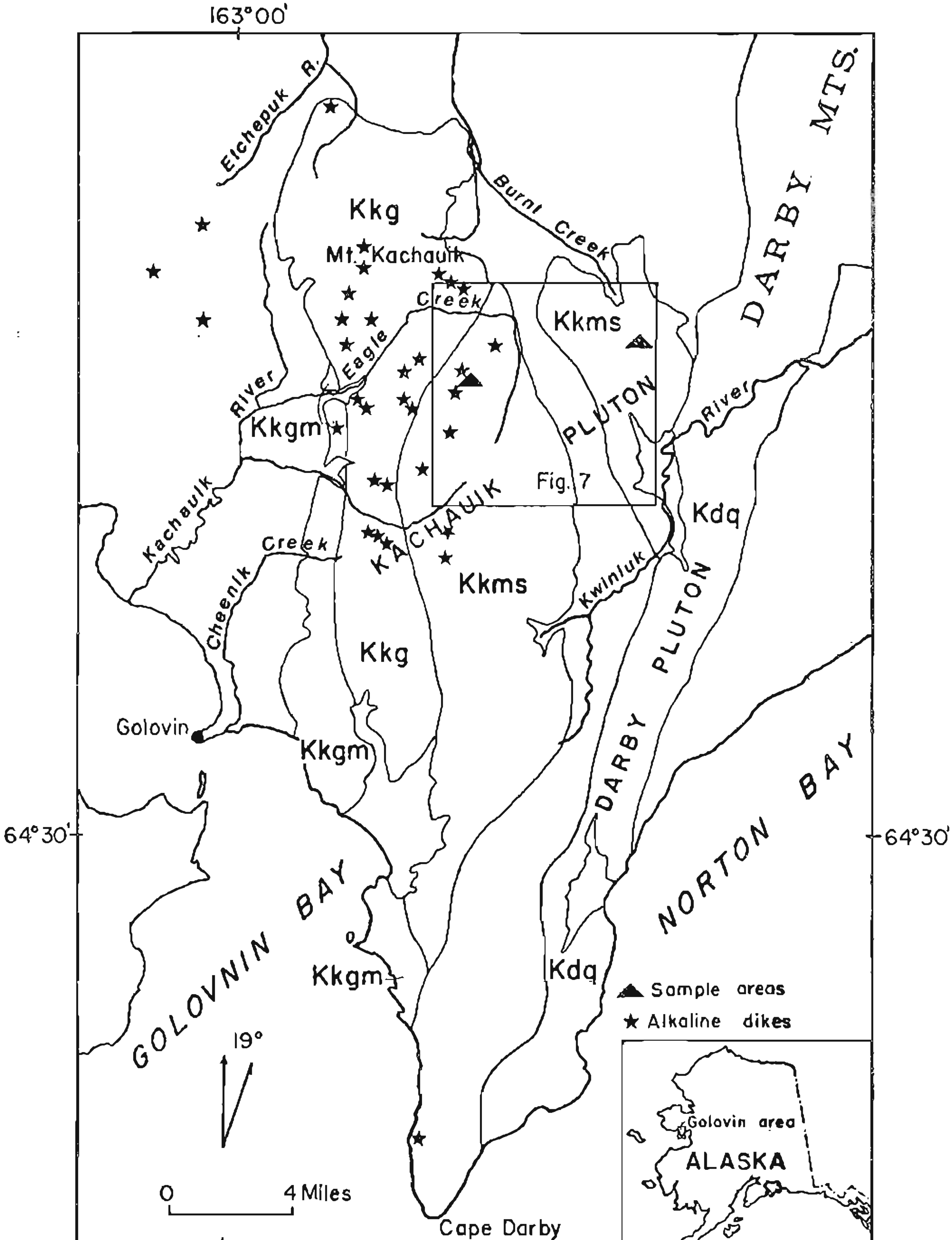

Figure 6. Generalized geology of the Darby Mountains area. Sources: Miller, Elliott, Finch, and Brooks, 1976.

The principal mineralized area occurs on top of a small flat knoll shown as hill 2109 in the SW 1/4 of Sec. 18, T. 9 S., R. 20 W. on the Solomon C-2 1:63,360 quadrangle map, (fig. 7) located on the crest of a north-south ridge bounded on three sides by Eagle Creek (fig. 7). The mineralized rock consists of medium- to coarse-grained syenite characterized by large (as much as 1.25 cm or 0.5 in) brownish-black allanite crystals constituting 20 to 40 percent of the rock. Because of extensive frost-heaving, none of the allanite-rich rock can be found actually in place; however, abundant pieces of float of this material as much as 30 cm (12 in) across occur scattered over a zone 9-14 m (30-45 ft) wide and extending some 60 m (200 ft) across the top of the knoll. This zone lies near the east margin of a northeast-striking pulaskite dike which extends for some 900 m (3,000 ft) along the ridge crest. Float of allanite-bearing syenite was found in several other places over a distance of 450 m (1,500 ft) along the eastern margin of the dike south of hill 2109 suggesting the mineralized zone may have considerable strike length. The dike is off-set as much as 15 m by faulting in at least two places.

The actual width of the mineralized zone is difficult to determine owing to the lack of true outcrop. The larger talus blocks of nonmineralized monzonite and syenite tend to mask the smaller blocks of allanite-bearing syenite on the slopes and on the ridge crest away from the flat-topped knoll at hill 2109.

The allanite-bearing syenite is strongly radioactive with a total count of up to 8,000 cps being recorded for pieces of float up to 12 inches across. This is 20 to 25 times background for the syenite and monzonite of the Kachauik pluton. In addition to allanite, the mineralized rock contains K-feldspar, plagioclase, and nepheline with minor hornblende and biotite. Zircon, apatite, and sphene are present as accessories. Nepheline has been previously noted at a few localities in the Kachauik pluton, but it does not appear to be widespread. Its occurrence next to a nepheline-bearing dike suggest that it may have been metasomatically introduced, perhaps along with the allanite.

Other pulaskite dikes occur on the west side of hill 2109 and strongly radioactive allanite-bearing syenite float was found along the margin of at least one of these dikes (sample 1, table 3).

Samples of the strongly radioactive allanite-bearing syenite and of the pulaskite dike were analyzed for uranium and thorium. These samples were selected as being typical of the most radioactive material found and were taken from float blocks as much as 30 cm (12 in) across. The uranium content of the radioactive allanite-bearing syenite averages 1,325 ppm (0.156 percent U_3O_8) by neutron activation analysis and thorium averages 7,990 ppm (0.91 percent ThO_2). A sample of the pulaskite (sample 2) dike yielded 34 ppm U (0.004 percent U_3O_8) and 96 ppm Th (0.011 percent ThO_2), which is about 7 times the uranium content for the average monzonite and syenite and about 4 times the thorium background.

SOLOMON (C-2) QUADRANGLE
ALASKA

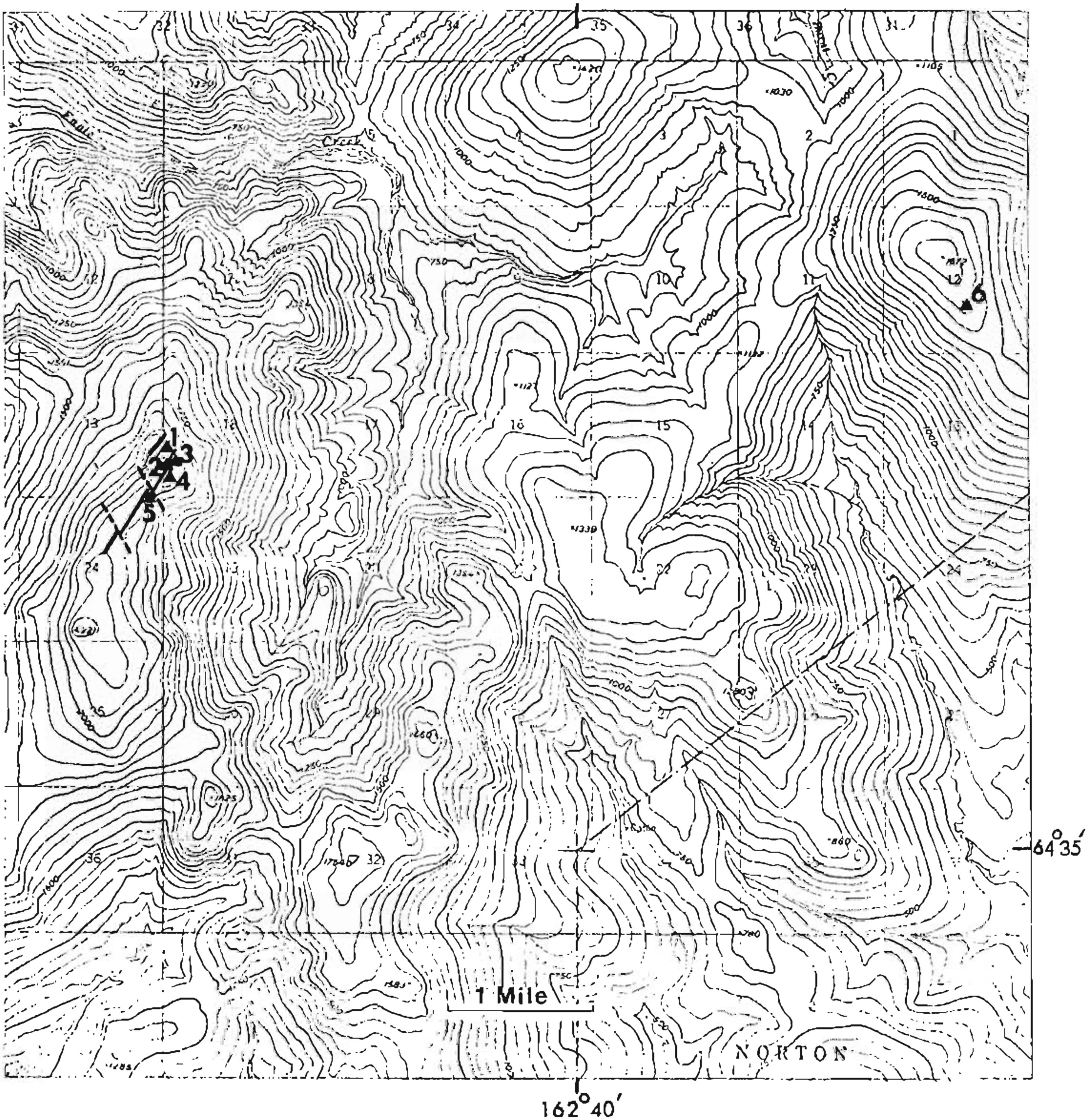

Figure 7. Location of mineralized areas and analyzed samples referred to in table 3. See figure 6 for general location. Source: Miller, Elliott, Finch, and Brooks, 1976.

These same rocks were analyzed for rare-earth content. It should be noted that these are semi-quantitative spectrographic analyses and therefore are only approximate. The analyses, however, indicate that the rare-earth content, particularly that of the cerium group of rare-earths, may exceed 2 percent in some samples.

On a low flat-topped spur 1.5 mi to the north in the NW 1/4 of Sec. 7, T. 9 S., R. 20 W. (fig. 7), radioactivity readings of 600 cps were recorded on the bog and tundra-covered ridge crest suggesting other mineralized areas may occur in this area.

Similar allanite-rich syenite was found occurring as isolated boulders on a largely tundra-covered ridge 10 km (6 mi) to the east in Sec. 12, T. 9 S., R. 20 W. north of Burnt Creek (fig. 7). A fist-sized sample (no. 6, table 3) taken from a large boulder yielded 392 ppm U (0.059 percent U_3O_8) and 9,200 ppm Th (1.05 percent ThO_2).

Allanite appears to be the principal uranium-, thorium-, and rare-earth-bearing mineral in the several samples examined in thin-section. A detailed study of the mineralogy has not been made, however, and other uranium minerals may be present. The allanite occurs as euhedra as much as 1.25 cm (0.5 in) long, is strongly metamict, and cut by numerous anastomosing fractures. A characteristic bright reddish-brown weathered crust is found on the weathered surfaces of many of the allanite crystals: according to Hata (1939), this material consists mainly of ferric hydroxide, alumina, silica, and carbon dioxide. Zircon, while moderately abundant, occurs only as an accessory.

The mineralized areas and much of the area of alkaline dike occurrence are in lands presently withdrawn for native village and/or regional corportation selections under the Alaska Native Claims Settlement Act (ANCSA) of 1971; the remainder of the area of alkaline dike occurrence is withdrawn under section D-2 of ANCSA for possible inclusion in national systems lands (Parks, Wildlife Refuges, etc.).

The extent and value of the mineralized areas described here is unknown owing to the relatively poor exposures and the brief time spent in the area. The width of the mineralized zones are unknown and could be quite narrow; their strike length, however, could be considerable. The uranium, thorium, and rare-earth contents of samples are sufficiently high as to indicate further study of the economic potential of the deposits is warranted.

Of perhaps equal importance is the fact that similar mineralized material was found associated with alkaline dikes in two other localities, one of which is 6 miles away from the hill 2109 locality. These dikes are enriched in uranium and thorium as compared to the average monzonite-syenite of the pluton and may represent a lithologic and/or structural control of the uranium, thorium, and rare-earth mineralization. Since the alkaline dikes are part of a dike swarm that crops out over at least 250 Km^2 (100 mi^2), this entire area appears worthy of more detailed exploration for uranium, thorium, and rare-earth elements.

Table 3. Uranium and thorium analyses in parts per million (ppm) of samples from the Kachauik pluton. Map number refers to Figure 7 (Miller, Elliott, Finds, Brooks, 1976.)

Map no.	Field no.	U ppm[1]	U ppm[2]	Th ppm[1]	Th ppm[2]
1	76 AMm112	1107	1000	6619	5700
2	76 AMm112C	34	- -	96	- -
3	76 AEr23	1162	1050	7692	6400
4	76 AM112B	1486	- -	9240	- -
5	76 AEr23B	1545	1500	8408	7000
6	76 AMm110	- -	392	- -	9200

[1] *Delayed neutron determination. The coefficient of variation of uranium and thorium is more than 1% for all samples. Analysts A.J. Bartel and R.J. Vinnola.*

[2] *Gamma-ray spectrometric analysis. The coefficient of variation of uranium and thorium is more than 2% for all samples. Analysts C.M. Bunker and C.A. Bush.*

Aerial Radiometric Survey

The aerial radiometric survey produced a "perferred" anomaly over the quartz monzonite of the Darby pluton in the northern part of the Solomon A-1 quadrangle (flight-line 71), and over the granodiorite of the Kachauik pluton (flight-line 73). Three suspect anomalies were calculated from the survey: one each over the Kachiauk and Darby plutons and one over Cretaceous conglomerate on the northeast flank of the Darby Mountains.

Ground Radiometric Survey

Results of the ground radiometric survey are shown in figures 8 and 9. The readings were high even for alkaline intrusive rocks: 200 to 600 cps over most of the upland area, compared to about 50 cps in the surrounding lowlands. The maximum reading, 1,200 cps, was obtained at stream-sediment sample location J92 in one of the uppermost reaches of the Kwiniuk River. The 1,200-cps count was obtained at a point in sandy and gravely loam on the bank of a small stream. A soil sample at the point yielded 9 ppm U and 90.8 ppm Th. Bedrock was not exposed, but the area is underlain by granodiorite of the Kachauik pluton.

The Dry Canyon pluton on the west flank of the Darby Mountains in the Solomon D-2 quadrangle is anomalously radioactive - 400 to 700 cps. The radiometric survey was supported by unusually high U and Th in bedrock and stream-sediment samples. A flight line of the aerial radiometric survey passed over the northern end of the pluton. Three consecutive data points recorded only 1-2 standard deviations and an aerial radiometric anomaly was not reported.

Suggestions for Exploration

Above-average U and Th in stream-sediment and water samples, and a broad radiometric anomaly in the headwaters of Vulcan and Clear Creeks of

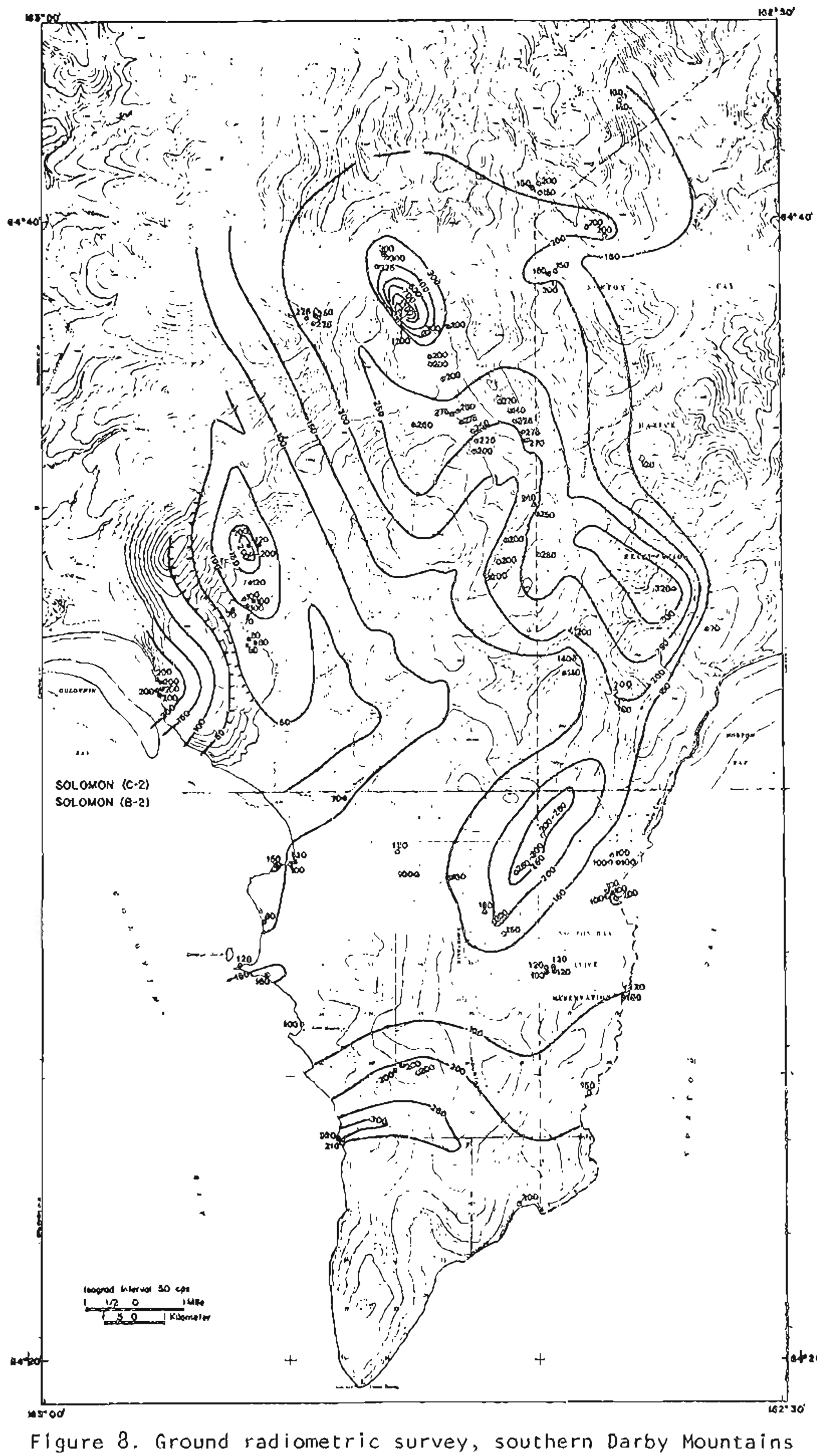

Figure 8. Ground radiometric survey, southern Darby Mountains area, Solomon B-2 and C-2 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

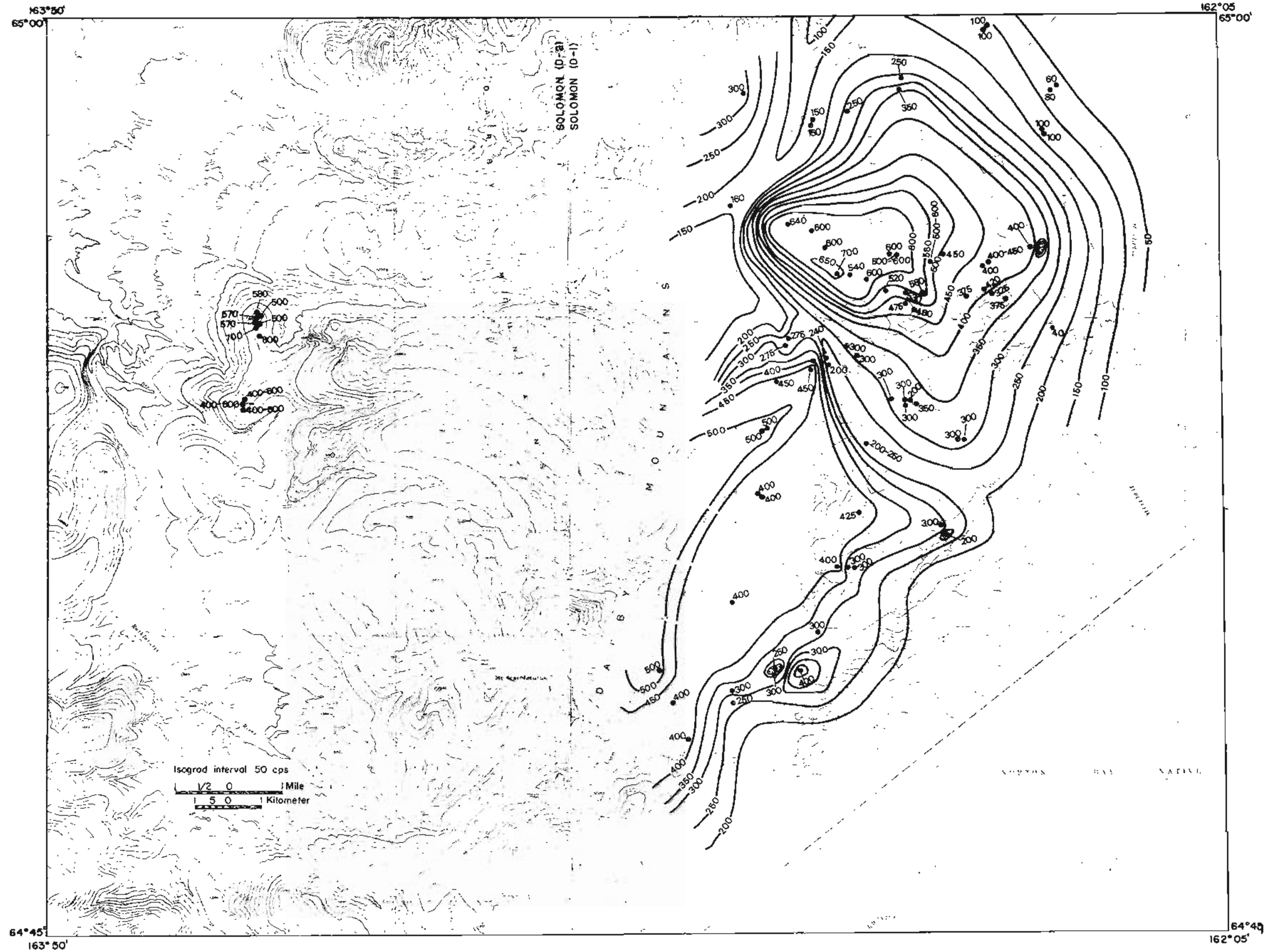

Figure 9. Ground radiometric survey, northern Darby Mountains area, Solomon D-1 and D-2 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

the central and east-central Darby Mountains may indicate a favorable area for uranium exploration. Follow-up work is also suggested in the vicinity of sediment sample J92 and in the headwaters of the Kwinik River, where a scintillometer reading of 1,200 cps was obtained. Examination of the Dry Canyon pluton is considered warranted on the basis of sediment samples and the ground radiometric survey.

The highly radioactive alkaline dikes in the western part of the area, which contain up to 0.15 percent U_3O_8 and 1.05 percent Th as reported by the USGS, are very encouraging finds in this region and indicate the need for detailed investigations.

Selawik Hills Area

The Selawik Hills (pl. 3) lie in the southern part of the Selawik quadrangle and along the northern edge of the Candle quadrangle. The field party was based at the Native village of Buckland on the Buckland River during the 1 week in the vicinity. Sampling and radiometric surveys were concentrated on the alkaline rocks of the Selawik Hills pluton and the small Inland Lake and Selawik Lake plutons that lie a short distance north of the Selawik Hills (fig. 2). The geologic setting is described in appendix E under "Hogatza Plutonic Belt of West-central Alaska." The Selawik Hills area has already attracted uranium explorationists. During the summers of 1975 and 1976, the Wyoming Minerals Corporation, a subsidiary of Westinghouse, conducted a drilling program in the central part of the Selawik Hills in the Selawik A-3 quadrangle. Results are not available to the writer, but it was rumored that deep holes were drilled to test the pluton for secondary enrichment at depth.

Stream-Sediment Sampling

A total of 84 stream-sediment samples were collected. Results of the analyses are:

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0.0-27.4	5.3963	13.8971	3
Uppm (LASL)	1.80-100	13.3966	44.6608	3
Th ppm	1.0-96.9	31.9267	79.8525	2
K_2O%	0.93-7.23	2.6755	4.8203	2

There is a considerable descrepancy between the RAA and LASL analyses. Los Alamos did not receive all the samples, but those they did analyze were nearly all notably above the average for U in alkaline intrusive rocks. Except for samples G66-G81, most of the uranium values reported by RAA were not unusual. These 15 samples were collected in the Selawik A-4 quadrangle, in the western part of the Selawik Hills. However, the analyses by Los Alamos showed above normal U to be much more widespread; 28 samples contained over 10 ppm. The higher U values reported by Los Alamos seem more consistent with the high radiometric background and high Th values.

Water Sampling

Uranium values from 57 water samples collected in the Selawik Hills ranged from 0.00 to 1.75 ppb. The results are surprisingly low for an area of known high radioactivity:

	Maximum	Mean	Threshold	Anomalies
H_2O (ppb)	1.7000	0.4962	1.2276	5

Only six of the water samples exceeded 1 ppb. Four of these (G75-G78) were collected from the southwestern flank of the Selawik Hills, south of the center of the Selawik A-4 quadrangle. The corresponding stream-sediment samples are above average for both U and Th.

Bedrock Sampling

A total of 66 bedrock samples from the Selawik area were analyzed. Results are:

	Range	Mean	Threshold	Anomalies
U ppm	0.0-139	10.8833	60.3041	3
Th ppm	0.0-618	46.0958	239.2816	3
K_2O%	0.0-17.05	7.7311	15.3131	3

Rock samples G1R-G10R, collected from the Inland Lake pluton in the Selawik B-3 quadrangle, suggest a potential uranium area. This poorly exposed alkaline complex underlies a group of low hills located 6 to 10 miles north of the Selawik Hills. The rocks, according to Miller (1972, table 2) include pulaskite, malignite, foyaite, nepheline syenite, and alaskite. Two samples of the group, G8R and G10R, contained unusual amounts of U, 86.0 and 92.0 ppm, respectively. The corresponding Th values are 70.3 and 37.0 ppm, respectively. An outstanding characteristic of the pluton is the exceptionally high K_2O content, 10.65 to 17.19 percent.

Two other bedrock samples with unusual U and Th contents are samples G53R and G54R, which contain 139.0 and 44.0 ppm U, and 618.0 and 277.5 ppm Th, respectively. These samples were obtained from an altered felsic dike that is poorly exposed on the southeast side of a low spur (hill 860) in sec. 30, R. 8 N., T. 9 W. near the center of Selawik A-4 quadrangle. The dike, possibly a syenite, was found to be highly radioactive and produced up to 2,000 cps on the outcrop. One radioactive mineral was identified by the DGGS laboratory as tantalian rutile (struverite; Fe [Ta, Nb] TiO) which occurs in small (1 mm) crystals. The dike is about 3 feet wide and is exposed at three points within a distance of 200 feet. The strike is northwest. Radioactivity of adjacent igneous rocks along the crest of the spur to the west is also high (400 to 600 cps).

While an extension of the radioactive dike was sought along a projection of the strike to the southeast, it was not found. However, a highly anomalous stream-sediment sample (G73) collected 1.1 miles southeast of the dike outcrop and possibly on strike was found by the Los Alamos laboratory to contain 100 ppm U. RAA reported 27.4 ppm U.

The group of four anomalous water samples described under "Water Sampling," above, were collected about 3 miles to the southwest of these bedrock and sediment samples. Although the samples were found in different drainages, their near proximity may be significant and add evidence for a possible U concentration in the general area.

Aerial Radiometric Survey

Texas Instruments reported two preferred anomalies over the Selawik Hills: one on the north slope on flight-line 57 in the Selawik A-3 quadrangle and one on flight-line 58 over the southeastern part of the Selawik A-2 quadrangle. A suspect anomaly was shown at the intersection of flight-lines 57 and 457 in the southwest part of A-4 quadrangle. Spacing of the flight lines does not permit correlations with sampling results.

Ground Radiometric Survey

Results of ground radiometric investigations in the Selawik Hills area are shown in figures 10, 11, and 12. The general background was found to be relatively high over the plutonic rocks, averaging possibly 300 cps (compared with a low of 30 cps encountered at the edge of the Selawik Hills). Two radiometric highs are conspicious in the A-4 quadrangle: one shows a maximum value of 700 cps near the summit of a 1,360-foot hill in the north-central part, and one surrounding the radioactive dike mentioned under "Bedrock Sampling," above. Another high appears as a broad anomaly in the central part of the Selawik A-3 quadrangle.

Suggestions for Exploration

Much of the Selawik Hills area could not be sampled or examined even in a cursory manner within the time allowed for this part of the program. In light of the U and Th values found in the samples and the anomalous radioactivity, however, it is believed that more complete investigations can produce additional anomalies and define drilling targets. Forbes and Jones found that uranium is associated with biotite in this area.

The radioactive dike and adjacent bedrock in the central part of the Selawik A-4 quadrangle, the nearby sediment-sample containing 100 ppm U, and the relatively high U content in water samples 3-4 miles to the south suggest a several-square-mile area that warrants detailed study. The broad radiometric anomaly and moderately high stream-sediment samples in Selawik A-3 quadrangle also indicate a favorable area for exploration; this area includes Wyoming Minerals' claims. Wyoming Minerals reportedly has drilled the intrusive rocks to depths of several hundred feet in an effort to determine if there has been secondary enrichment of U, but no data are available to the writer.

The highly potassic stocks in the Selawik lowlands contain as much as 92 ppm U in dikes; this suggest that detailed study in this locality is warranted.

The Zane Hills Area

The DGGS field party was based near UV Industries' gold dredge camp at Hogatza on Bear Creek while conducting field work in the Zane Hills

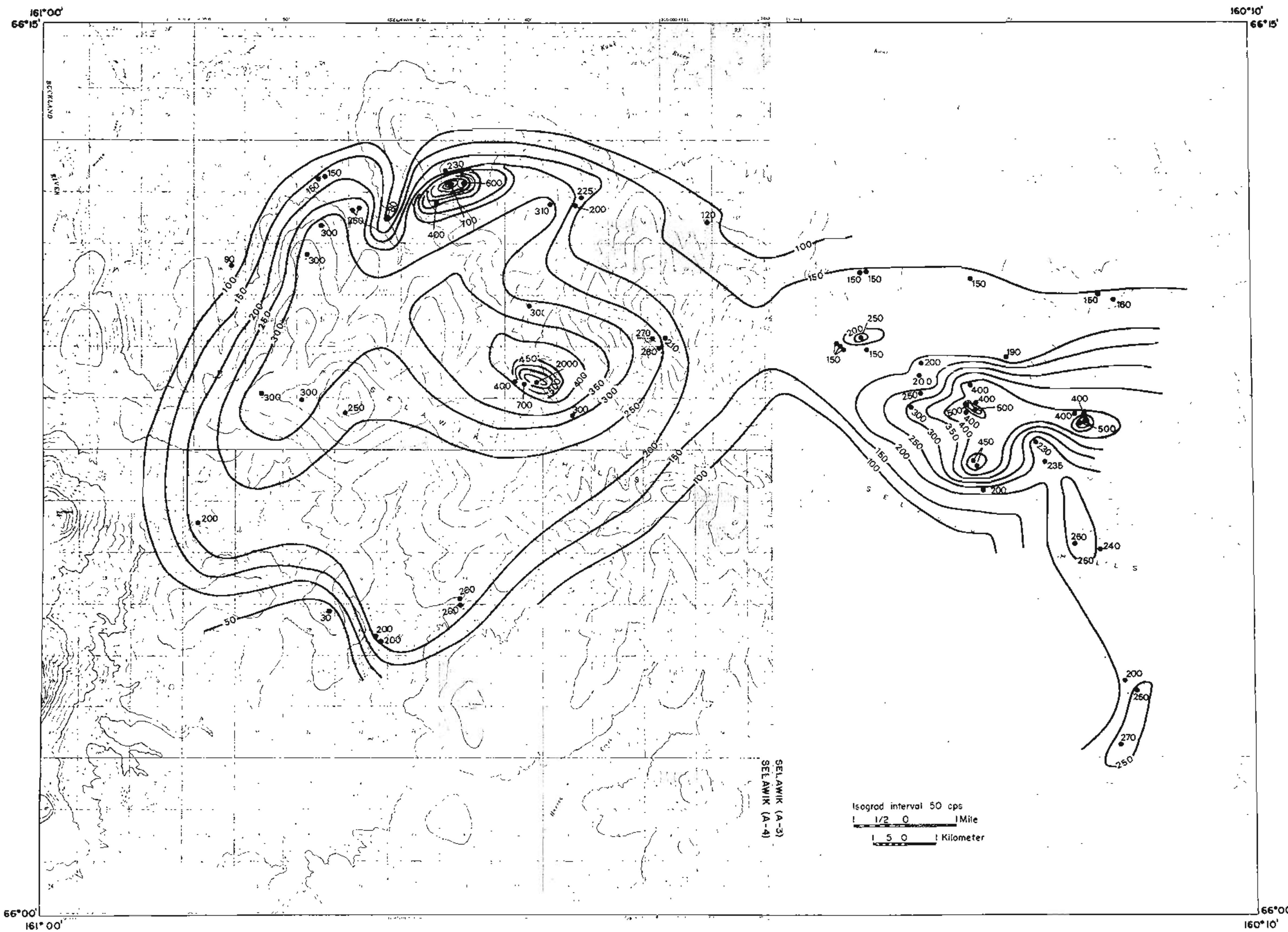

Figure 10. Ground radiometric survey, Selawik Hills, Selawik A-3 and A-4 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

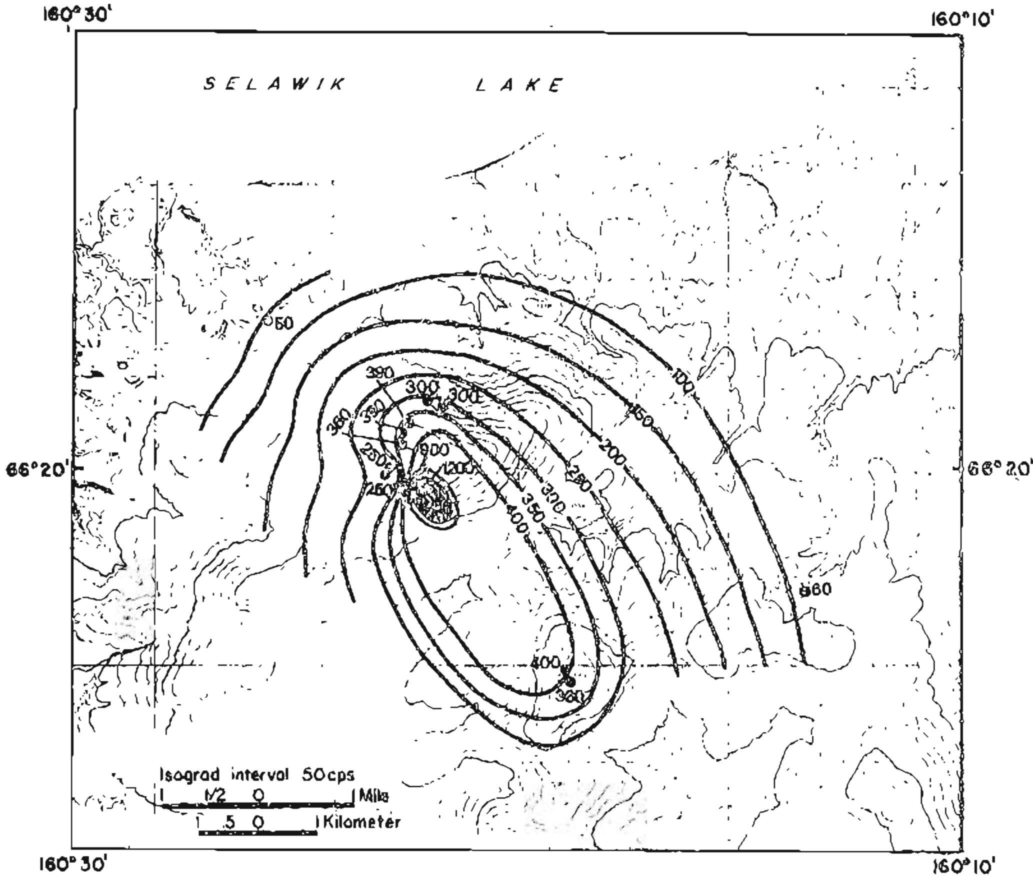

Figure 11. Ground radiometric survey, western Selawik Hills, Selawik B-3 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

and Purcell Mountains (pl. 4). The area lies in the Hughes and Shungnak quadrangles (fig. 2). There is a good landing strip at Hogatza, but it is privately owned and permission must be obtained prior to use.

Anomalous amounts of U in the quartz monzonite border phase of the Zane Hills and mineral occurrences in both the Zane Hills and Purcell Mountains have been known for some time (Miller and Ferrians, 1968) and the region is considered favorable for uranium exploration. A summary of the geology is included in appendix E, under "Hogatza plutonic belt of west-central Alaska," and the petrology is discussed by Forbes and Jones in the section on granitic rocks.

Parts of the Cretaceous Zane Hills and Wheeler Creek plutons were sampled (pl. 4). The Zane Hills pluton is predominantly granodiorite, but monzonite and quartz monzonite constitute about 10 percent of the rocks. The Wheeler Creek pluton, which forms a large part of the Purcell Mountains, is composed of granodiorite, quartz monzonite, and alaskite.

Stream-Sediment Sampling

A total of 96 stream sediments were collected in the Zane Hills area. The values from the analyses are:

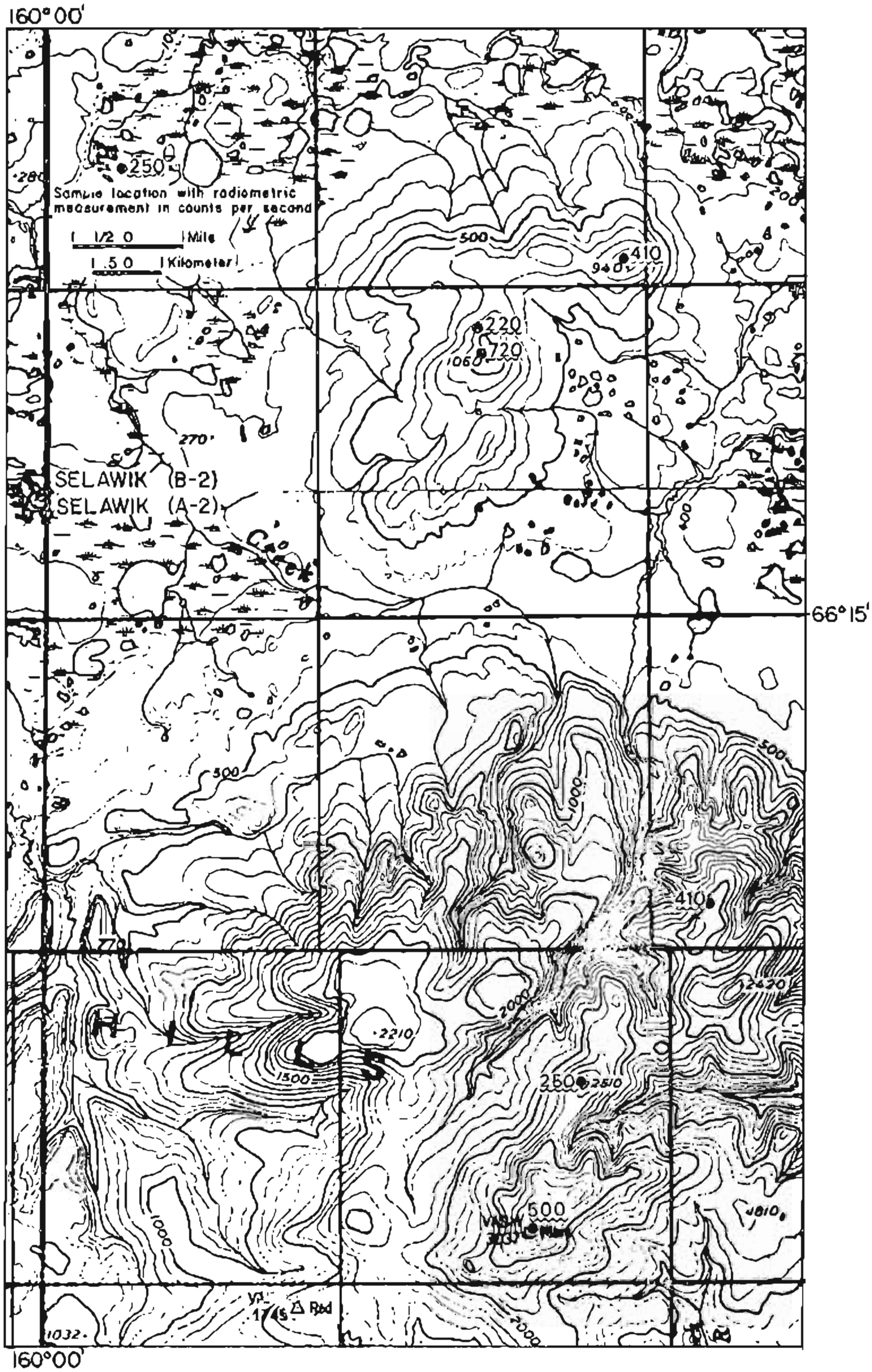

Figure 12. Ground radiometric survey, Selawik Hills-Inland Lake area, Selawik A-2 and B-2 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0.8-57.0	11.7126	35.3198	6
Uppm (LASL)	3.3-77.0	22.3518	59.0502	7
Th ppm	4.5-120.0	30.2095	72.6465	5
K_2O%	0.97-3.69	2.0772	3.245	4

The U analyses reported by Los Alamos average over 50 percent above those reported by RAA, but both sets of analyses contain numerous relatively high values.

The border zones along the southeastern-southwestern edges of the Zane Hills yielded stream sediments with contents higher than those found in other parts of the pluton, U up to 60 ppm, Th up to 98 ppm. These areas have been described by Miller and Ferrians (1968).

A second particularly anomalous area is the western part of the Wheeler Creek pluton (samples H33-H39 and H52-H57) in the Purcell Mountains. The area lies in the Shungnak A-3 and B-3 quadrangles. Uranium was as much as 77.0 ppm and Th as much as 120.0 ppm. The anomalous area lies across the contact of alaskite on the west and monzonite and quartz monzonite on the east.

Water Sampling

A total of 84 water samples from the Zane Hills and Purcell Mountain were analyzed for U.

	Maximum	Mean	Threshold	Anomalies
H_2O ppb	3.95	1.1220	2.669	5

The nine samples in the series D30-D38 compose an anomalous group. These samples were collected from the Caribou Creek drainage in the southern part of the Zane Hills. Sometimes they support the U values reported from stream sediments and bedrock, but in other cases there is no correlation. The U value of 3.95 ppb is the highest obtained from any water samples collected during the entire 1975 DGGS project.

Bedrock Sampling

A total of 49 bedrock samples were collected from the Zane Hills and Purcell Mountains. Their analyses produced the following values:

	Range	Mean	Threshold	Anomalies
U ppm	0.60-49.0	6.6872	24.632	2
Th ppm	2.08-126.3	27.5588	73.9118	2
K_2O%	0.75-8.15	4.1629	7.3887	1

Eleven of the 49 rock samples were noticeably above average for granitic rocks (over 6 ppm), but the remaining seem low for this area. This may be partly due to incomplete extraction of U from silicate accessory minerals. None of the calculated anomalies for the three elements is for the same sample. The U:Th ratio exceeds 3.6 in one sample, H4R.

Anomalous U was found in pegmatite dikes. Two samples, H4R and H5R, yielded 49.0 and 19.4 ppm U, respectively. These are from the east side of Zane Hills near the contact with the volcanic rocks on a spur 14.5 miles northwest of Hogatza.

Samples H30R-H38R are noticeably high in U. These samples represent alaskite from the western end of the Wheeler Creek pluton in the Purcell Mountains. The U values for six rocks of this group range from 9.0 to 32.7 ppm.

Aerial Radiometric Survey

The aerial survey by Texas Instruments produced a preferred anomaly over Caribou Mountain on the east side of the Zane Hills, 4 to 8 miles west of Hogatza. Five bedrock samples from this locality (D5R-D9R) were collected by the DGGS party, but none was anomalous in U, Th, or K_2O. A ground radiometric anomaly of 600 cps, however, was measured on the east side of Caribou Mountain peak.

A broad aerial radiometric anomaly was produced over the central part of the Purcell Mountains at the junction of flight-lines 56 and 461. No samples were collected within the anomalous area, but anomalous stream sediments (H42, H53) were obtained about 3 miles to the west.

Several suspect anomalies were calculated in the Hughes and Shungnak quadrangles, but their significance is questionable. Some appear over tundra-covered lowlands.

Ground Radiometric Survey

The radiometric background of the Zane Hills pluton is generally high (figs. 13, 14, and 15); the average was found to be 200 cps or more. Radiometric highs are present on Caribou Mountain (600 cps) and across the southern end of the Zane Hills south of Caribou Creek, where radiometric readings were as much as 1,000 cps. A broad area in the central part of the Purcell Moutains is a radiometric high where counts are 400 to 500 cps.

Correlation of radiometric readings with the U and Th contents of stream sediments and rock samples is usually good, but sometimes poor. Again, the incomplete extraction from some of the bedrock samples is a possibility.

Suggestions for Exploration

Anomalous U and Th values were obtained from stream-sediment, bedrock, and water samples in the Zane Hills and Purcell Mountains, and radiometric highs are present. The anomalous localities warrant more detailed sampling, and the areas not sampled by the DGGS should also be investigated. The broad geochemical and radiometric anomalous part of the Purcell Mountains alaskite seems to offer promise for a uranium deposit. Forbes and Jones recommend concentrating on the augen gneiss unit which they discovered.

The adjacent lowlands of the Pah River Flats and the Selawik and Koyukuk Rivers may deserve study for possible sedimentary-type uranium deposits.

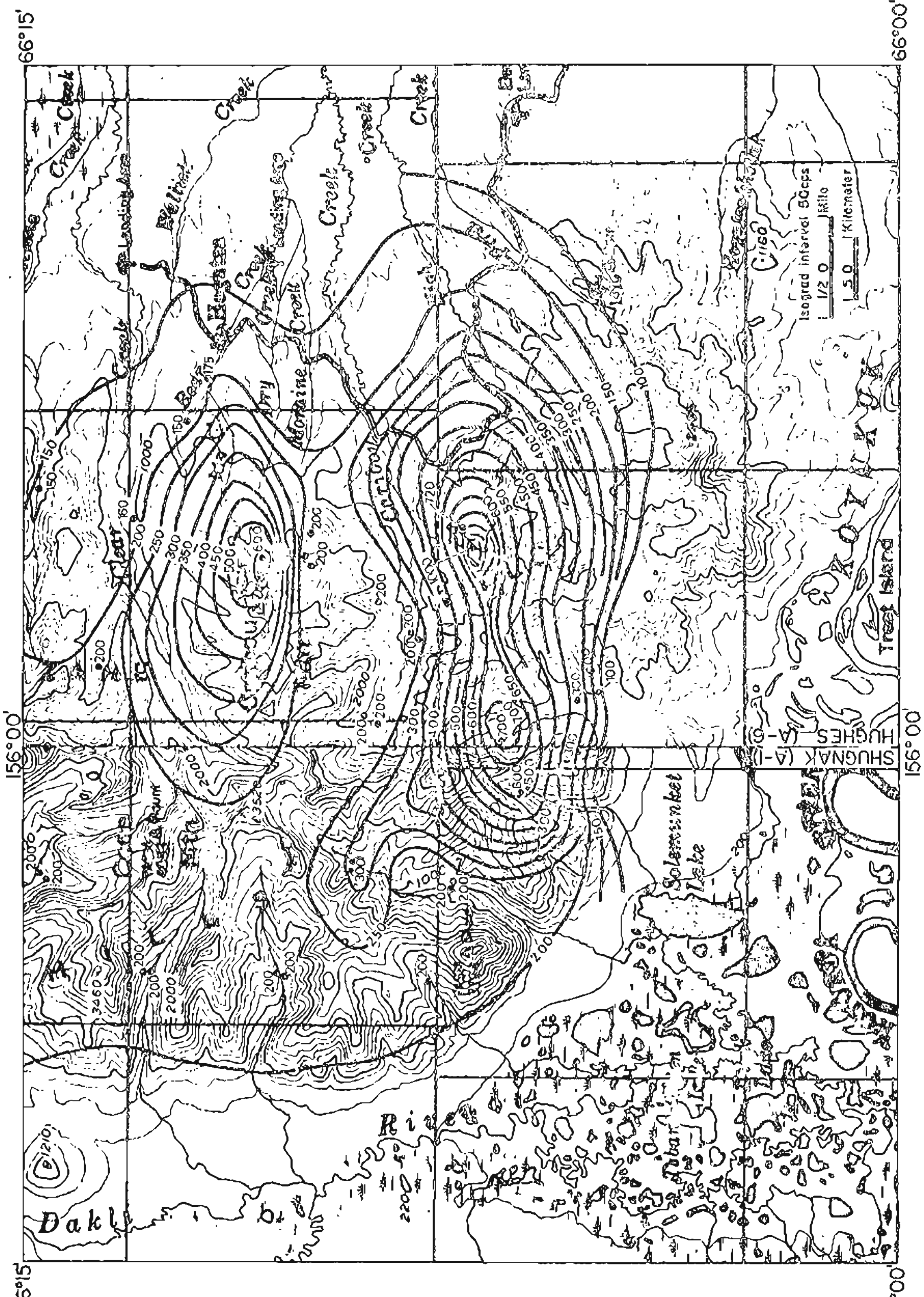

Figure 13. Ground radiometric survey, southern Zane Hills, Shungnak A-1 and Hughes A-6 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

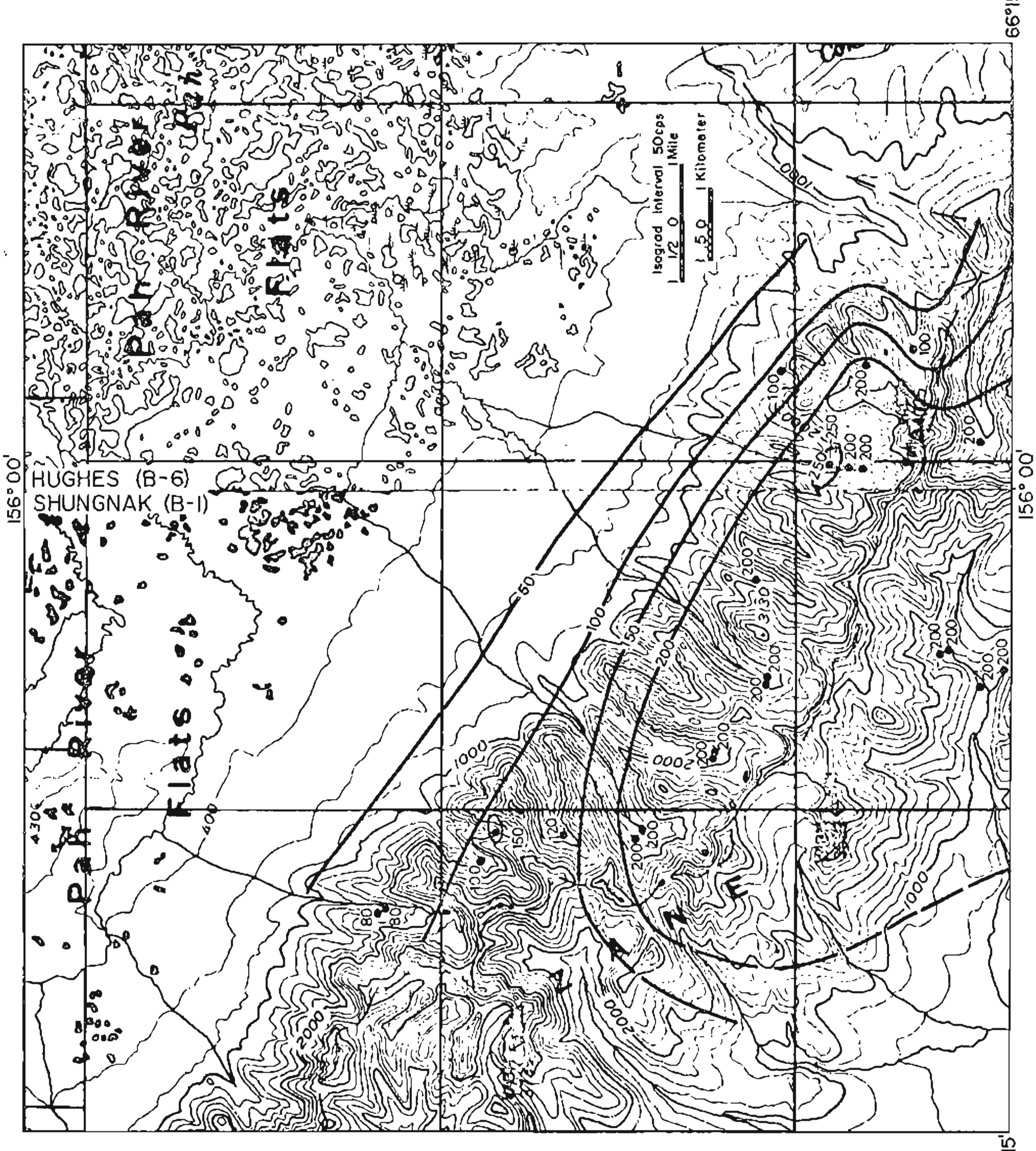

Figure 14. Ground radiometric survey, northern Zane Hills, Shungnak B-1 and Hughes B-6 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

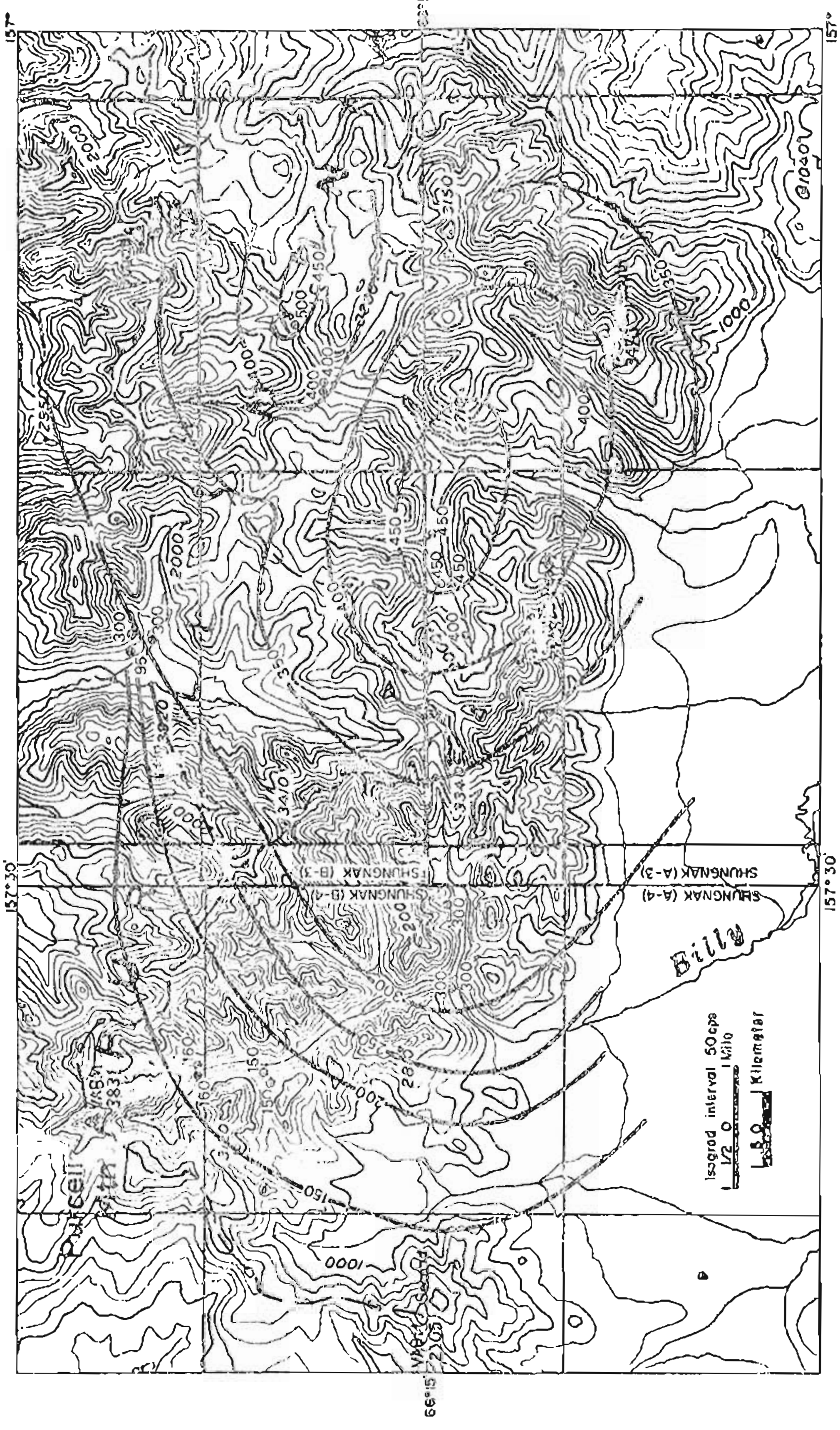

Figure 15. Ground radiometric survey, Purcell Mountains, Shugnak A-3, A-4, B-3, and B-4 quadrangles; by G.R. Eakins and C.L. Carver, 1976.

Copper River Basin

The Copper River basin is a confined area about 80 miles across with narrow outlets. It is filled with a variety of glacial and fluvial sediments of Cretaceous and Tertiary ages that are considered possible hosts for sedimentary U. The area lies in the Gulkana and eastern part of the Talkeetna Mountains quadrangles (fig. 16). The Cretaceous and Tertiary sediments are poorly exposed, but samples of Tertiary sandstones were obtained along the Richardson Highway in the northwestern part of the basin and near the Glenn Highway in the southeastern part. Areas of intrusive rocks in the Talkeetna Mountains along the western margin of the basin were sampled to determine their favorability as host to vein deposits or sources for sedimentary deposits. The geology is discussed in appendix E under the section on the Copper River basin-Chitina River valley. Minor exploration activity for petroleum and uranium by industry was still being conducted during 1975 and 1976.

Field work was conducted from a lodge on the Glenn Highway with helicopter support during a 5-day period. Sample location sites appear on plates 5, 7, and 10.

Stream-Sediment Sampling

In the Copper River basin area, 96 stream-sediment samples were collected. Statistics of their analyses are:

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0.30-2.80	1.30	2.45	4
Uppm (LASL)	0.15-3.30	1.44	2.80	3
Th ppm	0.50-16.0	4.29	9.71	5
K_2O%	0.20-2.00	0.97	1.60	2

U and Th values in all samples were consistently low, especially when compared with those collected in west-central Alaska. One anomalous sample (C5) was from Cache Creek in the southern part of Gulkana A-6 quadrangle in an area underlain by Tertiary or Mesozoic sediments. The other three anomalous sediment samples were from scattered locations in the headwaters of the Susitna River (Talkeetna Mountains B-2 and C-2 quadrangles) in areas underlain by Mesozoic and older volcanic and sedimentary rocks. The low values and a lack of clustering of the anomalous results prevent the outlining of good target areas.

Water Sampling

Water samples were collected from 74 locations in the Copper River basin:

	Range	Mean	Threshold	Anomalies
H_2O ppb	0.25-1.95	0.91	1.74	3

The three U anomalies are from scattered locations. One of the three anomalies (C6) is from an anomalous stream-sediment location at Slide Mountain and may be significant. Anomalous sample K82 was from the headwaters of Tyone Creek in the northeast part of the Talkeetna

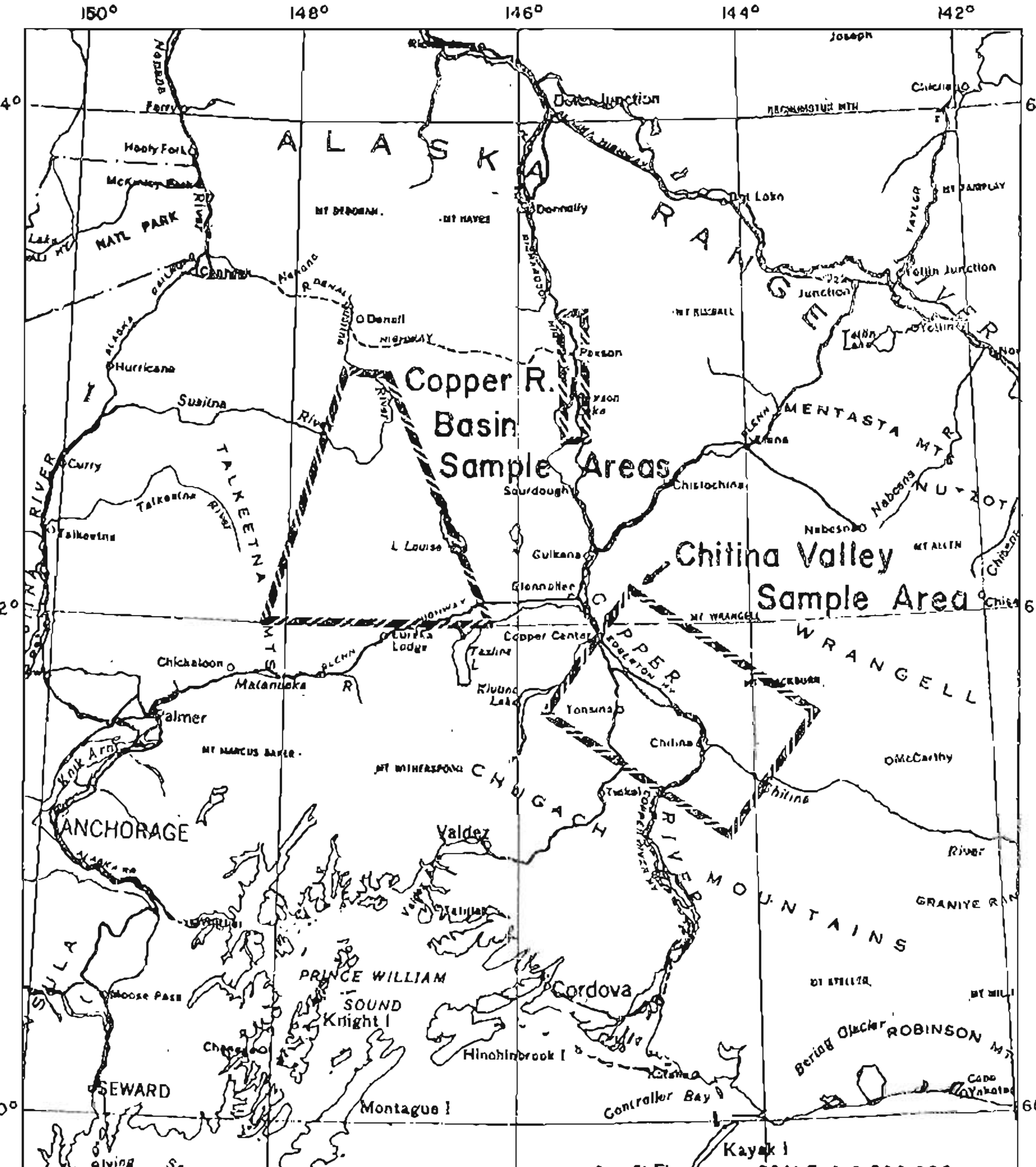

Figure 16. Index map of the Copper River basin and Chitina River valley areas, south-central Alaska.

Mountains A-1 quadrangle. This locality is underlain by Cretaceous and Tertiary sediments. The third sample (K88) was collected on a tributary to Mazuma Creek in the southwestern corner of Talkeetna Mountains A-2 quadrangle. This is in an area of Tertiary volcanics.

Bedrock Sampling

Fifteen intrusive rock samples from the Copper River basin were analyzed for U, Th, and K_2O. These included a variety of granites and quartz diorite. The values obtained from the analyses are:

	Maximum	Mean	Threshold	Anomalies
U ppm	1.20	0.76	1.46	0
Th ppm	26.0	3.77	17.45	1
K_2O%	2.70	1.07	2.56	1

The unusually low U and Th values are disappointing and seem abnormally low for the types of rocks sampled. No U anomalies were found in this group and only one each for Th and K_2O. The low radiometric responses produced by rocks in the area was the reason so few were submitted for chemical analyses.

Aerial Radiometric Survey

The aerial radiometric survey conducted during 1975 covered the Gulkana quadrangle and the eastern part of the Talkeetna Mountains quadrangle. On plate 5, one preferred and two suspect anomalies appear on flight-line 93, two preferred anomalies on flight-line 95, and one on flight-line 578.

Sampling by the DGGS party, preliminary results of the ERDA follow-up study in 1976, and a lack of U or Th anomalies from ground surveys indicate that these weak aerial radiometric anomalies have little significance in this area. It is reported that at least one industry exploration party also examined the aerial radiometric anomalies produced by the Texas Instruments survey in the Copper River basin, with negative results.

Ground Radiometric Survey

Radioactivity of all types of rocks in the area examined by the DGGS party was at a very low level. Readings taken at numerous intrusive and sedimentary bedrock exposures and sample sites with hand-carried scintillometers ranged from a low of 20 to a maximum of 70 cps. The highest count was detected on Tertiary sediments on Slide Mountain in the Gulkana A-6 quadrangle. These readings are lower than those generally found to be average backgrounds in most regions, and they showed so little variation that no radiometric maps are included in this report.

Suggestions for Exploration

No targets for U exploration were found in the limited areas examined in the Copper River basin or eastern Talkeetna Mountains by either the DGGS party or the aerial radiometric survey. Possibly the most anomalous area was that on the east and north flanks of Slide Mountain in the Gulkana A-6 quadrangle (samples C1-C6). The area is underlain by Tertiary and Mesozoic sediments.

Mesozoic and Tertiary nonmarine sediments in the subsurface may possibly be hosts for epigenitic uranium, but so far there is no evidence for this. The Wrangell Mountains on the east and the Alaska Range on the north side of the basin seem to contain better source rocks than the Talkeetna and Chugach Mountains on the west and south, respectively. Further study of these possible source rocks and the depositional history of the basin may suggest the best locations for exploratory drilling.

Some plutonic rocks in the Talkeetna Mountains that were not examined by the DGGS party but mapped during 1972 and 1973 by Division personnel may be favorable for U. Felsic intrusives (map unit Jms) of Mesozoic age in the Kings-Kashwitna Rivers area extend in a northeast belt for at least 10 miles (DGGS Annual Report for 1973, p. 14-16). This unit and other granitic and gneissic rocks in the area have not been examined for their uranium potential.

The Chitina River Valley

The Chitina River valley area is of interest for its U potential because of the presence of probable nonmarine Cretaceous sandstones and the rich Kennecott copper mines. Reconnaissance sampling by helicopter was conducted during a 4-day period from a base in the town of Chitina. The Chitina River valley is within the Valdez and McCarthy quadrangles and opens into the southeastern part of the Copper River basin (fig. 16). The Mesozoic sediments exposed in the valley provide some information on the subsurface of the Copper River basin, where bedrock is not exposed. Summaries of the geologic setting are included in appendix E under "Copper River basin-Chitina Valley" section and in a DGGS open-file report (Henning, 1973).

Stream-Sediment Sampling

Stream-sediment samples were collected from 105 locations in the Chitina River valley area (pls. 6 & 7):

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0.30-3.20	1.38	2.77	5
Uppm (LASL)	0.46-6.30	2.11	3.86	4
Th ppm	0.80-11.80	4.78	9.16	5
K_2O%	0.31-2.10	1.24	1.94	2

The U contents of the sediments for the area are low, but the results may reflect subtle anomalies in the bedrock. Two of the stream sediment anomalies (E28 and E29) were found in the northwest part of the McCarthy C-4 quadrangle and one (E14-LASL) was from a tributary to the Kotsina River in the northwest part of the McCarthy C-4 quadrangle. Bedrock in the areas of these samples is Triassic Nikolai Greenstone or Triassic-Jurassic limestone.

Three anomalous U samples (L22, L24, and L28) were collected in granitic rock terrain. L22 and L24 are from the northwest corner of Valdez B-1 quadrangle; L28 is from the south-central part of the Valdez C-2 quadrangle.

Four of the five Th anomalies are from tributaries to Young Creek, an area underlain by Cretaceous sediments. While no U anomalies were found in the stream sediments in the area, two water-sample and four of the five K_2O anomalies were produced. The combined Th and K_2O and the U in water anomalies suggest that the Cretaceous sediments should be investigated more thoroughly.

Water Sampling

Three of the 74 water samples from the Chitina Valley area were anomalous:

	Range	Mean	Threshold	Anomalies
H_2O ppb	0.20-3.50	0.81	2.01	3

Two of the anomalous samples were rather closely spaced, on tributaries to Young Creek that drain Cretaceous sedimentary bedrock. The other anomaly was from a tributary to McCarthy Creek that drains from Cretaceous sediments in the McCarthy B-5 quadrangle. Considering the generally low values of U found in water samples, these appear to be relatively strong anomalies (2.10, 2.75, and 3.50 ppb).

Bedrock Sampling

Thirty-seven rock samples from the Chitina River valley were analyzed:

	Range	Mean	Threshold	Anomalies
U ppm	0.40-2.50	1.23	2.65	0
Th ppm	0.20-11.30	3.14	8.53	2
K_2O%	0.05-3.00	1.55	3.18	0

The above summary includes the results of analyses of both granitic and sedimentary rocks. Two possible anomalous samples, E16R and E17R, contained 2.5 ppm U. Both of these were from the western part of MacColl Ridge. Sample E16R is from a small fine-grained felsic intrusive body, and sample E17R is of Cretaceous siltstone.

Aerial Radiometric Survey

No aerial radiometric survey had been flown by ERDA at the time of the investigation. A single radiometric anomaly was reported by the USGS from a flight up the Chitistone River valley. Bates (1953) recorded an aerial scintillometer reading of 1.0 mr/hr at one point with a background of only 0.15 mr/hr. This area was not reached by the DGGS party.

Ground Radiometric Survey

Radiometric responses measured with hand-carried scintillometers were unimpressive, and generally were below 70 cps on all types of bedrock; counts of 40 to 50 cps were usual. Inspection of the ores at several mines in the Kennecott copper area did not yield any detectable radioactivity. No radiometric survey map was constructed for this region.

The strongest radiometric reading encountered (160 cps) was in the soil bank of a small gully on the east side of a north-flowing tributary to Elliott Creek in the Valdez C-1 quadrangle. This site is on the northwest flank of Iron Mountain and is underlain by Triassic limestone and argillite. The spot with the high radioactivity is very small, but is interesting because it is four times the background in the area and is in soil rather than an exposed rock. Stream-sediment samples from near this location were almost anomalous---3.40 ppm by Los Alamos' determination. The site seems to warrant some digging to expose the bedrock.

Above-average radiometric readings for the area (90 cps) were found on MacColl Ridge, over Cretaceous sediments. A value of 100 cps was recorded for the granite pluton south of the Chitina River in Valdez B-1 quadrangle.

Suggestions for Exploration

The cursory investigation of the Chitina River valley area indicated two areas deserving additional work: the Cretaceous sediments on both sides of Young Creek and the site of a radiometric anomaly on a tributary to Elliott Creek.

The combination of slightly anomalous Th and K_2O in sediment samples and U in water samples may be significant in areas of Cretaceous sediments. The writer suggests that the lower parts of the section on the south side of Castle Bluffs be investigated because these beds are difficult to reach and were not examined.

The importance of the radioactive anomaly on Elliott Creek is unknown; although not very strong, it was quite pronounced for that area. Little work would be required to test this site below the soil cover.

The aerial radiometric anomaly reported in the Chitistone Canyon by the USGS in 1953 is of unknown significance, but adds to the interest of the region.

Eagle-Charley River Area

A brief investigation of the Eagle-Circle district in the Yukon River drainage in east-central (fig. 17) Alaska was conducted by the DGGS during 1975. P.L. Dobey and R.M. Klein spent approximately 1 week collecting samples to aid in determining the potential for oil shale and petroleum in the region. Eighteen of their stream-sediment samples and 16 water samples from a 70-mile-long northwest-trending belt in the northeast corner of the Eagle quadrangle and the southern part of the Charley River quadrangle were submitted for U, Th, and K_2O analyses. These were collected from areas occupied by sedimentary units ranging in age from Devonian to Tertiary (pl. 8). A general description of the geology is included in appendix E. Map numbers and general locations are shown in table 4.

Table 4. Sample locations, Eagle-Charley River area

Map No.	Location
M1	Sediment and water sample, Trib. Coal Creek
M2	Sediment and water sample, Sam Creek

Table 4. (Cont.)

Map No.	Location
M3	Sediment and water sample, Sam Creek
M4	Sediment and water sample, Michigan Creek
M5	Sediment and water sample, mouth of Nation River
M6	Sediment and water samples, Trout Creek
M7	Sediment and water samples, Trout Creek
M8	Sediment and water samples, Trout Creek
M9	Sediment and water sample, Tutonduk River
M10	Sediment and water sample, Bryant Creek
M11	Sediment and water sample, Bryant Creek
M12	Sediment and water sample, American Creek
M13	Sediment and water sample, Bluff Creek and Taylor Highway
M14	Sediment and H_2O sample, American Creek
M15	Sediment and H_2O sample, American Creek
M16	Sediment and H_2O sample, American Creek
M17	Water sample, Marion Creek and Taylor Highway
M18	Sediment and H_2O sample, American Creek campground and Taylor Highway

Stream-Sediment Sampling

A summary of analyses of 18 stream-sediment samples from the Eagle and Charley River quadrangles is given below:

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0.6-2.50	1.30	2.36	1
Th ppm	1.3-1.7	1.54	1.81	0
K_2O%	4.0-22.5	10.69	22.83	0

The one anomalous stream-sediment sample was collected along the Totanduk River in the southeast corner of the Charley River quadrangle. The area is underlain by a series of Precambrian and lower Paleozoic beds. It appears the sample in question was taken near an outcrop of Road River shale.

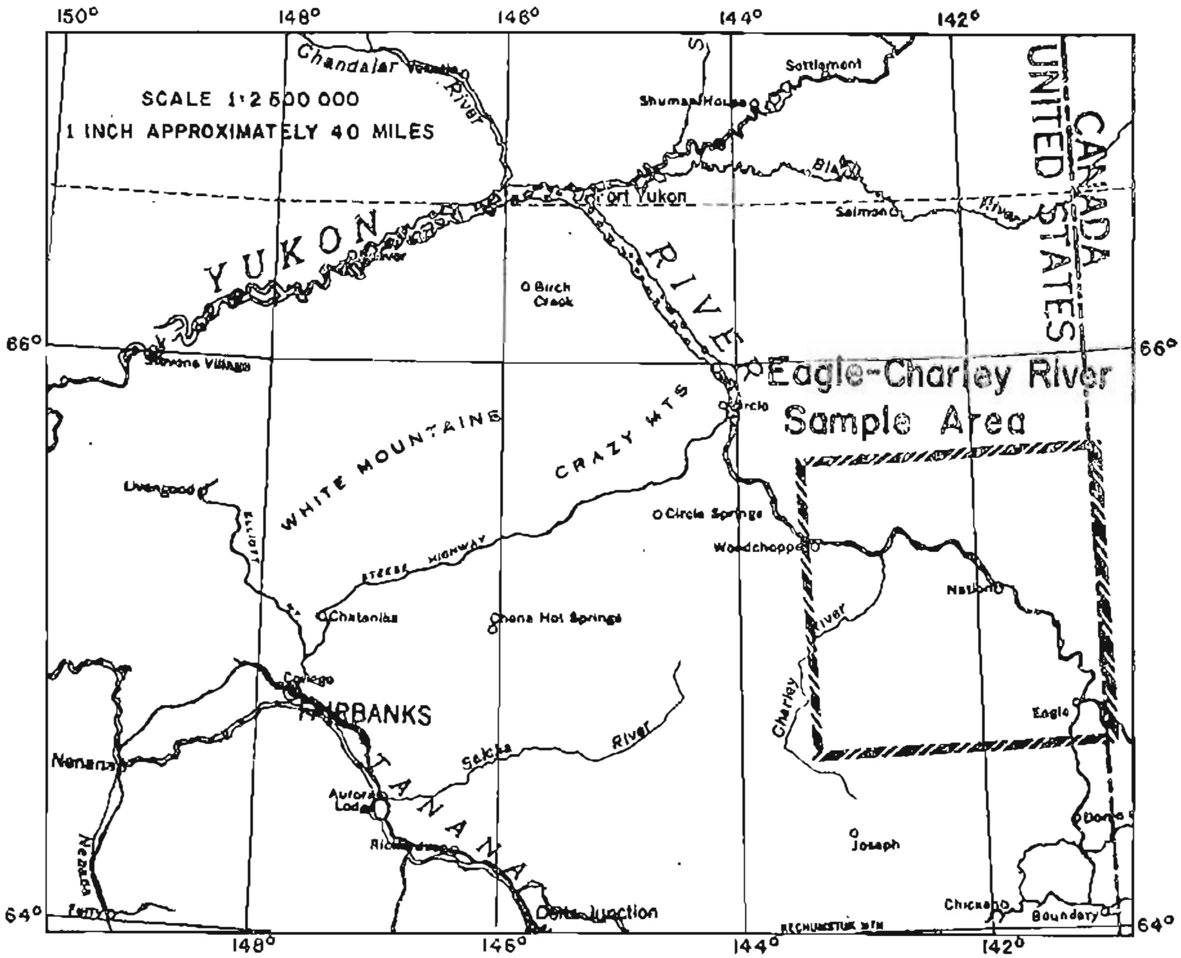

Figure 17. Index map of Eagle-Charley River sample area, east-central Alaska.

Water Sampling

Results of analyses of 16 water samples collected at the above-listed sediment sample sites are as follows:

	Range	Mean	Threshold	Anomalies
H_2O ppb	0.1-2.2	0.81	2.07	1

The computer analyses produced one anomaly (2.1 ppb) from American Creek, just outside the town of Eagle (map M12). This area is predominantly underlain by Tertiary sandstones, tuffs, and siltstones.

Bedrock Sampling

No bedrock samples were submitted for U analyses.

Aerial Radiometric Survey

An aerial radiometric survey was not conducted in this region, but will be flown during 1977, according to a Texas Instruments proposal.

Ground Radiometric Survey

Readings taken with hand-carried scintillometers at the water and sediment sample locations vary from 80 to 400 cps. The three 400-cps readings were at sample locations M6, M7, and M8, closely spaced sites on Mesozoic Glenn Shale. This unit is predominantly a carbonaceous shale which includes siltstone, quartzite, limestone, and oil shale.

Radiometric readings on a number of scattered outcrops of Glenn Shale yielded values of 120 cps. Tertiary shales and sandstones produced between 75 and 165 cps.

Suggestions for Exploration

The east-central Alaska region has had a limited amount of reconnaissance investigations for uranium. Samples from the Mississippian Calico Bluff formation, however, contain up to 0.02 percent eU (Wedow, White, and Moxham, 1951, p. 106; Wedow, 1954, p. 3, 4), and recent reports (Jonasson and Goodfellow, 1976) describing U discoveries in northern Yukon Territory suggest that the favorable trend may extend into Alaska north of the Yukon River. The writers (p. 72) concluded the following environments to be favorable for exploration:

> *(1) Proterozoic sedimentary and volcanic rocks which are hosts to known occurrences of uranium and copper mineralization.*
>
> *(2) Ordovician Road River shales which have shown potential as a low-grade high-tonnage source of uranium.*
>
> *(3) Cretaceous (or younger) alkali granites, syenites, and quartz monzonites which were shown to contain areas of high uranium and fluorine concentrations within a given stock.*
>
> *(4) Major stratigraphical and structural breaks (i.e. unconformities, faults) between Helikian rocks and younger Proterozoic and Paleozoic rocks.*

Sediments of Precambrian through Tertiary in age in the region (including the Kandik basin) may have a potential for U, and more extensive investigations are certain to follow.

Healy D-1 Quadrangle and Vicinity

A DGGS party headed by W.G. Gilbert conducted a sampling program in the Healy D-1 quadrangle (fig. 18) in conjunction with detailed geologic mapping of the north flank of the central Alaska Range. Submitted for U, Th, and K_2O analyses were 208 stream-sediment samples collected during the 1975 field season. No water or bedrock samples were analyzed for these materials, and neither aerial nor ground radiometric surveys have been conducted over the area.

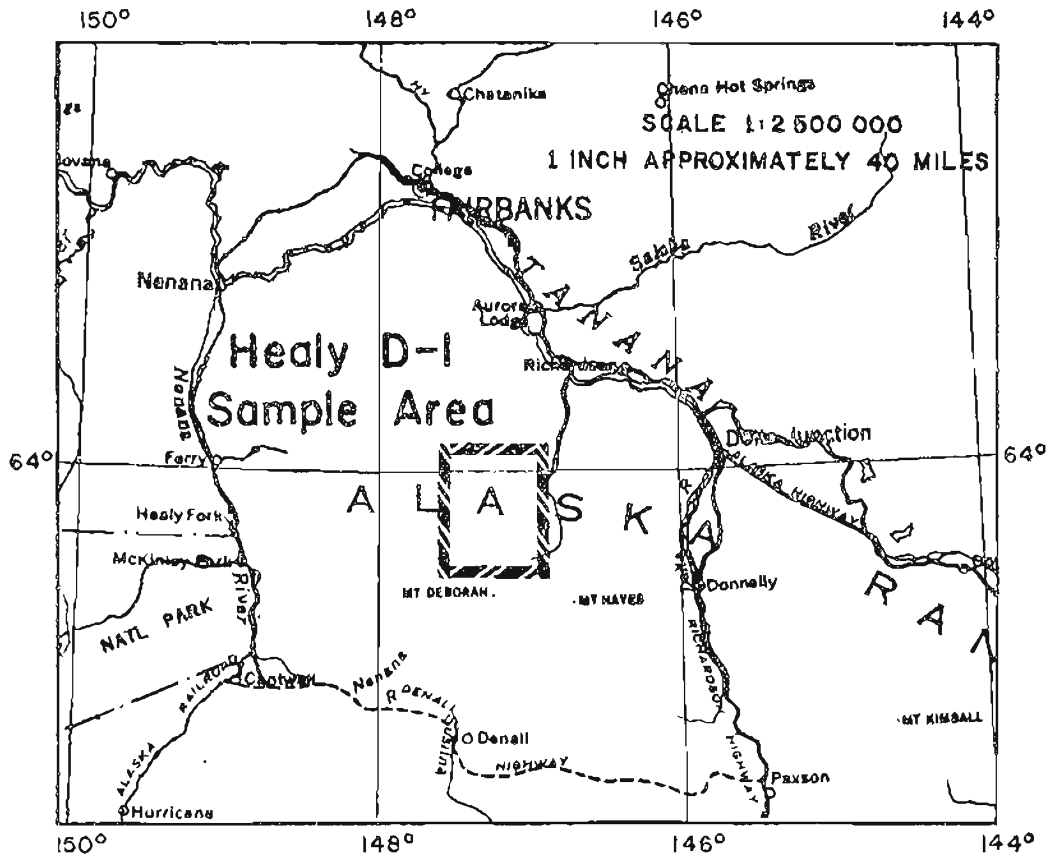

Figure 18. Index map of the Healy D-1 sample area, north flank of the Alaska Range.

The area occupies the foothills and mountains on the north flank of the central part of the Alaska Range, where altitudes in the southern part reach 8,159 feet. Bedrock includes the Precambrian or Early Paleozoic Birch Creek Schist, Keevy Peak Formation, and the Totatlanika Schist. Granitic rocks of Mesozoic age are exposed in the southern half of the D-1 quadrangle, and Tertiary Coal-Bearing Group sediments are present in the northeastern part. The Tertiary sediments are of interest to uranium prospectors because they display characteristics similar to those that are U hosts in Wyoming, and industry explorationists have found U anomalies in stream sediments and water about 50 miles west in this group. The granitic rocks were also considered to warrant study for their U potential. A discussion of the Tertiary Coal-Bearing group is included in appendix E.

Stream-Sediment Sampling

Location of 208 stream-sediment samples from the Healy D-1 area appears on plate 9. Results of the computer analysis are summarized below; analyses were done by Resource Associates of Alaska only; none were submitted to Los Alamos.

	Range	Mean	Threshold	Anomalies
Uppm (RAA)	0.3-10.0	2.13	5.40	10
Th ppm	2.0-72.5	19.28	40.56	8
K_2O%	1.4-5.2	3.08	4.70	9

There are a number of anomalies, but none is particularly high. All the U anomalies are over or near (2 miles or less) outcrops of granitic rock. Th and K_2O anomalies are scattered, but Th appears to be relatively high overall for the rock types in the area.

Suggestions for Exploration

On the basis of the stream-sediment sampling alone it is difficult to judge the potential for U in the Healy D-1 quadrangle. Statistically, there are a number of anomalies, but none is high enough to be especially interesting. It appears the anomalies are associated with the granitic bodies in the southern part of the quadrangle.

The granitic rocks and the Tertiary Coal-Bearing Group, however, should not be condemned, because both have reportedly yielded U anomalies at other locations on the north flank of the Alaska Range and remain underexplored. The Tertiary Coal-Bearing Group is also present up to 200 miles west in the Minchumina basin area, where It is favorably situated structurally and near possible source rocks, but as far as the writer knows, it remains untested for U.

CONCLUSIONS

Uranium exploration in Alaska is still in a preliminary stage. Knowledge of the geology of much of the state is inadequate and the best methods to use for uranium exploration in this region demand more research. Field methods to date indicate that stream-sediment sampling and ground radiometric surveys are suitable in areas of bedrock exposures. Water sampling results are erratic, and results of this type of sampling are still being evaluated by ERDA-sponsored programs. Work by the Geological Survey of Canada (Jonassen and Goodfellow, 1976) indicates that fluorine shows a close relation to U in stream waters and should be used as an indicator. The aerial radiometric survey of Alaska being conducted on a wide-spaced pattern by ERDA may help define general areas favorable for uranium, or by chance may locate a concentration of radioactive minerals; but because of the wide spacing of flight lines and manner of calculating and reporting anomalies, the results may be misleading and the survey can miss local anomalous areas.

Geologic studies could include interpreting the tectonic and depositional history of the basinal areas, a study of major unconformities, and study of lineaments on Landsat (ERTS) images and their relation to U anomalies.

Discoveries of vein-type uranium deposits will probably precede discoveries of sedimentary types, simply because there are considerable areas of exposed alkaline plutonic rocks, and the basins are masked by tundra and water. Most current exploration is directed towards intrusive rock terrains in southeastern Alaska, the Seward Peninsula, the Hogatza plutonic belt, and to a lesser extent the central Alaska Range and the Yukon-Koyukuk regions. Late-stage differentiates generally are the most favorable phases for uranium.

Some exploration for sedimentary-type uranium deposits has been conducted in the Tertiary Coal-Bearing Group on the north flank of the Alaska Range, in the Susitna lowland, and in the Tertiary and Cretaceous sediments on the central part of the North Slope. Recent discoveries of uranium associated with copper mineralization in Precambrian sedimentary rocks in northern Yukon Territory, Canada, suggest that similar occurrences could exist in north-central Alaska. Lacking good exposures of sandstones like those in the rimrock country of the Colorado Plateau, evaluation of the uranium potential of the basins in Alaska can be expected to be slow and expensive. Drilling may be the only adequate method, but such tools as track etch, radon-gas sampling, geobotanical prospecting, and geophysics may be useful in some areas. A preliminary project to test the application of radiometric, magnetic, gravimetric, induced polarization, and very low frequency electromagnetic methods to locating roll fronts was conducted in the Selawik lowlands in Alaska during the 1976 field season by J.W. Cady of the USGS[1] and S.W. Hackett of the DGGS. Early results suggest these methods may prove helpful.

The writer considers all the plutons that were examined by the DGGS party in west-central Alaska to be favorable areas for uranium exploration. Rock types, radiometric surveys, and high U and Th contents of numerous stream-sediment and rock samples indicate U and Th enrichment. The headwaters of the Peace River on the northeast flank of Granite Mountain was thought to be one of the most positive target areas for radioactive materials. This area was restaked during the summer of 1976. Alkalic dikes in the Darby Mountains and Zane Hills contain anomalous amounts of U and Th and offer encouragement for exploration. Other localities within the region believed to be more favorable than others are discussed in the text of both parts I and II. More comprehensive investigations are surely needed.

The Copper River basin and its margins produced little encouragement in the areas that were examined. But the nonmarine sediments in the subsurface, which could not be evaluated because of lack of exposures, may warrant exploratory drilling.

The Chitina River valley did not yield strong anomalies, but the Cretaceous sediments at MacColl Ridge appear to have characteristics similar to sedimentary uranium host rocks in the western U.S., and a more comprehensive study is suggested. A radioactive anomaly on the northwest flank of Iron Mountain, though very local, is interesting. The source of the radioactivity was not identified.

[1]Branch of Theoretical and Applied Physics, Denver, CO.

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Appendix A

STREAM-SEDIMENT-, ROCK-, AND WATER-SAMPLE ANALYSES WITH RADIOMETRIC DATA

Sediment-, rock-, and water-sample data collected and analyzed were categorized into seven groups according to geologic and geographic setting. The groups are: (1) Granite Mountain area (Candle quadrangle), (2) the Darby Mountains (Solomon and Bendeleben quadrangles) and the Selawik Hills area (Selawik quadrangle), (3) the Zane Hills and Purcell Mountains area (Hughes and Shungnak quadrangles), (4) the Copper River basin area (Talkeetna Mountains, Mount Hayes, and Gulkana quadrangles), (5) the Chitina River valley area the (McCarthy and Valdez quadrangles), (6) the Eagle-Charley River area (Eagle and Charley River quadrangles), and (7) the Healy area (Healy quadrangle).

Means, standard deviations, and threshold values of concentrations of uranium, thorium, and potassium oxide were calculated for samples in each of the above-mentioned areas. Threshold values, above which sample concentrations are considered to be anomalously high and therefore of special interest, are concentrations two standard deviations above the sample mean. Samples containing concentrations considered anomalous have been underlined in the following table.

Correlation coefficients were calculated to see if there was a relationship between the stream-sediment analyses for uranium by Resource Associates, sediment analyses for the uranium by Los Alamos Scientific Laboratories, and the uranium in water samples. The histograms included in appendix B plot the concentrations of uranium in these three categories.

Correlation coefficients were also calculated to discern any relationship between the uranium concentrations reported by Resource Associates and the thorium and potassium oxide concentrations reported by the DGGS laboratory.

Table A-1. Stream-sediment, bedrock, and water analyses and radiometric data. Concentrations considered anomalous are underlined; those near anomalous are dashed.

Granite Mountain Area
Sediment and Water

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[2]	H_2O ppb (LASL)[2]	cps
B1	5E168S	8.40	13.50	0.62	0.92			
B2	5E164S	5.80	15.40	0.38	1.20	0.14	0.10	50
B3	5E163S	3.60	13.50	0.27	0.52	5.60	0.25	50
B4	5E165S	2.70	23.20	0.12	1.58	7.90	0.65	
B5	5E166S	4.40	10.70	0.41	1.35	5.80	0.35	45
B6	5E162S	2.10	11.00	0.19	1.12	2.30	0.25	
B7	5E161S	1.50	3.65	0.41	0.98	3.30	0.40	50
B8	5E159S	2.40	17.70	0.14	1.84	8.50	0.35	90
B9	5E160S	2.70	16.70	0.16	1.93	6.00	1.25	90
B10	5E158S	2.00	32.80	0.06	1.80	17.90	0.00	100
B11	5E157S	3.70	27.10	0.14	1.70	10.40	0.15	100
B12	5E156S	6.20	29.20	0.21	1.72	13.30	0.30	100
B13	5E155S	6.20	16.40	0.38	1.69	10.40	0.05	100
B14	5C198S	7.10	18.30	0.39	1.39	9.40	0.35	100
B15	5C197S	9.20	30.00	0.31	1.82	17.70	1.10	100
B16	5C194S	6.60	11.50	0.57	1.43	9.70		100
B17	5C193S	4.60	10.00	0.46	1.68	7.60	1.00	100
B18	5C191S	11.70	15.50	0.75	1.25	12.80	0.40	90
B19	5C192S	6.90	19.50	0.35	1.72	10.00	0.45	90
B20	5C190S	10.90	24.00	0.45	2.15	15.10		100
B21	5C189S	3.60	10.50	0.34	1.61	9.00	0.75	100
B22	5C188S	6.10	20.00	0.31	2.46	10.60	0.60	100
B23	5C187S	8.80	17.50	0.50	2.33	17.10	1.30	100
B24	5E77S	5.60	3.80	1.47	2.62	12.10	0.50	250
B25	5C72S	2.10	11.20	0.19	1.41		2.15	60
B26	5E73S	0.70	2.50	0.28	0.62	7.10		20
B27	5E76S	0.	3.06	0.	0.64	1.40	1.50	20
B28	5E74S	0.30	2.24	0.13	0.79	1.60	1.00	20
B29	5E75S	1.0	0.00		0.82	1.90	1.45	20
B30	5C68S	18.80	8.25	2.28	1.45	4.30	0.45	100
B31	5C67S	2.90	37.50	0.08	2.46	35.00	1.65	250
B32	5C69S	2.10	15.50	0.14	1.25	54.00		150
B33	5E72S	1.70	2.50	0.68	1.01	4.10	0.65	
B34	5E71S	10.20	32.70	0.31	1.98	24.00	0.85	200
B35	5E70S	10.80	7.50	1.44	1.43	20.00	0.95	250
B36	5E69S	11.30	50.50	0.22	1.73	85.00	1.10	300
B37	5E68S	8.80	53.50	0.16	2.34	8.10	0.50	350
B38	5E64S	7.90	24.30	0.33	3.07	14.70	0.75	200
B39	5E63S	2.40	37.60	0.06	2.56	14.70	1.05	100
B40	5E65S	4.90	25.50	0.19	3.01	3.70	0.85	
B41	5E66S	5.20	50.50	0.10	2.97	10.80	0.55	250
B42	5C65S	4.90	13.50	0.36	2.29	6.80	0.30	
B43	5C61S	4.50	16.80	0.27	1.93	6.30	0.55	
B44	5C62S	4.30	21.30	0.20	2.37	10.10	1.95	40
B45	5E61S	9.60	21.00	0.46	2.01	14.50	0.30	
B46	5E60S	7.60	16.50	0.46	2.08	14.60	1.20	200

[1]Analyses performed by Resource Associates of Alaska, Inc.
[2]Analyses performed by Los Alamos Scientific Laboratory.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	$\%K_2O$	U ppm (LASL)[1]	H_2O ppb (LASL)[1]	cps
B47	5E59S	11.90	22.30	0.53	2.81	18.40	1.15	140
B48	5E58S	12.50	26.30	0.48	2.85	18.00	0.50	140
B49	5C58S	6.50	78.50	0.08	2.63	14.90	1.25	250
B50	5C59S	9.20	47.50	0.19	2.53	21.60	1.30	200
B51	5E55S	20.30	19.30	1.05	1.94			
B52	5E42S	1.20	3.00	0.40	3.03	1.60	1.00	40
B53	5C39S	2.40	16.60	0.14	1.05	2.30	0.50	40
B54	5C40S	2.60	7.75	0.34	1.09	4.00	0.50	40
B55	5E41S	3.10	6.90	0.45	2.40	5.90	0.50	40
B56	5C38S	3.00	9.57	0.31	1.29	5.60	0.35	50
B57	5C37S	1.50	3.30	0.45	1.00	2.40	0.55	50
B58	5E40S	2.70	7.60	0.36	1.34	4.90	1.00	
B59	5C36S	8.50	24.50	0.35	1.72	13.50	0.55	250
B60	5E23S	5.60	34.80	0.16	2.74	10.70	0.70	
B61	5E25S	24.40	73.50	0.33	4.14	53.00	1.05	200
B62	5E27S	21.20	78.60	0.27	3.72	49.00	1.70	250
B63	5E28S	10.70	68.50	0.16	3.89	29.00	1.40	275
B64	5C31S	9.00	20.00	0.45	2.14	14.30	1.35	150
B65	5C30S	9.60	27.00	0.36	2.00	18.10	1.65	150
B66	5C29S	9.70	12.20	0.80	1.83	14.90	1.30	140
B67	5C23S	9.40	11.40	0.82	1.73			170
B68	5C22S	7.10	33.00	0.22	1.78		0.70	100
B69	5C21S	7.20	13.90	0.52	2.00	11.50	1.00	100
B70	5C16S	10.50	24.90	0.42	2.75	15.60	1.00	200
B71	5C17S	28.00	22.30	1.26	2.17	44.00	0.95	170
B72	5C20S	7.30	20.00	0.37	2.60	11.20	1.85	100
B73	5E21S	2.40	16.30	0.15	1.66			150
B74	5E22S	7.60	35.30	0.22	4.67	39.00	0.45	100
B75	5E36S	6.50	37.40	0.17	1.03	17.40	0.45	275
B76	5E37S	7.40	26.30	0.28	1.31	14.00	1.30	250
B77	5E33S	8.60	47.00	0.18	2.76	22.00	0.50	200
B78	5E34S	6.20	36.00	0.17	2.40	12.90	1.25	
B79	5C33S	3.80	27.30	0.14	2.08	15.30	1.30	120
B80	5C32S	3.70	22.30	0.17	1.89	9.20	0.85	150
B81	5E35S	5.20	17.80	0.29	2.00	10.30	0.90	
B82	5E43S	3.30	23.00	0.14	1.76	10.80	0.80	80
B83	5C42S	6.20	33.80	0.18	2.22	14.90	0.50	100
B84	5C41S	8.70	13.50	0.64	2.04	6.40	0.40	100
B85	5C46S	2.90	14.80	0.20	1.97	5.40	1.35	30
B86	5C49S	2.30	4.00	0.58	1.49	3.50	0.50	60
B87	5C48S	3.20	10.00	0.32	1.89	3.90	0.80	60
B88	5C50S	2.10	7.00	0.30	1.72		0.40	80
B89	5C51S	2.70	11.00	0.25	1.71	10.70	0.40	70
B90	5E49S	2.00	11.60	0.17	1.75	3.30	0.35	150
B91	5C52S	1.70	8.00	0.21	1.74			60
B92	5C54S	2.70	10.50	0.26	1.70	5.20	1.05	90
B93	5E51S	2.00	9.00	0.22	1.26	3.20	0.25	
B94	5C53S	1.90	34.50	0.06	1.30			65
B95	5E50S	2.00	9.20	0.22	1.49		0.80	160
B96	5C55S	2.70	11.50	0.23	1.02			40
B97	5C56S	2.90	5.75	0.50	1.48	2.40	1.15	40
B98	5E54S	1.00	10.40	0.10	1.62		0.65	60

[1] See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	H_2O ppb (LASL)[1]	cps
B99	5E53S	3.30	10.40	0.32	1.84	4.00	0.30	60
B100	5C43S	1.20	3.50	0.34	0.87	1.50	0.95	24
B101	5C45S	1.90	3.00	0.63	0.87	1.40	0.60	24
B102	5C44S	1.70	4.50	0.38	0.86	1.50	0.50	24
B103	5C47S	3.30	20.00	0.17	2.06			40
B104	5E46S	1.70	13.40	0.13	1.13		1.15	40
B105	5E31S				2.41		0.75	200
B106	5E30S	6.70	33.50	0.20	2.47	19.70	0.40	250
B107	5E32S	7.90	50.00	0.16	2.46	17.60	0.45	275
B108	5C15S	16.80	16.80	1.00	2.25	24.00	0.55	190
B109	5C14S	6.80	16.50	0.41	2.77	12.60	0.60	240
B110	5C13S	9.80	18.30	0.54	2.49	21.00	0.35	190
B111	5E2S	3.30	19.80	0.17	2.87		0.30	230
B112	5E3S	7.10	26.50	0.27	3.20		1.00	250
B113	5E20S	6.70	29.50	0.23	2.71	14.10	0.35	200
B114	5E19S	18.00	20.20	0.89	2.30	28.00	0.65	200
B115	5E17S	3.70	14.30	0.26	2.49			120
B116	5E18S	3.70	16.80	0.22	2.64	8.00	0.90	150
B117	5E16S	6.40	21.30	0.30	2.80	12.70	0.60	160
B118	5C12S	15.50	56.50	0.27	3.20	41.00	1.20	192
B119	5C11S	14.60	3.55	4.11	2.23	30.00	1.55	85
B120	5E4S		37.0		4.05		0.40	250
B121	5E7S	5.20	27.50	0.19	2.30		0.90	200
B122	5E6S	4.90	19.60	0.25	2.48		0.40	250
B123	5C1S	2.50	10.90	0.23	2.17	5.20	0.30	110
B124	5E1S	2.50	25.50	0.10	1.03		0.70	80
B125	5E5S	0.	10.30	0.	2.41		0.60	40
B126	5C2S	2.50	10.40	0.24	2.22	5.40	0.35	80
B127	5E8S	6.70	61.20	0.11	2.63		0.55	200
B128	5E9S	1.30	6.50	0.20	0.94	2.50	0.35	50
B129	5C5S	3.60	13.60	0.26	1.82	6.90	0.50	125
B130	5C3S	4.00	26.70	0.15	2.39	9.20	0.50	160
B131	5C4S	4.50	12.10	0.37	1.52	6.40	0.65	50
B132	5E14S	4.00	11.80	0.34	1.62	6.20	0.15	50
B133	5E15S	3.70	12.00	0.31	1.57	5.10	0.55	60
B134	5C10S	1.20	3.35	0.36	1.39	3.40	0.85	36
B135	5E11S	2.70	14.80	0.18	1.43	3.80	0.95	50
B136	5E12S	3.10	9.00	0.34	1.46	4.00	0.65	50
B137	5C7S	88.00	25.80	3.41	2.30	91.00	0.35	20
B138	5C6S	0.90	20.70	0.04	1.06	2.70	0.35	30
B139	5E10S	2.10	15.30	0.14	1.45	3.30	0.60	30
B140	5C8S	2.20	5.59	0.39	1.25	60.00	0.90	30
B141	5C9S	1.40	4.73	0.30	1.06	4.40	0.75	36
B142	5E13S	1.40	11.00	0.13	1.40	3.40	0.75	160
B143	5E67W						0.45	80
B144	5E62W						0.60	
B145	5C64W						1.40	
B146	5C34W						0.25	
B147	5C35W						0.45	

1. See p. A-2.

Granite Mountain Area
Rock Samples

Map No.	Field No.	U ppm	Th ppm	U/Th	%K20	cps
B1R	CM9A	12.60	45.50	0.28	5.86	400
B2R	CM9-1	4.20	51.30	0.08	8.90	400
B3R	CM9-2	5.40	31.50	0.17	8.34	30
B4R	CM12	0.	2.80	0.	0.10	30
B5R	CM11-1	0.	2.80	0.	0.27	18
B6R	CM11-2	0.	0.80	0.	0.31	18
B7R	CM10-1	0.	1.80	0.	0.29	17
B8R	CM10-2	0.	1.30	0.	0.27	17
B9R	CM1	0.	0.0		0.68	30
B10R	CM2-1	8.00	86.00	0.09	2.09	110
B11R	CM2-2	0.70	0.10	7.00	0.40	110
B12R	CM2-3	5.30	70.00	0.08	5.25	110
B13R	CM3-1	2.10	9.30	0.23	3.70	
B14R	CM3-2	4.80	39.50	0.12	4.86	
B15R	CM3-3	0.40	0.50	0.80	0.18	
B16R	CM4A	4.90	40.80	0.12	5.93	280
B17R	CM4-1	8.30	73.00	0.11	7.35	600
B18R	CM4-2	6.20	43.80	0.14	4.10	600
B19R	CM5-1	4.20	83.50	0.05	5.60	270
B20R	CM5-2	2.90	18.80	0.15	4.90	270
B21R	CM13	4.30	22.80	0.19	5.22	200
B22R	CM14	2.30	24.50	0.09	4.65	220
B23R	CM15	2.60	25.00	0.10	4.72	220
B24R	CM16	2.80	19.30	0.15	4.54	260
B25R	CM17	1.00	17.80	0.06	4.99	220
B26R	CM18	1.30	24.00	0.05	4.95	240
B27R	CM8-1	3.80	21.50	0.18	4.15	420
B28R	CM8-2	4.90	43.50	0.11	5.77	420
B29R	CM6-1	5.00	33.30	0.15	6.40	300
B30R	CM6-2	3.60	30.30	0.12	4.27	300
B31R	CM20	2.60	21.30	0.12	4.50	250
B32R	CM21	2.00	18.50	0.11	4.66	185
B33R	CM19	1.20	7.50	0.16	2.00	74
B34R	5E14R	0.	6.30	0.	1.35	40
B35R	5C66R	6.80	1.50	4.53	0.21	20
B36R	5C64R	0.90	0.80	1.13	0.27	20
B37R	5C63R	5.00	32.50	0.15	3.20	150
B38R	5C62R	2.40	13.00	0.18	5.20	200
B39R	5C61RA	4.40	19.30	0.23	8.66	200
B40R	5C61RB	2.70	12.50	0.22	6.25	200
B41R	HP5-1	1.10	7.80	0.14	2.05	150
B42R	HP5-2	1.50	9.30	0.16	2.60	150
B43R	HP5-3	8.00	45.50	0.18	7.00	150
B44R	5C60R	2.90	10.50	0.28	3.12	
B45R	5C60RA	1.20	5.80	0.21	5.89	
B46R	5C59R	2.40	12.50	0.19	8.70	200
B47R	5C58R	4.00	38.00	0.11	4.34	250
B48R	HP1-1	2.60	27.30	0.10	4.20	335
B49R	HP1-2	4.90	9.30	0.53	3.85	
B50R	HP1-3	5.00	62.50	0.08	2.86	
B51R	HP4-1	7.90	21.50	0.37	5.40	390

Map No.	Field No.	U ppm	Th ppm	U/Th	%K_2O	cps
B52R	HP4-2	6.50	56.30	0.12	9.15	
B53R	HP4-3	4.00	21.80	0.18	7.00	
B54R	HP3	6.50	31.50	0.21	6.55	420
B55R	HP2-1	6.60	35.50	0.19	8.75	460
B56R	HP2-2	7.20	36.50	0.20	6.21	
B57R	HP2-3	6.00	33.80	0.18	6.85	
B58R	HP2-4	4.70	38.80	0.12	7.75	
B59R	HP7-1	4.50	39.30	0.11	8.91	550
B60R	HP7-2	28.00	54.50	0.51	4.00	
B61R	HP8-1	8.40	32.50	0.26	5.92	390
B62R	HP8-2	5.70	40.50	0.14	6.25	
B63R	HP10	3.30	32.50	0.10	3.43	300
B64R	HP11	2.40	43.80	0.05	3.40	250
B65R	5E15RA	4.20	23.50	0.18	2.80	325
B66R	5E15RB	4.00	21.50	0.19	6.64	
B67R	5C71R	1.60	3.00	0.53	1.41	50
B68R	5E16RA	7.30	25.80	0.28	6.80	215
B69R	5E16RB	0.90	6.80	0.13	7.75	
B70R	HP12	3.70	23.30	0.16	4.20	250
B71R	HP13	3.50	25.00	0.14	4.49	220
B72R	HP14	2.60	22.80	0.11	4.75	225
B73R	QC1	0.70	1.50	0.47	0.68	25
B74R	QC2	1.00	1.00	1.00	2.41	30
B75R	QC3	3.10	19.50	0.16	0.35	40
B76R	QC4	1.3	0.		0.42	30
B77R	QC5	0.90	3.30	0.27	0.50	45
B78R	QC6	1.50	6.00	0.25	0.50	40
B79R	QC7	1.90	3.30	0.58	0.30	
B80R	QC8	0.40	1.80	0.22	0.35	25
B81R	QC9	0.40	1.80	0.22	0.27	30
B82R	QC10-1	2.00	3.30	0.61	0.75	100
B83R	QC10-2	1.70	7.80	0.22	3.40	
B84R	QC10-3	2.70	15.00	0.18	5.72	100
B85R	QC10-4	3.10	9.80	0.32	3.06	100
B86R	QC11	3.00	22.80	0.13	4.87	200
B87R	QC12	3.00	20.80	0.14	4.30	150
B88R	QC14	0.	3.00	0.	0.63	30
B89R	QC14-2	0.	1.20	0.	0.26	
B90R	5C57R	6.10	27.50	0.22	5.25	120
B91R	GM1	1.50	0.68	2.21	0.63	28
B92R	GM2	1.80	0.78	2.31	0.02	24
B93R	GM2A	2.30	1.67	1.38	1.08	
B94R	GM3A	1.70	0.63	2.70	0.23	120
B95R	GM3B	1.70	2.60	0.65	0.37	
B96R	GM3C	2.30	3.65	0.63	0.20	
B97R	GM3D	1.50	4.43	0.34	0.79	
B98R	GM3E	6.20	41.10	0.15	7.00	
B99R	GM3F	6.20	45.80	0.14	7.71	
B100R	GM3G	6.80	42.70	0.16	7.50	120
B101R	GM4	1.70	30.20	0.06	5.02	250
B102R	GM5	0.80	22.60	0.04	5.32	250
B103R	GM6	0.60	17.40	0.03	3.83	250
B104R	GM7	1.60	50.50	0.03	6.00	350

Map No.	Field No.	U ppm	Th ppm	U/Th	%K_2O	cps
B105R	GM8	2.00	88.50	0.02	6.25	420
B106R	GM9	1.00	50.10	0.02	5.21	375
B107R	GM10	0.90	19.80	0.05	5.17	280
B108R	GM11	1.20	50.00	0.02	5.19	330
B109R	GM12	1.90	38.00	0.05	4.94	320
B110R	GM13	1.60	19.20	0.08	3.57	195
B111R	GM14	2.90	18.40	0.16	4.20	245
B112R	GM15	1.90	16.10	0.12	4.25	320
B113R	GM16	2.40	9.11	0.26	5.45	250
B114R	GM16A	2.50	10.40	0.24	5.37	250
B115R	GM16B	0.90	26.10	0.03	5.47	250
B116R	GM17	3.50	56.30	0.06	5.57	450
B117R	GM18	0.90	15.00	0.06	5.37	
B118R	GM18A	3.20	44.80	0.07	5.42	
B119R	GM19A	1.90	52.10	0.04	4.62	400
B120R	GM19B	2.70	17.60	0.15	5.59	400
B121R	GM20	5.40	62.50	0.09	5.95	600
B122R	GM20A	4.50	67.70	0.07	6.42	600
B123R	GM21	3.10	66.70	0.05	4.53	500
B124R	GM22	3.60	27.10	0.13	4.45	250
B125R	GM23	2.10	20.80	0.10	4.87	190
B126R	GM24	2.90	25.50	0.11	3.98	240
B127R	GM25	2.50	28.60	0.09	4.36	320
B128R	GM26	2.10	32.30	0.07	4.23	300
B129R	5C17RA	6.80	32.00	0.21	6.12	200
B130R	5C17R	0.	2.30	0.	0.72	160
B131R	5C19R	0.	0.		0.30	
B132R	5C18R	0.	1.00	0.	0.50	40
B133R	5C23R	1.90	37.00	0.05	4.35	160
B134R	5E8R	2.20	39.80	0.06	5.21	300
B135R	5C24R	4.90	32.50	0.15	5.21	200
B136R	5C25R	7.70	31.30	0.25	4.49	270
B137R	5C27R	5.50	54.50	0.10	4.50	300
B138R	5C28R	18.00	93.00	0.19	5.62	365
B139R	GM27	4.00	27.60	0.14	4.05	300
B140R	GM28	3.00	8.85	0.34	3.69	124
B141R	5C33R	4.20	58.50	0.07	5.20	110
B142R	GM30	3.10	21.90	0.14	7.67	200
B143R	GM29	3.80	1.25	3.04	0.39	200
B144R	GM29A	3.60	16.10	0.22	4.56	200
B145R	GM32	3.30	20.30	0.16	4.57	200
B146R	GM33	3.40	26.60	0.13	4.45	220
B147R	GM34A	2.20	17.70	0.12	5.90	200
B148R	GM34B	4.50	74.00	0.06	5.45	200
B149R	5E1R	258.00	156.00	1.65	6.13	
B150R	5E2R	0.	0.50	0.	0.68	40
B151R	5E4R	10.90	290.00	0.04	4.82	200
B152R	5E5R	0.	2.00	0.	0.27	50
B153R	5E6R	3.60	14.30	0.25	2.69	150

The Darby Mountains
Sediment and Water Samples

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	H_2O ppb (LASL)[1]	cps
A1	5C168S	1.30	13.50	0.10	1.67	5.20	0.80	80
A2	5C170S	2.50	10.20	0.25	1.31	4.20		
A3	5C171S	1.20	9.44	0.13	1.51			
A4	5C172S	2.10	9.44	0.22	1.75			60
A5	5C173S	2.00	10.70	0.19	2.57			60
A6	5C167S	0.80	6.38	0.13	1.37	2.80	0.30	
A7	5C166S	2.80	15.60	0.18	1.82	3.90	0.50	80
A8	5C165S	24.00	16.10	1.49	2.67	30.00	2.00	250
A9	5C163S	8.50	28.80	0.30	2.87	18.00	0.90	250
J1	5C162S	17.10	20.40	0.84	2.47	25.00		100
J2	5C161S	7.00	33.20	0.21	2.94	12.80		100
J3	5C151S	12.00	36.50	0.33	2.41	18.30	0.60	80
J4	5C150S	3.30	16.10	0.20	1.72	4.50	0.40	60
J5	5E145S	13.40	28.60	0.47	2.13	13.90	1.85	
J6	5C149S	28.00	27.00	1.04	2.10	49.00	1.05	100
J7	5C148S	10.30	61.20	0.17	2.31	21.00	0.40	100
J8	5E147S	53.00	61.20	0.87	2.58	30.00		
J9	5E146S	51.00	25.00	2.04	2.65	45.00	1.00	
J10	5C157S	16.40	84.70	0.19	3.45	32.00		350
J11	5C158S	11.60	19.10	0.61	2.74	13.90		250
J12	5C160S	21.00	29.30	0.72	1.49	43.00		250
J13	5C159S	2.20	20.40	0.11	3.73	7.20		
J14	5C152S	4.30	9.70	0.44	1.71	6.60	1.05	150
J15	5C153S	5.40	26.30	0.21	2.99	9.90	0.80	150
J16	5E149S	11.30	14.20	0.80	1.47	3.20		300
J17	5E148S	11.30	7.73	1.46	1.42	3.60	1.25	
J18	5C155S	1.60	9.18	0.17	1.52	3.00	0.45	
J19	5C154S	15.60	6.12	2.55	2.80	25.00	1.05	
J20	5E140S	58.00	43.90	1.32	2.64	51.00	1.15	600
J21	5E139S	51.00	67.80	0.75	2.74	73.00		600
J22	5C145S	81.00	114.00	0.71	2.78	111.00	0.60	450
J23	5E141S	4.20	62.50	0.07	1.95			400
J24	5E141A	78.00	28.10	2.78	2.37			400
J25	5C146S	58.00	130.00	0.45	3.25	73.00	1.45	300
J26	5E142S	6.90	21.40	0.32	1.38	6.70	1.35	120
J27	5E143S	8.30	24.00	0.35	1.93		1.35	200
J28	5C147S	24.20	46.40	0.52	2.70	62.00	0.95	300
J29	5C143S	64.00	96.90	0.66	2.77	78.00	0.80	300
J30	5C142S	20.00	74.00	0.27	2.99			300
J31	5E138S	22.20	41.30	0.54	3.33	22.00		
J32	5C139S	35.00	56.00	0.63	3.08	50.00	1.90	240
J33	5C141S	52.00	53.50	0.97	2.55	13.70	2.30	300
J34	5C140S	47.00	46.50	1.01	2.94			300
J35	5C138S	39.00	57.10	0.68	3.45	36.00	2.05	200
J36	5E132S	21.00	28.10	0.75	2.10	30.00	1.25	300
J37	5E133S	15.40	25.50	0.60	1.88	20.00		200
J38	5E134S	49.00	19.90	2.46	2.10	49.00	1.45	350
J39	5C134S	20.00	46.50	0.43	3.25	29.00	1.70	300
J40	5C135S	15.90	79.50	0.20	3.31	37.00	1.65	300
J41	5E135S	36.00	40.30	0.89	3.27	22.00	2.20	300
J42	5E130S	40.00	53.10	0.75	2.35	37.00	0.60	
J43	5C131S	19.10	72.00	0.27	2.35	36.00	1.65	250

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	H_2O ppb (LASL)[1]	cps
J44	5E128S	17.00	40.80	0.42	2.15	42.00	1.30	
J45	5E129S	36.00	46.90	0.77	2.49	43.00		
J46	TC129S	17.30	61.00	0.28	2.50			500
J47	5C130S	41.00	54.00	0.76	2.44	33.00		500
J48	5E127S	20.40	41.30	0.49	2.30	33.00	0.95	400
J49	5E126S	23.50	37.80	0.62	2.12	35.00	0.40	400
J50	5E131S	5.00	18.90	0.26	1.86			425
J51	5C132S	29.00	62.60	0.46	2.40	38.00	1.25	300
J52	5C133S	59.00	73.70	0.80	2.31	45.00	1.15	200
J53	5C125S	23.00	40.00	0.58	2.36	35.00	1.65	300
J54	5C126S	30.00	11.00	2.73	1.23	40.00	1.00	300
J55	5C128S	9.80	42.50	0.23	1.92	45.00	0.45	400
J56	5C127S	29.00	99.00	0.29	2.34			400
J57	5C124S	33.00	86.00	0.38	2.48	41.00	1.30	400
J58	5E125S	13.90	66.00	0.21	2.88	32.00	1.65	300
J59	5C122S	36.00	49.00	0.73	2.06	51.00	0.55	250
J60	5C123S	56.00	77.90	0.72	2.64			300
J61	5E124S	22.60	91.80	0.25	1.87		1.95	400
J62	5E122S	64.00	30.30	2.11	3.25	108.00	1.15	250
J63	5E123S	49.00	35.70	1.37	2.46	64.00		300
J64	5C120S	23.00	52.00	0.44	1.86	37.00	0.95	500
J65	5E121S	33.00	62.20	0.53	3.59		1.65	400
J66	5C185S	1.30	2.81	0.46	1.59			600
J67	5C184S	6.70	65.30	0.10	4.83			600
J68	5C183S	14.60	149.50	0.10	5.54			600
J69	5E152S	5.40	18.20	0.30	1.85			600
J70	5E150S	9.90	47.50	0.21	2.71			600
J71	5E151S	0.	16.10	0.	2.95			600
J72	5C182S	77.00	121.40	0.63	3.30			600
J73	5C181S	5.70	70.40	0.08	2.83			600
J74	5E153S	3.70	14.40	0.26	1.85			
J75	5C180S	8.80	17.30	0.51	2.46			600
J76	5E154S	3.70	15.00	0.25	2.16			
J77	5C90S	5.80	31.10	0.19	4.16	7.50	1.00	150
J78	5C91S	7.40	26.30	0.28	4.70	11.00	0.45	150
J79	5C87S	6.30	20.20	0.31	3.25	10.20	0.25	200
J80	5C88S	7.10	10.50	0.68	1.86	8.40		150
J81	5C89S	6.70	14.80	0.45	1.82	9.00	0.85	150
J82	5E89S	7.70	23.10	0.33	3.77	13.10	0.35	200
J83	5E90S	9.20	26.30	0.35	3.41	18.30	0.35	200
J84	5C85S	8.10	15.30	0.53	1.71	7.70	0.75	150
J85	5C84S	7.30	22.00	0.33	3.23	16.40	0.80	160
J86	5C86S	8.20	24.50	0.33	2.85			200
J87	5E91S	8.50	60.50	0.14	3.06	14.10	1.45	300
J88	5E92S	5.90	28.50	0.21	2.91	13.60	0.25	300
J89	5C92S	6.80	37.00	0.18	2.72	9.80	0.80	250
J90	5C94S	3.80	32.70	0.12	3.11	10.20	0.40	250
J91	5E80S	8.90	65.50	0.14	3.20	12.20	0.50	250
J92	5E81S	9.30	90.80	0.10	3.69	26.00		1200
J93	5E82S	8.50	36.00	0.24	3.56	11.50	0.70	
J94	5E83S	6.90	33.40	0.21	4.03	9.30	0.90	300
J95	5C73S	4.50	14.00	0.32	2.17		1.80	200
J96	5C74S	2.70	33.90	0.08	2.79	10.80	0.95	200

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	H_2O ppb (LASL)[1]	cps
J97	5C75S	6.40	34.80	0.18	3.82	10.70		200
J98	5C76S	5.40	30.60	0.18	3.98	9.00	0.80	200
J99	5C78S	8.30	60.50	0.14	3.90		0.95	300
J100	5C77S	1.80	43.00	0.04	4.60	11.70		250
J101	5C79S	6.00	33.20	0.18	3.84	10.50	0.40	250
J102	5C80S	6.70	36.00	0.19	3.90	11.20	0.35	300
J103	5C81S	6.30	32.00	0.20	3.90	9.80	1.75	250
J104	5C82S	5.20	78.80	0.07	3.04			200
J105	5C83S	5.30	37.20	0.14	4.18	9.60	0.35	220
J106	5E88S	4.20	20.20	0.21	4.60	5.70	0.30	175
J107	5E87S	2.90	12.30	0.24	3.56	7.30	0.00	200
J108	5E86S	5.10	26.50	0.19	3.59	6.80	0.20	200
J109	5E85S	0.40	24.20	0.02	5.20	7.40	0.25	200
J110	5E84S	0.	18.10	0.	5.29	7.90	0.25	
J111	5E117S	5.40	10.60	0.51	2.20	11.10	1.25	200
J112	5E118S	3.50	4.43	0.79	2.09	8.40	1.30	120
J113	5E116S	5.60	18.80	0.30	2.05	9.20	0.40	
J114	5E120S	2.10	6.60	0.32	2.94	7.60	1.05	
J115	5E119S	4.00	7.55	0.53	2.20	8.90	1.25	
J116	5C112S	4.70	11.20	0.42	2.05	8.40	0.45	
J117	5C116S	6.60	14.50	0.46	3.13	11.90	0.60	
J118	5C113S	5.50	15.10	0.36	2.25	9.60	0.95	
J119	5C115S	8.50	21.70	0.39	1.82	13.00	1.15	
J120	5C119S	6.60	84.00	0.08	2.16	37.00	1.35	
J121	5C118S	4.80	19.60	0.24	2.63	8.10	1.85	
J122	5C179S	4.60	10.50	0.44	2.18			200
J123	5C178S	3.00	9.18	0.33	2.17			200
J124	5C174S	4.90	13.30	0.37	1.67			200
J125	5C175S	4.50	10.20	0.44	2.22			200
J126	5C176S	3.70	8.42	0.44	2.37			200
J127	5C177S	3.80	8.16	0.47	2.10			200
J128	5C117S	3.70	9.70	0.38	2.89	6.90	1.65	80
J129	5E98S	2.70	24.70	0.11	1.84	5.70	0.35	
J130	5E97S	4.70	12.50	0.38	1.94	10.20	0.60	150
J131	5E95S	5.40	60.00	0.09	2.34	12.00	0.50	200
J132	5E99S	5.90	60.50	0.10	2.38	14.40		180
J133	5E96S	0.	32.30	0.	2.45	14.80		
J134	5E100S	5.00	26.00	0.19	2.74			475
J135	5E94S	20.00	4.70	4.26	1.69	23.00	0.75	200
J136	5C111S	4.00	21.20	0.19	3.69	7.40	0.95	100
J137	5E115S	3.60	14.40	0.25	0.76	8.10	0.65	
J138	5E114S	3.00	13.80	0.22	2.34	5.80	0.65	100
J139	5E113S	0.90	5.55	0.16	2.68	8.40	0.55	100
J140	5E112S	2.60	5.43	0.48	2.83	5.80	0.90	160
J141	5C108S	2.00	7.14	0.28	3.73	4.40	1.95	100
J142	5C106S	3.60	17.90	0.20	2.75	9.90	1.60	200
J143	5C107S	3.80	25.80	0.15	4.08	10.20	0.90	200
J144	5E111S	6.60	10.70	0.62	2.64	10.40	1.35	
J145	5E110S	9.00	6.55	1.37	3.24	12.40	0.25	
J146	5E108S	5.20	10.70	0.49	2.45	7.20	0.65	200
J147	5E109S	4.40	12.90	0.34	2.49	7.10	0.30	
J148	5C104S	1.70	20.40	0.08	2.93	6.90	0.90	150
J149	5E107S	6.80	12.50	0.54	2.44	9.20	0.40	160

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	$\%K_2O$	U ppm (LASL)[1]	H_2O ppb (LASL)[1]	cps
J150	5E106S	7.10	29.00	0.24	2.30	10.00	0.65	120
J151	5E103S	12.20	12.00	1.02	2.07	11.80	0.00	100
J152	5E105S	5.50	9.20	0.60	1.60	5.70	0.25	120
J153	5E102S	4.60	13.50	0.34	1.39	10.30	0.00	120
J154	5E101S	5.90	13.20	0.45	2.14	10.00	0.15	
J155	5E104S	11.70	13.60	0.86	1.87	12.70	1.05	120
J156	5C102S	9.30	26.80	0.35	2.17	14.90	0.20	100
J157	5C103S	9.60	33.70	0.28	2.35	13.90	0.65	100
J158	5C101S	9.00	20.20	0.45	2.34	12.70	0.70	100
J159	5C99S	7.30	17.10	0.43	2.85			300
J160	5C96S	5.10	27.80	0.18	2.77	8.30	0.60	100
J161	5C98S	8.10	18.10	0.45	2.27	11.20	0.85	100
J162	5C97S	8.00	21.40	0.37	2.58	9.00	0.70	100
J163	5C95S	5.60	18.70	0.30	2.81			250

1. See p. A-2.

The Darby Mountains
Rock Samples

Map No.	Field No.	U ppm	Th ppm	U/Th	$\%K_2O$	cps
J1R	5E29R	<u>15.70</u>	51.00	0.31	4.75	300
J2R	DA43-1	0.	3.00	0.	1.57	160
J3R	DA43-2	0.50	20.30	0.02	0.47	160
J4R	DA43-3	0.	0.52	0.	0.71	160
J5R	DA43-4	0.90	11.90	0.08	2.40	160
J6R	DA42	2.60	56.70	0.05	4.50	600
J7R	DA46	5.70	33.30	0.17	4.43	660
J8R	DA47-1	8.20	51.00	0.16	4.37	
J9R	DA47-2	3.00	19.20	0.16	4.95	
J10R	DA40	4.50	35.90	0.13	4.94	595
J11R	DA41	2.80	48.40	0.06	4.45	600
J12R	DA48-1	5.80	64.30	0.09	4.42	610
J13R	DA48-2	2.70	57.80	0.05	4.92	
J14R	DA49-1	8.80	24.50	0.36	5.39	
J15R	DA49-2	8.80	16.60	0.53	5.08	520
J16R	DA50	4.80	46.30	0.10	5.17	540
J17R	DA51	2.90	44.20	0.07	4.32	600
J18R	5E37RB	<u>13.50</u>	32.80	0.41	5.08	625
J19R	DA34-1	<u>14.50</u>	53.10	0.27	4.33	520
J20R	DA34-2	5.10	32.30	0.16	5.16	520
J21R	DA32	7.30	44.20	0.17	5.02	500
J22R	DA38	2.80	19.80	0.14	0.62	460
J23R	DA33A	9.80	19.70	0.50	3.76	420
J24R	DA45	7.90	13.50	0.59	4.71	530
J25R	DA44	5.00	27.60	0.18	4.04	475
J26R	DA37	10.90	14.60	0.75	4.86	480
J27R	DA39	1.30	44.80	0.03	4.07	580
J28R	DA27A	2.10	25.50	0.08	4.01	375
J29R	DA28	4.50	29.70	0.15	4.89	420
J30R	DA29N	4.80	28.60	0.17	4.82	325
J31R	DA30	2.30	28.10	0.08	4.96	375

Map No.	Field No.	U ppm	Th ppm	U/Th	%K2O	cps
J32R	DA31-1	2.60	9.89	0.26	0.49	40
J33R	DA31-2	1.70	5.21	0.33	0.70	40
J34R	5C129R	10.00	48.50	0.21	4.58	500
J35R	5C120R	5.60	43.50	0.13	5.25	500
J36R	5C121R	6.70	42.50	0.16	4.85	400
J37R	5E38R	7.00	0.70	10.00	0.08	
J38R	DC8-1	6.40	34.90	0.18	12.04	
J39R	DC8-2	5.40	42.70	0.13	11.83	
J40R	DC8-3	5.40	56.30	0.10	11.92	
J41R	DC5-1	5.40	72.40	0.07	9.21	580
J42R	DC5-2	4.50	31.50	0.14	9.16	580
J43R	DC4	9.00	44.80	0.20	11.18	570
J44R	DC1	7.50	67.70	0.11	10.65	570
J45R	DC2-1	4.80	71.40	0.07	10.35	700
J46R	DC2-2	11.00	82.30	0.13	8.55	700
J47R	DC2-3	20.30	66.10	0.31	10.77	700
J48R	DC3-1	7.40	46.90	0.16	10.34	600
J49R	DC3-2	5.40	41.10	0.13	10.55	600
J50R	DC6-1	4.30	62.50	0.07	10.47	
J51R	DC6-2	5.90	34.90	0.17	11.13	
J52R	DC6-3	3.90	66.10	0.06	11.33	
J53R	DC7-1	9.00	76.00	0.12	6.53	
J54R	DC7-2	10.00	64.60	0.15	7.09	
J55R	DC7-3	7.30	58.30	0.13	6.97	
J56R	5E23R					
J57R	DA7	2.10	14.00	0.15	7.80	270
J58R	DA7A	1.90	10.80	0.18	6.65	140
J59R	DA8-1	7.40	65.00	0.11	4.91	225
J60R	DA8-2	3.50	72.50	0.05	4.80	225
J61R	DA8-3	2.80	59.50	0.05	4.70	225
J62R	DA8-4	4.30	26.00	0.17	6.10	225
J63R	DA8-5	9.60	85.60	0.11	4.84	225
J64R	DA9A	5.70	43.50	0.13	4.86	275
J65R	DA9B	2.70	13.50	0.20	7.80	275
J66R	DA10-1	7.20	57.50	0.13	5.40	500
J67R	DA10-2	8.00	64.00	0.13	5.00	500
J68R	DA10-3	6.80	67.00	0.10	4.25	500
J69R	DA10-4	7.10	77.50	0.09	4.10	500
J70R	DA11	0.	8.00	0.	4.60	120
J71R	DA6	2.30	26.10	0.09	7.00	240
J72R	DA5A1	4.30	47.00	0.09	8.70	250
J73R	DA5A2	3.00	21.00	0.14	8.96	250
J74R	DA5A3	2.20	25.50	0.09	7.60	250
J75R	DA5-1	2.00	27.00	0.07	5.67	280
J76R	DA5-2	5.20	42.00	0.12	8.90	280
J77R	DA5-3	2.10	37.00	0.06	7.15	280
J78R	DA1	2.20	30.00	0.07	4.46	320
J79R	DA12A	0.	7.30	0.	2.60	70
J80R	DA12B	0.	21.00	0.	3.23	70
J81R	5E24R	4.00	36.00	0.11	6.49	200
J82R	DA2A	0.	7.00	0.	0.02	
J83R	DA2B	0.90	10.80	0.08	5.55	
J84R	DA2C	2.30	13.30	0.17	4.60	

Map No.	Field No.	U ppm	Th ppm	U/Th	%K_2O	cps
J85R	DA3		15.3			140
J86R	DA4	1.00	13.80	0.07	5.13	200
J87R	5E33R	7.80	10.30	0.76	4.12	200
J88R	5E32R	4.00	8.00	0.50	2.25	
J89R	DA24	3.10	12.30	0.25	8.00	150
J90R	DA22-1	0.	8.50	0.	4.10	120
J91R	DA22-2	0.90	29.80	0.03	6.87	120
J92R	DA21	1.50	19.30	0.08	1.37	100
J93R	DA20	3.00	23.30	0.13	4.85	150
J94R	DA23	1.30	5.30	0.25	5.81	
J95R	DA23-1	1.30	29.80	0.04	4.60	120
J96R	5C105R	2.10	15.80	0.13	4.80	200
J97R	5C107R	2.30	25.00	0.09	5.07	200
J98R	5E26R	2.10	11.00	0.19	4.49	
J99R	5E25R	2.80	22.30	0.13	5.20	250
J100R	5E31R	1.80	20.30	0.09	5.40	160
J101R	5E30R	1.20	14.80	0.08	4.20	160
J102R	DA14	6.00	53.50	0.11	5.16	180
J103R	DA13N	2.90	29.30	0.10	4.69	220
J104R	DA15-1	6.80	25.30	0.27	5.22	250
J105R	DA15-2	5.70	14.80	0.39	5.22	250
J106R	DA15-3	19.00	18.00	1.06	4.83	250
J107R	DA15-4	7.40	26.30	0.28	5.21	250
J108R	DA17	1.50	8.50	0.18	5.22	
J109R	DA16-1	1.10	18.80	0.06	4.74	180
J110R	DA16-2	3.70	3.50	1.06	5.90	180
J111R	DA16-3	2.70	6.80	0.40	4.79	180
J112R	DA16-4	6.30	11.50	0.55	1.20	180
J113R	5C100R	1.00	19.30	0.05	5.00	250
J114R	5C99R	7.50	22.80	0.33	3.08	275
J115R	5C95R	3.50	31.00	0.11	5.00	225
J116R	DA181N	2.30	20.80	0.11	3.80	200
J117R	DA18-2	2.40	9.30	0.26	5.05	200

Selawik Hills Area
Sediment and Water Samples

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
G1	5E242S	1.70	10.00	0.17	1.48	3.90	0.20	
G2	5E240S	1.50	3.50	0.43	1.20	3.30	0.35	
G3	5E241S	1.80	5.00	0.36	2.00	3.80	0.55	
G4	5E244S	0.90	5.00	0.18	1.73	4.00	0.20	
G5	5E243S	2.20	1.50	1.47	1.20	4.90	0.00	
G6	5E248S	1.40	1.00	1.40	0.98	2.10	0.65	60
G7	5E249S	1.50	14.50	0.10	0.93	1.80	0.25	
G8	5E247S	2.50	14.50	0.17	1.25	3.60	0.55	
G9	5E234S	1.30	6.00	0.22	1.25	2.60	0.45	
G10	5E235S	1.10	7.50	0.15	1.83	3.20	0.50	

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
G11	5E237S	4.70	13.50	0.35	4.39		0.50	300
G12	5E238S	4.00	10.00	0.40	7.23	10.00	1.20	
G13	5E236S	1.10	20.50	0.05	1.31	3.10	0.50	50
G14	5E239S	1.10	8.00	0.14	1.72	3.50	0.40	
G15	5E246S	2.50	5.00	0.50	1.53	4.80	0.15	
G16	5E245S	1.00	15.00	0.07	1.61	4.20	0.40	
G17	5E252S	1.30	1.00	1.30	1.43	2.70	0.15	
G18	5E251S	1.70	2.50	0.68	1.3		0.10	
G19	5E250S	1.50	11.00	0.14	1.20	3.10	0.45	
G20	5E181S	3.10	20.60	0.15	2.76	5.50	0.35	
G21	5E180S	3.80	30.70	0.12	3.38	7.00	0.80	160
G22	5E179S	7.50	92.70	0.08	3.79	37.00	0.45	150
G23	5E182S	6.50	96.90	0.07	4.00	31.00	0.60	
G24	5E176S	5.50	35.70	0.15	3.84	21.00	0.00	400
G25	5E175S	7.60	41.10	0.18	3.28	11.00	0.05	600
G26	5E174S	5.70	48.40	0.12	3.27	18.00	0.15	
G27	5E177S	7.40	27.10	0.27	3.40	53.00	0.10	
G28	5E178S	5.70	35.40	0.16	2.80	11.50	0.55	
G29	5E183S	8.00	37.00	0.22	2.87	10.60	0.00	
G30	5E184S	6.80	62.50	0.11	3.21	13.00	0.15	200
G31	5E185S	5.50	52.60	0.10	3.39	10.90	0.60	450
G32	5E189S	4.60	74.50	0.06	4.85	25.00		400
G33	5E188S	7.40	56.30	0.13	2.98	19.90	0.00	500
G34	5E191S	5.80	67.20	0.09	2.86	16.20	0.65	400
G35	5E190S	7.40	54.20	0.14	2.88	27.00		400
G36	5E192S	5.50	71.40	0.08	3.66	17.00	0.15	150
G37	5E195S	3.80	16.60	0.23	2.21	6.00	1.05	200
G38	5E193S	2.30	26.50	0.09	2.48	7.10	0.45	250
G39	5E207S	4.40	75.00	0.06	2.80			
G40	5E208S	8.70	48.00	0.18	3.57			
G41	5E209S	4.80	62.00	0.08	3.33			
G42	5E211S	9.30	69.50	0.13	3.26			
G43	5E210S	10.10	41.00	0.25	4.02			
G44	5E204S	0.50	17.50	0.03	3.57			
G45	5E203S	7.00	56.50	0.12	3.75			
G46	5E201S	0.50	22.00	0.02	3.50			
G47	5E194S	3.60	29.00	0.12	2.42	7.20	0.40	200
G48	5E199S	0.	18.00	0.	2.00			150
G49	5E200S	1.90	44.50	0.04	3.44			250
G50	5E198S	3.70	11.50	0.32	2.20			150
G51	5E196S	1.40	13.50	0.10	1.71			150
G52	5E197S	3.30	47.00	0.07	3.47			150
G53	5E233S	2.20	27.00	0.08	3.16			120
G54	5E227S	3.80	22.50	0.17	2.50	9.50	0.35	
G55	5E228S	2.20	32.00	0.07	3.12	8.50		
G56	5E229S	6.40	65.50	0.10	3.19	16.20	0.40	
G57	5E231S	4.30	7.50	0.57	2.30	6.70	0.40	
G58	5E232S	2.70	8.50	0.32	2.20	6.70	0.70	
G59	5E197B	5.50	13.50	0.41	1.83			150
G60	5E199B	5.00	43.50	0.11	2.08			
G61	5E198B	4.40	26.30	0.17	2.36			
G62	5E201B	11.80	95.00	0.12	3.28			250

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	$\%K_2O$	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
G63	5E202S	0.	11.00	0.	3.86			80
G64	5E206B	5.50	32.00	0.17	2.87			
G65	5E204B	6.00	35.00	0.17	2.70			
G66	5E220S	10.70	45.50	0.24	4.03	17.00	0.10	
G67	5E219S	15.00	26.00	0.58	1.66	21.00	0.70	
G68	5E221S	7.30	70.00	0.10	2.06	16.70	0.15	
G69	5E222S	10.10	32.50	0.31	2.95	14.60	0.35	
G70	5E218S	7.30	37.50	0.19	2.48	11.00	0.50	200
G71	5E223S	4.50	59.50	0.08	3.84		0.00	
G72	5E224S	15.90	55.00	0.29	3.70	44.00	0.50	300
G73	5E225S	27.40	32.00	0.86	3.04	100.00	0.20	
G74	5E209B	11.50	32.00	0.36	3.37			
G75	5E212S	10.50	36.50	0.29	2.46	15.10	1.25	200
G76	5E213S	11.70	31.00	0.38	2.28	21.00	1.55	200
G77	5E215S	9.40	18.30	0.51	3.45	14.50	1.25	200
G78	5E214S	7.70	15.00	0.51	2.30	8.60	1.75	200
G79	5E217S	2.50	9.00	0.28	1.53	5.20		200
G80	5E216S	10.20	52.50	0.19	3.20	12.90	0.30	
G81	5E207B	9.10	35.00	0.26	3.22			
G82	5E167S	2.30	4.10	0.56	1.20	2.70	0.35	
G83	5E169S	2.40	5.99	0.40	0.90	2.40	0.35	30
G84	5E170S	3.30	7.75	0.43	1.09	3.20	0.60	30

1. See p. A-2.

Selawik Hills Area
Rock Samples

Map No.	Field No.	U ppm	Th ppm	U/Th	$\%K_2O$	cps
G1R	AP5	2.70	15.60	0.17	14.75	425
G2R	AP4	7.80	44.80	0.17	14.36	360
G3R	AP3	6.60	44.80	0.15	14.84	350
G4R	AP2-1	1.50	41.70	0.04	17.19	250
G5R	AP2-2	2.20	26.00	0.08	13.50	250
G6R	AP1-1	1.00	16.10	0.06	17.05	250
G7R	AP1-2	1.50	27.10	0.06	16.49	250
G8R	AP6A	86.00	70.30	1.22	10.65	200
G9R	AP6B	9.60	8.33	1.15	11.67	510
G10R	AP6C	92.00	37.00	2.49	11.13	900
G11R	AP8	5.60	45.80	0.12	7.77	400
G12R	AP7	6.40	42.70	0.15	6.48	360
G13R	AP11	3.40	20.80	0.16	6.99	410
G14R	AP9	3.30	21.40	0.15	8.37	220
G15R	AP10-1	16.20	51.00	0.32	7.46	720
G16R	AP10-2	15.70	54.20	0.29	8.20	720
G17R	SP27	0.	22.30	0.	4.00	410
G18R	SP28	2.40	24.30	0.10	4.17	250
G19R	SP29-1	1.60	20.30	0.08	5.22	500
G20R	SP29-2	5.10	31.50	0.16	7.83	500
G21R	SP29-3	3.10	31.50	0.10	6.40	500

Map No.	Field No.	U ppm	Th ppm	U/Th	$\%K_2O$	cps
G22R	SP5	2.40	17.50	0.14	6.60	270
G23R	SP4	3.10	24.50	0.13	6.53	250
G24R	SP3	1.70	10.00	0.17	7.65	260
G25R	SP1-1	2.00	4.50	0.44	5.18	240
G26R	SP1-2	2.00	25.80	0.08	4.55	
G27R	SP1-3	1.10	17.30	0.06	6.39	
G28R	SP2	0.	5.80	0.	5.84	265
G29R	SP6	3.50	21.30	0.16	5.65	250
G30R	SP7-1	0.80	3.00	0.27	5.30	230
G31R	SP7-2	5.10	23.80	0.21	5.30	230
G32R	5E39R	0.60	7.00	0.09	7.83	425
G33R	5C200R	0.	2.50	0.	5.66	400
G34R	5C199R	9.00	70.50	0.13	6.86	400
G35R	5E41R	7.90	430.00	0.02	8.50	
G36R	SP8	3.20	21.50	0.15	6.48	200
G37R	SP9	6.50	33.00	0.20	6.45	
G38R	5E42R	6.00	21.00	0.29	6.37	250
G39R	SP12	3.50	9.30	0.38	4.71	250
G40R	SP11	7.70	28.30	0.27	7.08	700
G41R	SP10-1	4.40	40.00	0.11	6.80	600
G42R	SP13	6.70	25.30	0.26	5.44	400
G43R	SP24-1	0.	23.50	0.	7.77	310
G44R	SP24-2	3.50	56.50	0.06	2.25	310
G45R	SP26	1.70	33.30	0.05	7.60	225
G46R	SP25	0.	7.50	0.	11.00	220
G47R	SP23	8.40	21.50	0.39	1.34	300
G48R	SP19	1.60	27.30	0.06	11.70	270
G49R	SP20-1	0.	11.50	0.	12.40	210
G50R	SP20-2	0.	9.50	0.	13.80	210
G51R	SP21-1	0.	6.00	0.	9.14	260
G52R	SP21-2	0.	6.50	0.	9.60	260
G53R	SP22	139.00	618.00	0.22	7.20	780
G54R	SP22A2	44.00	277.50	0.16	7.10	780
G55R	SP22B1	1.70	8.80	0.19	8.48	780
G56R	SP22B2	12.20	171.30	0.07	6.05	780
G57R	SP22C	2.60	21.80	0.12	10.40	580
G58R	SP18-1	0.0	0.0			30
G59R	SP18-2	0.	1.70	0.	0.31	30
G60R	SP18-3	0.0	0.0		0.55	30
G61R	SP17	2.40	25.50	0.09	5.00	250
G62R	5E43R	4.60	16.50	0.28	6.44	250
G63R	5E45R	0.70	0.40	1.75	0.	300
G64R	SP14	3.80	11.00	0.35	6.20	275
G65R	SP15	5.30	27.80	0.19	6.40	300
G66R	SP16	5.30	27.30	0.19	5.60	300

Zane Hills-Purcell Mountains Area
Sediment and Water Samples

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
D1	5E353S	0.	9.00	0.	1.53			
D2	5E350S	0.80	11.50	0.07	1.50			
D3	5E349S	1.80	16.00	0.11	1.62	5.40	0.75	
D4	5E289S	2.00	15.50	0.13	1.42			100
D5	5E294S	7.90	17.50	0.45	2.33	15.50	0.65	250
D6	5E293S	7.50	42.00	0.18	2.30	14.60		200
D7	5E291S	7.20	15.00	0.48	2.18	10.40	0.55	
D8	5E292S	8.20	20.00	0.41	2.33	10.10		200
D9	5E290S	10.20	44.00	0.23	2.33		0.75	
D10	5E286S	8.20	15.00	0.55	2.00	16.00	0.60	200
D11	5E285S	7.70	24.50	0.31	1.40	14.80	0.50	100
D12	5E288S	6.70	50.00	0.13	1.56	17.20	0.75	
D13	5E287S	6.60	11.50	0.57	1.46	11.10	0.70	
D14	5E282S	7.90	48.50	0.16	2.07	16.10		200
D15	5E283S	5.70	22.00	0.26	2.75	15.10		
D16	5E284S	5.70	27.00	0.21	1.92	16.10	0.35	150
D17	5E257S	30.00	20.50	1.46	2.15	44.00	0.40	200
D18	5E255S	11.90	17.50	0.68	2.18	22.00	0.30	
D19	5E256S	13.30	57.00	0.23	2.00	38.00	0.20	160
D20	5E310S	2.80	7.50	0.37	1.24	4.50	1.00	
D21	5E309S	5.30	12.00	0.44	1.73	8.50	1.25	
D22	5E308S	2.70	12.50	0.22	2.45	5.30	0.65	150
D23	5E258S	6.90	61.50	0.11	2.14	16.30	0.45	
D24	5E259S	17.80	18.00	0.99	1.92		0.65	
D25	5E262S	4.60	12.00	0.38	1.64	7.60	1.65	
D26	5E261S	7.50	20.00	0.38	1.66	15.50	0.70	
D27	5E260S	18.00	18.40	0.98	1.75	54.00	0.85	200
D28	5E271S	23.40	41.50	0.56	2.17	26.00	0.95	200
D29	5E270S	21.30	37.00	0.58	2.18	40.00	0.70	200
D30	5E268S	5.10	42.00	0.12	2.62	13.80	3.25	200
D31	5E269S	14.50	57.50	0.25	2.06	34.00	1.95	200
D32	5E267S	14.90	40.50	0.37	2.51	29.00	2.95	200
D33	5E265S	1.40	7.00	0.20	0.97		1.70	
D34	5E266S	2.40	4.50	0.53	1.09	3.30	2.70	
D35	5E263S	7.80	56.00	0.14	1.55	12.90	3.95	
D36	5E264S	2.40	23.00	0.10	1.48		2.40	
D37	5E274S	35.00	67.00	0.52	2.70	60.00	1.90	700
D38	5E273S	15.90	78.00	0.20	2.06	44.00	2.15	300
D39	5E272S	2.50	7.50	0.33	1.00	3.40	0.85	100
H1	5E339S	4.30	6.50	0.66	1.41	4.90	0.20	
H2	5E341S	2.90	6.50	0.45	1.06	3.60	1.30	80
H3	5E340S	2.90	12.50	0.23	1.37		0.35	80
H4	5E348S	4.00	12.00	0.33	1.39			100
H5	5E342S	1.80	12.50	0.14	1.20	3.80	1.75	150
H6	5E343S	2.10	10.50	0.20	1.17	3.50	1.90	120
H7	5E344S	4.30	12.50	0.34	1.40	6.00	2.40	200

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
H8	5E345S	9.50	23.50	0.40	1.60	15.10		200
H9	5E346S	8.30	9.50	0.87	1.72		2.70	200
H10	5E356S	7.40	19.00	0.39	1.96	14.00	0.45	200
H11	5E352S	6.10	21.00	0.29	2.00	9.80	0.65	200
H12	5E354S	6.90	42.00	0.16	2.62	14.00	1.80	200
H13	5E355S	4.60	23.00	0.20	2.17		0.20	200
H14	5E306S	15.60	26.50	0.59	2.51	29.00	0.95	
H15	5E307S	13.30	27.00	0.49	1.32	23.00	0.55	200
H16	5E305S	8.80	40.50	0.22	2.50		1.45	
H17	5E304S	10.70	28.50	0.38	2.72	18.00	0.50	
H18	5E300S	13.20	32.00	0.41	2.47	28.00	1.40	200
H19	5E301S	5.40	62.00	0.09	2.30	19.20	0.85	200
H20	5E302S	7.10	38.50	0.18	1.91	13.90		200
H21	5E303S	5.90	35.00	0.17	2.18	17.40	0.65	200
H22	5E299S	6.10	24.50	0.25	2.00	26.00	0.20	200
H23	5E298S	7.60	34.00	0.22	2.26	14.70	0.75	200
H24	5E296S	9.70	30.50	0.32	2.50	18.10	1.30	200
H25	5E297S	7.60	32.00	0.24	2.49	12.00	1.35	200
H26	5E281S	6.70	33.50	0.20	1.99	16.40	0.85	300
H27	5E295S	3.80	13.00	0.29	2.02		0.45	200
H28	5E278S	8.50	28.00	0.30	2.25	18.40	1.55	200
H29	5E279S	12.90	50.00	0.26	2.13	31.00	1.80	200
H30	5E277S	10.90	30.50	0.36	1.54	19.70	1.60	300
H31	5E276S	37.00	61.00	0.61	2.49	77.0	1.05	600
H32	5E275S	25.00	23.50	1.06	1.63	35.0	2.60	600
H33	5E333S	9.90	44.50	0.22	2.67	22.00	0.75	500
H34	5E331S	29.00	73.00	0.40	3.24	35.00	0.70	400
H35	5E332S	26.00	75.00	0.35	3.32	52.00	0.65	400
H36	5E334S	12.90	19.50	0.66	2.17	15.20	0.30	
H37	5E336S	16.90	80.00	0.21	3.08	31.00	1.80	300
H38	5E338S	30.00	120.00	0.25	3.30	63.00	1.95	
H39	5E337S	21.00	65.00	0.32	2.78	40.00	1.70	
H40	5E328S	5.30	12.00	0.44	1.94	6.80	1.50	160
H41	5E327S	5.30	13.00	0.41	2.37	8.40	0.75	160
H42	5E325S	3.80	10.50	0.36	1.88	8.30	0.75	150
H43	5E326S	4.50	16.00	0.28	1.98	6.70	1.00	150
H44	5E329S	7.00	18.50	0.38	2.74	12.80		
H45	5E330S	17.80	21.50	0.83	2.74	23.00	0.55	
H46	5E323S	5.50	17.50	0.31	2.16	9.90	0.20	
H47	5E324S	4.70	15.00	0.31	2.53	10.10	0.70	
H48	5E322S	5.50	13.50	0.41	1.90	9.90	0.90	300
H49	5E321S	6.60	17.50	0.38	2.23	11.20		300
H50	5E312S	2.30	13.50	0.17	1.12	4.50	1.35	
H51	5E313S	2.50	9.00	0.28	1.17	4.40	1.05	400
H52	5E315S	57.00	47.00	1.21	2.47	59.00	0.55	
H53	5E314S	57.0			3.69	74.00	1.30	
H54	5E316S	16.10	37.00	0.44	2.89	27.00	0.20	450
H55	5E317S	22.70	54.00	0.42	3.14	39.00	0.45	450
H56	5E318S	45.00	44.50	1.01	3.00	77.00	1.05	450
H57	5E319S	56.00	64.00	0.88	2.67	69.00	1.40	400

1. See p. A-2.

Zane Hills-Purcell Mountains Area
Rock Samples

Map No.	Field No.	U ppm	Th ppm	U/Th	%K_2O	cps
D1R	ZH14	2.10	40.60	0.05	6.61	720
D2R	ZH13A	17.20	56.70	0.30	6.45	000
D3R	ZH13	6.80	24.50	0.28	8.15	000
D4R	ZH12	3.60	63.00	0.06	7.15	745
D5R	ZH11A	6.50	11.40	0.57	4.50	225
D6R	ZH11	1.50	15.10	0.10	3.37	225
D7R	ZH10	1.70	11.40	0.15	3.27	230
D8R	ZH9	2.50	12.00	0.21	4.03	235
D9R	ZH8	4.80	44.80	0.11	2.80	275
D10R	5E52R	1.80	10.30	0.17	1.68	
D11R	5E51R	1.10	6.00	0.18	1.10	70
H1R	ZH23	1.40	9.37	0.15	0.75	95
H2R	ZH22A1	3.40	17.70	0.19	4.85	300
H3R	ZH22A2	2.30	20.30	0.11	4.44	300
H4R	ZH22B1	49.00	13.50	3.63	6.25	300
H5R	ZH22B2	19.40	21.30	0.91	6.15	300
H6R	ZH21	3.20	11.50	0.28	2.53	235
H7R	ZH20	1.60	2.08	0.77	3.14	210
H8R	ZH20A	2.80	8.85	0.32	3.21	210
H9R	ZH19	1.60	12.50	0.13	3.15	190
H10R	ZH18	1.40	9.40	0.15	3.04	230
H11R	ZH17	0.70	12.50	0.06	2.99	210
H12R	ZH17A	1.20	11.00	0.11	3.27	210
H13R	ZH16	0.90	14.00	0.06	2.80	210
H14R	ZH15	1.20	14.60	0.08	2.97	210
H15R	ZH7	2.50	18.80	0.13	3.41	360
H16R	ZH6	2.40	13.50	0.18	3.21	250
H17R	ZH6A	1.70	13.50	0.13	3.35	250
H18R	ZH5	0.	14.10	0.	3.82	350
H19R	ZH5A	2.30	74.00	0.03	5.68	500
H20R	ZH4A	3.10	58.30	0.05	4.73	580
H21R	ZH4B	5.40	51.00	0.11	5.52	580
H22R	ZH4C	0.	11.50	0.	6.13	580
H23R	ZH3	3.70	59.90	0.06	5.85	650
H24R	ZH2	5.40	58.30	0.09	5.52	650
H25R	ZH1	0.60	2.08	0.29	0.55	475
H26R	ZH1A	8.40	51.00	0.16	6.19	100
H27R	5E53R	3.50	126.30	0.03	5.45	900
H28R	5E55R	6.50	21.00	0.31	3.35	
H29R	WC2	5.40	26.00	0.21	4.73	400
H30R	WC1	18.40	31.00	0.59	4.49	540
H31R	WC9	5.90	18.70	0.32	3.34	380
H32R	WC3	32.70	41.60	0.79	4.59	580
H33R	WC4	11.90	38.50	0.31	4.67	620
H34R	WC8	15.90	35.40	0.45	4.48	620
H35R	WC5	15.50	25.00	0.62	3.83	540
H36R	WC6-1	4.00	30.20	0.13	4.36	480
H37R	WC6-2	10.40	20.90	0.50	4.50	480
H38R	WC7	9.00	35.40	0.25	3.58	300

Copper River Basin
Sediment and Water Samples

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
C1	5E366S	1.40	10.00	0.14	1.20	1.70		
C2	5E365S	1.30	7.00	0.19	1.32	2.30	0.75	
C3	5E364S	2.00	11.50	0.17	1.34	2.70		60
C4	5E363S	1.80	14.50	0.12	1.55	2.40	0.85	
C5	5E362S	2.50	8.00	0.31	1.20	2.20	1.30	70
C6	5E367S	1.40	6.20	0.23	1.81	3.00	1.75	
K1	5E380S	2.00	5.50	0.36	1.02	1.90	0.40	60
K2	5E379S	1.70	7.50	0.23	1.13	2.60	0.35	60
K3	5E378S	2.50	5.70	0.44	0.84	2.50	1.10	40
K4	5E377S	2.00	5.50	0.36	0.88	2.50	0.70	40
K5	5M25S	0.50	1.20	0.42	1.50	1.20	1.00	45
K6	5M26S	0.	2.75	0.	1.00	2.20	1.00	45
K7	5M27S	0.	3.75	0.	1.43	1.20	0.35	45
K8	5M29S	1.60	5.75	0.28	1.15		0.85	28
K9	5M28S	0.	16.00	0.	1.40		1.15	28
K10	5K17S	2.80	3.80	0.74	0.75	3.30		38
K11	5M20S	1.10	4.25	0.26	0.71	2.30	0.90	43
K12	5K14S	2.10	4.00	0.53	0.89	1.00	0.60	38
K13	5K16S	1.90	3.30	0.58	0.75	1.80	1.25	38
K14	5M22S	0.	3.75	0.	0.44		1.00	35
K15	5K13S	0.80	2.30	0.35	0.56	1.30	1.55	38
K16	5M24S	0.	3.00	0.	0.53			25
K17	5M21S	1.00	3.00	0.33	0.62			35
K18	5K12S	0.	2.80	0.	0.89	1.30	1.55	40
K19	5K11S	1.40	2.80	0.50	0.76	1.00	1.40	20
K20	5K10S	1.00	1.80	0.56	0.75	0.69	0.75	30
K21	5K9S	1.00	3.30	0.30	0.80	1.40	0.90	09
K22	5K8S	0.40	5.80	0.07	0.92	1.60	0.75	40
K23	5K7S	2.40	3.80	0.63	0.87	1.90	0.65	40
K24	5C220S	0.80	6.74	0.12	0.77			40
K25	5C221S	0.	3.49	0.	0.73			35
K26	5E376S	2.50	2.70	0.93	0.95	1.60		40
K27	5E375S	1.30	6.00	0.22	0.77	1.80	0.45	45
K28	5E374S	1.60	2.70	0.59	0.80	1.60	1.05	50
K29	5E373S	1.30	6.20	0.21	1.10	1.20	1.30	50
K30	5K5S	0.	0.50	0.	0.99	0.90	0.70	40
K31	5K6S	0.40	0.50	0.80	0.87	0.51	1.55	42
K32	5E371S	0.30	6.20	0.05	1.13	1.30	0.80	60
K33	5E372S	1.00	5.70	0.18	1.24	1.90	0.60	60
K34	5M19S	0.	5.50	0.	0.47	0.23	0.50	25
K35	5M18S	0.	4.50	0.	0.40	0.23	0.25	25
K36	5M16S	0.	8.25	0.	0.44	0.31	0.55	30
K37	5M17S	0.	2.75	0.	0.71		0.70	30
K38	5M15S	0.	0.60	0.	0.82	0.15	0.55	30
K39	5M14S	0.	7.50	0.	0.82	0.40	1.00	30
K40	5M13S	0.80	3.50	0.23	1.09	0.47	0.75	40

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
K41	5M12S	0.	0.50	0.	1.05	0.28	0.85	30
K42	5M56S	1.60	2.10	0.76	1.00	1.38	1.35	40
K43	5M66S	1.10	2.75	0.40	1.12	0.90	1.40	
K44	5M65S	1.20	4.50	0.27	0.90	1.10	1.30	
K45	5M67S	1.40	2.75	0.51	0.90	0.93	1.55	
K46	5M64S	1.50	5.25	0.29	0.88	1.80		42
K47	5K31S	0.80	4.30	0.19	0.92	1.60	0.40	42
K48	5K32S	1.00	3.30	0.30	0.80	1.40	0.85	42
K49	5M63S	1.50	4.50	0.33	0.90	2.10		42
K50	5M62S	0.	3.50	0.	0.88	1.60		40
K51	5M61S	0.	3.75	0.	0.88	1.60		44
K52	5K28S	0.	2.50	0.	0.98	1.40	1.10	
K53	5K25S	0.70	2.80	0.25	0.76	1.20	1.40	
K54	5K24S	0.40	6.00	0.07	0.75			
K55	5K26S	2.10	4.30	0.49	0.73	1.50	0.95	
K56	5K27S	1.10	4.00	0.28	0.59	0.86		
K57	5K29S	0.60	3.00	0.20	0.83	1.30	1.20	
K58	5M59S	1.20	1.45	0.83	1.10	3.20	1.10	40
K59	5M60S	0.	2.55	0.	1.31	1.30	0.55	40
K60	5M58S	0.	2.50	0.	0.90	0.94	0.55	40
K61	5M57S	0.80	3.50	0.23	1.03	1.20		40
K62	5M6S	1.20	5.25	0.23	1.13	0.95	1.45	40
K63	5M5S	1.20	4.50	0.27	0.80	1.30	0.70	40
K64	5M4S	1.20	3.25	0.37	0.82	1.70	0.45	36
K65	5M8S	1.20	2.25	0.53	1.00	1.40	1.10	32
K66	5M7S	1.20	3.00	0.40	0.94	1.60	0.65	32
K67	5M9S	0.90	2.50	0.36	0.86	1.60	1.15	36
K68	5K3S	0.70	5.00	0.14	1.18	1.40	1.40	48
K69	5K2S	1.30	2.30	0.57	1.40	1.20	0.75	55
K70	5E368S	1.40	6.00	0.23	0.87	1.30		
K71	5M11S	1.30	4.50	0.29	0.88	1.80	0.40	
K72	5E370S	2.10	12.00	0.17	1.24	2.10		60
K73	5E369S	2.00	5.50	0.36	1.20	2.00		60
K74	5M52S	1.10	5.50	0.20	1.07	1.50	0.60	30
K75	5M54S	0.	6.50	0.	2.00	1.90		56
K76	5M53S	0.70	5.00	0.14	1.29	1.90		32
K77	5M50S	1.00	3.00	0.33	1.36	1.80	0.45	36
K78	5M51S	0.	2.50	0.	1.31	1.60	0.55	36
K79	5M55S	0.50	2.50	0.20	0.20	0.52	0.75	20
K80	5M49S	2.00	2.50	0.80	1.30	1.70	0.45	50
K81	5M48S	0.	6.50	0.	1.40	1.60	0.55	50
K82	5K23S	0.50	2.00	0.25	1.33	0.70	1.95	45
K83	5K22S	1.30	2.80	0.46	1.38			45
K84	5K20S	1.40	2.00	0.70	1.32	0.68	1.40	45
K85	5K21S	0.	1.80	0.	1.40			45
K86	5M68S	0.80	1.25	0.64	0.39	0.69	0.45	50
K87	5M69S	1.60	4.00	0.40	0.40	1.50	0.35	50
K88	5M70S	0.80	2.75	0.29	0.72	0.39	1.90	45
K89	5M72S	0.	1.75	0.	0.61	0.87	0.70	40
K90	5M71S	1.20	1.75	0.69	0.72	0.69	1.40	40

1. See p. A-2.

Map No.	Field No.	U ppm	Th ppm	U/Th	%K_2O	cps
*F1	5E1S	0.50	11.50	0.04	2.16	
*F2	5E2S	0.50	11.70	0.04	1.24	
*F3	5E3S	1.00	19.90	0.05	3.65	70
*F4	5E4S		21.2		3.82	50
*F5	5E5S		12.8		2.91	8
*F6	5E358S		14.5			
*F7	5E361S	1.30	5.00	0.26	0.48	
*F8	5E359S	1.50	13.00	0.12	0.51	
*F9	5E360S	1.00	7.50	0.13	0.80	

Copper River Basin
Rock Samples

Map No.	Field No.	U ppm	Th ppm	U/Th	%K_2O	cps
C1R	5E56RA	1.10	26.00	0.04	0.95	45
C2R	5E56RB	0.40	3.80	0.11	1.40	45
K1R	5E59R	0.	7.30	0.	2.70	100
K2R	5E58R	0.	6.50	0.	0.52	
K3R	5K17R	1.10	0.10	11.00	0.46	38
K4R	5K15R	0.90	0.30	3.00	1.10	
K5R	5M23R	0.	0.10	0.	0.50	
K6R	5K11R	0.	0.20	0.	0.24	20
K7R	5K9R	0.0	0.0		0.20	40
K8R	5E57R	0.40	0.10	4.00	0.40	35
K9R	5K4R	0.	0.20	0.	1.56	38
K10R	5E56R	0.40	0.70	0.57	0.87	
K11R	5M6R	0.60	3.50	0.17	2.26	40
K12R	5M1R	1.20	2.00	0.60	1.68	40
K13R	5M68R	0.	2.00	0.	1.26	50
F1R	5E55RA	1.00	0.70	1.43	0.38	
F2R	5E55RB	1.00	2.30	0.43	0.53	

*Sample mean and standard deviation of samples collected in Mt. Hayes quadrangle based on data from that quadrangle only.

Chitina Valley Area
Sediment and Water Samples

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
E1	5C306S	0.30	4.74	0.06	1.46	1.40	0.50	
E2	5C307S	0.	6.74	0.	0.86	0.66	0.90	
E3	5C325S	0.60	5.50	0.11	1.48	2.10	0.60	
E4	5C308S	0.30	5.24	0.06	1.32	1.10	0.90	
E5	5C309S	0.	2.99	0.	0.70	0.47	0.35	
E6	5C327S	0.	5.00	0.	0.44		1.00	
E7	5C328S	0.	3.25	0.	0.50		0.90	
E8	5C310S	0.	4.74	0.	1.36	1.20	0.45	
E9	5C311S	0.	5.50	0.	1.20	0.46	0.60	
E10	5C324S	0.60	3.75	0.16	0.96	1.90	0.60	
E11	5C313S	0.70	2.35	0.30	1.20	1.00	0.70	
E12	5C312S	0.	7.25	0.	1.20	1.00	1.25	
E13	5C317S	0.80	5.00	0.16	0.79	2.60	0.95	
E14	5C316S	1.60	5.00	0.32	0.96	<u>4.10</u>	1.40	
E15	5C315S	0.	<u>11.30</u>	0.	1.18	1.00	1.15	
E16	5C314S	0.80	3.50	0.23	0.57	1.70	0.60	
E17	5C301S	1.20	6.74	0.18	0.95	1.90	1.10	
E18	5C302S	0.70	6.99	0.10	1.00		0.50	
E19	5M130S	0.70	3.50	0.20	1.20	2.20		
E20	5M131S	1.30	3.50	0.37	1.30	2.20	0.20	
E21	5M132S	1.50	1.00	1.50	1.03	2.40		
E22	5M133S	1.50	4.75	0.32	1.64	1.70		
E23	5M136S	1.90	2.25	0.84	1.40	2.20	0.20	
E24	5M134S	0.80	3.25	0.25	1.27	2.00	0.20	
E25	5M135S	2.10	3.25	0.65	1.29	1.90		
E26	5M137S	1.80	2.75	0.65	1.62	2.20		
E27	5C300S	0.	4.49	0.	1.32	1.70	1.05	
E28	5M141S	<u>2.70</u>	4.50	0.60	1.47	2.60	0.75	
E29	5M142S	<u>2.70</u>	5.25	0.51	1.29	3.20	1.75	
E30	5M143S	1.50	3.50	0.43	1.36	3.00	0.75	
E31	5M145S	1.50	4.25	0.35	1.40	2.50	0.40	
E32	5M140S	2.40	2.50	0.96	1.02	2.20	0.60	
E33	5M147S	0.	2.00	0.	<u>2.10</u>	2.10	0.45	
E34	5M146S	0.	1.50	0.	1.70	2.10	0.50	
E35	5C304S	1.20	6.24	0.19	1.40	2.60	0.50	
E36	5M148S	0.90	2.75	0.33	1.39	2.40	<u>2.10</u>	
E37	5M151S	0.90	4.25	0.21	1.39	3.00	0.70	
E38	5M150S	0.50	3.00	0.17	1.20	1.50	0.20	
E39	5K69S	0.	5.30	0.	1.16	1.80		70
E40	5K70S	0.	0.80	0.	1.14	1.80		60
E41	5M106S	1.30	4.00	0.33	1.69	2.40		
E42	5M107S	0.50	4.25	0.12	1.49	2.00	0.35	
E43	5M108S	1.60	4.00	0.40	1.33	2.40		
E44	5E383S	1.80	<u>10.70</u>	0.17	1.40	2.40		50
E45	5M109S	1.10	6.75	0.16	1.60	2.80		
E46	5M110S	0.	5.25	0.	1.53	2.40	0.50	
E47	5M111S	1.70	4.00	0.43	1.68	2.50	0.30	
E48	5M112S	1.60	4.75	0.34	1.81	2.50	<u>3.50</u>	
E49	5M115S	1.50	<u>10.30</u>	0.15	1.69	1.15	1.35	
E50	5M113S	1.60	4.75	0.34	<u>1.93</u>	2.50		
E51	5M114S	1.50	<u>11.80</u>	0.13	1.46	2.00	1.10	

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
E52	5M116S	2.20	8.25	0.27	1.79	3.00	2.75	
E53	5M117S	1.50	6.25	0.24	1.31	2.60		
E54	5M125S	2.10	4.75	0.44	1.70	2.50		
E55	5M124S	1.50	6.25	0.24	1.55	2.60		
E56	5M128S	1.10	2.75	0.40	1.62	3.00		
E57	5M129S	2.00	5.00	0.40	1.65	2.90		
E58	5K61S	0.	2.30	0.	1.67	2.90		40
E59	5M123S	2.20	8.25	0.27	1.59	2.90		
E60	5M122S	1.50	6.75	0.22	1.71	2.90		
E61	5M121S	2.00	8.00	0.25	1.33	2.40		
E62	5M118S	1.50	11.00	0.14	1.88	3.40		
E63	5M119S	2.40	8.25	0.29	1.80	2.90		
E64	5M120S	2.00	8.00	0.25	1.29	3.00		
L1	5M104S	1.20	5.75	0.21	1.20	1.40	0.40	
L2	5M103S	1.10	2.00	0.55	1.45	1.60	0.20	
L3	5M101S	0.	3.00	0.	1.31	1.40	1.35	
L4	5E381S	1.80	6.20	0.29	1.32	1.40	1.10	50
L5	5E382S	2.10	5.20	0.40	1.31	1.60		50
L6	5M102S	0.	3.50	0.	1.50	1.50	0.35	
L7	5M100S	0.	4.00	0.	1.43	1.50	1.50	
L8	5C318S	0.80	4.75	0.17	1.20	1.10	1.50	
L9	5C319S	0.	5.25	0.	1.20	1.20	1.15	
L10	5E384S	1.40	6.49	0.22	1.02	3.20		
L11	5M153S	1.70	2.50	0.68	1.00	1.90	0.40	50
L12	5M154S	1.50	3.30	0.45	1.02	1.90		45
L13	5M152S	1.60	5.30	0.30	1.07	1.30	0.75	50
L14	5C320S	0.80	3.75	0.21	1.22	1.10	1.10	
L15	5C321S	0.60	4.50	0.13	1.19	1.20	1.30	
L16	5C322S	0.	4.75	0.	1.01	1.10	0.40	
L17	5C329S	0.	7.25	0.	1.40	1.40	1.60	50
L18	5C330S	0.70	3.50	0.20	1.12	1.40	0.55	
L19	5C331S	0.70	5.75	0.12	0.83	1.20	1.05	
L20	5C334S	1.20	2.95	0.41	0.95	1.90	1.10	50
L21	5C332S	1.20	5.75	0.21	1.07	3.40	0.45	160
L22	5K50S	3.40	5.30	0.64	1.06	4.00	1.50	67
L23	5K51S	1.10	6.50	0.17	1.22	3.20	1.65	100
L24	5K53S	3.50	7.30	0.48	1.49	3.80	0.85	60
L25	5M47S	0.	2.50	0.	0.70	1.30	0.30	
L26	5M46S	0.	5.75	0.	0.88	1.60	0.45	
L27	5M40S	0.50	3.40	0.15	1.09	2.20	0.50	55
L28	5M38S	3.20	1.50	2.13	0.31	6.30	0.25	
L29	5M39S	0.70	4.25	0.16	1.19	2.50	0.25	45
L30	5M36S	0.60	2.75	0.22	1.20	1.20		45
L31	5M37S	0.50	5.50	0.09	1.14	2.00	0.75	45
L32	5M41S	1.20	2.30	0.52	0.86	3.40	0.20	45
L33	5M42S	1.00	3.05	0.33	0.74	2.40	0.20	45
L34	5M43S	1.50	3.25	0.46	0.85	1.80	0.40	45
L35	5M44S	0.	4.25	0.	1.45	1.50		45
L36	5M30S	0.60	4.50	0.13	1.05	1.70	0.85	40
L37	5M35S	0.	3.25	0.	0.71	1.90		30

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	$\%K_2O$	U ppm (LASL)[2]	U ppb (LASL)[2]	cps
L38	5M31S	1.80	1.45	1.24	0.40	0.66		
L39	5M32S	0.60	3.50	0.17	0.60	1.90	0.20	55
L40	5M33S	0.80	4.00	0.20	0.93	1.90	0.20	60
L41	5M34S	0.90	5.50	0.16	0.73	2.00	0.80	

Chitina Valley Area
Rock Samples

Map No.	Field No.	U ppm	Th ppm	U/Th	$\%K_2O$	cps
E1R	5E74R	0.	1.40	0.	1.45	55
E2R	5K65R	0.	1.30	0.	1.80	60
E3R	5K64R	0.	3.00	0.	1.38	50
E4R	5K63R	0.40	3.00	0.13	1.51	60
E5R	5K62R	0.	0.20	0.	1.73	60
E6R	5E68R	0.	4.30	0.	0.77	75
E7R	5E69R	1.60	5.00	0.32	0.28	
E8R	5E70R		0.4		1.52	90
E9R	5E72R	1.60	3.00	0.53	0.80	50
E10R	5E71R	1.00	1.30	0.77	0.76	80
E11R	5K66R	0.	2.50	0.	2.31	80
E12R	5K67R	0.	2.30	0.	2.40	85
E13R	5K68R	0.	1.80	0.	1.81	
E14R	5K54R	0.	11.30	0.	2.63	75
E15R	5K55R	1.00	7.30	0.14	2.54	75
E16R	5E66R	2.50	0.90	2.78	0.87	40
E17R	5E65R	2.50	7.30	0.34	2.55	90
E18R	5E63R	0.40	1.80	0.22	1.32	75
E19R	5E64R	2.00	3.80	0.53	0.97	70
E20R	5K56R	0.40	4.80	0.08	2.00	
E21R	5K57RA	1.90	8.50	0.22	1.16	
E22R	5K58R	1.80	6.80	0.26	2.53	
E23R	5K59R	1.00	7.30	0.14	2.20	100
E24R	5E67R	0.	3.30	0.	2.10	90
L1R	5E62RA	0.	1.30	0.	1.82	
L2R	5E62RB	0.90	4.30	0.21	1.85	
L3R	5E73R	0.	0.40	0.	2.40	55
L4R	5E73RB	0.	0.60	0.	0.50	55
L5R	5M153R	0.	1.50	0.	1.34	50
L6R	5M155R	0.	1.00	0.	2.00	80
L7R	5K50R	0.	3.00	0.	3.00	90
L8R	5K51R	1.40	2.80	0.50	2.48	55
L9R	5E60R	0.70	0.40	1.75	0.20	55
L10R	5K19R	0.0	0.		0.05	55
L11R	5K18R	0.7	0.		0.19	55
L12R	5E61R	0.	0.80	0.	0.	55
L13R	5E61RB	0.40	1.30	0.31	0.50	55

Eagle-Charley River Area
Sediment and Water Samples

Map No.	Field No.	U ppm (RAA)[1]	Th ppm	U/Th	%K_2O	U ppm (LASL)[1]	U ppb (LASL)[1]	cps
M1	5D60S	0.90	1.60	0.56	8.00	23.00	0.20	
M2	5D54S	1.30	1.70	0.76	14.50	4.00	0.65	
M3	5D56S	2.00	1.30	1.54	5.00			
M4	5D25S	1.60	1.60	1.00	18.50		0.00	
M5	5D33S	0.60	1.70	0.35	20.50	8.60	0.55	90
M6	5K109S	1.00	1.50	0.67	22.50		0.45	400
M7	5K108S	0.90	1.60	0.56	5.00	75.00	0.10	400
M8	5K107S	0.90	1.60	0.56	5.50	15.60	0.20	400
M9	5D102S	2.50	1.50	1.67	4.50		0.20	80
M10	5K106S	0.90	1.60	0.56	15.50		1.40	105
M11	5K105S	1.50	1.50	1.00	14.50		0.90	120
M12	5K103S	1.20	1.50	0.80	4.00		2.20	
M13	5D3S	1.40	1.70	0.82	10.00			
M14	5K102S	0.80	1.50	0.53	14.00		0.35	80
M15	5K101S	1.30	1.70	0.76	4.50		1.00	80
M16	5K100S	2.10	1.49	1.41	11.00		1.80	80
M17	5D5S	0.70	1.30	0.54	4.00		0.80	
M18	5D4S	1.80	1.30	1.38	11.00		1.30	

Healy D-1 Quadrangle and Vicinity
Sediment Samples

Map No.	Field No.	U ppm (RAA)[1]	Th	U/Th	%K_2O
1001	WG1001	2.70	6.90	0.39	1.62
1002	WG1002	2.50	20.50	0.12	1.56
1003	WG1003	7.50	57.00	0.13	2.54
1004	WG1004	1.40	11.00	0.13	2.80
1005	WG1005	3.40	10.00	0.34	2.17
1006	WG1006	0.			2.35
1007	WG1007	0.	9.40	0.	1.74
1008	WG1008	1.00	6.80	0.15	2.31
1009	WG1009	1.20	8.30	0.14	1.64
1010	WG1010	2.00	10.50	0.19	3.15
1011	WG1011	1.00	6.60	0.15	2.09
1012	WG1012	2.30	35.50	0.06	3.03
1013	WG1013	2.10	16.50	0.13	4.33
1014	WG1014	1.00	11.90	0.08	2.55
1015	WG1015	8.10	38.50	0.21	3.40
1016	WG1016	8.90	22.50	0.40	3.04
1017	WG1017	1.40	12.30	0.11	2.00
1018	WG1018	4.80	13.00	0.37	2.89
1019	WG1019	3.40	19.00	0.18	2.97
1020	WG1020	2.50	21.50	0.12	4.55

[1]See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th	U/Th	%K2O
1021	WG1021	7.70	16.50	0.47	2.47
1022	WG1022	6.90	19.50	0.35	2.88
1023	WG1023	1.00	2.50	0.40	2.17
1024	WG1024	1.80	5.00	0.36	4.00
1025	WG1025	1.50	14.00	0.11	4.02
1026	WG1026	8.60	35.00	0.25	3.06
1027	WG1027	8.50	44.00	0.19	3.08
1028	WG1028	10.00	10.00	1.00	2.97
1029	WG1029	3.00	12.10	0.25	2.07
1030	WG1030	2.10	2.00	1.05	2.62
1031	WG1031	2.00	5.50	0.36	2.55
1032	WG1032	1.00	7.50	0.13	2.66
1033	WG1033	0.80	7.50	0.11	2.48
1034	WG1034	1.50	12.50	0.12	2.00
1035	WG1035	1.40	3.00	0.47	2.66
1036	WG1036	2.10	7.00	0.30	2.05
1037	WG1037	1.60	11.00	0.15	1.85
1038	WG1038	1.00	14.50	0.07	1.72
1039	WG1039	2.50	14.50	0.17	2.36
1040	WG1040	2.60	9.50	0.27	2.18
1041	WG1041	7.00	6.50	1.08	3.96
1042	WG1042	3.20	15.50	0.21	2.67
1043	WG1043	2.70	8.50	0.32	1.46
1044	WG1044	3.00	6.50	0.46	1.66
1045	WG1045	2.80	15.00	0.19	1.98
1046	WG1046	2.80	12.50	0.22	2.07
1047	WG1047	4.00	20.00	0.20	2.11
1048	WG1048	5.90	15.50	0.38	2.82
1049	WG1049	1.20	18.00	0.07	3.06
1050	WG1050	2.10	12.00	0.17	3.30
1051	WG1051	2.20	10.00	0.22	3.50
1052	WG1052	0.	7.50	0.	3.04
1053	WG1053	0.90	21.50	0.04	4.27
1054	WG1054	0.	9.00	0.	2.64
1055	WG1055	1.60	19.00	0.08	2.35
1056	WG1056	0.90	16.50	0.05	2.03
1057	WG1057	1.80	10.00	0.18	3.45
1058	WG1058	1.00	14.50	0.07	3.19
1059	WG1059	1.20	14.00	0.09	2.95
1060	WG1060	3.10	23.30	0.13	3.18
1061	WG1061	0.90	14.50	0.06	3.37
1062	WG1062	0.	12.50	0.	3.17
1063	WG1063	0.	16.00	0.	4.87
1064	WG1064	0.30	13.50	0.02	3.24
1065	WG1065	0.30	21.30	0.01	2.72
1066	WG1066	1.50	16.80	0.09	3.59
1067	WG1067	1.50	16.30	0.09	3.80
1068	WG1068	0.	31.80	0.	4.17
1069	WG1069	0.	17.50	0.	3.79
1070	WG1070	0.90	17.80	0.05	3.61
1071	WG1071	0.	10.00	0.	2.72

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th	U/Th	%K_2O
1072	WG1072	0.70	16.80	0.04	2.55
1073	WG1073	1.00	39.50	0.03	2.22
1074	WG1074	1.20	34.30	0.03	2.26
1075	WG1075	0.80	31.80	0.03	2.39
1076	WG1076	1.40	13.50	0.10	2.87
1077	WG1077	1.00	7.50	0.13	3.01
1078	WG1078	0.70	25.30	0.03	3.66
1079	WG1079	0.70	22.80	0.03	2.71
1080	WG1080	1.00	18.00	0.06	3.49
1081	WG1081	0.	18.00	0.	2.32
1082	WG1082		14.3		3.83
1083	WG1083	0.	9.30	0.	2.83
1084	WG1084	0.	19.30	0.	4.44
1085	WG1085	3.40	20.80	0.16	3.44
1086	WG1086	1.60	19.50	0.08	2.68
1087	WG1087	4.00	19.50	0.21	3.50
1088	WG1088	1.00	26.20	0.04	4.08
1089	WG1089	4.10	43.00	0.10	5.03
1090	WG1090	0.	16.30	0.	2.83
1091	WG1091	1.30	20.80	0.06	3.69
1092	WG1092	1.10	19.00	0.06	3.00
1093	WG1093	1.30	27.80	0.05	4.54
1094	WG1094	1.10	30.80	0.04	4.85
1095	WG1095	2.50	24.80	0.10	4.44
1096	WG1096	2.80	28.30	0.10	4.19
1097	WG1097	2.80	34.30	0.08	3.24
1098	WG1098	1.30	23.30	0.06	2.27
1099	WG1099	2.70	23.50	0.11	3.28
1100	WG1100	1.80	19.50	0.09	4.18
1101	WG1101	1.30	16.50	0.08	3.93
1102	WG1102	1.50	24.80	0.06	4.10
1103	WG1103	3.60	25.30	0.14	3.17
1104	WG1104	1.40	21.80	0.06	3.86
1105	WG1105	1.40	20.50	0.07	3.79
1106	WG1106	1.50	16.50	0.09	3.22
1107	WG1107	3.90	35.00	0.11	3.28
1108	WG1108	2.00	56.50	0.04	3.20
1109	WG1109	2.30	41.00	0.06	3.20
1110	WG1110	1.50	26.00	0.06	3.16
1111	WG1111	1.00	19.50	0.05	3.04
1112	WG1112	1.40	21.30	0.07	3.30
1113	WG1113	1.50	13.50	0.11	2.44
1114	WG1114	1.00	12.50	0.08	2.90
1115	WG1115	0.70	29.30	0.02	3.42
1116	WG1116	0.80	14.00	0.06	3.42
1117	WG1117	0.	18.80	0.	3.73
1118	WG1118	1.20	14.50	0.08	2.65
1119	WG1119	2.20	21.80	0.10	4.16
1120	WG1120	3.70	31.30	0.12	3.42
1121	WG1121	0.40	23.30	0.02	3.79
1122	WG1122	1.30	24.30	0.05	3.61

1. See p. A-2.

Map No.	Field No.	U ppm (RAA)[1]	Th	U/Th	%K_2O
1123	WG1123	1.10	23.80	0.05	4.71
1124	WG1124	1.70	30.30	0.06	5.04
1125	WG1125	1.30	25.80	0.05	3.82
1126	WG1126	1.90	23.80	0.08	4.19
1127	WG1127	0.90	18.00	0.05	2.71
1128	WG1128	1.20	37.00	0.03	3.73
1129	WG1129	0.50	19.50	0.03	4.31
1130	WG1130	1.30	19.50	0.07	3.92
1131	WG1131	1.50	27.30	0.05	3.03
1132	WG1132	1.30	18.00	0.07	4.07
1133	WG1133	1.70	28.50	0.06	3.42
1134	WG1134	1.80	6.25	0.29	2.61
1135	WG1135	1.60	13.80	0.12	2.77
1136	WG1136	2.50	13.00	0.19	1.97
1137	WG1137	2.90	34.00	0.09	2.11
1138	WG1138	1.90	24.00	0.08	3.17
1139	WG1139	1.90	22.50	0.08	2.76
1140	WG1140	2.20	35.30	0.06	2.13
1141	WG1141	2.40	33.50	0.07	2.36
1142	WG1142	1.70	24.00	0.07	2.28
1143	WG1143	1.90	25.30	0.08	3.62
1144	WG1144	1.40	22.30	0.06	3.33
1145	WG1145	0.50	13.30	0.04	2.69
1146	WG1146	1.10	16.80	0.07	2.44
1147	WG1147	2.40	12.50	0.19	2.46
1148	WG1148	2.0	0.		2.89
1149	WG1149	1.30	18.80	0.07	2.83
1150	WG1150	1.30	20.00	0.06	2.57
1151	WG1151	0.70	14.30	0.05	3.53
1152	WG1152	1.60	26.30	0.06	4.09
1153	WG1153	1.80	15.00	0.12	3.00
1154	WG1154	3.80	31.00	0.12	2.31
1155	WG1155	0.70	13.80	0.05	2.30
1156	WG1156	0.70	11.00	0.06	2.34
1157	WG1157	0.40	14.50	0.03	2.30
1158	WG1158	2.40	14.50	0.17	2.82
1159	WG1159	1.40	18.30	0.08	2.67
1160	WG1160	2.20	13.80	0.16	2.82
1161	WG1161	2.00	17.00	0.12	2.98
1162	WG1162	3.30	18.50	0.18	3.00
1163	WG1163	3.50	40.30	0.09	3.20
1164	WG1164	4.30	72.50	0.06	5.20
1165	WG1165	2.20	29.30	0.08	4.50
1166	WG1166	2.20	29.30	0.08	3.45
1167	WG1167	2.20	18.80	0.12	3.18
1168	WG1168	4.50	16.80	0.27	1.55
1169	WG1169	2.10	21.50	0.10	3.17
1170	WG1170	2.20	59.00	0.04	2.84
1171	WG1171	2.00	38.00	0.05	2.70
1172	WG1172	1.60	28.50	0.06	2.74
1173	WG1173	1.90	26.50	0.07	3.17
1174	WG1174	1.80	33.70	0.05	3.45

1. See p. A-2.

Map No.	Field No.	U ppm[1] (RAA)	Th	U/Th	%K₂O
1175	WG1175	3.30	7.00	0.47	2.44
1176	WG1176	1.70	26.75	0.06	3.97
1177	WG1177	1.90	10.00	0.19	1.90
1178	WG1178	1.10	10.00	0.11	3.08
1179	WG1179	1.90	11.00	0.17	3.54
1180	WG1180	1.00	9.75	0.10	2.04
1181	WG1181	1.30	29.75	0.04	3.12
1182	WG1182	0.60	7.00	0.09	1.59
1183	WG1183	1.40	18.25	0.08	2.70
1184	WG1184	1.50	16.25	0.09	3.80
1185	WG1185	1.70	14.00	0.12	2.47
1186	WG1186	1.00	11.00	0.09	2.19
1187	WG1187	2.10	17.50	0.12	3.56
1188	WG1188	1.60	3.75	0.43	1.40
1189	WG1189	2.60	11.25	0.23	3.41
1190	WG1190	2.60	10.50	0.25	2.84
1191	WG1191	2.30	16.00	0.14	2.78
1192	WG1192	2.20	5.75	0.38	2.75
1193	WG1193	2.20	6.00	0.37	2.08
1194	WG1194	2.10	8.74	0.24	2.46
1195	WG1195	2.10	25.00	0.08	4.22
1196	WG1196	3.20	12.25	0.26	4.82
1197	WG1197	2.80	7.50	0.37	4.95
1198	WG1198	1.20	7.75	0.15	3.53
1199	WG1199	1.30	24.00	0.05	3.07
1200	WG1200	1.50	6.75	0.22	3.24
1201	WG1201	1.10	32.25	0.03	4.65
1202	WG1202		15.75		3.50
1203	WG1203	0.50	11.75	0.04	3.08
1204	WG1204	1.40	26.50	0.05	4.90
1205	WG1205	2.10	18.20	0.12	3.12
1206	WG1206	2.20	15.20	0.14	2.72
1207	WG1207	1.70	25.70	0.07	4.38
1208	WG1208	0.80	14.20	0.06	2.78

1. See p. A-2.

Appendix B

HISTOGRAMS

Shown below are histograms of uranium values from sediment samples analyzed by Resource Associates of Alaska (^{U} RAA) and Los Alamos Scientific Laboratories (^{U} LASL) and water samples (^{U} H_2O) analyzed by LASL. The total number of samples is limited to those for which there are no data for these categories. The printed interval designations are the lower limits of class intervals.

Granite Mountain area

U RAA

```
95.000 )
90.000 )
85.000 )*
80.000 )
75.000 )
70.000 )
65.000 )
60.000 )
55.000 )
50.000 )
45.000 )
40.000 )
35.000 )
30.000 )
25.000 )*
20.000 )**
15.000 )****
10.000 )**********
5.000 )*********37
0. )*********58

MEAN 6.845
S DEV 9.178
N 112.
```

U LASL

```
95.000 )
90.000 )*
85.000 )*
80.000 )
75.000 )
70.000 )
65.000 )
60.000 )*
55.000 )
50.000 )*
45.000 )*
40.000 )**
35.000 )**
30.000 )*
25.000 )**
20.000 )******
15.000 )*********11
10.000 )*********28
5.000 )*********25
0. )*********30

MEAN 13.581
S DEV 14.984
N 112.
```

U H_2O

```
2.400 )
2.250 )
2.100 )
1.950 )*
1.800 )*
1.650 )***
1.500 )**
1.350 )***
1.200 )**********
1.050 )*******
0.900 )*********13
0.750 )**********
0.600 )*********11
0.450 )*********23
0.300 )*********20
0.150 )*****
-0.000 )***
-0.150 )
-0.300 )
-0.450 )

MEAN 0.745
S DEV 0.419
N 112.
```

Darby Mountains

U_{RAA}

```
85.000 )
80.000 )*
75.000 )
70.000 )
65.000 )
60.000 )**
55.000 )***
50.000 )**
45.000 )*
40.000 )*
35.000 )****
30.000 )**
25.000 )**
20.000 )*********
15.000 )****
10.000 )*******
5.000 )*********44
0. )*********31
-5.000 )
-10.000 )

MEAN 14.108
S DEV 16.345
N 113.
```

U_{LASL}

```
127.500 )
120.000 )
112.500 )
105.000 )**
97.500 )
90.000 )
82.500 )
75.000 )*
67.500 )*
60.000 )*
52.500 )
45.000 )********
37.500 )****
30.000 )*********12
22.500 )***
15.000 )******
7.500 )*********53
0. )*********22
-7.500 )
-15.000 )

MEAN 20.048
S DEV 19.875
N 113.
```

U_{H_2O}

```
2.550 )
2.400 )
2.250 )*
2.100 )*
1.950 )***
1.800 )***
1.650 )*******
1.500 )*
1.350 )******
1.200 )********
1.050 )*********
0.900 )*********14
0.750 )*********
0.600 )*********14
0.450 )*********
0.300 )*********15
0.150 )*********
0. )***
-0.150 )
-0.300 )

MEAN 0.884
S DEV 0.528
N 113.
```

Selawik Hills Area

U_{RAA}

```
32.000 )
30.000 )
28.000 )
26.000 )*
24.000 )
22.000 )
20.000 )
18.000 )
16.000 )
14.000 )**
12.000 )
10.000 )*****
8.000 )**
6.000 )*********11
4.000 )*********
2.000 )*********13
0. )*********13

MEAN 5.541
S DEV 4.650
N 56.
```

U_{LASL}

```
105.000 )
97.500 )*
90.000 )
82.500 )
75.000 )
67.500 )
60.000 )
52.500 )*
45.000 )
37.500 )*
30.000 )**
22.500 )**
15.000 )*********11
7.500 )*********12
0. )*********26
-7.500 )
-15.000 )

MEAN 13.630
S DEV 15.860
N 56.
```

U_{H_2O}

```
1.950 )
1.800 )
1.650 )*
1.500 )*
1.350 )
1.200 )***
1.050 )*
0.900 )
0.750 )*
0.600 )*******
0.450 )*********11
0.300 )*********12
0.150 )*********
-0.000 )*********
-0.150 )
-0.300 )
-0.450 )

MEAN 0.450
S DEV 0.382
N 56.
```

Zane Hills-Purcell Mountains Area

U_{RAA}

```
60.000 )
56.000 )***
52.000 )
48.000 )
44.000 )*
40.000 )
36.000 )*
32.000 )*
28.000 )***
24.000 )**
20.000 )****
16.000 )****
12.000 )*********
8.000 )*******
4.000 )*********29
0. )*********11
-4.000 )
-8.000 )

MEAN 13.149
S DEV 12.771
N 75.
```

U_{LASL}

```
85.000 )
80.000 )
75.000 )**
70.000 )*
65.000 )*
60.000 )**
55.000 )*
50.000 )**
45.000 )
40.000 )****
35.000 )****
30.000 )***
25.000 )******
20.000 )****
15.000 )*********14
10.000 )**********
5.000 )*********12
0. )*********

MEAN 23.284
S DEV 19.067
N 75.
```

U_{H_2O}

```
4.500 )
4.200 )
3.900 )*
3.600 )
3.300 )
3.000 )*
2.700 )**
2.400 )**
2.100 )*
1.800 )*******
1.500 )******
1.200 )********
0.900 )********
0.600 )*********21
0.300 )*********13
0. )*****
-0.300 )
-0.600 )

MEAN 1.115
S DEV 0.761
N 75.
```

Copper River Basin

U_{RAA}

```
2.550 )
2.400 )***
2.250 )
2.100 )**
1.950 )***
1.800 )**
1.650 )*
1.500 )***
1.350 )****
1.200 )*********13
1.050 )***
0.900 )******
0.750 )*****
0.600 )***
0.450 )***
0.300 )***
0.150 )
0. )*********16

MEAN 0.961
S DEV 0.710
N 70.
```

U_{LASL}

```
3.400 )
3.200 )*
3.000 )*
2.800 )
2.600 )*
2.400 )***
2.200 )****
2.000 )
1.800 )*******
1.600 )*********
1.400 )********
1.200 )*********12
1.000 )***
0.800 )******
0.600 )*****
0.400 )****
0.200 )*****
0. )*

MEAN 1.356
S DEV 0.671
N 70.
```

U_{H_2O}

```
2.250 )
2.100 )
1.950 )*
1.800 )*
1.650 )*
1.500 )****
1.350 )********
1.200 )*****
1.050 )******
0.900 )******
0.750 )**********
0.600 )*********
0.450 )*********12
0.300 )******
0.150 )*
0. )
-0.150 )
-0.300 )

MEAN 0.914
S DEV 0.420
N 70.
```

Chitina Valley Area

U_{RAA}

```
4.200 )
3.900 )
3.600 )
3.300 )**
3.000 )*
2.700 )**
2.400 )*
2.100 )*
1.800 )**
1.500 )**********
1.200 )*******
0.900 )******
0.600 )*********15
0.300 )******
-0.000 )*********18
-0.300 )
-0.600 )
-0.900 )

MEAN 0.945
S DEV 0.865
N 71.
```

U_{LASL}

```
6.800 )
6.400 )
6.000 )*
5.600 )
5.200 )
4.800 )
4.400 )
4.000 )**
3.600 )*
3.200 )****
2.800 )***
2.400 )**********
2.000 )*********12
1.600 )*********12
1.200 )*********15
0.800 )********
0.400 )***
0. )

MEAN 2.006
S DEV 0.951
N 71.
```

U_{H_2O}

```
4.200 )
3.900 )
3.600 )
3.300 )*
3.000 )
2.700 )*
2.400 )
2.100 )*
1.800 )
1.500 )******
1.200 )*****
0.900 )*********12
0.600 )*********14
0.300 )*********20
-0.000 )*********11
-0.300 )
-0.600 )
-0.900 )

MEAN 0.815
S DEV 0.607
N 71.
```

Appendix C

CORRELATION MATRIX

Variable 1 represents uranium, variable 2 represents thorium, and variable 3 represents potassium oxide.

Granite Mountain Area
(Coefficient ≥.215 represents significant correlation.)

	1	2	3
1.	1.00000	0.31092	0.30559
2.	0.31092	1.00000	0.63778
3.	0.30559	0.63778	1.00000

Darby Mountains
(Coefficient ≥.208 represents significant correlation.)

	1	2	3
1.	1.00000	0.54404	0.00215
2.	0.54404	1.00000	0.31250
3.	0.00215	0.31250	1.00000

Selawik Hills Area
(Coefficient ≥.283 represents significant correlation.)

	1	2	3
1.	1.00000	0.44735	0.33592
2.	0.44735	1.00000	0.54408
3.	0.33592	0.54408	1.00000

Zane Hills-Purcell Mountains Area
(Coefficient ≥.267 represents significant correlation.)

	1	2	3
1.	1.00000	0.47455	0.58899
2.	0.47455	1.00000	0.56517
3.	0.58899	0.56517	1.00000

Copper River Basin
(Coefficient ≥.267 represents significant correlation.)

	1	2	3
1.	1.00000	0.21841	0.07743
2.	0.21841	1.00000	0.29321
3.	0.07743	0.29321	1.00000

Chitina Valley Area
(Coefficient ≥.254 represents significant correlation.)

	1	2	3
1.	1.00000	0.17175	0.16597
2.	0.17175	1.00000	0.27791
3.	0.16597	0.27791	1.00000

Eagle-Charley River Area
(Coefficient ≥.561 represents significant correlation.)

	1	2	3
1.	1.00000	-0.31310	-0.21625
2.	-0.31310	1.00000	0.26562
3.	-0.21625	0.26562	1.00000

Healy D-1 Quadrangle and Vicinity
(Coefficient ≥.181 represents significant correlation.)

	1	2	3
1.	1.00000	0.25375	-0.03084
2.	0.25375	1.00000	0.34538
3.	-0.03084	0.34538	1.00000

Appendix D

DETERMINATION OF THORIUM, URANIUM, AND POTASSIUM OXIDE IN STREAM SEDIMENTS AND ROCKS

THORIUM

Digestion

Approximately 0.4 g of a -80 fraction is digested in a 1:1 mixture of hydrofluoric and nitric acids. The residue is then treated with excess boric acid to remove all traces of fluoride, and the remaining residue is taken up into 50 ml of a 1N solution of HNO_3; an equal volume of concentrated HNO_3 is then added to make an approximate 8N-HNO_3 solution.

Ion-Exchange Separation

The 8N-HNO_3 digestate is then passed through a 50-cm x 1.5-cm ion-exchange column filled with Dowex 1X8 Resin in the chloride form, which has been freshly converted to the NO_3^- form by running through it 100 ml of 8N-HNO_3. After all of the digestate has been run through the column, it is washed with another 100 ml 8N-HNO_3. The column is then eluted with 100 ml 6N-HCl into a clean beaker. This liberates all the thorium which has been complexed in the resin. The eluate is then evaporated to dryness on a hot plate.

Colorimetry

1) To the dried residue, add 5 ml 1N-HCl and 5 ml of 2-percent aquous solution of $KMnO_4$, and place on a hot place and evaporate.

2) To this, add 10 ml concentrated HCl and evaporate.

3) To the white dried residue, add another 10 ml concentrated HCl and 5 drops formic acid and evaporate. This destroys all remaining traces of nitrates which would interfer in the final step.

4) The residue is now treated with 5 ml concentrated HCl and transferred quantitatively to a 10-ml vol. flask.

5) Add 1 ml of a 0.2-percent solution of Arsenazo III and bring to 10 ml with H_2O.

6) Determine absorbance at 660 nanometers on a Beckman-25 spectrophotometer.

Thorium forms a purple complex with Arsenazo III. The intensity of the complex obeys Beer's law in the range 0.1 to 1.5 g Th/ml.

URANIUM

Digestion

A 1-g sample is digested in 1:1 HF/HNO_3. Fifteen ml of each are used three times. The digestate is then filtered with a 1-percent HNO_3 solution and brought to 100 ml.

Extraction

Five ml of sample, 5 ml of saturated aluminum nitrate, and 5 ml of ethyl acetate are placed into a 25-ml test tube and shaken for 3 minutes. The organic layer is allowed to separate. Then a 0.1-ml aliquat is taken from the organic layer and placed directly on a pellet made from 9 parts NaF, 45.5 parts potassium carbonate, and 45.5 parts sodium carbonate, and allowed to dry on a Pt dish. It is then placed into the oven for 25 minutes at 650°C.

Fluorescence

The pellets are then removed from the oven and their concentration is read off the Turner-110.

POTASSIUM OXIDE

1) Take 0.2-g sample and 1.0 g lithium metaborate and fuse for 25 min. at 1000°C in graphite crucible.

2) Dissolve pellet in 150 ml of 15-percent HNO_3 using magnetic stirrer; bring solution to 200 ml with distilled water.

3) Determine K on atomic absorption unit as percent K_2O.

APPENDIX E--GENERAL GEOLOGY OF AREAS INVESTIGATED

GRANITE MOUNTAIN—HUNTER CREEK PLUTON AREA

Location

Granite Mountain is the southernmost intrusive in a belt of plutons in the northwestern part of the Candle quadrangle, in the extreme eastern part of the Seward Peninsula (fig. 2). The approximate center of the pluton and summit of Granite Mountain is occupied by a White-Alice communications station operated by ITT Arctic Services, which is scheduled for deactivation in 1976. An Air Force runway, adequate for most any type of aircraft, is located on the west side of the mountain. Permission is required for its use. The nearest towns are Candle, 45 miles northwest; Buckland, 40 miles north; and Koyuk, 40 miles south. The highest point is 2,844 feet in altitude. The terrain is rather subdued and mostly tundra covered; there are no trees. The Granite Mountain pluton is nearly circular and occupies about 30 square miles.

General Setting

The geology of Granite Mountain has been mapped and discussed by Miller and Elliott (1969), Miller (1970, 1972), Patton (1967), and Gault and others (1953).

The Granite Mountain pluton is a mid-Cretaceous intrusive complex that has intruded Jurassic(?) and early Cretaceous andesitic volcanic rocks located on the western edge of a late Mesozoic mobile Yukon-Koyukuk province (Patton, 1973). Tertiary and Quaternary flows are extensive in the area surrounding Granite Mountain.

Two small plutons satellitic to Granite Mountain are the fishhook-shaped Quartz Creek pluton to the northwest and an unnamed stock near the northeastern part of the Granite Mountain pluton that occupies the headwaters of Peace River. The Quartz Creek pluton is of fine-grained biotite-hornblende quartz monzonite, and the small unnamed stock is composed of several varieties of syenite. All three plutons have associated mineral occurrences. The Granite Mountain pluton and the unnamed stock are anomalously radioactive and are considered to be potential sources of uranium.

Igneous Rock Types

The alkaline intrusive complexes of west-central Alaska are typically highly potassic and subsilicic. The surrounding country rock is Lower Cretaceous andesitic volcanic rock, and a contact aureole facies of hornfels extends outward for about 300 m.

The Granite Mountain pluton is a zoned complex that has been divided into four units (Miller, 1972, p. 2118-2121). It consists of a core of equigranular quartz monzonites; an inner crescentric zone of massive to porphyritic monzonite and quartz monzonite; an outer crescentric zone of foyaite; and a unit of garnet-bearing nepheline syenite. Also, pseudoleucite porphyry as xenolithic-like blocks in the foyaite and as dikes in the andesite country rock suggests early separation of leucite during fractional crystallization of alkaline magma.

The Quartz Creek pluton is predominantly fine-grained biotite-hornblende quartz monzonite that crops out along Quartz Creek and near the headwaters of the Kiwalik River. The northeastern part of the pluton is extensively altered.

The stock on the north flank of granite Mountain at the head of Peace River is composed of several varieties of syenite. The most abundant are a pink, medium-grained hornblende-biotite variety and a pink, fine-to medium-grained, porphyritic syenite composed of over 90 percent perthitic feldspar (Miller and Elliott, 1969, p. 12). Garnet-bearing nepheline syenite is also present. Anomalous quantities of metals and high radioactivity in the area make the stock particularly interesting from the standpoint of uranium exploration.

Economic Geology

The mineralization at the Granite Mountain pluton offers strong encouragement to exploration for vein-type uranium deposits. Fourteen lode deposits containing one or more minerals of lead, silver, gold, zinc, copper, or tungsten, and about 20 gold deposits have been listed for the area (Cobb, 1972). Placer gold deposits have been worked on a small scale at several streams on the eastern and southern part of the mountain since the early 1900's. A little platinum was reported as a by-product. Descriptions of new metaliferous deposits and stream-sediment analyses have been published by the U.S. Geological Survey (Miller and Elliott, 1969; and Elliott and Miller, 1969). Three areas were found to be of special interest and recommended for additional exploration by the authors: lead, zinc, and silver near Quartz Creek; molybdenum, bismuth, silver, copper, lead, and uranium deposits in the upper Peace River drainage; and a lead, zinc, and gold deposit at Bear Creek.

The Quartz Creek area contains numerous occurrences of argentiferous galena, sphalerite, pyrite, and arsenopyrite in an altered zone 18 miles long and 2 to 5 miles wide. The association of the sulphides with tourmaline is a striking feature. Stream-sediment samples yielded anomalous amounts of copper, antimony, and tin in addition to the metals already mentioned.

Anomalous concentrations of molybdenum, bismuth, gold, copper, and lead were found over a 2-square-mile area in the soils, stream sediments, and outcrops in the Peace River drainage basin. The metals are disseminated in a syenitic stock satellitic to the main Granite Mountain pluton. Pan concentrates collected during uranium investigations by the USGS (Gault and others, 1953) showed anomalously high concentrations of uranothorianite and a variety of other minerals, including galena, chalcopyrite, bornite, tetrahedrite, sphalerite, pyrite, and pyrrhotite. Gummite was also observed in some mineral grains. The source of the uranothorianite was not located, but West *in* Gault and others, 1953, p. 29-30) suggested the possibility of a lode at the head of Peace River.

Previous Investigations for Radioactivity

Ground investigations for radioactive materials were conducted in the eastern part of the Seward Peninsula by the USGS in the late 1950's (Gault and others, 1953). Significant amounts of radioactive minerals were found on the southern slope of Granite Mountain in placer concentrates from Sweepstakes and Ruby Creeks. Gault and others (1953, p. 1) described the findings:

> *A significant content of radioactive materials was recognized in a few placer concentrates from Sweepstakes and Ruby Creeks in the northeastern part of the Seward Peninsula, Alaska, when old collections were scanned for radioactivity in the spring of 1945.*
>
> *The later field investigations indicate that syenite is the only bedrock which has noticeable radioactivity, and stream concentrates that were radioactive were obtained only from creeks containing syenite in the gravels or flowing in areas underlain in part at least by the syenite. Crushed syenite samples from 14 localities show a content of radioactive material ranging from 0.001 to 0.013 percent equivalent uranium. The most radioactive unconcentrated material found is a 1-inch pegmatite dike cutting the syenite. The syenite stock is pre-Cretaceous and intrudes andesitic tuffs and flows that form the bedrock over much of the area.*
>
> *Two radioactive minerals have been recognized from the photographic effects obtained on alpha-ray plates, and are tentatively identified as uraninite-thorianite and hydrothorite. Almost all of the radioactive grains are uraninite-thorianite and only a few grains of hydrothorite were identified. Chemical analysis of a concentrate collected in 1917 from Sweepstakes Creek shows approximately equal amounts of uranium and thorium, and together they form more than 80 percent of weight of the sample. Chemical analyses of 5 of the samples collected in 1945 indicate a uranium content of 0.008 to 2.17 percent. In the sample which has 2.17 percent uranium, beta counts show 14.20 percent equivalent uranium and the difference is believed to be thorium.*

The occurrence of uranium and thorium in the headwaters of the Peace River on the southeast side of Granite Mountain has been described by West (1953, p. 28-31). Reconnaissance investigations for uranium during 1947 and 1952 revealed uranothorianite and gummite associated with copper sulfides, iron oxides, molybdenite, gold, silver, bismuth, and thorite in placers in a headwater tributary of the Peace River. Anomalous metal concentrations in stream sediments and outcrops occur over a 2-square-mile area underlain by a small satellitic stock of the Granite Mountain pluton (Miller and Elliott, 1969, p. 12). The syenite locally contains purple fluorite. Concentrates from the placers contained between 0.2 and 0.8 percent eU, or about 10 times the eU of the average uranothorianite-bearing concentrates from other locations in the eastern part of the Seward Peninsula. The investigator of the Peace River locality concluded that the most probable source of the uranothorianite and gummite was a vein located in the rather restricted drainage area above the placer deposits. The evidence for a vein source is the sulfides associated with the uranium minerals disseminated within the granitic rock itself. Although metallic lodes are known to occur in the general area, no uranium minerals were found in place.

Herreid (1965, p. 14) briefly visited the above mineralized area at the head of Peace River and obtained 350 ppm lead from a panned sample, and copper, lead, and molybdenum from stream sediments downstream. Heavy hematite staining of the creek gravels was reported.

After radioactive minerals had been found on the southern side of Granite Mountain, the USGS continued investigations with a field study of the north side, in the headwaters of Quartz Creek (Gault and others, 1953, p. 15-20):

> *The area to the north of Granite Mountain has even more uranothorianite (uraninite-thorianite of Gault, Black, and Lyons, 1946; and Frondel and Fleischer, 1959, p. 7) than the Sweepstakes Creek area and in addition carries uranium-bearing thorite(?).*

The gravels of Quartz Creek had formerly been mined for placer gold. The radiometric readings on the syenite bedrock was two to four times that of any of the surrounding rocks, and only the stream gravels derived from the syenite were radioactive. Tracing the radioactive gravels upstream, uranothorianite and thorite(?) were found in wash on the bank of a gulch in the headwaters of the south fork on Quartz Creek. The heavy fraction of two samples contained 0.06 and 0.088 percent eU (Killeen and White, 1953, p. 17). Concentrates from 21 stream gravel samples averaged 0.026 percent eU. Most of the radioactivity was attributed to uranothorianite and thorite, but radioactive zircon and sphene also contributed. The source of the uranium and thorium was thought to be either undiscovered veins or disseminations in the syenite of Granite Mountain.

DARBY MOUNTAIN AREA

Location

The Darby Mountains are situated in the southeastern part of the Seward Peninsula in the eastern half of the Solomon quadrangle and in the southeastern corner of the Bendeleben quadrangle (figs. 2 & 6). The range extends from Cape Darby on the south end of the peninsula between Golovnin Bay and Norton Bay to about 80 miles northward where it merges with the Bendeleben Mountains. The low mountains in the southwest part of the area was called the Kwiktalik Mountains, but there is no distinct separation from the Darby Mountains.

The maximum altitude of the Darby Mountains is 3,169 feet. While this is a relatively low range composed mostly of rounded, tundra-covered mountains and hills, it has been glaciated and the higher parts display steep-sided U-shaped valleys, cirques, and rock pinnacles.

There are no roads in the region, but short landing strips are present at the small native villages of Elim and Golovin on the coast at Golovnin and Norton Bays, respectively. A longer air strip and buildings at the abandoned FAA station at Moses Point were used as a base for the work during this investigation. Permission for its use is required from the Elim Natives.

The weather in the Darby Mountains is similar to that of much of the Seward Peninsula and is characterized by frequent fog, rain, and windstorms. The average annual rainfall at Nome is 17.88 inches and the average temperature is 26.1°F.

General Geologic Setting

The general geology of the Darby Mountains area has been described by Mendenhall (1901); Smith and Eakin (1911); West (1953); Miller and others (1972); Miller and Bunker (1975) and Herreid (1965). The northern part of the Darbys is also covered by Sainsbury's geologic map of the Bendeleben quadrangle (1974). The most complete coverage is the reconnaissance geologic map by Miller and others, and the following bedrock descriptions are largely derived from the report accompanying that map. The petrology has been discussed in considerable detail by Miller and Bunker (1975).

The core of the Darby Mountains consists predominantly of a Cretaceous pluton that extends 50 miles from near Cape Darby northward to the south side of Death Valley. The southwestern part of the Darby Mountains is composed largely of the Kachauik pluton, which is separated from the Darby pluton by a narrow (1-3 miles) migmatic zone (fig. 6). The plutons are bordered by Precambrian metasediments and Devonian carbonates.

The Darby Mountain pluton is a relatively homogeneous quartz monzonite, but Miller and Bunker found indications of lateral zoning. Modes show a slight and gradual decrease in mafic minerals and plagioclase from south to north and a corresponding increase in K-feldspar and quartz.

Miller and Bunker (1975, p. 1) have pointed out that the Darby plutons contain well above average amounts of U and Th (11.2 ppm and 58.7 ppm, respectively) and the Kachauik pluton ranges from average to above average U and Th (5.7 ppm and 22.5 ppm, respectively).

The most characteristic features of the Darby pluton are its uniform coarse-grained porphyritic texture, homogeneous composition, and relative abundance of magnetite and allanite. Lesser amounts of sphene, apatite, zircon, fluorite and rutile are present as accessory minerals.

The Kachauik pluton occupies about 205 square miles in the western part of the Darby Mountains. It is a composite intrusion. The west half is composed of granodiorite and quartz monzonite and the east half consists of a monzonite-syenite unit which has been subdivided into four subunits by Miller and others (1972).

A small stock on the western flank of the Darby Mountain about 6 miles north of the northern end of the Kachauik pluton is the Dry Canyon pluton. This intrusive body is of interest because it is composed of nepheline syenite and because of its highly anomalous radioactivity.

Investigations by DGGS did not extend northward to the Windy Creek stock or the Bendeleben pluton. Their compositions and U and Th contents reported earlier by Miller and Bunker (1975) indicated that time would be more profitably spent in the Darby Mountains.

The K-Ar dates of the plutons reported by Miller and Bunker (1975, p. 10) indicate a Late Cretaceous age of between 88 and 94 m.y. for the Darby pluton. The age of the Kachauik pluton is less certain, but the two dates reported are 86.1 $\pm$ 3 m.y. and 93.9 $\pm$ 3 m.y.

The investigation by the Alaska State Division of Geological Survey was directed at determining the uranium potential of the plutons in the Darby Mountain area, and little attention was devoted to the surrounding metamorphic or sedimentary rocks. However, investigations of the potential of the basins or lowlands are needed. Little is known about the Cenozoic sediment in the lowlands on either side of the Darby Mountains. Tundra, muskeg, and lakes mask the sediments and no subsurface exploration has been done. Detailed petrographic and radioelement studies of the plutonic rocks are a part of this report prepared by Dr. R.B. Forbes and B. Jones.

A small interior basin west of the northern Darby Mountains is located in the upper Fish River lowlands (McCarthy's Marsh), in the south-central part of the Bendeleben quadrangle and the north-central part of the Solomon quadrangle. Nothing is known about the sediments under the Quaternary deposits, but the confined shape of the basin and the composition of the nearby bedrocks make it interesting to speculate on the possibility of uranium being concentrated in the sediments. The curving Bendeleben Mountains on the north, the Darby Mountains on the east, and unnamed hills to the south and west form a bowl-shaped basin about 20 miles from east to west and 10 to 15 miles from north to south. The basin is drained by the Fish River, which flows southwest through a narrow valley.

West of the Kachauik Mountains the lowlands around Golovnin Lagoon and along the lower Niukluk River may have received sediments from the Darby and Kachauik Mountains. Although their presence is not known, nonmarine Tertiary sediments derived from the favorable source rocks may lie beneath the Quaternary cover and have a potential for uranium.

Economic Geology

The Darby Mountains have not been found to be mineral-rich, but numerous prospects and geochemical anomalies have been reported that suggest a potential for several metals.

The one mine that has produced is the Omilak mine, located in Precambrian marble on the west side of Omilak Mountain near the northern end of the Darby Mountains. It produced a few hundred tons of lead-silver ore prior to 1900 (Herreid, 1965). Additional lead and zinc occur at a prospect on Dry Creek south of the Omilak Mine.

Placer tin has been reported from alluvium on Otter Creek on the east side of the northern end of the Darby Mountains (Herreid, 1965, p. 5). A lode gold prospect was explored in quartz-mica schist a half mile south of the Otter Creek tin placer. Placer gold prospecting has been conducted on several tributaries to the Tubutulik River.

Geochemical stream-sediment sampling (Miller and others, 1971; Miller and Grybeck, 1973) has yielded highly anomalous copper, nickel, cobalt, chromium, manganese, iron, boron, scandium, and vanadium from the eastern side of the Darby Mountains. Gossan zones with high bismuth and molybdenum are present in the northern part of the range.

Previous Investigations for Radioactivity

As early as 1948 a reconnaissance for radioactive deposits revealed high uranium and thorium contents in the Darby and Kachauik plutons (West, 1953). During the course of the investigation 248 panned concentrates were collected from streams, beach gravels and slope wash. These were further concentrated in the laboratory. Anomalous (over 0.02 percent equivalent uranium) values were obtained over widespread areas, but principally in the northeastern part of the Darby pluton and the southwestern side of the Kachauik pluton. The radioactivity was essentially in minerals derived from felsic igneous rocks. The most common radioactive minerals were sphene, allanite, hematite, and zircon. A uranium-bearing niobate mineral was found in slope wash near the shore on Golovnin Bay. Thorianite was identified near the head of Kwiniuk River. Anomalous niobium was noted in the Clear Creek-Vulcan Creek area.

More recent study of the Darby, Kachauik, and Bendeleben plutons by the U.S. Geological Survey (Miller and Bunker, 1975) has provided considerable data on the petrology and uranium and thorium contents. Results of the investigation showed compositional and textural differences indicating different sources for the three plutons and different average amounts of uranium and thorium.

Thirteen samples from the Darby Pluton contained above average amounts of U and Th (11.2 ppm and 58.7 ppm, respectively); the maximum values were 19.89 ppm U and 83.75 ppm Th. The Bendeleben pluton was found to contain normal amounts of U and Th (4.38 ppm and 22.35, respectively).

While the number of samples was too few to define the most anomalous areas for U and Th, the authors concluded that the Darby pluton is similar to the Conway Granite in New Hampshire, which has been considered a potential low-grade U-Th resource and is definitely a U-Th rich province.

HOGATZA PLUTONIC BELT OF WEST-CENTRAL ALASKA

The following discussion of the Hogatza Plutonic Belt is from Eakins (1975, p. 113-142).

Alkaline intrusive rocks occur in a belt extending 225 miles from the Seward Peninsula and Kotzebue Sound eastward to Hughes on the Koyukuk River. Patton (1970, p. 1; 1973, p. A4) applied the name Hogatza Plutonic Belt to this feature. The belt is roughly 20 miles wide and lies principally in the western part of the Candle quadrangle and the southern parts of the Selawik, Shungnak, and Hughes quadrangles (figs. D1, D2, D3). This region is in the northern part of the Yukon-Koyukuk province, named after the principal rivers. The compositions of the plutons and the associated radioactivity anomalies make this one of the most interesting regions in the state for uranium-potential study.

The mountains and hills in the region are generally low and rounded and largely covered by soil and vegetation. Weathering has reduced most outcrops to rubble, and good exposures of the bedrock are scarce. Summits reach a maximum altitude of 3,300 feet in the Selawik Hills and 4,050 in the Zane Hills. Elsewhere the altitudes are less than 3,000 feet. The lowlands north of the plutonic belt are swampy, lake dotted, and masked by alluvium and morainal deposits.

The region lies approximately on the boundary between the zones of continuous and discontinuous permafrost. The average annual temperature

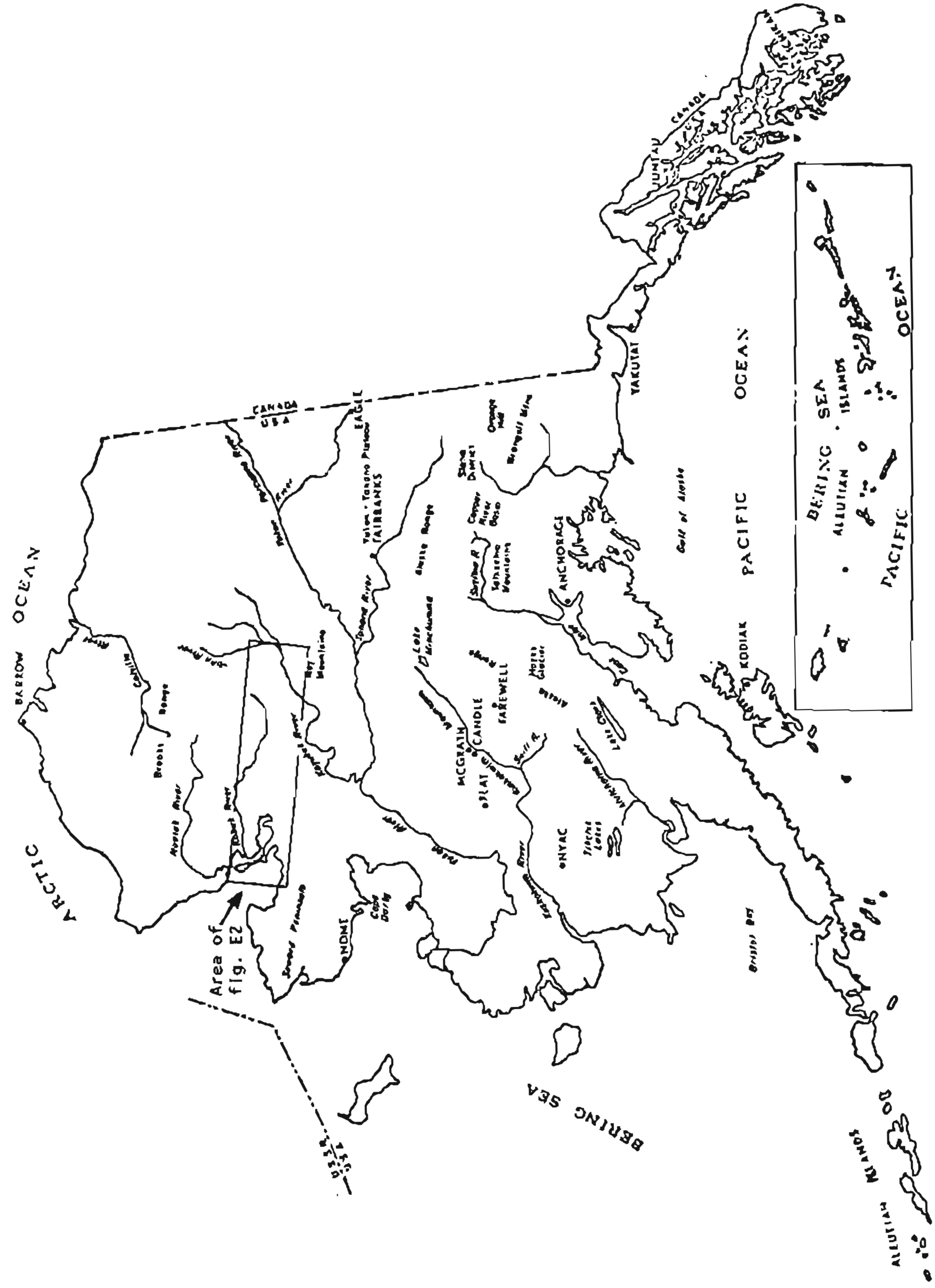

Figure E1. Location of the Hogatza plutonic belt.

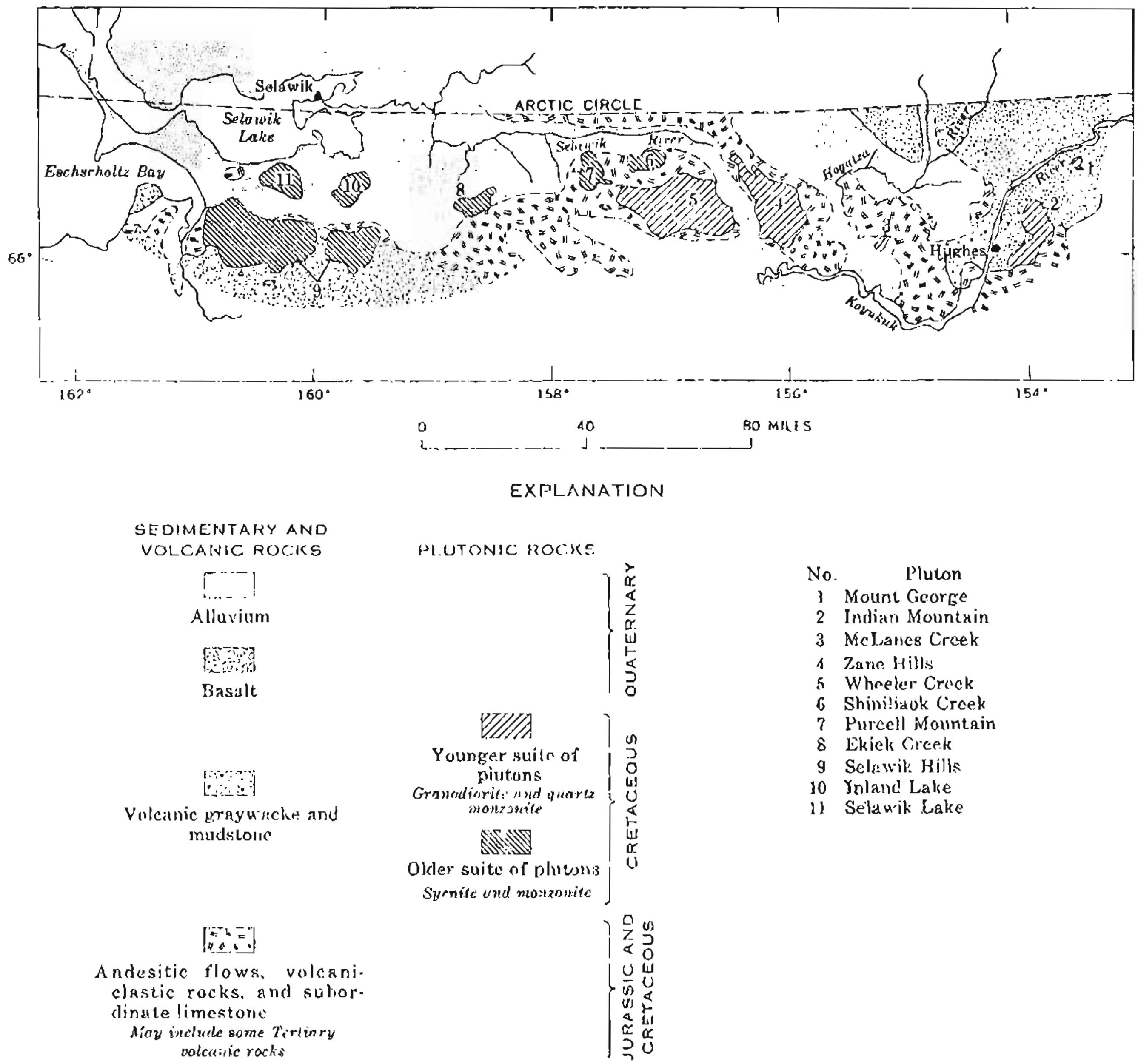

Figure E2. Generalized geologic map of west-central Alaska, showing location of plutons. Source: Miller, Patton, and Lanphere, 1966.

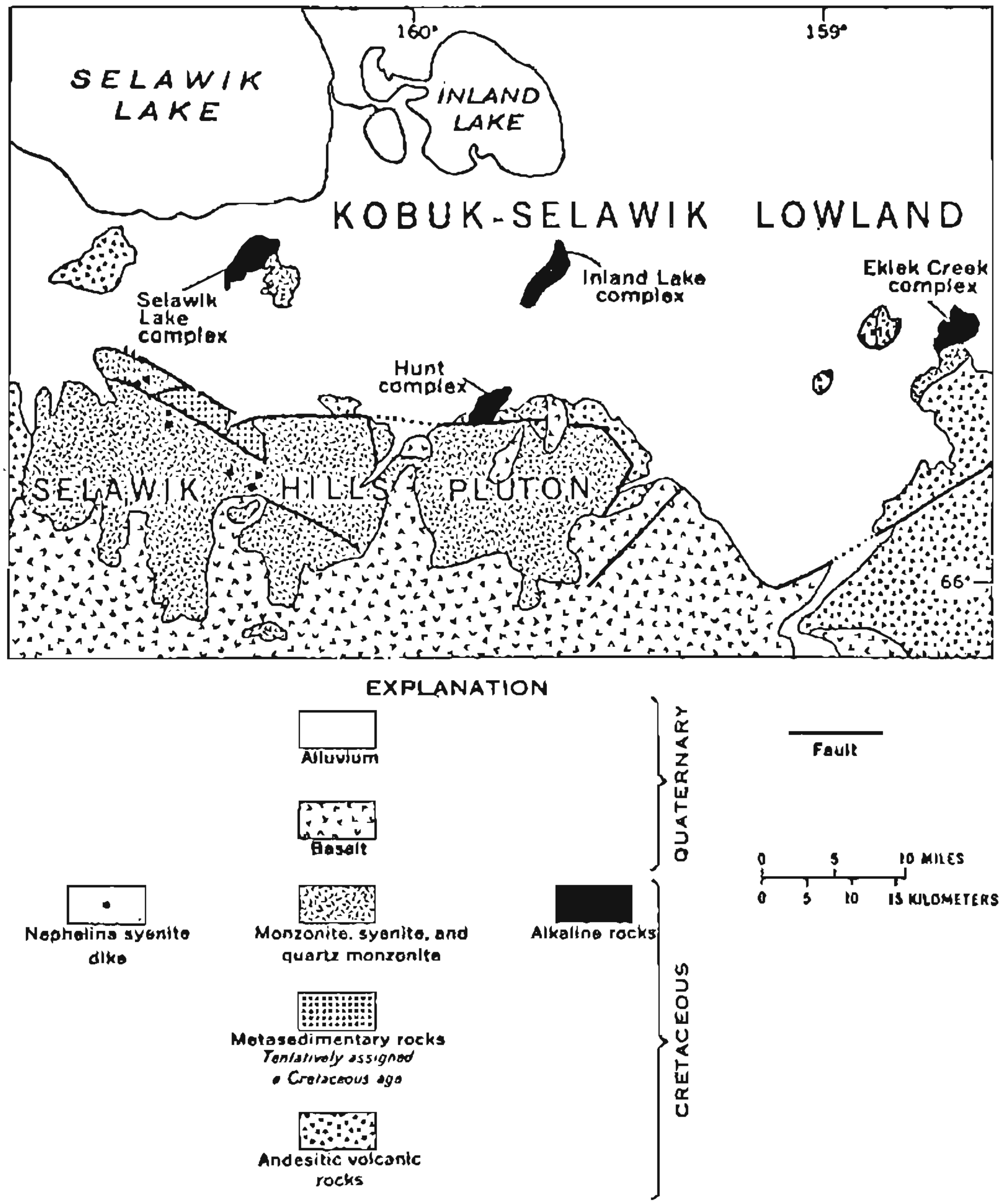

Figure E3. Generalized geologic map of the Kobuk-Selawik lowland and Selawik Hills (after Patton and Miller, 1968). Source: Miller, 1972.

at Kotzebue is 20.7°F. The climate is arid; the average annual precipitation recorded for Kotzebue is 8.18 inches. Small, widely spaced settlements exist at Hughes, Hog River, Gabolio and Selawik.

The region is relatively inaccessible and has been little prospected. However, geologic mapping, geochemical sampling, and radiometric surveys by the U.S. Geological Survey since about 1966 have revealed interesting possibilities for base metals and uranium in the intrusive rocks. Little is known about the sediments underlying the lowlands flanking the uplift or their potential for petroleum and uranium.

Early reconnaissance geology and mapping in the region was done by Smith (1913) and Eakin (1916). Patton (1973) divided the sediments into three general sequences: 1) a Lower Cretaceous volcanic-mudstone sequence; 2) a younger sequence of Lower to Upper Cretaceous age, which was subdivided into four units; and 3) an Upper Cretaceous-lower Tertiary sequence. Because of the poor exposures, the exact stratigraphic relationships of the three sequences are not clear.

The oldest rocks of the basin are Lower Cretaceous in age and consist mostly of volcaniclastics, including lithic tuffs, breccias, conglomerates, and tuffaceous graywacke and mudstone which are believed to underlie the entire province. The thickness near Hughes is 5,000 feet, but the total may be several times this amount. Potassium-argon ages ranges from 134 $\pm$ 5 m.y. to 117 $\pm$ 4.3 m.y.

Lower and Upper Cretaceous rocks are present along the northern border and northeastern part of the province. These were referred to by earlier geologists as the Bergman Group (Schrader, 1904; Martin, 1926; Imlay and Reeside, 1954). Patton, however, abandoned the name and divided the sequence into four units:

(1) Volcanic graywacke and mudstone, to 5,000 feet thick. It contains an abundance of feldspar, some lithic tuff, and carbonized plant debris.
(2) Calcareous graywacke and mudstone---possibly as much as 5,000 feet of shallow-water calcareous graywacke and mudstone. The sediments coarsen westward, where they become conglomeratic and coal-bearing.
(3) Sandstone, siltstone, shale, and coal. Portions of this unit may be of interest to uranium potential studies, but its distribution is restricted to the lower Yukon-Koyukuk province.
(4) Marginal marine trough deposits. Nonmarine quartz conglomerate can be traced by scattered outcrops for about 450 miles along the northern and northeastern margins of the Yukon-Koyukuk province. The thickness was found to be 3,000 feet along the lower Kobuk River. The unit is described as principally a quartz conglomerate, but it contains minor amounts of quartz sandstone, shale, thin bituminous coal beds, and ash-fall tuffs in the northern part of the Selawik quadrangle.

Upper Cretaceous and Lower Tertiary rocks include felsic extrusive and hypabyssal rocks. The flows are as much as 2,000 feet thick. The intrusives consist of swarms of dikes, sills, and plugs that cut the older Cretaceous volcanic and sedimentary rocks.

Poorly consolidated nonmarine coal-bearing beds of Tertiary age have been found at two localities in the northwestern part of the province. Sandstone and gravel are exposed in a 30-foot bluff on the Mangoak River in the Selawik lowland (Patton and Miller, 1968); lignitic coal was found at the base of the bluff. A 2-foot seam of coal has been reported from a silt bluff near Elephant Point on Kotzebue Sound. Both deposits are probably confined to small structural and topographic basins or fault zones.

Petroleum companies have done limited work in the province in an effort to determine the petroleum possibilities. Subsurface data are not available from industry, but it is rumored that seismic surveys indicate several thousand feet of Tertiary and Mesozoic sediments with a good potential for oil are present in Kotzebue Sound. Standard Oil of California is preparing to drill three wells in the area in a joint venture with the Northwest Area Native Association, Inc.

The unexplored Selawik Basin immediately north of the belt of alkalic plutons offers a setting warranting subsurface work to determine if possible uranium host rocks are present. The south flank of the pluton belt is covered by Tertiary and Quaternary volcanics and appears less likely to have suitable sediments.

The Pah River Flats is a 20- by 30-mile topographic depression bounded by the Lockwood Hills on the north, the Kokhila Hills on the east, and by the Babantaltlin Hills on the southeast. The hills are underlain by Cretaceous graywacke and mudstone and Jurassic and Cretaceous volcanics. The west and southwest edges of the depression are bordered by the Zane Hills pluton, which has yielded showings of copper, silver, gold, and molybdenum, and anomalous radioactivity. Border phases of the pluton near Caribou Mountain show radioactivity five to 10 times the background radioactivity of the rest of the pluton, and 20 ppm uranium on analysis (Miller and Ferrians, 1968, p. 9).

The central part of the Pah River Flats is occupied by innumerable small lakes and muskeg. The saucer shape and poor drainage of this basin, which is adjacent to possible source rocks, suggest a favorable site for uranium concentration in sediments. However, available geologic maps of the area do not indicate the presence of a suitable host rock and drilling will be required to determine if any Late Cretaceous or Tertiary sandstones are present beneath the surficial deposits. The village of Hogatza, a few miles south of Pah River Flats, could serve as a base for exploration.

Plutonic Rocks

The 225-mile-long pluton belt extends from the eastern edge of the Seward Peninsula eastward to a point about 15 miles east of Hughes on the Koyukuk River. The belt trends east-west along the Hogatza uplift in the southern parts of the Selawik, Shungnak, and Hughes quadrangles, and trends north-south in the western half of the Candle quadrangle. The main part of the uplift borders the south side of the Selawik basin and the Pah River Flats.

Sixteen separate plutons ranging from 3 to 350 square miles have been described and mapped (Miller and others, 1966, 1970; Patton, 1967; Patton and Miller, 1966, 1968; and Miller, Patton, and Lanphere, 1966). The largest (table D1) is the Selawik Hills pluton, which is 40 miles long and averages roughly 10 miles in width. The aggregate exposed area of the plutons is about 1,200 square miles. Portions are overlain by volcanic flows and welded tuffs of Late Cretaceous, Tertiary, or Quaternary ages so that the actual size of the pluton is greater than the outcroppings.

The alkaline nature of the plutonic rocks is discussed by Miller (1972, p. 2122):

> *The field and analytical data show that the alkaline rocks of western Alaska are epizonal plutonic rocks that are highly undersaturated in silica and rich in alkalis. Total alkali content ranges from a low of 5.5 percent in biotite pyroxenite to 17.9 percent in kalsilite-bearing juvite. These are not peralkaline rocks--with one exception, the molar ratio of total alkalis to aluminum is less than one.*
>
> *Many chemical characteristics of the alkaline rocks of western Alaska and Cape Dezhnev, while illustrating the alkaline nature of the rocks, are similar to those found in many alkaline-rock provinces. The western Alaska alkaline suite is unusual, however, in its high K_2O content and high K_2O/Na_2O ratio. K_2O is over 6 percent by weight in 14 out of 22 analyzed samples and is as high as 16.6 percent.*

Table D1. Sizes of the plutons in the Hogatza pluton belt, west-central Alaska

Name	Area (mi.^{2})
Late Cretaceous Suite	
Zane Hills pluton	180
Wheeler Creek pluton	271
Indian Mountain pluton	85
Mt. George pluton	6
McLanes Creek pluton	8
Total	550
Mid-Cretaceous Suite	
Shiniliaok Creek pluton	30
Purcell Mountain pluton	40
Hawk River stock	5
Ekiek Creek Complex	5
Selawik Hills pluton	354
Hunt Complex	5
Inland Lake Complex	12
Selawik Lake Complex	7
Hunter Creek pluton	165
Granite Mountain pluton	27
Quartz Creek pluton	3
Total	653
Totals for both suites	1,203

The alkaline character, wide distribution, and reports of anomalous radioactivity of the plutons in the Hogatza pluton belt suggest a highly favorable region for uranium investigations, especially in light of the recent development of large uranium reserves in alaskite at the Rossing deposit in southwestern Africa. While the entire belt warrants careful study, the alaskite occurrences may be of particular interest, and a description of the Wheeler Creek pluton alaskite is quoted from Miller (1970, pp. 101 and 103):

> *Alaskite of the Wheeler Creek pluton*--*Coarse-grained alaskite underlies the west end of the Wheeler Creek pluton and intrudes rocks ranging from Lower Cretaceous andesitic volcanics to the Upper Cretaceous dacitic hypabyssal rocks. Alaskite outcrops are characterized by rounded pink-colored hills with little vegetation and a mantle of grus. The alaskite itself is characterized megascopically by large (up to 1 cm) black smoky quartz anhedra in a setting of pink feldspar anhedra. The rock is characteristically coarse-grained with an allotriomorphic granular texture. The abundance of the smoky quartz distinguishes this unit from the minor alaskite and aplite dikes that locally cut the Zane Hills pluton. The rock is generally a true alaskite, with less than 1 percent mafic minerals, although locally the mafic content reaches as much as 8 percent near the contact and in the alaskite dikes cutting the quartz monzonite-granodiorite to the east.*

Alaskite is present in other plutons in the Hogatza belt either as a major rock type or in dikes. The southern and western parts of the Selawik Hills pluton has been mapped as predominantly quartz monzonite and alaskite (Patton and Miller, 1968). The rest is largely syenite and monzonite. The composition, large size, and radioactivity anomalies of the Selawik Hills pluton make this an attractive area to explore for vein or Rossing-type uranium deposits. The present of purple fluorite associated with pulaskite and perthosite in the alkaline complexes in the Selawik lowlands (Miller, 1970, p. 46) may also be an indication of anomalous radioactivity. The possibility that this large pluton and others in the pluton belt have contributed significant amounts of uranium to concealed sediments in the lowlands warrants careful investigation.

Structure

The northern Yukon-Koyukuk province is in a highly mobile region that was subjected to repeated magmatism during Cretaceous and early Tertiary times. The Hogatza uplift extends from the Seward Peninsula and follows the east-west grain of the region. The Kobuk fault (or trench) trends along the northern border of the province. Small faults are visible in most bedrock exposures. While the sedimentary rocks are moderately to strongly deformed they have not been regionally metamorphosed.

The Kobuk-Selawik Lowlands is a major feature of the region, but aeromagnetic profiles suggest that igneous rocks are at shallow depth and it seems unlikely that Cretaceous or Tertiary sedimentary rocks are very thick beneath the Quaternary surficial deposits. Compilation of gravity surveys in northwestern Alaska by D.F. Barnes of the USGS shows a belt of gravity highs that extends through the Selawik Basin and militates "against the presence of the sedimentary basin postulated in preliminary petroleum investigations" (U.S. Geol. Survey, 1967, p. A91). Farther west, however, Cretaceous and younger sediments as much as 10,000 feet thick may underlie Kotzebue Sound (Patton, 1970, p. 1).

Economic Geology

Because certain mineral assemblages may be indicative of favorable environments for uranium, brief summaries of known mineralization are described below by areas. The areas will be mentioned in sequence, beginning at the western end of the belt.

Selawik Hills Pluton

The Selawik Hills pluton extends 45 miles east-west and underlies most of the Selawik Hills south of the Selawik Lowland. It consists principally of monzonite and syenite and is exposed over an area of about 350 square miles. The only information on the economic geology is that provided by stream-sediment sampling (Elliott and Miller, 1969, p. 6):

> *Many of the samples (1-38) from several small streams on the north flank of the Selawik Hills have slightly anomalous concentrations of lead (18 samples with 70 ppm and 6 samples with 100 ppm); and one sample, locality 32, contained 300 ppm lead, 200 ppm zinc, and 3 ppm silver. At bedrock locality X, near sediment locality 32, minor amounts of disseminated galena, sphalerite, and pyrite were noted in quartz-calcite veins and in pink syenite. Composite grab samples of the sulfide-bearing rock contained up to 2 percent lead and up to 1 percent zinc, but the extent of the mineralized area could not be determined due to poor exposure.*
>
> *Beryllium was detected in concentrations of 10 and 15 ppm in four sediment samples (44, 45, 48, 51) from small streams on either side of the ridge south of Clem Mountain. One sediment sample (59) from Hunter Creek, just above the Left Fork, contained 50 ppm tungsten and 30 ppm molybdenum.*

Abnormal radioactivity of phonolite, fluorite-bearing nepheline syenite, syenite, and trachyte was reported in the Selawik Hills pluton (Miller, 1968, table 4). The high radioactivity of the rocks is probably due in part at least to the high K_2O content, which ranges from 4.8 to 8.4 percent and averages 6.2 percent (Miller, 1970, p. 28).

Kobuk-Selawik Lowlands Pluton

Two poorly exposed alkaline complexes crop out as low hills between the Selawik Hills and Selawik Lake (fig. D3). These are designated as the Selawik Lake and Inland Lake complexes (Miller and others, 1966, p. D159), and are 7 and 12 square miles in area, respectively. The complexes consist of a variety of unusual alkaline rock types. Chemical analyses of the rocks show that lead, strontium, lanthanum, and arsenic are relatively high (Miller, 1970, p. 57). Unusual amounts of fluorine and zirconium are also present: up to 0.57 percent F and 0.20 percent ZrO_6. The only information on the economic geology is derived from two stream-sediment samples from the west side of the Selawik Lake pluton. One sample produced slightly anomalous cobalt (50 ppm) and copper (70 ppm) (Elliott and Miller, 1969, p. 10). Anomalous radioactivity of the plutons was reported from an aerial radiometric survey (Miller and Anderson, 1969).

Ekiek Creek Complex

The Ekiek Creek pluton is a small intrusive, about 5 square miles in area, located about halfway between the Selawik Hills and the Purcell Mountains (fig. D3). It contains a wide variety of alkaline rocks. Two stream-sediment samples from the east side of the pluton did not show any anomalous metal values, but the aerial radiometric survey showed the northern end of the pluton to be anomalous (600 counts per second).

Shiniliaok Creek Pluton

The Shiniliaok Creek pluton occupies about 30 square miles in the north-central part of the Purcell Mountains (fig. D2). It is composed chiefly of medium-grained monzonite and syenodiorite. Tourmaline occurs as a widespread accessory and as massive veins in fault zones (Miller, 1970, p. 39). Little is available concerning the economic geology. A few widely spaced stream-sediment samples did not yield significant anomalies (Miller, 1969).

Zane Hills Pluton

The Zane Hills pluton is 180 square miles in area and forms a large part of the Zane Hills. The settlement of Hogatza (Hog River) is located on the east flank of the Zane Hills. The highest point in the area is Cone Mountain, 4,053 feet high. Granodiorite constitutes about 9 percent of the pluton;monzonite and quartz monzonite compose most of the rest. Alaskite and aplite dikes are common. Placer gold mining began at Bear Creek, on the east side of the pluton, in the early 1900's. A gold dredge was installed in 1957 and operated until 1975; it accounted for a substantial part of the state's gold production during that period. Unpublished reports indicate that cassiterite and platinum were also found in the Bear Creek placers. Bedrock and stream-sediment sampling (Miller and Ferrians, 1968, p. 6-10; Miller, 1969) revealed mineralization in the Zane Hills pluton at several locations. Massive pyrite is associated with silver and gold near the north end of the pluton. Zinc and molybdenum anomalies were also found nearby. Uphill from the Hogatza placer mine on Bear Creek, sediment samples were found to contain anomalous amounts of silver, bismuth, copper, and molybdenum. Two strongly anomalous areas of radioactivity were found in quartz monzonite: on the east side of Caribou Mountain and at the southern end of the pluton. The radiometric anomalies of these border phases were five to 10 times as high as readings over most of the pluton.

Purcell Mountain Pluton

The Purcell Mountain pluton is chiefly quartz monzonite and crops out over a 40-square-mile area in the Purcell Mountains. The only known mineral deposit is a gold placer mine on Shovel Creek on the northwest slope of

Purcell Mountain. The mine was worked for about 10 years during the 1950's and 1960's, but the production is unknown. The gold may have been derived from quartz-tourmaline-sulfide veins near a contact between the quartz monzonite pluton and andesitic volcanics (Cobb, 1972, p. 35).

Hawk River Pluton

The Hawk River pluton, located 6 miles southeast of Purcell Mountain peak and about 2 miles southwest of the Wheeler Creek pluton, occupies 5 square miles. The small Hawk River stock consists of olivine-bearing monzonite cut by an east-west-trending fault (Miller, 1970, p. 38). A quartz-rich zone 6-1/2 miles long by 1-1/2 miles wide trends northeast between the Hawk River, Purcell Mountain, and Wheeler Creek plutons. Grab samples from this zone contained anomalous values of copper, arsenic, lead, and zinc. Stream sediments indicated anomalous lead, copper, and silver (Miller and Ferrians, 1968, p. 10-11).

Wheeler Creek Pluton

The Wheeler Creek pluton underlies about 271 square miles of the Purcell Mountains. It is separated from the Zane Hills on the east by a 6-mile-wide valley. Most of the pluton is composed of porphyritic quartz monzonite and granodiorite. The west end of the pluton consists of coarse-grained alaskite which is characterized by smoky quartz. The alaskite body is about 36 square miles in outcrop area. Stream-sediment sample analyses did not reveal any mineralized areas (Miller, 1969), and no ore deposits are known.

Previous Radioactivity Investigations

Anomalous radioactivity has been reported from the plutons in west-central Alaska as a result of aerial and ground radiometric surveys, chemical analyses of the intrusive rocks, and testing of panned concentrates from stream gravels. High background counts can be expected over much of the pluton belt because of the unusually high potassium content of the rocks; however, uranium and thorium minerals have definitely been identified. Favorable mineral assembleges also are suggestive of possible vein-type uranium deposits.

An airborne radioactivity survey in conjunction with an aerial magnetometer survey covered 1,320 square miles of the southern Kobuk-Selawik lowland (Miller and Anderson, 1969). The background over the lowlands and volcanic rocks was generally less than 100 cps (counts per second). The highest count (700 cps) was obtained over granitic rocks at the northern tip of the Selawik Hills pluton. Counts of 500 cps were obtained over both the nepheline syenite of the Selawik Lake, Inland Lake, and Ekiek Creek plutons---a figure five to 10 times higher than that of the surrounding terrain.

Another aerial radioactivity survey was a single flight line made from near Kiwalik south of Kotzebue Sound eastward 80 miles, which covered the southern edge of the above-mentioned survey and traversed the northern part of the Selawik Hills. The survey was sponsored by the USGS. The maximum count reported was 1,600 cps, registered over the northern tip of the Selawik Hills pluton. Other anomalies of 800 to 1,000 cpm were obtained along with flight line. The background was between 300 and 400 cpm.

Two areas of the Zane Hills pluton near Caribou Mountain have been found to have strong radioactivity anomalies. These areas have been described and mapped by Miller and Ferrians (1968, p. 9-10):

> *Border phases of the Zane Hills pluton in two areas along the southeastern margin of the pluton show anomalous radioactivity-five to ten times the background radioactivity of the rest of the pluton. These border phases are composed of medium- to coarse-grained, trachytoid to gneissic, hornblende-biotite quartz monzonite and monzonite readily distinguishable in the field from the typical massive, granitic-textured granodiorite of the rest of the pluton.*
>
> *An analysis of porphyritic quartz monzonite from this border phase shows 20 ppm of uranium. This is five to six times more than the published averages for rocks of this composition (Smith, 1963, p. 402). Examination of thin sections of this rock shows that biotite and hornblende contain numerous inclusions surrounded by pleochroic halos indicative of radioactivity. Some of these halos are obviously around zircon crystals, but other much more intense halos are around grains of a colorless to faintly yellow, isotropic mineral of high relief. A thin section of this porphyritic quartz monzonite was exposed to a thermal neutron beam in a reactor in order to cause the fission of* U^{235}. *The fission events were recorded in a piece of lexan which covered the section. Later, etching of the lexan showed the anomalously occurring uranium in the sample to be associated with the colorless isotropic mineral.*
>
> *Although the uranim-bearing mineral is only a minor constituent in the samples studied, it may be more abundant elsehwere in the radioactive border phase-possibly in amounts large enough to be important economically, or other uranium minerals may be present. A panned concentrate collected in 1964 from Caribou Creek on the southeastern side of the Zane Hills contained 200 ppm of thorium, which was probably derived from this more radioactive border phase of the pluton.*

COPPER RIVER BASIN-CHITINA VALLEY

Location

The Copper River basin is a topographic and structural basin in south-central Alaska. It is bounded on the north by hills along the southern flank of the Alaska Range, the Wrangell Mountains on the east, the Chugach Mountains on the south, and the Talkeetna Mountains on the west (fig. 16). Fringe areas considered include the upper end of Matanuska Valley, the Gulkana upland along the southern flank of the Alaska Range, and the Chitina River Valley, located between the Wrangell and Chugach Mountains. The Copper River basin is roughly about 80 miles across from east to west and is mostly within the Valdez and Gulkana quadrangles of the U.S. Geological Survey topographic map series. The eastern and southern parts of the Copper River area are accessible by the Richardson, Glenn, and Edgerton Highways. The Denali Highway crosses the northern end. Small landing fields are located at a number of the settlements along the highways.

The early history and development of the region are closely tied to the famous Kennecott Copper Corporation mines located in the Wrangell Mountains near McCarthy, on the north side of the Chitina Valley. Recent interest in the region has been directed towards determining the petroleum possibilities of the Mesozoic section of the Copper River basin.

The altitude of the lowlands in the basin is between 2,000 and 3,000 feet above sea level. It is occupied by numerous lakes and is drained principally by the Copper River, which has its outlet in the Gulf of Alaska; drainage is poorly developed over a large area, and ground travel is difficult. The mountains bordering the basin are high and rugged and have been the source of many glaciers which have supplied drift coverage in the lowlands and created the innumerable small glacial lakes. Glaciers are still abundant in the Alaska, Wrangell, and Chugach ranges. Mt. Blackburn and Mt. Sanford in the Wrangells are both over 16,000 feet high. The 14,000-foot-high Mt. Wrangell volcano emits smoke and steam.

The climate is much more arid than in the coastal regions: at Copper River townsite the average annual precipitation is barely 9 inches. The region is in the belt of discontinuous permafrost.

The geology of portions of the province has been described and mapped by Chapin (1918), Mertie (1927), Moffit (1938), Capps (1940), and Andreason and others (1964).

Sedimentary Rocks

The Copper River Basin is Cenozoic but the southern part includes a thick sequence of Mesozoic sediments of the Matanuska geosyncline (Payne, 1955). The deepest test well in the basin was drilled to 8,837 feet and was still in Jurassic sediments. Most of the units have been dated approximately by marine fossils but complicated structure, rapid changes in lithology and thicknesses, and extensive erosion make some correlations doubtful and confusing. Although most of the pre-Tertiary units are clearly marine or marginal marine, there are several thick sandstone and conglomerate sections of interest exposed in the Chitina valley area and to a lesser extent in the southwestern part of the basin in and north of the upper Matanuska Valley. The stratigraphic units are remnants of the once-extensive deposits which in part extend beneath the Quaternary cover in the Copper River basin. Some of the Mesozoic sandstones are arkosic and tuffaceous, and contain a small amount of carbonaceous material, discussed in the following summary of the stratigraphy. The Tertiary beds are of continental origin and are probably the most interesting rocks in the region with respect to uranium potential, although outcrops are very limited. Generalized stratigraphic sections for the east and west sides of the basin are shown in figures D4 and D5.

Descriptions of much of the stratigraphy is necessarily based upon work in the upper part of the Chitina valley, as much as 100 miles from the Copper River basin lowlands, where outcrops are available for examination and where mining has been important. Grantz (1965) produced a detailed map and cross sections of the western flank of the basin that show subdivisions of the Mesozoic units and illustrate the complex structure along the eastern side of the Talkeetna Mountains. The intrusive rocks and metamorphic complexes in the northern and northwestern parts of the Copper River basin have most recently been mapped by T.E. Smith (1973, p. 3-6). Limestone is dolomitic in part and the host for the massive copper deposits near Kennicott, where it is up to 3,000 feet

Period	Epoch	Formation	Thickness
Quat.	Miocene-Pliocene	Wrangell Lava	0-5,000'
Tert.	Miocene	Frederika Fm.	2,000'
Cretaceous	Upper Cretaceous	MacCall Fm.	2,500'
		Chititu Fm.	5,500'
		Schultz Fm.	225'
		Moonshine Creek Fm.	3,500'
	Lower Cretaceous	Kennecott Fm.	1,500'
Jurassic	Upper Jurassic	Root Glacier Fm.	0-4,000'
	Middle and Upper Jurassic	Nazina Mountain Fm.	0-1,400'
		Kotsina Conglomerate	2,000-2,500'
Triassic	Lower Jurassic	Lube Creek	300'
	Upr. Triass. & Lwr. Jurassic	McCarthy Shale	1,500-3,000'
		Nizina Limestone	1,100'
	Upr. Triassic	Chitistone Limestone	1,900'
	Mid. &/or Upr. Triassic	Nikolai Greenstone	5,000'
Permian	Lower Permian	Hansen Creek Fm.	900'
		Station Creek Fm.	6,500'

Base not exposed

Figure E4. Generalized stratigraphic section--east side, Copper River Basin (Chitina Valley area), Alaska. (Source: Alaska Geological Society Stratigraphic Committee, 1969-70.)

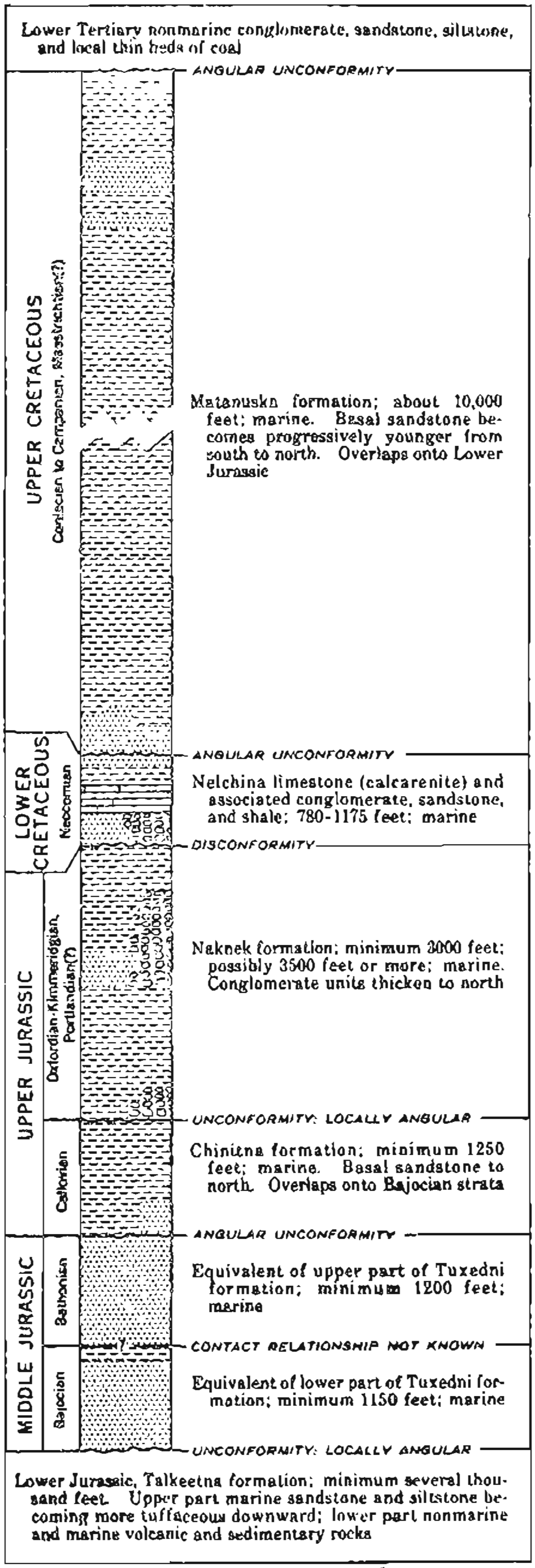

Figure E5. Generalized stratigraphic section--west side, Copper River basin (Nelchina area), Alaska. Source: Grantz, 1965, U.S. Geol. Survey Bull. 1094, pl. 4.

thick. A 300-foot-thick formation consisting of impure spiculite and coquina overlies the McCarthy Shale in the McCarthy C-5 quadrangle (MacKevett, 1971, p. 15).

Several thousand feet of altered marine pyroclastics rocks of the Lower Jurassic Talkeetna Formation are present as lavas and tuffaceous sediments in the Talkeetna and Chugach Mountains (Grantz, 1965). Marine sedimentary rocks of Early Jurassic age occur in the upper Chitina valley. Thus the southeastern part of the Copper River basin may contain a Lower Jurassic rock facies transitional between the lava-bearing Talkeetna Formation and the sedimentary rocks of the upper Chitina valley (Andreason and others, 1964, p. 138). Moffit (1938, p. 62) states that Middle and Upper Jurassic rocks are widely distributed in the Chitina valley, but occupy only a small total area. They include several thousand feet of tuff, shale, limestone, sandstone, and conglomerate. While the Jurassic sediments are considered to be of marine origin, one unit of tuffaceous conglomerate may be of interest with respect to possible uranium content. This unit, the Kotsina Conglomerate (Moffit, 1938, p. 62-64) unconformably overlies the Nikolai Greenstone and Triassic shale and limestone on the east side of the Copper River and north of the Chitina River between the Kotsina and Cheshnina valleys. The unit is at least 1,500 feet thick, and consists of pebbles of argillite, diorite, greenstone, and quartz in a tuffaceous matrix. Moffit (1938, pl. 2) indicates the Kotsina Conglomerate underlies about 50 square miles and forms steep cliffs in the mountains.

The Middle Jurassic is represented in the southwestern part of the Copper River basin area by the Tuxedni Formation which overlies the Talkeetna Formation (Chapin, 1918, pl. 11; Grantz, 1960, 1965). It is considered to be entirely marine and to consist of buff sandstone, soft sandy shale, and a smaller amount of dark-brown arkosic sandstone containing "black minerals" (Chapin, 1918, p. 32). It may reach 1,000 feet in thickness in the Matanuska Valley.

Cretaceous marine sediments occupy a large part of the upper Chitina valley. The beds include black shale, sandstone, conglomerate, grit, and sandy shale, but no limestone. Large masses of granite and quartz diorite cut the beds. A distinct unconformity separates the Cretaceous from the older sediments and it is notably less folded and faulted. The Cretaceous sediments in the Chitina Valley and adjacent area have been described by Moffit (1938, p. 78) as forming a sequence with a total thickness of at least 6,000 feet, but nowhere is there a complete Cretaceous section.

More recently, Jones and MacKevett (1969) divided the Cretaceous rocks in the McCarthy quadrangle, north of the Chitina Valley, into five formations: the Kennicott, Moonshine, Schulze, Chititu, and McColl Ridge.

Following a general uplift at the close of the Cretaceous or at the beginning of Tertiary time, a wide, low depression was developed in the Copper River region. Tertiary continental sediments, which included sandstone, conglomerate, siltstone, claystone, and locally, beds of coal, were deposited over this area. The rocks are considered to be Eocene on the basis of poorly preserved plant remains (Moffit, 1938, p. 97). Lava flows and pyroclastic deposits of Tertiary to Recent age are extensive around the volcanic centers in the Wrangell Mountains.

Because glacial and alluvial deposits of Quaternary age now mask the older sediments in the basin by thicknesses of 600 feet or more in places and possibly as much as 1,000 feet (Andreason and others, 1964, p. 138), the thickness and distribution of the Tertiary are not well known. A limited amount of information is provided by seven electric logs for petroleum test wells, but detailed descriptions of the lithologies do not seem to be available. The combined thickness of the Quaternary and Tertiary sediments ranges from 0 to 2,630 feet, as shown by the top of the Cretaceous. The thickest section was penetrated by Atlantic's Rainbow 1, 30 miles northwest of Gulkana Junction.

Tertiary sediments can be seen in outcrop in two general areas in the Copper River basin region: in the northeastern part between the Chistochina River and the Richardson Highway, and in the southwestern part north of the Glenn Highway and on the western side of the Talkeetna Mountains (Grantz, 1960a, 1960b, 1965).

Eocene sediments in the northeast part consist of more than 2,000 feet of section, which has been named the Gakona Formation (Mendenhall, 1905, p. 52-53). The largest outcrop lies adjacent to the eastern side of Gakona Glacier and covers 20 to 25 square miles. A basal conglomerate here is not less than 500 feet thick and is made up of coarse, indurated igneous rocks that dip eastward and appear to pass beneath soft, fissile or massive, gray or buff-colored shales which, with interbedded gravel, sand, and lignite beds, extend to the head of the west fork of the Chistochina River.

Igneous Rocks

A wide variety of intrusive and extrusive rocks are present in the hills and mountains surrounding the Copper River basin. These were emplaced during numerous periods of activity. Flow rocks are exposed over large areas, but intrusive rocks, while widely distributed, crop out in relatively few places.

Volcanic flows are present as a major part of the Carboniferous and older sequences extending across the northern margin of the Copper River basin in the foothills of the Alaska Range. Lavas are also constituents of the Carboniferous sequences in the Chitina valley (Andreason and others, 1964, pl. 24; and Chapin, 1918, pl. 11). A 4,000-foot sequence of basaltic lavas is present in the Wrangell Mountains as a part of the Permian Station Creek Formation (Smith and MacKevett, 1970, p. Q6).

The Talkeetna Mountains include a large core of quartz diorite and granite to the west of the Copper River basin. The intrusives range in age from Carboniferous to Cretaceous. Tuffs and flows, in general andesitic but ranging in composition from rhyolite to basalt, are also present in the Talkeetna and Chugach Mountains as the lower part of the Talkeetna Formation. In this general area numerous small light-colored granitic and porphyritic intrusives are scattered between the Copper River and Klutina River. A belt of felsic rocks trending northeast between the headwaters of the Kashwitna River and the west fork of Kings River has been mapped by members of the Alaska State Survey (ADGGS, 1974, p. 14-15). This belt has been mapped for 8 miles, but its total extent is not known. Rocks range in composition from quartz monzonite to granite, and locally may be classified as alaskite. These rocks may have a potential for vein-type uranium deposits.

Younger intrusives, Upper Jurassic to post-Eocene, occur in the Chitina valley and adjacent areas. These include granodiorite, quartz latite, quartz diorite, granite, and syenite (Moffit, 1938, p. 106-107).

The Triassic Nikolai Greenstone overlies the Lower Permian lavas and sediments and occupies numerous areas in the Wrangell Mountains and along on the north side of the Chitina valley for 100 miles. It is a thick sequence of basalitic flows, well known because of the associated copper deposits in the Kennicott mines near McCarthy. The primary minerals in the lava, in order of abundance, are augite, labradorite, iron ores, apatite, olivine, and orthorhombic pryoxine (Moffit, 1938, p. 39). The lavas that actually make up the bulk of the Wrangell Mountains are those of the Wrangell Lava Formation of Eocene and Quaternary age. Andesite is the chief rock type, but some basalt and dacite are present. Basaltic lavas and minor felsic extrusives and pyroclastics, containing Eocene plants, possibly equivalent to the Wrangell lava, are widespread in the southern Talkeetna Mountains.

The literature on the igneous rocks of the Copper River basin region indicates that basic compositions, especially basaltic and andesitic, may predominate. However, intermediate to acidic intrusives are present in a large part of the Talkeetna Mountains, and small amounts crop out in the southern part of the basin west of the Copper River and in the Chitina valley. Many types of both sedimentary and igneous rocks were probably being eroded during deposition of the Eocene nonmarine sediments in the Copper River basin, and it appears that intermediate to acidic types could have contributed significant amounts.

Structure

The Lower Jurassic Seldovia and Talkeetna geanticlines trend through the northern part of the Chugach Mountains and the northern half of the Copper River basin, respectively (Payne, 1955). Between the geanticlines lie sedimentary rocks deposited in the Matanuska geosyncline during the Mesozoic era. These sediments trend into the Matanuska Valley to the west and into the Chitina valley to the southeast. The Mesozoic sediments form a sequence having a thickness of at least 8,900 feet where the axis of the narrow Matanuska geosyncline crosses the southern part of the Copper River basin.

The Castle Mountain thrust fault, which is a major feature on the north side of the Matanuska Valley, probably extends eastward into the Copper River basin as a set of northeast-trending branch faults. Folding of the bedded rocks in the region is pronounced in the Carboniferous rocks but becomes progressively less so in the younger strata. Mesozoic beds on the western edge of the basin next to the Talkeetna Mountains are generally flat lying, except where faulted (Grantz, 1960). The Tertiary sediments are apparently nearly horizontal wherever found in the basin.

Economic Geology

It is estimated that about 3,500 square miles of the Copper River basin is underlain by Late Mesozoic marine rocks that correlate with the sequence containing indications of petroleum in the Cook Inlet. Sandstones of Middle

Jurassic to Late Cretaceous age are believed to offer the best possibilities for petroleum in the Copper River basin (USGS, 1964, p. 53). Evidence of petroleum consists of a fetid odor in a few of the Cretaceous beds, gas shows in test wells, and several gas seepages at the surface. As of 1969, eight unsuccessful wells had been drilled to depths ranging from 2,793 to 8,837 feet.

The Tertiary sediments are not considered likely to be petroleum reservoirs, but they may thicken locally and contain some oil of Mesozoic origin and methane gas. This possibility is of interest because petroleum hydrocarbons are believed to sometimes provide a reducing environment for uranium deposits (Taucher, 1971, p. 5).

Numerous publications include descriptions of the many ore deposits in the region, which, if the McCarthy area is included, is one of the richest mineralized parts of Alaska. Gold and copper have been most developed. Excerpts from Berg and Cobb (1967, p. 37-65) are given in an effort to summarize the information on the geology and show the variety of minerals in the three recognized mining districts within the study area.

Chistochina District

> *The Mesozoic rocks are economically important in the Chistochina district because they include the Nikolai Greenstone and overlying Chitistone Limestone, which, in the Kotsina-Kuskulana area, are host to numerous copper lodes.*
>
> *Copper, gold, silver, and molybdenum lodes in the Chistochina district were prospected from about 1898 to 1940; the greatest exploration activity was prior to 1930. Iron, lead, zinc, and bismuth also occur in some of the lodes, but no attempt has been made to exploit these metals. Most of the prospects are between the Chitina River and the crest of the Wrangell Mountains in an area drained by the Kotsina and Kuskulana Rivers. A typical copper deposit in the Nikolai Greenstone in the Copper Creek area is in sheared or brecciated greenstone and consists of small irregular veinlets of quartz, calcite, and epidote, and subordinate bornite, chalcopyrite, chalcocite, enargite, malachite, azurite, pyrite, and limonite. It commonly is within a few hundred feet of the top of the greenstone.*
>
> *The most thoroughly explored copper deposit on Copper Creek is the Mullen prospect where the lode consists of veins of calcite, pyrite, bornite, chalcopyrite, covellite, limonite, malachite, and azurite in brecciated limestone. Samples of the two principal veins assayed 1.55-5.82 percent copper, a trace of gold, and as much as 0.28 ounces of silver per ton. Total indicated resources of the two veins is about 1,360 tons.*

Other minerals reportedly present in the Chistochina district include tetrahedrite and bismuthinite on the Kluvesna River; sphalerite and galena with copper and iron minerals have been found in the Slana areas in the northeastern part of the Copper River basin; molybdenum, mainly in a pegmatite dike, was found on Rock Creek, also in the Slana area.

Nelchina District

The Nelchina district is the area drained by east-flowing tributaries of the Copper River from Gulkana on the north to, but excluding, the Tusnana River on the south.

Lodes in the Nelchina district have been prospected for gold, silver, manganese, and chromite. The gold lodes, which also contain a little copper, lead, and zinc, are mainly in an area southeast of Tonsina Lake, the site of considerable exploration early in the present century. On Dust Mountain, at the northeastern end of the intrusive, a body of massive chromite as much as 10 feet thick is exposed for a distance of 75 feet. Samples of the richest material assay 36.0-57.7 percent chromite, with a chrome-iron ratio of 1.20-3.06. Assays also show traces of nickel and platinum.

Nizina District

The district is dominated in the south by the Chugach Mountains, in the northeast by the St. Elias Mountains, and in the northwest by the Wrangell Mountains. Within these regions of high relief and large fields of perennial ice and snow, the only large lowland area is the valley of the Chitina River.

Lodes containing copper, silver, gold, lead, zinc, molybdenum, and nickel occur in the Nizina district, but only the lodes bearing copper and precious metals have been the sources of substantial amounts of ore. The period of greatest lode prospecting and mine development was from 1900 to 1938, when more than a billion pounds of copper was recovered, nearly all from the Kennicott mines. The group of properties known as the Kennecott mines includes the Bonanza, Jumbo, Erie, and Mother lode mines, located at altitudes of 4,000-6,000 feet in the mountains about 7 miles north and north-northeast of McCarthy. The underground workings in the four mines were interconnected and totaled about 70 miles in length, the deepest workings reaching an altitude of about 2,800 feet. The mines exploited several ore bodies, the most important of which were the famous Bonanza and Jumbo veins---veins that were unique in that they constituted the largest masses of almost pure copper ore that have ever been discovered. The Kennecott mines were in almost continuous operation from 1911 to 1938, during which time they yielded most of the copper produced from Alaska. The Kennecott ore bodies were in Chitistone Limestone a little above the contact with the Nikolai Greenstone. The ore occurred as veins, irregular massive replacements, and stockworks, mostly in partly dolomitic beds in the lowest 300 feet of the Chitistone Limestone.

About three-fourths of the ore mined at Kennecott consisted of sulfide minerals, of which an estimated 95 percent was chalcocite. The remaining sulfides were chiefly covellite and sparse to trace amounts of enargite, bornite, chalcopyrite, luzonite, tennantite, pyrite, sphalerite, and galena. Besides the important copper deposits, other lodes in the Nizina district have been explored for gold, silver, lead, molybdenum, antimony, and nickel.

Previous Radioactivity Investigations

The USGS examined the southwestern part of the Wrangell Mountains on the north side of the upper Chitina valley near McCarthy (Moxham and Nelson, 1952, p. 1-3). Apparently little or no data on the mines and ores in the district are available. Results of tests on nine samples collected in the McCarthy area by Moxham and Nelson are given below:

Sample	Location	Type of material	Radioactivity (in percent eU)
10	Dan Creek	Shale (Kennicott formation)	0.002
11	Dan Creek tributary	Panned concentrate	0.000
12	Rex Creek	Shale (Kennicott formation)	0.002
13	Young Creek	Panned concentrate	0.001
14	North of McCarthy	Shale (McCarthy formation)	0.000
15	North of McCarthy	Greenstone (Nikolai formation)	0.002
16	Near Kennicott	Granite	0.001
25	O'Neill Mine, Dan Creek	Sluice-box concentrate	0.000
86	Chititu Mines, Inc. Rex Creek	- - - - -do- - - - - -	0.000
Spots checks	(1)	Shale (Kennicott formation	Insignificant

1Several localities.

A single sample of the heavy-mineral fraction of gravel from Golconda Creek, a tributary to Chikina and Chitina Rivers, produced eU of 0.004 percent.

The area in the Chugach Mountains including the west tributaries to the Copper River between the Tiekel and Gulkana Rivers has been called the Klutina district. Twenty-seven radioactivity measurements of rocks and stream concentrates from the area, taken from Moxham and Nelson (1952, p. 4), ranged between 0.001 and 0.003 percent eU.

Several localities in the extreme northeastern part of the Copper River basin, in the Chistochina district, were tested during 1953 and 1954:

Locality	Type of deposit	Radioactivity	References
Rock Creek	Molybdenite-bearing permatite	0.004 percent eU or less	Wedow and others, 1953, p. 6, 7; Nelson and others, 1954
Mineral Point area	Altered shear zone containing copper, gold, silver, and traces of nickel(?)	0.001 percent eU	Wedow and others, 1953, p. 6, 8; Nelson and others, 1954
Glenn Highway between Slana and Mineral Lake	Tests of concentrates from gravels of streams crossing highway	0.003 percent eU or less	Wedow, Killeen, and others, 1954, p. 16-18

Locality	Type of deposit	Radioactivity	References
Silver Creek area	Quartz veins, containing silver-bearing galena and tetrahedrite with some gold cutting diorite	Veins contain 0.001 percent eU; diorite contains as much as 0.005 percent eU	Wedow, Killeen, and others, 1954, p. 16-18; Wedow and others 1953, p. 6, 8; Nelson and others, 1954
Indian group	Quartz veins containing silver-bearing galena and tetrahedrite, chalcopyrite, malachite, and azurite	0.004 percent eU	Wedow and others, 1953, p. 6, 7; Nelson and others, 1954

An anomalous radioactivity reading was reported from an airborne survey. R.G. Bates recorded in Trace Elements Preliminary Reconnaissance report A-1726, December 3, 1953, a scintillometer reading of 1.0 mr/hr in the canyon of the Chitistone River. The background was 0.15 mr/hr. No ground investigation was made. Although only a single reading was reported, it seems to be significantly high and to warrant follow-up testing. The mouth of the Chitistone River valley is 10 miles east of McCarthy.

TERTIARY DEPOSITS AND GRANITIC ROCKS OF THE EAGLE-CHARLEY RIVER AREA

A belt of nonmarine sedimentary rocks of Upper Cretaceous to Pliocene(?) age lies along the south side of the Yukon River from the International boundary to Woodchopper and Webber Creeks, which are east of Circle (fig. 17). The Upper Cretaceous-Tertiary sediments lie within a few miles of (and are topographically lower than) the large Mesozoic, granitic Charley River batholith to the south, which presents a favorable situation for the accumulation of sedimentary-type uranium. The sediments of the belt are within the 1:250,000 Charley River and Eagle quadrangles.

The geology of the Charley River quadrangle has been mapped by Brabb and Churkin (1969), and the geology of the Eagle quadrangle was compiled by Foster (1972). The Upper Cretaceous-Tertiary deposits of the Eagle-Circle area were specifically studied by Mertie (1942), who also published a report on the general geology of the region (1930).

The Upper Cretaceous-Tertiary belt occupies a trough formed along the Tintina fault zone (or Tintina Trench), which is an extension of the Rocky Mountain Trench and a major structural feature in east-central Alaska. The fault zone is also referred to as the Eagle Trough. The area underlain by Upper Cretaceous-Tertiary sediments along the trough is from 2 to 15 miles wide and 80 miles long. The area is one of low, rounded ridges, and continues northwestward along the Yukon River valley into the loess-covered terraces and lake-dotted plain of the southeastern part of the Yukon Flats.

The hills are heavily wooded. South of the trough area, mountains of the Yukon-Tanana Upland rise gradually to altitudes of over 5,000 feet. On the north side of the trough and the Yukon River, the Ogilvie Mountains form a rather rugged group with a maximum altitude of about 4,600 feet.

The Yukon-Tanana Upland is drained by north-flowing streams that rise in the highland to the south and have superimposed courses to the Yukon River in narrow valleys. The major tributaries to the Yukon River on the north side of the trough are the Nation and Kandik Rivers.

The town of Eagle, on the Yukon, is near the southeastern end of the trough and is accessible by the Taylor Highway. The northwestern end of the trough is near Woodchopper Creek, which is a southern tributary of the Yukon. A short road connects the lower parts of Woodchopper and Coal Creeks. The town of Circle is located a little farther downstream on the Yukon and is accessible by the Steese Highway. Other parts of the area can be reached by boat on the Yukon River and its tributaries. Short landing fields are located at Eagle and Circle, and at one time landing strips were used at the Nation and Woodchopper settlements.

The climate is similar to that of the Fairbanks area. The yearly mean annual temperature is 25°F, and the average precipitation is 10 inches. Permafrost is discontinuous throughout the area.

The Tertiary and Cretaceous sediments in the trough are in a synclinal belt and they probably are in sedimentary contact with both the metamorphic and granitic rocks of the Yukon-Tanana Upland on the south and the highly indurated Precambrian, Paleozoic, and Mesozoic sediments of the Ogilvie Mountains on the north. While the Tertiary belt closely follows the course of the Yukon River, the contacts are separated by a narrow belt belonging to the Precambrian-Tertiary sequence of the Ogilvie Mountains or the Kandik Basin.

Sedimentary Rocks

A large number of geological formations and groups ranging in age from Precambrian through Tertiary have been mapped in the area (Brabb and Churkin, 1969; Foster, 1972). The north side of the trough and Tintina Trench is occupied by one of the most complete stratigraphic sections in Alaska. The area north of the Yukon River is termed the Kandik Basin. The pre-Tertiary rocks south of the Tintina fault do not correlate with those on the north side because of the great right-lateral displacement along the Tintina fault, which may be as great as 260 miles (Davies, 1972). The rocks on the south side of the trough are mostly metamorphosed sediments and greenstones of Paleozoic age and Mesozoic granitic rocks. Descriptions of most older rocks do not seem to suggest that they would be favorable hosts for uranium. However, one older sedimentary formation that may possibly be of interest to uranium explorationists is the Nation River Formation, which is exposed on both sides of the Yukon River from a short distance downstream from Eagle to about 6 miles below the mouth of the Nation River. Early reports dated the Nation River Formation as probably Permian, but Brabb and Churkin (1967) have shown that it is most likely Late Devonian. The Nation River Formation consists of up to 4,000 feet of nonmarine clay shale, sandstone, and conglomerate which has been said to resemble Tertiary sediments.

Study of the Upper Cretaceous-Tertiary sediments in the Eagle-Circle district by Mertie (1942) was primarily for determining the source of the placer gold which was mined from streams south of the Yukon River, most notably at American, Coal, Woodchopper, and Fourth of July Creeks. Mertie's conclusion was that the immediate source of the gold was the Upper Cretaceous-Tertiary sandstones and conglomerates but the original source was the granitic rocks to the south. The Upper Cretaceous-Tertiary sediments were probably laid down in an alluvial basin which was originally much more extensive than it is today.

Outcrops of the Upper Cretaceous-Tertiary rocks are not extensive because they are generally little indurated and nonresistant to weathering, though some units are locally well indurated. Exposures can be found in stream valleys. However, no complete section is exposed anywhere and partial sections have not been combined to yield a composite section.

Generalized descriptions of the lithologies are taken from Mertie (1942, p. 224-225):

> *The materials composing the Tertiary conglomeratic rocks and sandstones tend to be fairly uniform in lithologic character, but at some localities where these rocks lie close to the underlying Paleozoic and Mesozoic rocks their composition varies markedly from the usual composition. At most places the pebbles of the conglomeratic rocks consist of chert of various colors, quartzite, and vein quartz, which are the types of rocks that are practically indestructible, except by abrasion. Locally, and especially near the base of the formation, pebbles and cobbles of granitic rocks, greenstone, schist, argillite, and even limestone have been observed. In most of the conglomeratic rocks, the pebbles are relatively small, the maximum diameter being 4 or 5 inches and the average between 1 and 2 inches. But at certain horizons near the base of the sequence, coarse conglomerate has been observed, as for example on American and Crooked Creeks. The best example of coarse conglomerate, however is along the ridge that separates Crooked Creek from Trout Creek. Here large residual cobbles and boulders of quartzite as much as 2 feet or more in diameter lie at the surface and represent the debris derived from the surficial alteration or slaking of coarse conglomerate. The sandstones of the series are not materially different from the conglomerates, except for the smaller size of the component grains. Under the microscope the finer rock forming minerals, both of the conglomerates and sandstones, are found to be quartz, orthoclase, plagioclase, hornblende, and mica, together with iron ores, zircon, garnet, and other heavy minerals derived from granitic rocks and crystalline schists. At places the heavy minerals are concentrated in stratified layers and in general appear to be more plentiful than in their original parent rocks. Most of the shale is sandy, but in the stratigraphic horizons where coal is found clay shales are also found. The coal that occurs in these Tertiary rocks was studied years ago by Collier and was found from numerous analyses to be dominantly a high-grade lignite, with some subbituminous varieties. At the present time, with ample wood for domestic use and with cheap oil for large-scale mining operations, these low-grade coals are of little economic importance.*

The base of an Upper Cretaceous-Tertiary conglomerate along the west bank of Mission Creek appears to lie directly on pre-Upper Cretaceous granite, and in other areas arkosic sandstone can be observed to have been locally derived directly from granite, with which it is in contact. Besides granite, other constituents of the conglomerate include chert, schist, quartz, quartzite, and greenstone. Fragmental plant remains are interbedded with sandstones at various localities. Gold was found to be irregularly distributed in certain sandstone and conglomeratic beds and almost certainly was derived from weathering of the granitic rocks.

Igneous Rocks

Several Paleozoic and possible Precambrian igneous rock units have been mapped in the Eagle and Charley River quadrangles. A sequence of basalts and sedimentary rocks believed by Mertie to be Early Mississippian are known as the Circle Volcanics. Mesozoic granite, including some diorite and related rocks, form a large complex south of the Yukon River. Tertiary lava flows, mainly rhyolite but including some dacite, are present. This study is concerned principally with the Mesozoic granitic rocks which appear to have the greatest potential as uranium source rocks for the Upper Cretaceous-Tertiary trough sediments and as possible hosts for vein-type uranium.

The Mesozoic granitic rocks occupy a zone 80 miles long and from 10 to 50 miles wide with smaller outlying masses of similar rocks both north and south of the main massif. The total area is 1,900 square miles. The main body, the Charley River batholith, is named from the Charley River, which cuts the batholith about halfway between Eagle and Circle. Other batholiths and smaller granitic bodies occupy much of the Yukon-Tanana Upland in east-central Alaska.

The felsic rocks identified by Mertie (1930, p. 150) consist of muscovite granite, alaskite, muscovite-biotite granite, amphibolite, epidote granite, and quartz monzonite. Subsilicic types are granodiorite, quartz diorite, and diorite. Basic rocks include gabbro, peridotite, and pyroxenite. The granitic and dioritic rocks, however, are most typical of the region. Locally, primary granite gneiss is developed along the contact of the intrusives with the country rocks. Tertiary and Mesozoic dikes of both felsic and mafic compositions are common near the intrusive rocks. Ultramafic rocks of the Eagle quadrangle are described by Foster and Keith (1974).

The plutonic rocks of the main complex in the southwestern part of the Charley River quadrangle are termed adamellite (quartz monzonite) by Brabb and Churkin (1969). Their description follows:

> *Medium-to coarse-grained adamellite. Biotite is chief accessory mineral. Hornblende less abundant. Muscovite and garnet occur locally. Adamellite has zenoliths of schist and is cut by aplite dikes. The adamellite forms generally structureless bodies discordant with surrounding schist, but in some places the adamellite seems to grade into quartz biotite gneiss.*

The Mesozoic plutonic rocks in the Eagle quadrangle are described by Foster (1972):

UNDIFFERENTIATED GRANITIC ROCKS--Primarily quartz monzonite and granodiorite, but includes granite to diorite with local aplite, alaskite, and pegmatite. Fine to coarse grained; equigranular to coarsely porphyritic. Biotite-hornblende granodiorite abundant. Commonly crops out in tors. Most of larger plutons probably Mesozoic in age but includes Tertiary plutons.

HORNBLENDE GRANODIORITE--Primarily coarse-grained hornblende granodiorite and quartz monzonite but includes some gabbro and syenite. Probably Mesozoic in age.

SYENITE OF MOUNT VETA--Primarily hornblende syenite porphyry, but locally equigranular. Includes hornblende quartz-monzonite and diorite. Potassium-argon age on hornblende of 177 m.y. $\pm$ 5 m.y. (Potassium-argon report no. 54 (Menlo Park), 1969, by J. von Essen).

While both Mount Veta and Mount Fairplay are about 75 miles south of the Yukon River in the Yukon-Tanana Upland and outside the Eagle-Circle region, the syenitic rocks are of interest because of the possibility of uranium associations (Foster, 1967). The Mount Fairplay area has long been known to have a very high radioactivity background, and even though it was the site of a uranium staking "rush," no commercial uranium deposits were found.

Another rock unit of possible interest because it may consist of Precambrian orthogneiss is the Pelly Gneiss (Mertie, 1937, p. 201-202). This unit occurs in scattered, rather ill-defined areas throughout much of the Yukon-Tanana Upland of eastern Alaska.

Structure

The most significant structural feature of the Eagle-Circle district is the Tintina Trench, extending 600 miles or more from Canada into east-central Alaska. Right-lateral displacement has been calculated to be as much as 260 miles. The trench forms a lowland now partly occupied by the Upper Cretaceous-Tertiary sediments of the Eagle-Circle district. Subordinate faults and folds related to movement in the fault zone are well developed in Precambrian-Paleozoic rocks and Cretaceous granite. Displacement of Quaternary alluvium shows that movement has continued (Davies, 1972).

The Tertiary rocks have been deformed into appressed folds. Bedding, though locally dipping northward, dips dominantly southward and it is presumed that the Tertiary rocks lie in a belt of appressed folds overturned to the north.

Economic Geology

Gold in placer workings have long been known in the region. All the streams mined for gold lie south of the Yukon River, as do the granitic intrusive bodies. The valleys of Coal and Woodchopper Creeks contained the most important placers in the Upper Cretaceous-Tertiary belt. While mining has been dormant for a number of years, a dredge of Coal Creek is currently being reactivated.

The Upper Cretaceous-Tertiary deposits have acted as a proximate source for the gold, which in turn was concentrated in various tributaries of the Yukon River. The original source was the granitic plutons south of the Upper Cretaceous-Tertiary belt. All the important placers are on the valley floors, but less significant placers occur as bench deposits on higher and older erosional surfaces. Silver and platinum are alloyed with the placer gold: up to 18 percent silver and 0.42 percent platinum.

Lode deposits in the immediate vicinity of the Eagle Trough are scarce. Mineralization was staked in 1948 on sulfide-bearing rock containing cobalt bloom and a basaltic greenstone on Eagle Bluff just outside the town of Eagle along Mission Creek (Saunders, 1952). Very little work has been done on the prospects. A few lode prospects in the Circle district were explored for gold, copper, and lead. A copper prospect 50 miles east of Eagle on Copper Creek about 6 miles above its confluence with the Charley River occurs in highly metamorphosed rocks which may be a roof pendant in the Charley River batholith. Chalcopyrite, malachite, and azurite are the chief metallic minerals (White and Tolbert, 1954, p. 7-9).

Some low-grade coal has been exposed at several stream valleys that cut the Upper Cretaceous-Tertiary beds, but apparently it is not suitable for exploitation. One site, believed to be in the Nation River Formation, has been mined for coal, and about 2,000 tons were used to fuel river streamers (U.S. Geol. Survey, 1964, p. 80). Oil shales, containing as much as 28 gallons of oil per ton, within the Triassic-Lower Cretaceous Glenn shale, are well known but relatively thin (Mertie, 1930, p. 132). An occurrence of asbestos has been found near the center of the Eagle quadrangle in a serpentinized mass that appears to have intruded metamorphic rocks (Foster, 1969).

Radioactivity Investigations

Several reconnaissance investigations for radioactivity by the U.S. Geological Survey and one by DGGS has been conducted in west-central Alaska. Wedow (1954) investigated the Eagle area in 1948 on behalf of the U.S. Atomic Energy Commission, and reported the following data:

> *Reconnaissance of radioactive deposits in sedimentary rocks of Proterozoic and Paleozoic age, and granite of Mesozoic(?) age together with its Tertiary sedimentary derivatives, was conducted in the Eagle-Nation area, east-central Alaska in 1948. None of the rocks examined contains more than 0.003 percent equivalent uranium except for black shale beds in the upper Mississippian Calico Bluff formation and in granite of Mesozoic(?) age and its sedimentary derivatives. The more radioactive black shale beds in the Calico Bluff formation range in thickness from 1/2 to 7 feet. Two units near the base of the formation appear to be persistent in the area: Radioactive unit A, with an average thickness of 6.6 feet, contains an average of 0.007 percent equivalent uranium and 0.004 percent uranium; radioactive unit B, with an average thickness of 5.2 feet, contains an average of 0.006 percent equivalent uranium and 0.003 percent uranium. Phosphatic pellets from unit B at one locality contain 0.022 percent equivalent uranium, 0.019 percent uranium, and 15 percent P_2O_5. Samples of granite of Mesozoic(?) age and its Tertiary sedi-*

mentary derivatives average 0.005 and 0.004 percent equivalent uranium, respectively. Biotite is the chief radioactive mineral in the granite and its radioactivity is ascribed to the presence of uranium and thorium, which occur either as impurities or in minute inclusions of other, as yet unidentified, minerals. Traces of uranium and thorium in zircon, sphene, and monazite also contribute to the total radioactivity of the granite. Zircon and monazite are the major uranium-and thorium-bearing minerals of the Tertiary sedimentary rocks derived from the granite.

The investigators concluded that the radioactivity at the Copper Creek prospect was due to uranium as impurities in bornite and malachite. They also noted that the investigations were limited and that greater concentrations may occur in the area of the mineralized roof pendant in the batholith.

Results from other areas tested by DGGS in west-central Alaska (Eakins, 1969, p. 13-14) are given:

Tertiary shale, sandstone, and coal beds exposed along Chicken Creek at the town of Chicken and in a gravel pit near Chicken did not yield significant readings. The Silver Queen Lode, just below the highway about four miles north of Chicken and near Mile Post 71 did not show measureable radioactivity. The prospect consists of a 30-foot tunnel following a gouge zone with showings of galena.

Two feet of gouge in a fault zone in a conspicuous outcrop of marble in a road cut at Mile Post 114 gave three times the background count, or between 0.03 and 0.04 Mr/Hr. Tertiary sandstones and shales exposed in borrow pits along the Taylor Highway from a few miles south of Eagle to Eagle contain sandstone shales, and siltstones. The very fine-grained silty sandstones and siltstones were noticeably higher in radioactivity than the cleaner, coarser sandstones. Counts up to 0.03 Mr/Hr were obtained.

A foot traverse along American Creek from Eagle south for five miles was made to examine Tertiary sandstones and conglomerates exposed in bluffs along the creek. At three locations localized anomalies were encountered where faults cut these beds. The maximum readings were 0.03 Mr/Hr. Mission Creek enters the Yukon just west of the town of Eagle near the base of Eagle Bluff. The prominent Eagle Bluff stands between Mission Creek and the Yukon. In the 1940's several claims covering showings of gold, copper, nickel, and cobalt were staked along a fault zone on the Mission Creek side of Eagle Bluff. A foot traverse in this area did not produce any radioactive anomalies, but all seven claims were not examined in detail. No mining has been done on the claims.

Frequent checks with counters along the Yukon River between Eagle and the Canadian border revealed no anomalies in the Paleozoic rocks exposed. The Nation River conglomerate exposed no anomalous readings. The Mississippian Calico Bluff formation exposed on Calico Bluff about eight miles downriver from Eagle has been reported to contain radioactive black shales. The writer measured readings up to 0.05 Mr/Hr in black shales near the base of the bluff. A climb from the river to the top of the bluff produced lesser readings. Tertiary beds exposed on the south side of the Yukon from two to seven miles *west of the mouth of the Seventymile River produced only very low radioactivity. A maximum reading of 0.05 Mr/Hr was obtained from one narrow brecciated zone cutting the beds.*

The Upper Cretaceous-Tertiary nonmarine sediments in the Eagle Trough are essentially untested for uranium. The beds extend 80 miles along the northern boundary of a region containing extensive granitic plutons which have displayed radioactivity anomalies from the air and on the ground. For the most part, the sandstones contain 0.002 percent eU. At least part of the Upper Cretaceous-Tertiary sequence has been shown to have been derived from the granitic bodies and to contain carbonaceous and coaly material. However, beds are generally folded and dips frequently are between 45° and 90°.

Many of the alkalic plutons in a broad region of the Yukon Tanana Upland in east-central Alaska offer possibilities for nonsedimentary uranium deposits. Scattered small areas have been investigated and eU contents of up to 0.007 percent and averaging 0.005 percent have been found in the granite and related rocks.

TERTIARY COAL-BEARING BASINS, NORTH FLANK OF THE ALASKA RANGE

Nonmarine coal-bearing sediments occur intermittently in a 250-mile-long belt on the north flank of the Alaska Range from a point 25 miles east of Farewell eastward to 20 miles east of Donnelly on the Richardson Highway (see Geologic Map of Alaska: Dutro and Payne; 1957). These sediments lie mostly in the northern foothills of the Alaska Range physiographic division of Wahrhaftig (1965, p. 35-36, pl. 1). The foothills consist of flat-topped, east-trending ridges 2,000 to 4,500 feet in altitude which form a belt reaching 20 miles in width along the Nenana River. Most of the foothills are unglaciated, but some valleys were widened during the Pleistocene Epoch by glaciers from the Alaska Range. Streams draining the north slope of the Alaska Range flow northward through the foot hills to the Tanana River valley, except in the western part of the belt, where drainage is into the headwaters of the Kuskokwim River. The Alaska Range forms a great arc extending 600 miles from the Canadian border to Lake Clark in southwestern Alaska, where it merges with the Aleutian Range. The crest of most of the range is between 7,000 and 9,000 feet in altitude, but mountain masses are higher.

Most of the Tertiary basins in the foothills are relatively accessible; none are too remote from towns, and the terrain is not extremely rugged. The belt is crossed by two north-south highways and a railroad: the Richardson Highway crosses the belt near the eastern end, and the Anchorage-Fairbanks Highway and the Alaska Railroad cross the Alaska Range through the Nenana River valley at the eastern edge of Mount McKinley Park. Precipitation is less than 20 inches a year. Permafrost is extensive. The foothills belt is covered by the Big Delta, Fairbanks, Kantishna River, Mount Hayes, Healy, and Mount McKinley 1:250,000 topographic maps. Geologic maps of eight 15-minute quadrangles were recently issued and provide detailed information on much of the Healy and Fairbanks quadrangles (Wahrhaftig, 1970a-h). The surficial geology of the central part of the Alaska Range and Nenana River valley is covered by Wahrhaftig (1958).

The best known part of the Tertiary coal-bearing belt is along Healy Creek, where Usibelli Coal Mines, Inc. produces coal near the settlement of Healy and Suntrana. The coal is used to fuel two power plants, which serve Fairbanks and the military bases in the region. Healy Creek is part of the Nenana coal field, which includes several separate but closely grouped basins in a 40-mile-long area, mostly between the Nenana and Wood Rivers. This group of basins includes Healy Creek, Lignite Creek, Rex Creek, Tatlanika Creek, Mystic Creek, and Wood River coal bains. The Nenana coal field has been described by Martin (1919), Barnes and others (1951), and Warhhaftig and others (1969).

Another locality where coal has been mined from the Tertiary beds on the north flank of the Alaska Range is the Jarvis coal field, located 100 miles east of Healy on the east side of the Richardson Highway near Donnelly.

Little detailed information is available on other Tertiary basins in the belt, but it is hoped that the following discussion, which mostly describes the rocks in the Nenana coal field on the north flank of the central part of the Alaska Range, will apply somewhat to all the Tertiary coal basins in the belt.

Sedimentary Rocks

Rocks in the valley of Healy and Lignite Creeks include the Precambrian (or Paleozoic Birch Creek Schist), the Tertiary Coal-Bearing Group, and the Tertiary Nenana gravels. For lack of a more up-to-date stratigraphic table, the one below (table E2) is reproduced from Barnes and others (1951) with the understanding that the Birch Creek Schist may be wholly or partly Paleozoic in age and that the Coal-Bearing Group has been revised upward from a formation to group status and formally divided into five new formations (Wahrhaftig and others, 1969).

Table E2. Generalized stratigraphy of the Nenana coal field,

Age	Formation	Description	Thickness (feet)
Quaternary	Terrace gravels		0-200
	Unconformity		
Tertiary	Nenana gravel	Conglomerate, with boulders of Birch Creek schist.	200+
		Conglomerate, reddish-brown, with boulders of green ophitic diorite, granite, graywacke, and older conglomerate, and thin shale beds.	2,100
		Conglomerate, brown, with boulders of graywacke, conglomerate, green ophitic diorite, granite, graywacke, and conglomerate.	
		Conglomerate, brown, with boulders of graywacke, conglomerate, green ophitic diorite, and dacite.	1,000
		Conglomerate, brown, with boulders of graywacke, conglomerate, and dacite.	900
	Coal-bearing formation	Upper member: Sandstone, siltstone, claystone, and shale, with a few thin coal beds. Characterized by abundance of granite, volcanics, green ophitic diorite in pebble zones.	500—945
		Middle member: Sandstone, siltstone, claystone, numerous thick coal beds. Characterized by abundance of quartz, quartzite, chert, and argillite, and scarcity of granite, volcanics, and green ophitic diorite in pebble zones.	430—1,000
		Lower member: Sandstone, claystone, siltstone, and conglomerate, with numerous thick coal beds. Persistent brown-weathering claystone at top.	50—1,500
	Unconformity		
Pre-Cambrian	Birch Creek schist	Quartz-mica schist.	?

A discussion of the many Paleozoic and Mesozoic formations and intrusive rocks composing the Alaska Range is beyond the scope of this study, which is concerned mostly with the Tertiary Coal-Bearing Group. The underlying Birch Creek Schist, however, is prominent in the Tertiary basins and deserves mention. It consists of highly contorted quartz-mica and quartz-chlorite schist with some interbedded phyllite, argillite, and black carbonaceous schist. These are all cut by numerous veins of milky quartz. When fresh, the schist is green. It weathers to shades of gray, green, and black, and becomes fissile.

Another unit that is exposed in the hills north of Healy is the Totatlanika Schist of pre-Devonian age. It consists of gray to black quartz muscovite and graphitic schist with interbedded argillite and metamorphosed volcanic rocks.

The Tertiary coal-bearing sequence lies unconformably on the Birch Creek Schist in the Nenana coal field. The coal-bearing rocks are well exposed in the Healy Creek valley and in the open-pit coal mines operated by Usibelli. Figures E6 and E7 show the structure of the coal-bearing beds in the Healy Creek valley and the relation to adjacent formations. Figure E6 shows the structure of Lignite Creek. The geology has been mapped on the Healy D-7 quadrangle (Wahrhaftig, 1970c).

The Coal-Bearing Group is up to 2,000 feet thick and shows a wide variation in thickness and lithology within short distances. Apparently it was deposited in valleys or depressions in the Birch Creek Schist. Later deformation tilted the beds and in places formed synclines. It is unconformably overlain by up to 4,000 feet of the Tertiary Nenana Gravel. South of the Healy Creek valley the beds are fairly flat lying for a distance of several miles.

Structure

The Birch Creek Schist basement is intensely deformed, tightly folded, and crumpled. In many places the bedding has been obliterated. The foliation strikes east and northeast and dips to the south. The Totatlanika Schist is generally less deformed than the Birch Creek Schist.

The uranium potential of the Tertiary Coal-Bearing Group is of principal concern here, and a discussion of the structure of this sequence is reproduced from Barnes and others (1951, p. 180-182):

> *The north flank of the Alaska Range is characterized by a series of broad eastward-trending folds, formed in middle Tertiary time, that are broken in places by both normal and reverse faults. The Tertiary rocks, including the Nenana gravel and the coal-bearing formation, are found in the troughs of the synclines, whereas schists and intrusive rocks older than the coal-bearing formation crop out in the cores of the anticlines. Through the center of the area under discussion passes a major syncline, which is bordered on the north by an anticline and on the south by a tilted fault block that forms the foothill range just south of the mapped area. The syncline, which is 10 to 15 miles wide at the Savage River, probably extends from the*

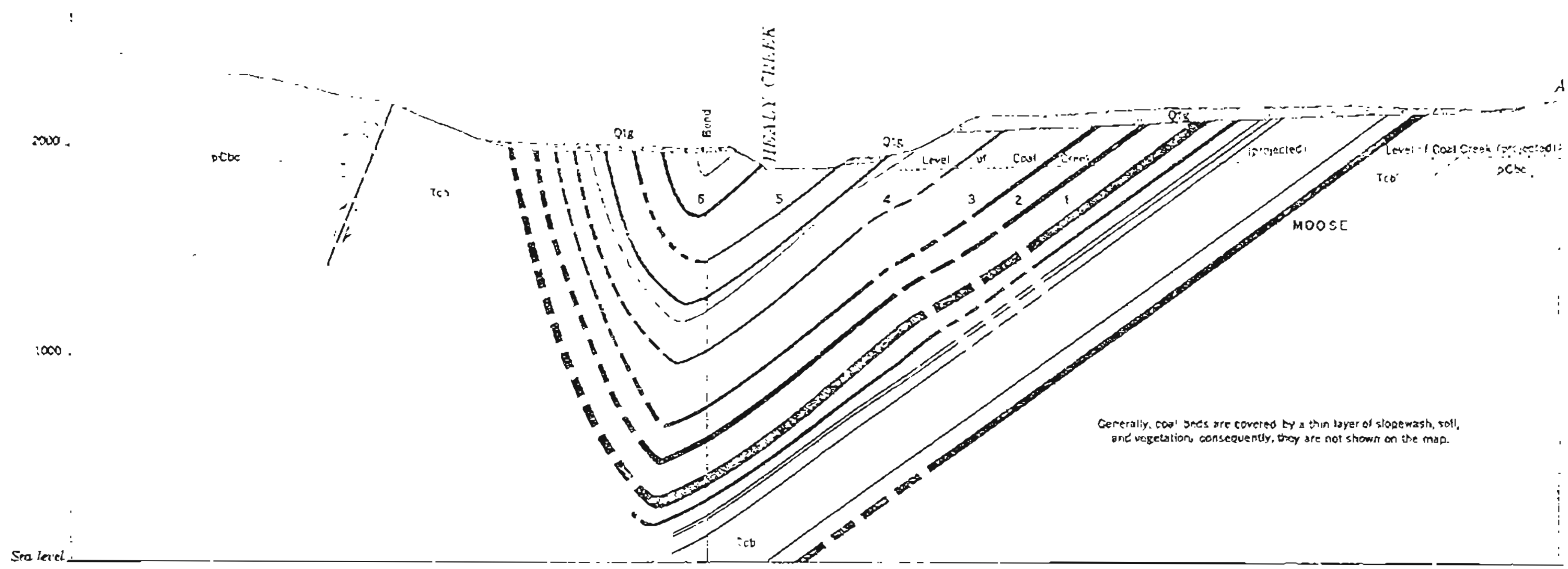

Figure E6. Cross section of the upper Healy Creek valley, looking east. Source: Barnes and others, 1951, U.S. Geol. Survey Bull. 963-E, pl. 18.

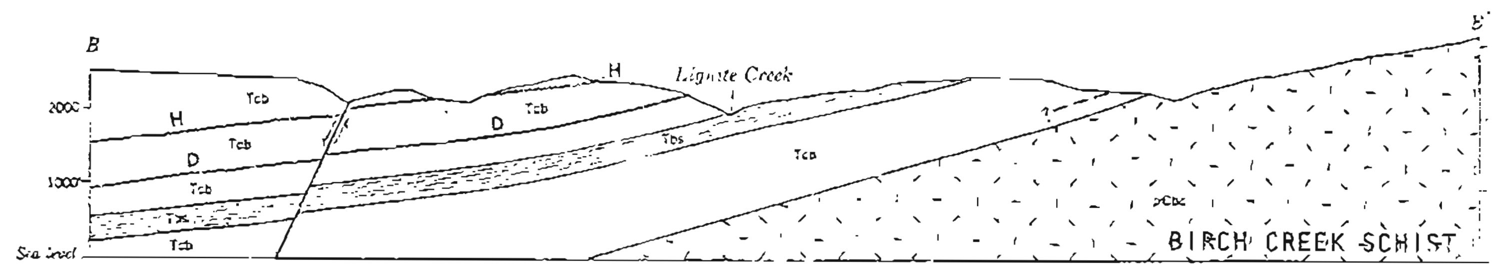

Figure E7. Cross section of the Lignite Creek coal basin, looking east. Source: Barnes and others, 1951, U.S. Geol. Survey Bull. 963-E, pl. 20.

Mystic Creek coal basin on the east to the Toklat River on the west, a distance of 80 miles.

Economic Geology

The Kantishna mining district is the area drained by the Kantishna River and its tributaries. It lies mostly in a group of foothills named the Kantishna Hills, which are underlain by Birch Creek Schist. A number of lode deposits have produced small amounts of gold, silver, antimony, and lead ores from quartz veins. About 1,700 tons of metallic antimony were shipped from the Stampede Mine. Several deposits are within the boundaries of Mount McKinley National Park. The largest of these is on the north slopes of Mount Eielson, where massive argentiferous galena and other sulfides occur in limestone.

A locality of interest from the standpoint of uranium investigations is the Purkey-Pile prospects, just outside the western boundary of Mount McKinley National Park on the west side of the headwaters of Boulder Creek, a small tributary of the Swift Fork of the Kantishna River. There are three separate prospects within about 3 miles of each other in metamorphosed sedimentary rocks near a small granite stock. The prospects have showings of silver, lead, zinc, and tungsten minerals (Maloney and Thomas, 1966). Six samples from the Mespelt prospect yielded anomalous eU values from 0.037 percent to 0.14 percent.

A small deposit of tarry bituminous material originally thought to be a petroleum seep is located 1 mile above the mouth of Cripple Creek, which flows northwest into Healy Creek. It is in gravels overlying the Tertiary Coal-Bearing Group. Martin (1923, p. 137-147) concluded that the material is actually a coal tar produced by distillation from burning coal.

Previous Investigations for Radioactivity

The writer examined the Tertiary coal-bearing group in the Healy Creek valley with Geiger counters (Eakins, 1969, p. 12-13). The area was crossed at several points by walking up gullies so that each bed in the sequence was tested for radioactivity, and foot traverses were made along the entire 12-mile-long area where the coal-bearing beds were exposed. The maximum radioactivity in sandstones, shales, and the Birch Creek Schist was about 0.04 mr/hr, or three times the normal background. No radioactivity was detected at the site of the Delta coal mine at the head of Ober Creek in the Jarvis coal field (Eakins, 1969, p. 15). No other reports of investigations of the Tertiary coal-bearing group on the north flank of the Alaska Range are available. However, it was rumored that a private company was doing stream-sediment and water sampling for uranium in the Healy area last summer (1974), and that uranium anomalies were located.

Radioactivity tests of 50 rock specimens collected by the 1947 Bradford Washburn Mount McKinley expedition produced 0.009 percent eU in a manganiferous vein quartz sample; granitic rocks produced as much as 0.004 percent eU (Matzko, 1951; Wedow, 1956, p. 27). Veins in the Mount Eielson area and in the Kantishna Hills area did not produce over 0.001 percent eU (White and others, 1952, p. 7-9; Wedow, 1956, p. 28). Analyses of samples from the Purkey-Pile Mespelt prospect near the western border of Mount McKinley National Park are listed (Maloney and Thomas, 1966, table 3):

Sample No.	Description	Oz/ton Ag	Au	Percent Pb	Bi	Eu	Cu	Sb	Sn	W
6T	Thomas, 1959, grab of talus.	82.91	.01	46.4	-	-	0.42	2.52	-	-
7T	Thomas, 1959, chip of talus.	29.22	Tr	-	-	0.075	.05	-	0.03	0.01
8T	. . . . .do.	1.87	Tr	-	-	.14	-	-	.06	.04
9T	Thomas, 1959, grab of talus.	1.75	Tr	-	-	.073	-	-	.03	.02
10T	. . . . .do.	10.71	Tr	-	-	.039	-	-	.03	.03
11T	. . . . .do.	.18	Tr	-	-	.037	-	-	.03	.02

The reported eU values justify an investigation of the area. There has not been any production from the claims, though they have been held since 1921. An old 40-foot shaft on the Mespelt prospect is now caved in. A 7- by 5- by 15-foot shaft on the Jules-Knudson prospect was last reported full of water. A little trenching and road work by bulldozer is the only other work that has been done. The prospects are in a remote area of very rugged terrain.

INVESTIGATION OF ALASKA'S URANIUM POTENTIAL

Part 2 - Uranium and Thorium in Granitic and Alkaline Rocks in Western Alaska

By Brian K. Jones and Robert B. Forbes
– Geophysical Institute, University of Alaska –

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ABSTRACT

One hundred eight rock samples were selected from traverses across five plutons in western Alaska and analysed for uranium, thorium, and potassium. Modes were determined using point-counting techniques. The highest uranium concentrations detected were 86 and 92 ppm from a mineralized dike intrusion zone in the Selawik Lake Complex.

Correlation coefficients were calculated in an attempt to relate the mineralogy to uranium and thorium content. When the sample set is considered as a whole there is little significant correlation. However, the analysis of individual plutons yields strong correlations between mineralogy and radioactivity. The mineralogical variable that correlates with uranium or thorium varies from one pluton to the next.

Based on these correlations, mineralogical guidelines are offered for the selection of uranium enriched variants in four of the five plutons.

INTRODUCTION

Project Objectives

With increasing interest in the location and development of new uranium reserves, the state of Alaska has become a prime target area for exploration. Most of Alaska has been geologically mapped at the reconnaissance level and to date uranium investigations have been limited. Granitic and alkaline rocks on the eastern Seward Peninsula, and large granitic plutons and alkaline stocks in the Hogatza Plutonic belt of the Yukon-Koyukuk Basin have been known to contain high concentrations of uranium and thorium, since early prospecting efforts (Gault et al., 1953, West, 1953, and West and White, 1952).

In 1975 Gilbert R. Eakins of the State of Alaska Geological and Geophysical Surveys received a contract from the U.S. Energy Research and Development Administration (ERDA) to conduct an extensive bedrock and stream sediment sampling investigation of this region. This thesis represents a significant portion of the hard rock section of the investigation headed by Dr. Robert B. Forbes of the Geology Department and Geophysical Institute, University of Alaska.

Previous Work

Moffit (1905) was the first to note the existence of large calc-alkaline plutons and smaller stocks in western Alaska. He also documented the occurrence of melanite garnet and aegerine at Granite Mountain. Smith and Eakin (1911) reported nepheline-bearing veins in the Darby Mountains. The alkaline complexes in the Kobuk-Selawik lowland were discovered and first discussed by Patton and Miller (1968) (see also Patton and others, 1968; and Miller, 1972).

Uranium investigations began in the area in the late 1940's, as documented by the publication of a number of U.S. Geological Survey Circulars by West (1953), West and White (1952), and Gault and others (1953).

More recent interest in the uranium potential of the region has resulted in a number of hard-rock uranium investigations (Miller and Bunker, 1975a and b; Miller, 1975; Staatz and Miller, 1976). A definitive study of the petrology of the Hogatza Plutonic belt was conducted by Miller (1970), and a more specific study of the alkaline complexes was also published by Miller (1972).

Although the common association of anomalously high values of uranium and thorium with rocks containing feldspathoids is well documented, high concentrations of the radioactive elements are not limited to the alkaline variants alone. The Darby Pluton in the southeastern Seward Peninsula is an example of a particularly uraniferous pluton (Miller and Bunker, 1975a, and Miller, 1975) although it is composed chiefly of a silicic quartz monzonite. The occurrence of above average amounts of uranium and thorium in plutonic rocks that range in age over a period of at least 35 million years, that have a compositional range from biotite granodiorite to nepheline syenite, and are in significantly different geologic settings suggests the existence of a uranium-thorium province (Miller, 1975).

Geologic Setting

Alkaline and calc-alkaline igneous rocks occur in a belt approximately 750 km long in western Alaska. This belt of plutons extends across the northern Yukon-Koyukuk province from the Koyukuk River to Kotzebue Sound, where it is called the Hogatza Plutonic Belt; cuts across the eastern Seward Peninsula, and may include intrusives on St. Lawrence Island and eastern Siberia.

The rocks along this zone are predominantly granodiorite and quartz monzonite, with some syenite, monzonite and granite (Miller, 1970). Associated with the larger plutons are a number of small, highly potassic alkaline stocks (Miller, 1972). A number of these plutons have been sampled in the past and were found to contain anomalous concentrations of uranium and thorium, but little systematic exploration has been done.

The Hogatza Plutonic Belt is intruded into the Yukon-Koyukuk province, an area of late Mesozoic andesitic rocks, volcanic graywacke and mudstone. It has been a highly mobile tectonic province which has been subjected to repeated magmatism during Cretaceous and Tertiary time (Patton, 1970a).

Precambrian rocks of the Seward Peninsula consist chiefly of gneiss, pelitic and chloritic schists, and carbonate rocks. The Paleozoic Era in the Seward Peninsula is dominated by carbonates. These rocks have been imbricately thrust faulted to the east and north during two periods of faulting in Cretaceous time (Sainsbury, 1969). The boundary between the Seward Peninsula and the Yukon-Koyukuk province appears to be a thrust fault, with Paleozoic carbonate rocks thrust eastward over Cretaceous volcanic rocks (Patton, 1967, Sainsbury, 1969). K/Ar age dates indicate that crystallization of the plutons in the western Hogatza Plutonic Belt occurred about 100 million years ago (Miller, 1970). Radiogenic ages and spatial relations suggest that the alkaline rocks are co-magmatic with the larger monzonite, syenite, and quartz monzonite plutons of the western Hogatza plutonic belt (Miller, 1970). Ages in the eastern section of this belt appear to be much younger, about 86 million years.

Field Investigations

During the 1975 field season, 108 rock samples were collected from two large plutons and three small stocks on the eastern Seward Peninsula, and the Hogatza Plutonic Belt. These plutons include the Darby Pluton, Zane Hills Pluton, Selawik Lake Complex, Dry Canyon Creek Stock, and the Granite Mountain Pluton.

The plutons were selected for sampling because of previously reported occurrences of anomalously high concentrations of radioactive elements. Locations maps for this study are shown in Figures 1 and 2.

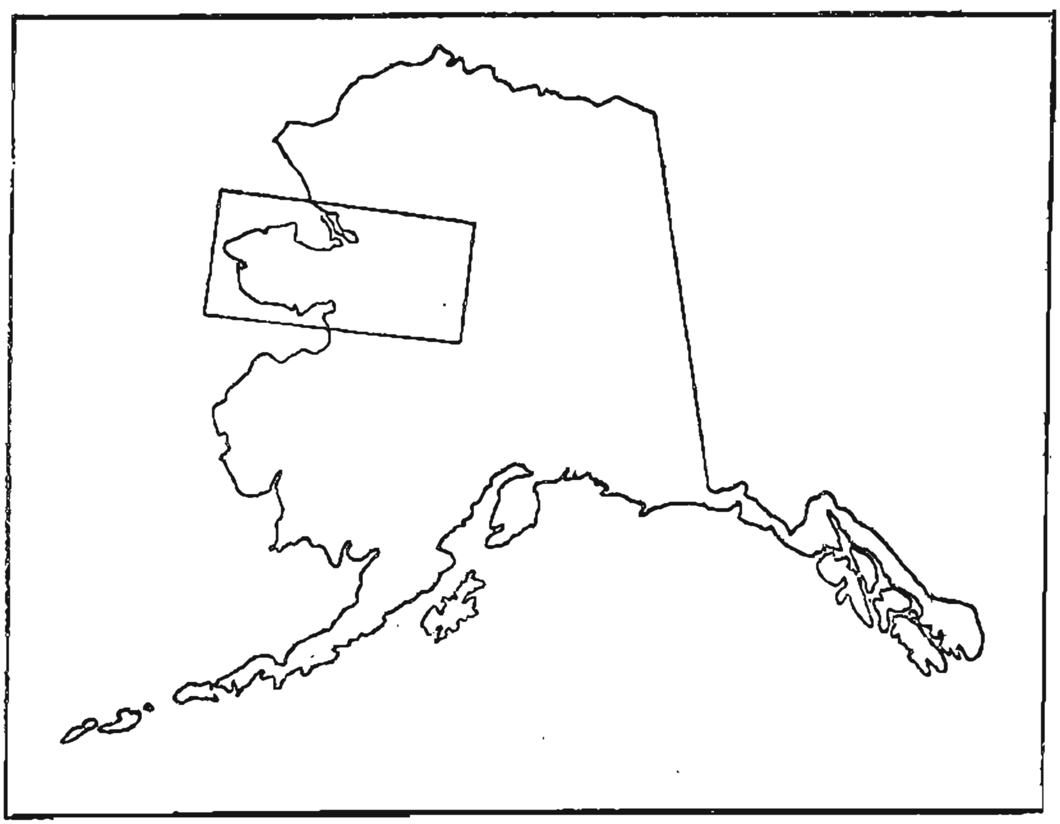


Figure 1. Location map, Seward Peninsula and Yukon-Koyukuk study area.

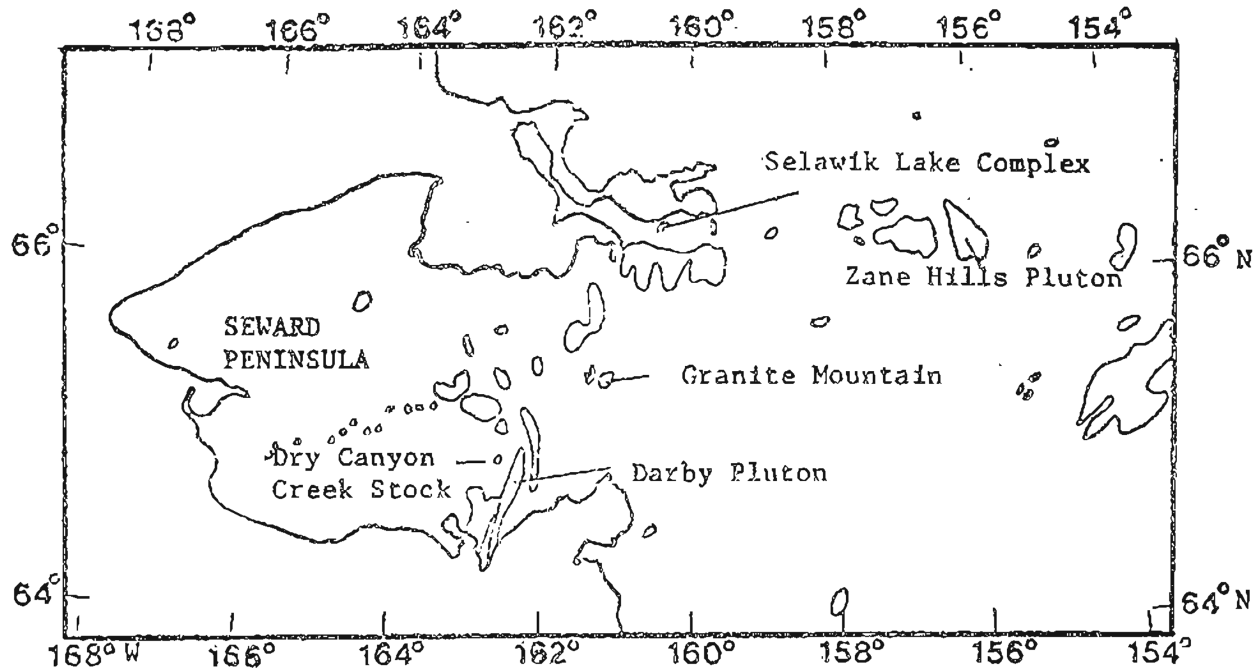


Figure 2. Locations of plutonic rocks on the Seward Peninsula and Yukon-Koyukuk Basin which were examined in this study.

Granite Mountain

This small stock was selected for study because it is a zoned alkaline intrusive (Miller, 1972). It seemed to be the best possible locality within the thesis area to study the distribution of uranium and thorium in rocks showing systematic variation in their modes. Although outcrops are sparse at Granite Mountain, near continuous rubble crop occurs along the traverse line, and rock samples were collected at intervals of approximately 300 meters.

Darby Pluton

The Darby Pluton is a long narrow quartz monzonite intrusive known to contain anomalous concentrations of uranium and thorium. Analyses of 11 samples reported by Miller and Bunker (1975a) yielded average values of 11 ppm uranium and 59 ppm thorium. Because of its large size, and the available time, it was not possible to sample all of the pluton at close intervals. As a result, a single east-west traverse was completed in an area of known high radioactivity. This area is in the vicinity of Vulcan Creek, 33 km north of the village of Elim, where West (1953) discovered high concentrations of uranium in pan concentrates, and Miller and Bunker (1975a) collected three rock samples that averaged 16 ppm uranium. Outcrop and rubble crop are abundant along this traverse and samples were taken at intervals of approximately .5 km.

Zane Hills

Two sample traverses were made through the Zane Hills. A northern traverse was conducted through an area of granodiorite known to contain rather low concentrations of uranium and thorium. The purpose of this traverse was to determine the mineralogy associated with uranium poor rocks and to examine the variability in such a pluton, where the mode is consistent.

A second traverse was conducted in the southern Zane Hills, through two zones of monzonite known to contain anomalously high concentrations of uranium and thorium. Outcrop was abundant in both of these traverses. Samples were taken at intervals of about 1 km.

Selawik Lake

The Selawik Lake Complex is a small potassic stock located north of the Selawik Hills. It was known to contain uranium concentrations as high as 6. ppm and thorium concentrations of 22. ppm. Outcrop is poor and most of the samples collected came from the rubble crop.

Dry Canyon Creek

The Dry Canyon Creek Stock, located on the west side of the Darby Mountains is a potassic stock containing high concentrations of thorium but low uranium values. Most of the samples were taken from the rubble crop.

Analyses from the Selawik Lake Complex and the Dry Canyon Creek Stock were taken to see where the uranium is concentrated in these rocks and with what types of minerals it is associated.

RESEARCH OBJECTIVES AND FINDINGS

Proposed Objectives

1. To gain additional information of the mineralogy and petrology of the alkaline and alkalic rocks within the study area.

2. To examine carefully areas of anomalous radioactivity.

3. To determine which minerals in the rock contain uranium and thorium, and the distribution of these elements between major, minor, and accessory minerals.

4. To make correlations between mineralogy and the uranium concentrations found in the rocks.

5. To predict which rock types would be expected to contain high concentrations of radioactive minerals.

6. To compare airborne gamma-ray spectrometry data with analyses of rock samples collected along traverses beneath the flight lines.

Findings

1. Petrographic analysis of alkaline rocks revealed a number of minerals that had not been previously described in the thesis area. In

addition, the textures and structures of these rocks were described in greater detail than they had been previously. Additional modal analyses were determined from the plutons examined and a number of interesting field relations and new plutonic units were discovered.

2. Areas of anomalous radioactivity were studied, and rocks were collected that contained uranium values as high as 92 ppm.

3. Uranium analyses of mineral separates plus the careful study in thin sections for those minerals showing pleochroic haloes, indicate where uranium and thorium are concentrated in the rock.

4. Correlations between rock types, major and minor minerals, and uranium and thorium were made using graphical and basic statistical techniques.

5. Predictions were made on the basis of the above determinations and mineralogical guides suggested for the selection of samples that should contain anomalous uranium and thorium.

6. Comparison between ground-truth and airborne data could not be made because of the coarse interval selected for the listing of the airborne analytical data published by Texas Instruments, the contractors for the airborne study, and the assumptions made during the processing of that data concerning the geology. It appears that the techniques used, particularly the corrections for known geology are detrimental to the usefulness of these surveys.

ROCK CLASSIFICATION

The classification scheme used for the alkaline rocks in this study is shown in Figure 3. This comparatively simple scheme was presented by Sorensen (1974) as taken from Sarantsina and Shinkarev (1967). Rock names are assigned on the basis of three constituents; percent nepheline, percent alkali feldspar, and percent mafic minerals. The most significant advantage of this particular chart is that it minimizes the number of unusual names given to alkaline rocks. Abundant rock names greatly restrict the audience that would be able to comprehend easily the subject matter of a petrologic report. A large field of nepheline syenite exists within the diagram. This is where most of the rock modes studied fall. Mineralogical modifiers are used to describe the particular variety of nepheline syenite.

The Plagioclase-K-feldspar-Quartz classification chart as used in this study for name assignments for granitic rocks is shown in Figure 4.

THE ROCKS

Granite Mountain

As mapped by Miller (1972), the Granite Mountain Pluton covers an area of approximately 70 km^2. It is a zoned alkaline-calc-alkaline stock with nepheline syenite and garnet syenite at the outer rim, surrounding a unit

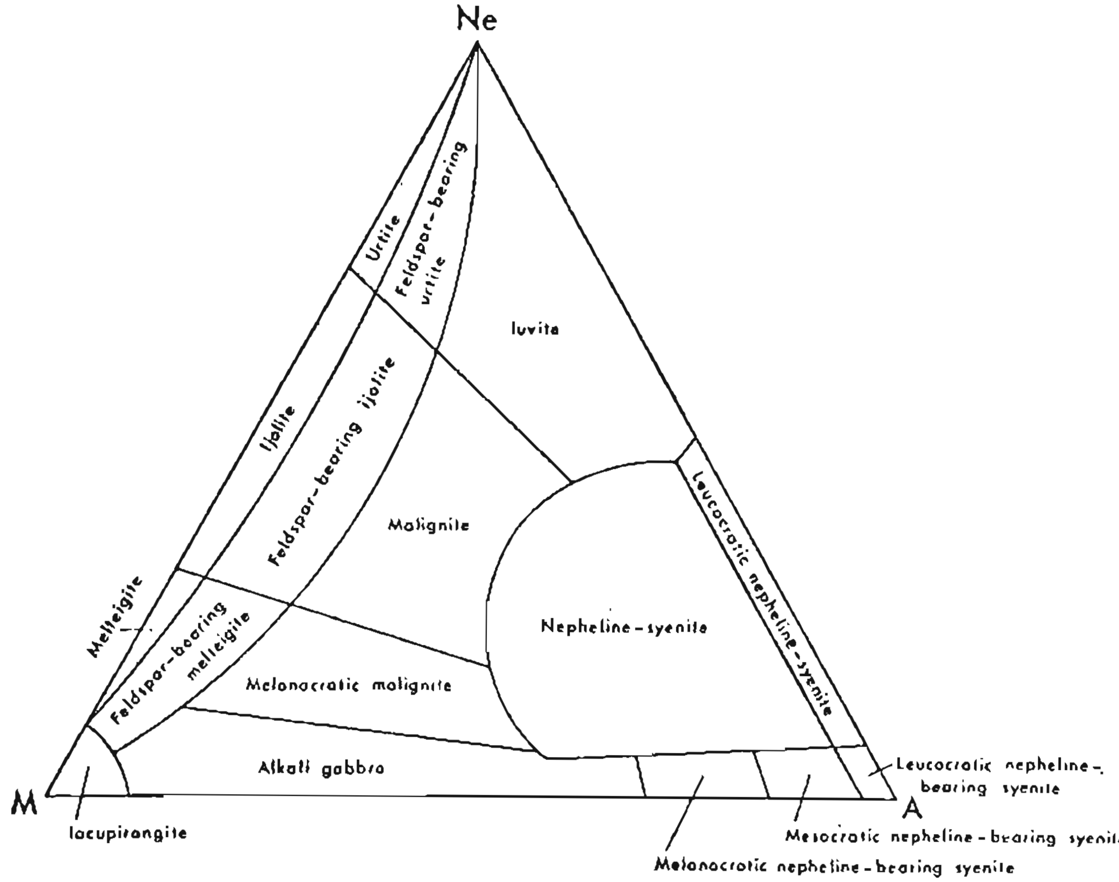


Figure 3. Classification of the alkaline rocks.

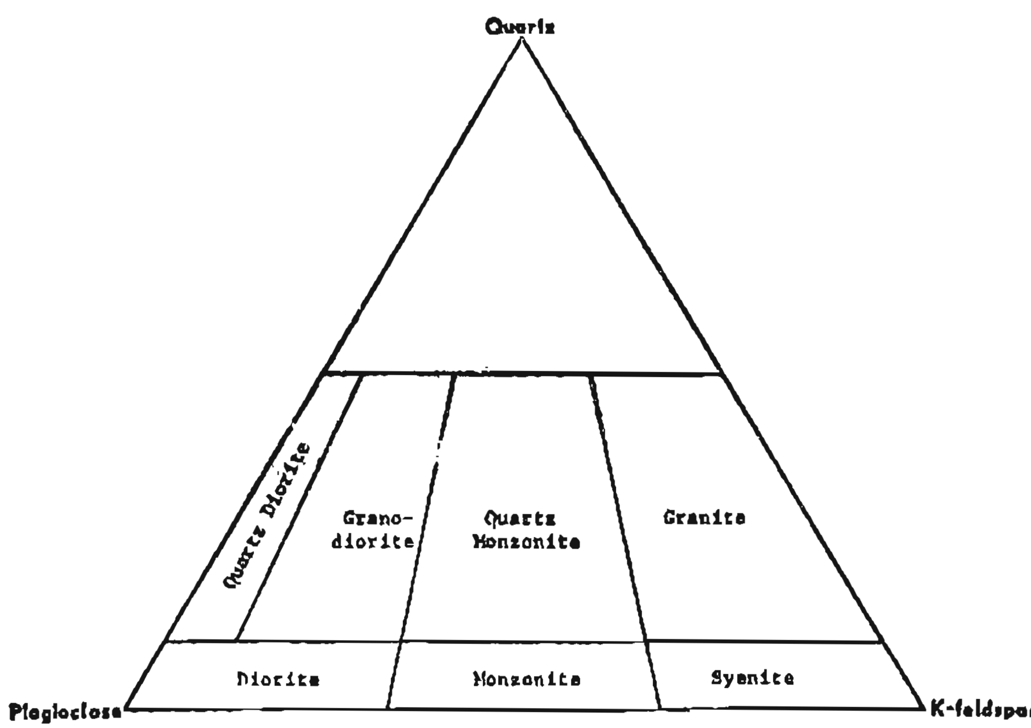


Figure 4. Granitic rock classification.

of medium-grained monzonite. The core of the intrusive is an equigranular medium-grained quartz monzonite. A geologic map of the Granite Mountain pluton is shown in Figure 5.

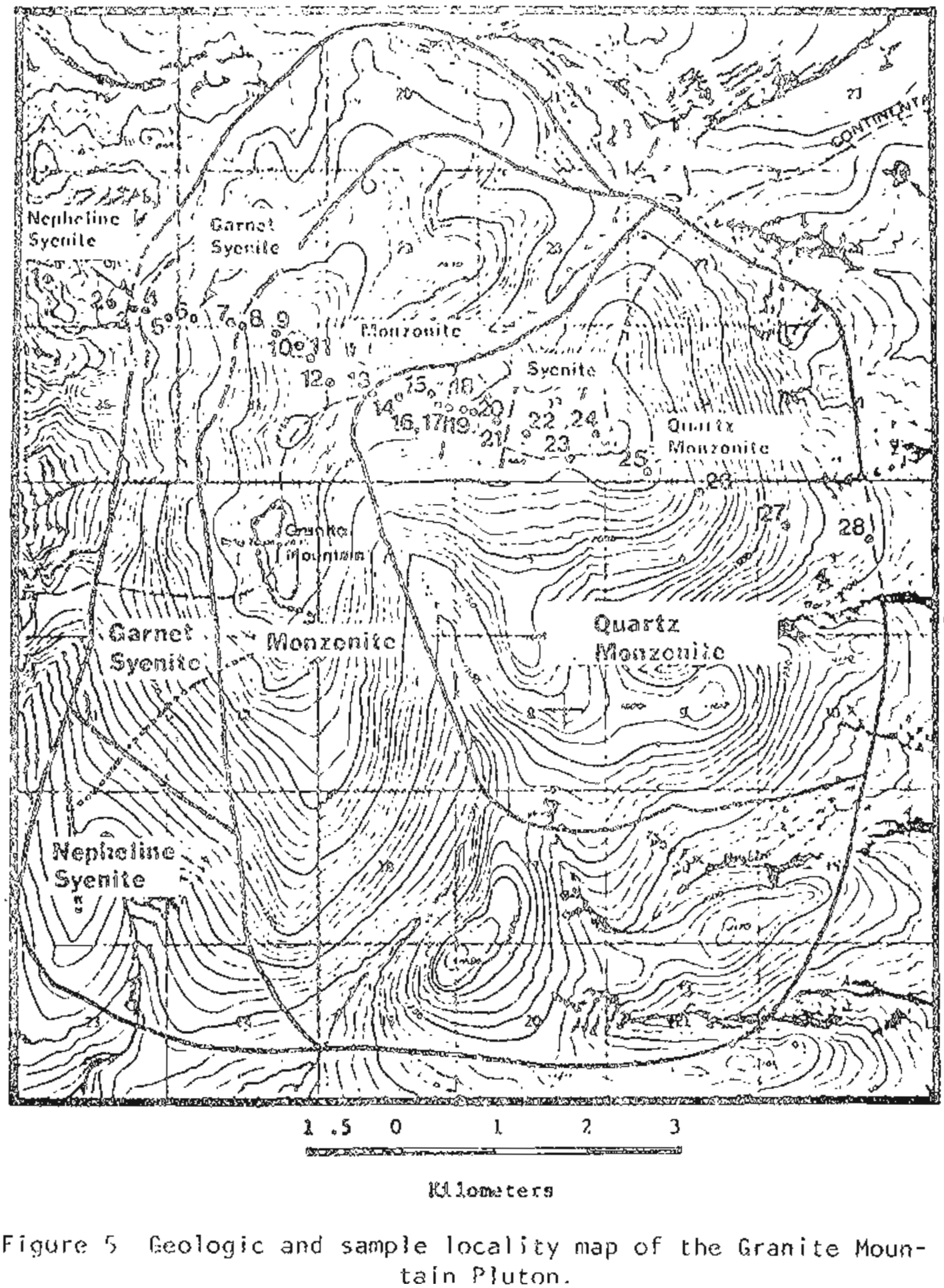


Figure 5 Geologic and sample locality map of the Granite Mountain Pluton.

In the figure, solid lines and rock names in large print represent the geology as taken from Miller (1972). Heavy dots are sample localities from the present investigation and the dashed lines and rock names shown in smaller print are contacts and rock types as determined from petrographic examination of these samples. Rock modes, as determined in this study, are shown in Figure 6 (see Appendix A for point-counting techniques). There are major differences between the geology as determined by Miller (1972) and what we determined during our detailed traverse.

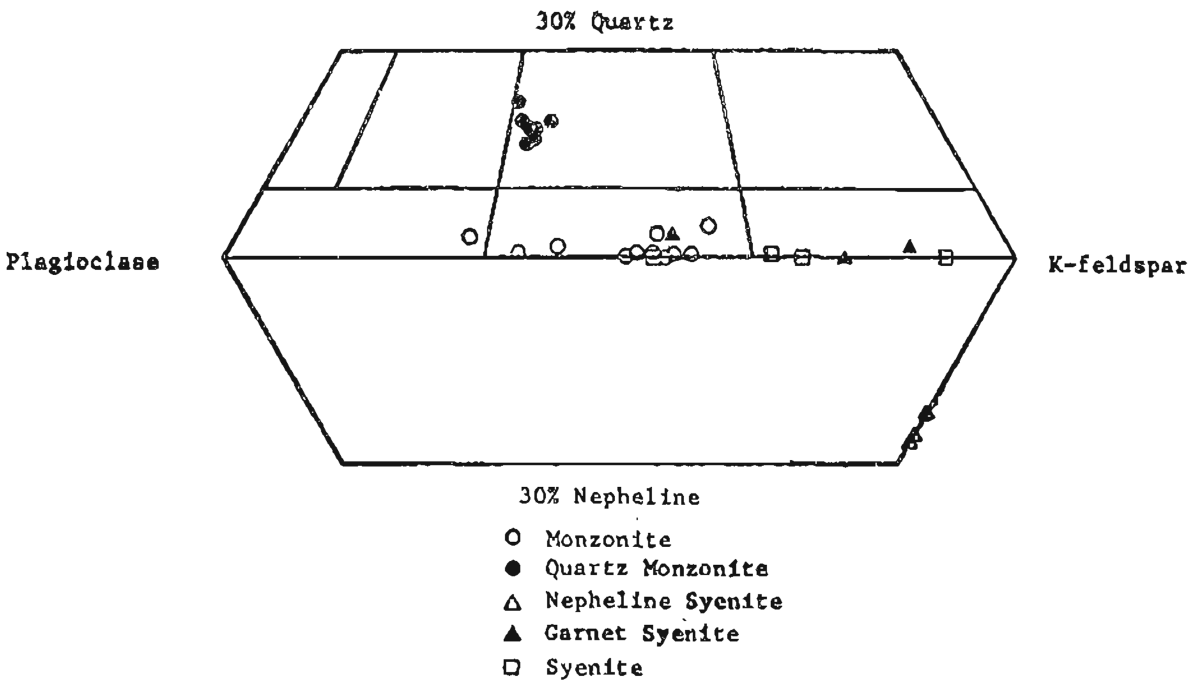


Figure 6. Rock modes from the Granite Mountain Pluton.

Contact Relations

As seen from aerial photographs a distinct lineament is coincident with the west boundary of the Granite Mountain Intrusive. Andesite breccia was found at location 2, Figure 5. There is little or no evidence of re-crystallization of the andesitic country rock adjacent to the intrusive. These observations suggest that the western contact is a fault.

The eastern contact is covered by tundra and its nature in the vicinity of the traverse was not determined.

The exact location of the western contact along the traverse was fixed with the use of a scintillation counter (Figure 7). Although the area is covered by tundra, the location at which the scintillation count begins to increase is also marked by a distinct vegetation change. The contact has been mapped at this vegetation change.

Nepheline Syenite

A newly recognized nepheline syenite unit is inferred at sample locality 3 because of the discovery of relatively abundant nepheline syenite float. This sample locality is located on a broad saddle, with andesitic rocks to the west and syenite and monzonite to the east. The only likely source for the nepheline syenite float is the bedrock beneath the tundra-covered saddle. Making this assumption we are able to map a thin unit of nepheline syenite.

The modal composition of the nepheline syenite as determined by point counting three rock samples is shown in Table 1.

Table 1

Modal Percentages of the Granite Mountain Nepheline Syenite

Mineral	Mean	Standard Deviation	Range
Nepheline	18.6	15	16.5--21.2
Orthoclase	56.3	3.12	52.8--58.7
Aegerine	5.6	1.42	4.3--7.1
Biotite	4.3	.6	3.6--4.8
Garnet	14.3	5.9	7.5--18.3
Apatite	trace		
Orthite	trace		
Opaques	trace		
Zeolites	trace		
Cancrinite	trace		

The nepheline syenite has a medium-grained hypidiomorphic granular texture with no mineral foliation. However, there is evidence of shearing and cataclasis between large orthoclase grains.

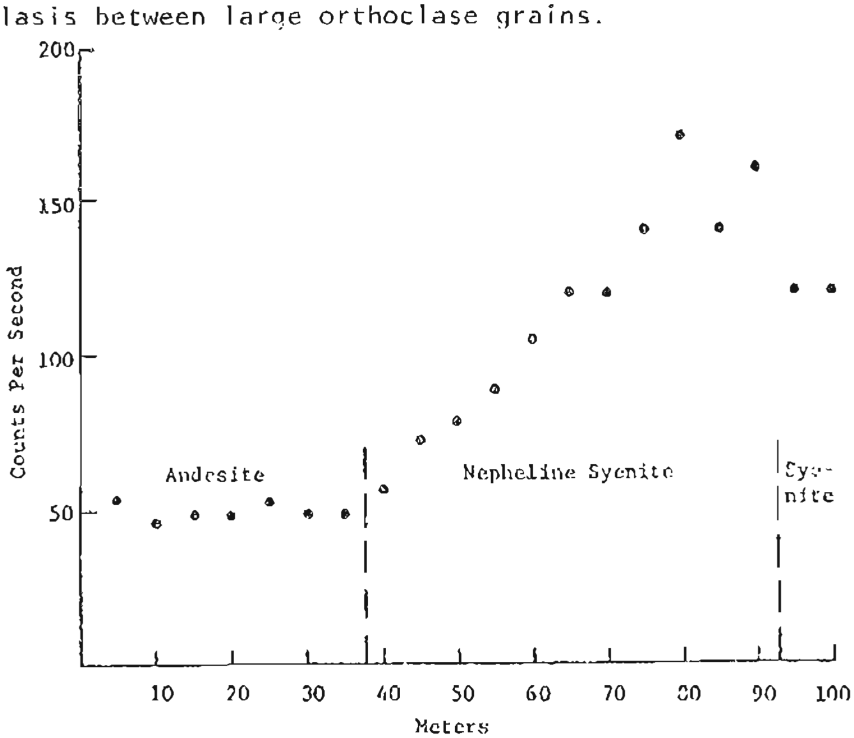


Figure 7. Scintillation counter readings across the west margin of the Granite Mountain Pluton.

Perthitic orthoclase occurs as subhedral grains up to 5 mm in length. Nepheline is interstitial in the feldspar fabric, and can be distinguished in the outcrop because it develops negative relief on weathered surfaces. In thin section, the nepheline can be distinguished by higher relief than feldspar; most grains show some form of alteration to cancrinite, clay minerals or zeolites.

Aegerine is deep green, occurring in subhedral grains with an optic angle of $60^{o}(-)$. Euhedral dark-reddish brown melanite garnet, a titanium-rich form of andradite, is also abundant.

The contact with the garnet syenite to the east cannot be observed because of the tundra cover. Miller (1972) believes that the contacts within the zoned intrusive are sharply gradational. The existence of similar looking malanite garnets in the two units suggests a genetic interrelationship.

Garnet Syenite

The garnet syenite unit is characterized by porphyritic and gneissic textures. Orthoclase feldspar, constituting as much as 60 percent of the rock occurs in large dull-white colored crystals up to 5 cm in length. The garnet syenite unit as shown in Figure 5 has been mapped more in terms of texture than mineralogy. The mode varies substantially within the unit and half of the rocks examined in this study were monzonites. The distinctive porphyritic and gneissic textures found in the unit are in sharp contrast to the fine-to-medium-grained subhedral textures of the monzonite and quartz monzonite to the east.

Miller's (1972) petrographic modal summary of this rock unit is given in Table 2.

Table 2

Modal Percentages of the Granite Mountain Garnet Syenite (after Miller, 1972)

Mineral	Modal %
Quartz	absent
Nepheline	accessory
K-feldspar	31-60%
Plagioclase	22-38%
Mafic minerals: (hornblende, garnet and clinopyroxene)	15-30%

In the petrographic examination of six samples from 4 localities within the unit, the modal percentages fell within the limits determined by Miller, with the exception that quartz was found in all sections in minor amounts.

Accessory minerals include large euhedral sphene crystals, apatite, and traces of secondary carbonate.

The pleochroic scheme of the amphibole is: x=bluish green, y=deep green to black, z=light yellowish green, suggesting high concentrations of Na and Fe. The amphibole appears to be in the eckermannite-arvedsonite family of amphiboles, a group of amphiboles characteristic of alkaline igneous rocks and their associated pegmatites (Deer and others, 1963).

Monzonite

Table 3 shows percentages of mineralogy of 10 thin sections and rock slabs from the monzonite unit at Granite Mountain.

Table 3

Modal Percentages of the Granite Mountain Monzonite

Mineral	Average Mode	Std. Dev.	Range
Quartz	.42	0.48	.1-2.9
Plagioclase	39.9	7.2	32.7-55.8
K-feldspar	44.9	7.6	23.4-57.6
Amphibole	7.4	4.2	2.5-13.4
Pyroxene	5.4	2.3	2.2-13.9
Sphene	0.5	.3	.1-1.2
Apatite	.5	.2	.1-.9
Opaques	.6	.3	.1-1.3

The monzonite is generally equigranular showing no distinctive planar foliation. Grains average 1-3 mm in size and often show evidence of shearing and cataclasis along their margins. Although this is the predominant texture, a few samples of a coarser monzonite were collected in the unit that showed gneissic and porphyritic textures similar to those found in the garnet syenite unit. The existence of these samples suggests that the granitic texture in the monzonite is the result of grain size, and that the monzonite may have been sheared by the same process that effected the outer syenite unit.

Plagioclase An_{15-28} occurs in zoned, largely untwinned crystals .5-3 mm in size with altered calcic cores. it is locally antiperthitic. K-feldspar is very perthitic and occurs in subhedral crystals. Quartz is not abundant and is interstitial to the feldspars.

Amphibole and aegerine-augite are the major mafic constituents, comprising as much as 17% of the rock. Although chemical analyses are not available for this rock unit the existence of aegerine-augite suggests that the ratio of alkalies to silica may exceed 1/6, that necessary to classify this rock as alkaline (see Appendix 2).

Sphene and apatite are abundant in most of the thin sections. Other accessories include fluorite and zircon.

Syenite

East of the monzonite unit, a zone of pyroxene hornblende syenite, similar texturally to the garnet syenite unit was discovered. The syenite unit was discovered. The syenite unit is .75 km wide along the traverse line. Although it was not mapped throughout the pluton, our reconnaissance of the zone in a north and south direction revealed that the unit persists for at least 500 meters.

The syenite unit as shown in Figures 5 and 6 consists of a number of rock types exhibiting a characteristic gneissic and porphyritic texture, dominated by coarse grains of K-feldspar in a matrix of plagioclase and mafic minerals.

Of the six samples examined from four localities within the syenite unit, four of these rocks are actually syenite, the remaining two are monzonite. Leucocratic quartz monzonite vein-rocks were also found.

Perthitic orthoclase in subhedral, aligned, grains is the predominant mineral within the syenite unit, constituting up to 91% of the rock. Plagioclase An_{18-23} is subhedral and largely interstitial to the K-feldspar. Much of it has been altered to sericite. Traces of fine-grained interstitial quartz were found in all of the thin sections studied.

The composition of the amphibole is variable as indicated by a variety of pleochroic schemes seen in different specimens. In some of the variants the amphibole is a brown hornblende; other samples show the blue-green pleochroism indicative of Na-rich amphiboles.

The pyroxene is zoned aegerine-augite, displaying a light greenish color in the center of the crystals, the color growing more intense towards the rim.

Some sections show indications of late stage introduction of silica and albite in small veins of myrmekitic intergrowths. Cataclasis is evident, particularly along the grain boundaries of the feldspar.

Titanium concentrations for the two syenite units in the Granite Mountain Pluton are almost identical. A chemical analysis of a sample of the garnet syenite yielded 0.59% TiO_2 (Miller, 1972). The titanium content of the syenite unit, as determined through point counting analysis, is 0.40%. Additional accessory minerals include apatite and zircon.

Although the contact between the monzonite and syenite units could not be seen because of the absence of outcrop, the lithologic change was observed to occur over an area of a few meters suggesting a sharp contact.

Quartz Monzonite

The contact between the syenite unit and the quartz monzonite occurs in a tundra covered saddle (Figure 5), and the exact location was not pin pointed. Texturally the quartz monzonite is quite different from the syenite units, but is similar to the monzonite to the west.

Seven samples were collected from the quartz monzonite unit. The modes of these samples are quite similar, as are their textural features (Figure 6).

The quartz monzonite is medium-grained and roughly equigranular. The texture is characterized by plagioclase mantled by large microcline crystals in optical continuity. Presumably the liquid magma became depleted in sodium and calcium during crystallization and the plagioclase became unstable. The magma, now enriched in potassium began to crystallize K-feldspar around the crystallization sites initiated by the sodic plagioclase. All of the granitic uranium-bearing rocks of the eastern Seward Peninsula and northern Yukon-Koyukuk basin examined in this study display this unusual texture.

The most abundant mineral phase is plagioclase, An_{25-32}. It is normally zoned with altered cores. Microcline is very perthitic. Interstitial quartz constitutes as much as 21.% of the rock. The abundance of quartz appears to increase towards the east.

The amphibole has a slight greenish tint, and in some cases is seen rimming biotite crystals. A few small augite crystals were observed. Biotite is found is some samples, partially altered to pennine. Accessory minerals include sphene, apatite, and traces of minute zircon crystals.

Although the quartz monzonite does not display a gneissic fabric in hand specimen, on the microscopic scale there is definite evidence of cataclastic deformation which occurred largely in the solid state. Granulation as the result of shearing has occurred along feldspar boundaries. In addition quartz grains commonly show wavy extinction. All of the zones in the Granite Mountain Pluton appear to have been subjected to cataclastic deformation, but because of their different average grain sizes during the cataclastic event, each unit has responded differently. Examination of the intergranular boundaries suggests that the quartz monzonite has been subjected to shear stresses similar to those that deformed the syenite unit to the west. The persistence of the granitic texture is a result of the smaller grain size and the absence of elongated feldspar laths.

Alteration in the feldspars, pennine replacing biotite, and the occurrence of amphibole rimming biotite suggests that the quartz monzonite has been affected by a period of thermal metamorphism.

Potassium Analyses

Whole rock potassium analyses were made of variants from the Granite Mountain Pluton using atomic absorption spectrometry. These data are shown graphically in Figure 8. A general decrease in potassium occurs towards the east, disturbed by a number of major fluctuations, particularly within the syenite units.

Comments on the Genesis of the Granite Mountain Pluton

The existence of a similarly zoned alkaline complex at Cape Deshnev in Siberia suggests that the zone is not the result of anatexis of the country rock (Miller, 1972). Miller suggests that the zoning is the result of multiple injection by a magma, with the initial composition of a leucite prophyry that has separated into two magmas and differentiated, forming the four major rock types at Granite Mountain. Miller notes that such a differentiation scheme has been suggested by Fudali (1963) and Bowen (1928) for similar zoned alkaline complexes.

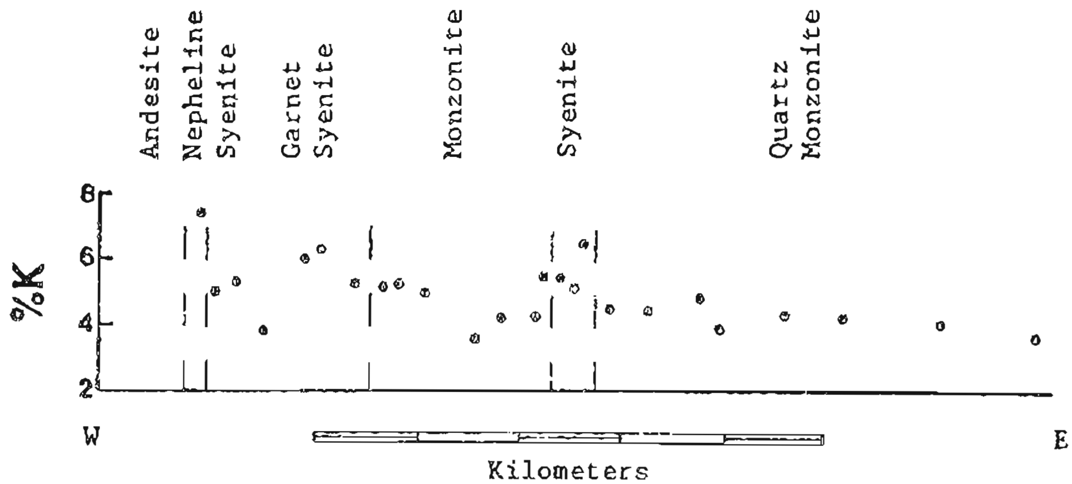


Figure 8. Variation in potassium across the Granite Mountain Pluton

The existence of the additional syenite unit adjacent to the quartz monzonite at Granite Mountain makes models for the origin of this stock even more difficult. The study of the geology along this traverse in detail suggests that the zoning is much more complex than was believed by Miller (1972) during his initial reconnaissance. In addition, the continuous increase in quartz from west to east suggests that we are only observing half of the pluton. Before the crystallization history can be determined, detailed geologic mapping will have to be conducted over the entire pluton. At present the nature of the contacts is largely speculative. The absence of actual outcrop makes the determination of contact relations difficult, and the complete lichen cover makes geologic investigations tedious.

Darby Pluton

The Darby Mountains form a prominent north-trending mountain range in the eastern Seward Peninsula, extending from Cape Darby to the Bendeleben Mountains, a distance of about 85 km. The Darby Pluton, a sinuous quartz monzonite body, comprises the east side of this mountain range. In sharp contrast to the Granite Mountain intrusive, the Darby Pluton is enriched in silica and contains as much as 32% quartz.

High uranium values from the Darby Mountains were discovered in pan concentrates of stream sediment samples by Gault and others (1953). Miller and Bunker (1975a) conducted a hard rock sampling survey of the Darby Pluton, the adjacent Kachauik Pluton and the Bendeleben Pluton.

An east-west traverse approximately 12 km in length, was conducted during this study across the Darby Pluton in the vicinity of Vulcan Creek. In the area of the traverse, the western edge of the pluton is in intrusive contact with low-to-medium-grade metamorphic rocks of Precambrian age (Miller and others, 1972) On the east side, the Darby Pluton is in fault contact with Devonian dolomite.

Thirty rock samples were collected from the 22 localities shown in Figure 9. There is considerable variability in the mode across the traverse as indicated by the scatter in Figure 10.

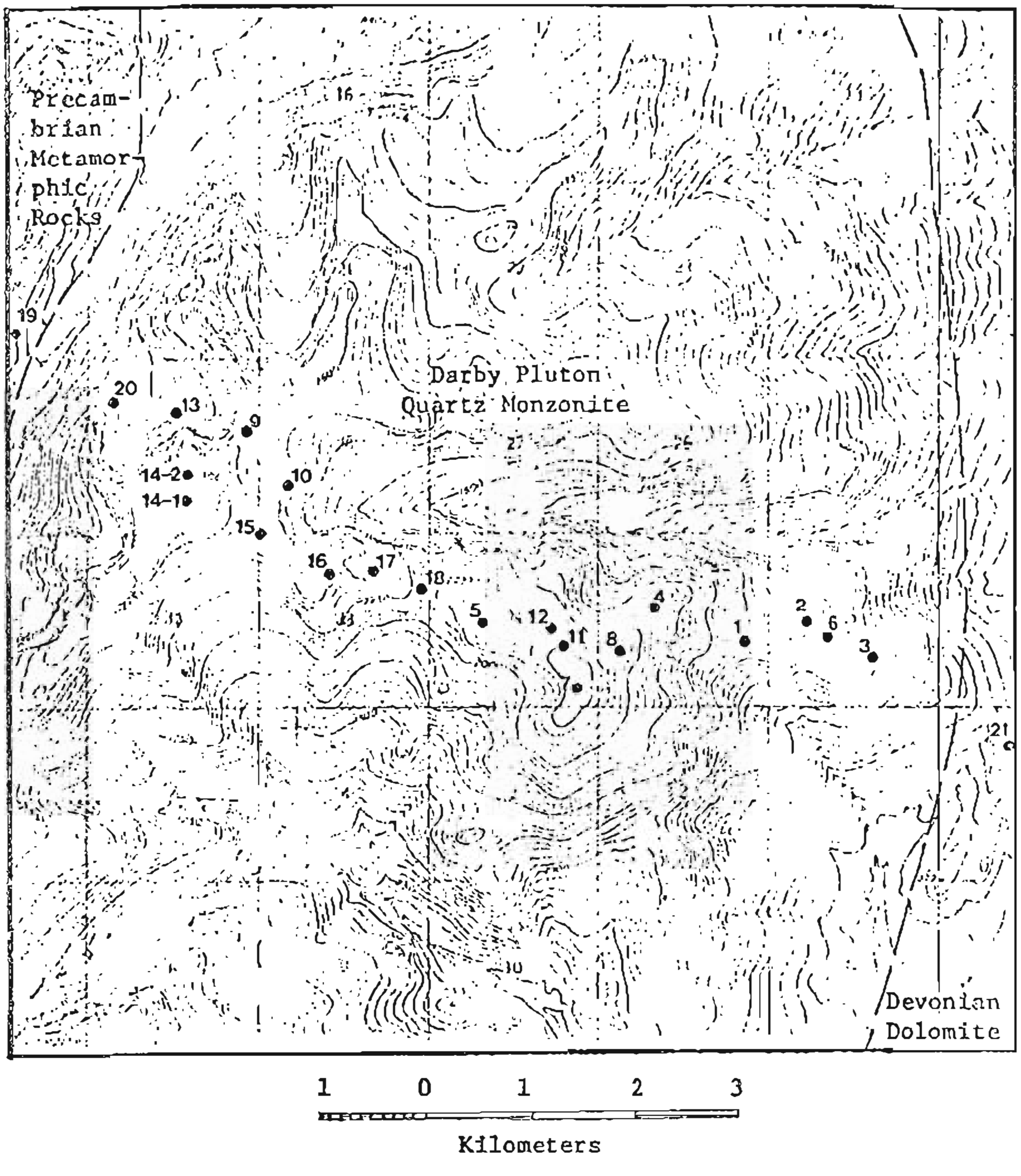


Figure 9. Geologic and sample locality map of the Darby Pluton. • Sample localities.

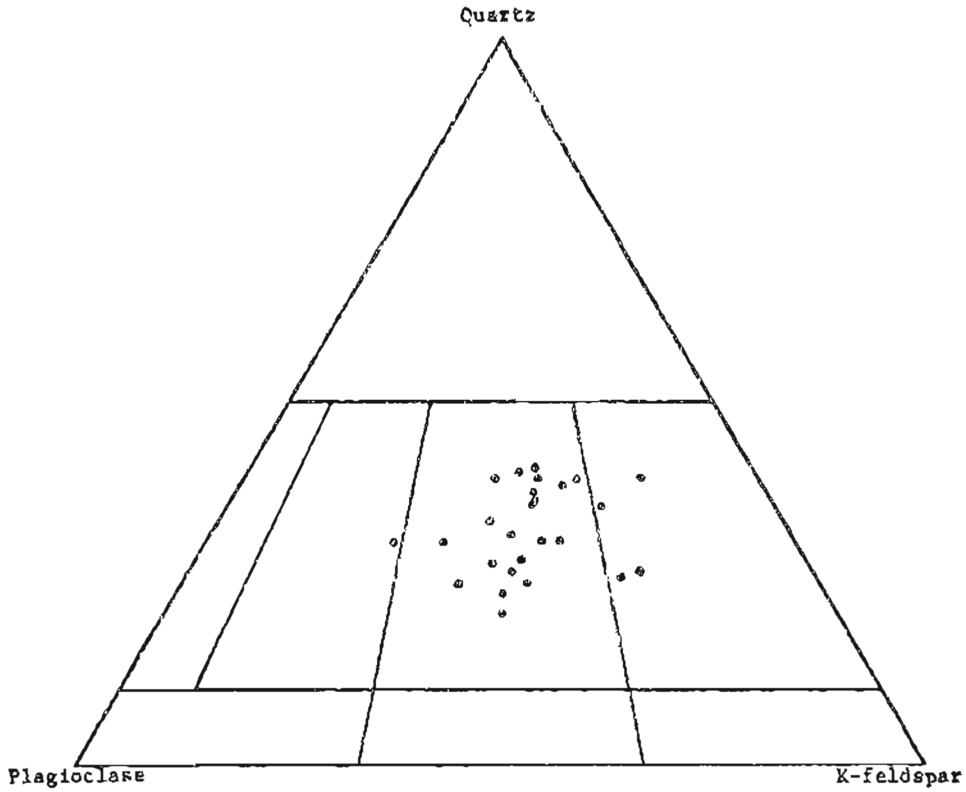


Figure 10. Rock modes from the Darby Pluton.

The quartz monzonite of the Darby Mountains is a coarse-grained hypidiomorphic granular rock showing no tendency towards foliation of mineral grains. Orthoclase and plagioclase occur in approximately equal amounts. K-feldspar crystals are typically the largest phase in the rock, up to 2 cm in length. The K-feldspar is perthitic and subhedral. Plagioclase An_{18-27} occurs as interstitial anhedral grains and subhedral crystals showing normal zoning and some alteration of the more calcic cores.

Quartz occurs as interstitial grains and occasionally as large crystals of subhedral habit. Biotite is the only mafic mineral and constitutes no more than 5% of the rock. It is partially altered to chlorite in some specimens.

Potassium Analyses

Potassium analyses from the rock samples collected from the Darby Pluton are presented in graphical form in Figure 11. There appears to be no significant systematic change in the potassium content across the pluton.

Zane Hills

The Zane Hills form a small mountain range trending N30W, located on the Koyukuk River near the east end of the Hogatza Plutonic Belt. They are cored by the Zane Hills pluton, a Cretaceous batholith consisting of granodiorite, monzonite, hybrid diorite, and a previously undescribed unit consisting of augen gneiss and dike rocks. A geologic and sample locality map is shown in Figure 12. Modes are shown in Figure 13.

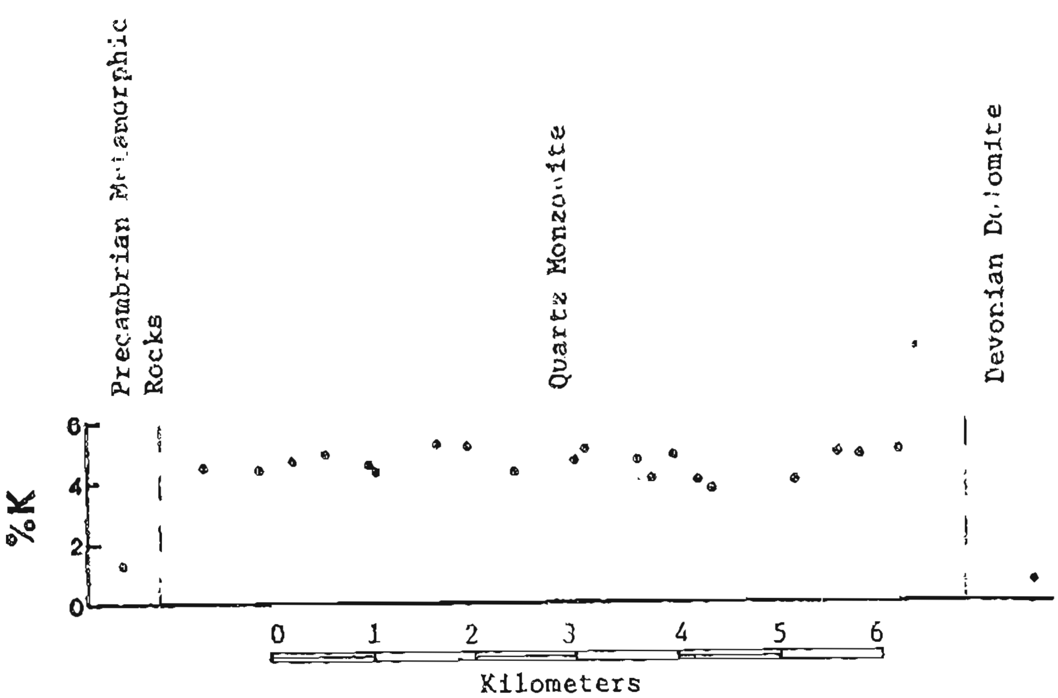


Figure 11. Variation in potassium across the Darby Pluton.

Granodiorite

The major plutonic phase in the Zane Hills is an equigranular medium-grained granodiorite, divided by Miller (1970) into a northern hornblende granodiorite zone and a southern biotite granodiorite zone. Ten samples were collected in a traverse through the hornblende biotite zone.

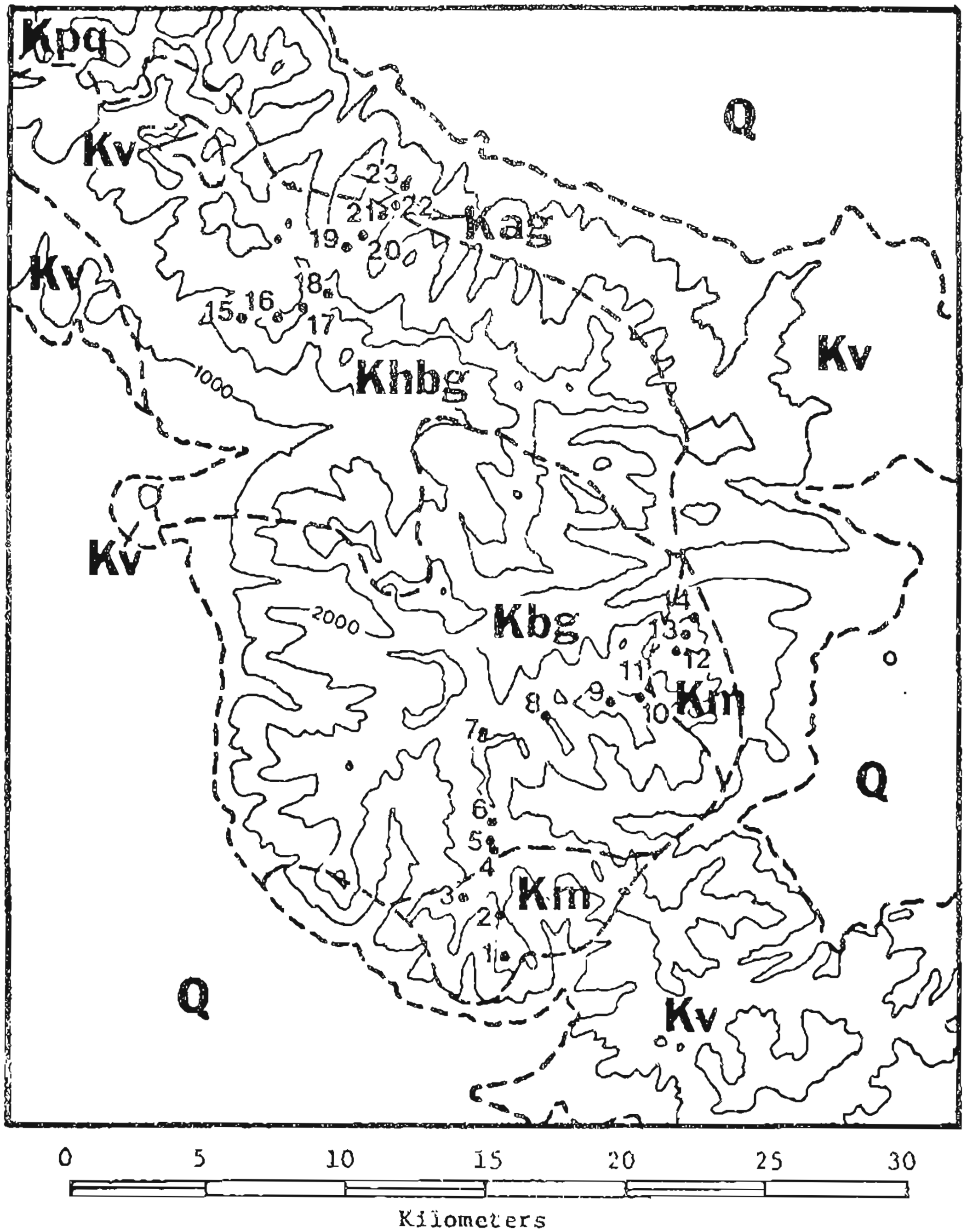
Plagioclase is the most abundant mineral, occurring in subhedral grains with oscillatory zoning. Microcline is found as subhedral crystals rimming the plagioclase in a similar texture to that seen at Granite Mountain. Quartz constitutes as much as 20 percent of the rock and is found as anhedral crystals. Biotite is the most abundant mafic mineral, comprising approximately 2.5% of the rock. The biotite is often partially altered to chlorite. Sphene and apatite are the main accessory minerals.

A striking characteristic of the Zane Hills Granodiorite is its textural homogeneity.

Auger Gneiss

Along the east margin of the Zane Hills, an augen gneiss zone, approximately 1 km wide, was located along the north traverse.

Plagioclase occurs as large rounded augens, up to 1 cm in size, in a fine grained matrix of K-feldspar, plagioclase, and quartz. The mafic minerals, hornblende and biotite, are banded and smeared around the large plagioclase crystals in an unmistakable cataclastic texture. Petrographic



Explanation

Khbg	Hornblende biotite granodiorite	Kpq	Porphyritic quartz monzonite
Kbg	Biotite granodiorite		
Km	Monzonite	Kv	Volcanic rocks
Kag	Augen gneiss	Q	Alluvium

Figure 12. Geologic and sample locality map of the Zane Hills (after Miller, 1970).

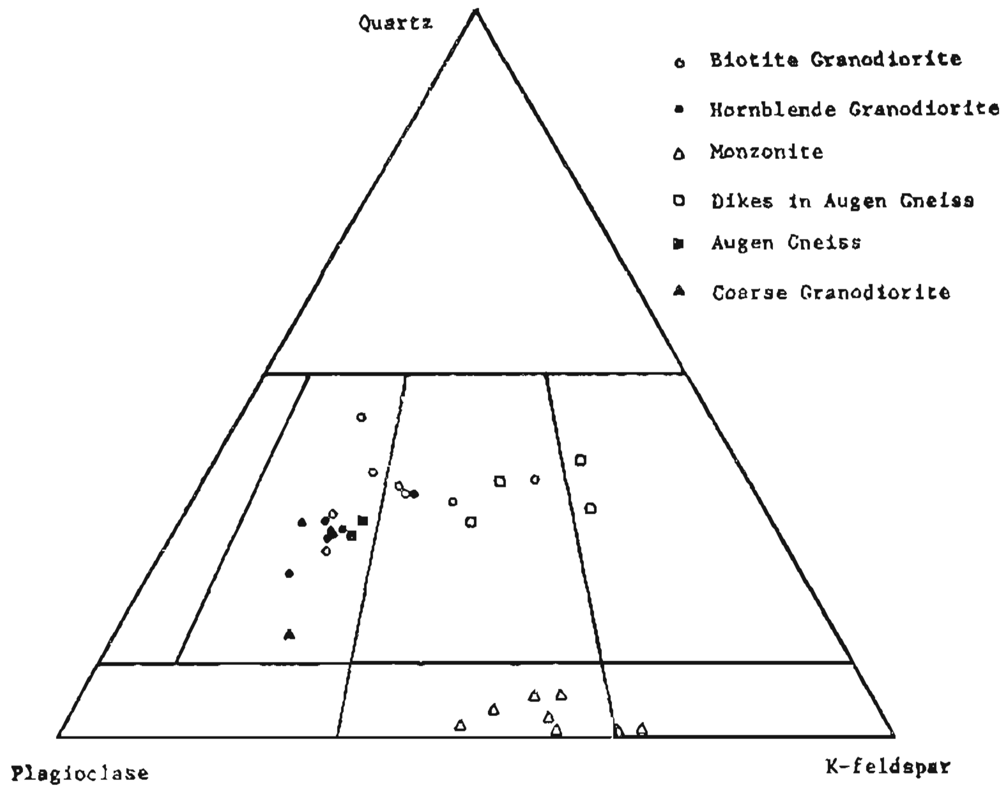


Figure 13. Rock modes from the Zane Hills.

analyses of stained rock slabs and thin sections from these samples show that the mode within this zone is identical to the Zane Hills granodiorite (Figure 13). The augen gneiss appears to be a recrystallized phase of the granodiorite, subjected to intensive shearing. The existence of this phase along the eastern margin of the Zane Hills pluton suggests a fault contact with the andesitic country rock.

Within the augen gneiss zone other rock types were found, including fine-grained gneissic dikes and aplite and pegmatite dikes.

Monzonite and Hybrid Diorite

Two zones of monzonite and hybrid diorite, containing anomalous concentrations of uranium and thorium are exposed along the southern margin of the Zane Hills (Figure 12) (Miller, 1970).

The monzonite is variable in texture from roughly equigranular to gneissic. Two stages of plagioclase crystallization are apparent. Plagioclase An_{10-25} occurs in medium to large subhedral grains and as fine-grained late stage myrmekitic intergrowths with quartz. Perthitic microcline occurs in large subhedral grains, up to 3 cm in size, or interstitially. Interstitial quartz is present in minor amounts. A sea-green amphibole is the major mafic mineral, making up as much as 15% of the rock. Brown biotite is abundant, whereas pyroxene is found only in minor amounts. Accessory minerals include sphene, apatite, zircon, and rutile.

The hybrid diorite is a contact metamorphic rock. Its origin is the result of the incorporation of xenoliths into the granodiorite magma (Miller, 1970) and the composition of this phase is variable. Hornblende makes up as much as 70% of these rocks, often seen rimming pyroxenes. The common texture is banded and porphyritic with large amphibole and plagioclase crystals in a fine-grained felsic matrix. Plagioclase has altered to sericite in some cases. This rock type contains few accessory minerals.

Miller (1970), in his investigation of the plutonic rocks of West-Central Alaska, used the term alkaline rock in the sense of Turner and Verhoogen (1960); 'a rock in which the alkali content is sufficiently high as compared to silica for specially alkaline minerals such as feldspathoids to appear.' Thus Miller's usage of the term is distinctively different from the chemical classification used in this report (see Appendix 2). The Zane Hills monzonite does not contain feldspathoids. As a result Miller does not consider it to be part of the alkaline belt and places the eastward limit of this belt at the Ekiek Creek Pluton, 170 km to the west. A chemical analysis of the monzonite from the Zane Hills is shown in Table 4.

Table 4

Chemical Analysis of Monzonite from the Zane Hills taken from Miller, (1970).

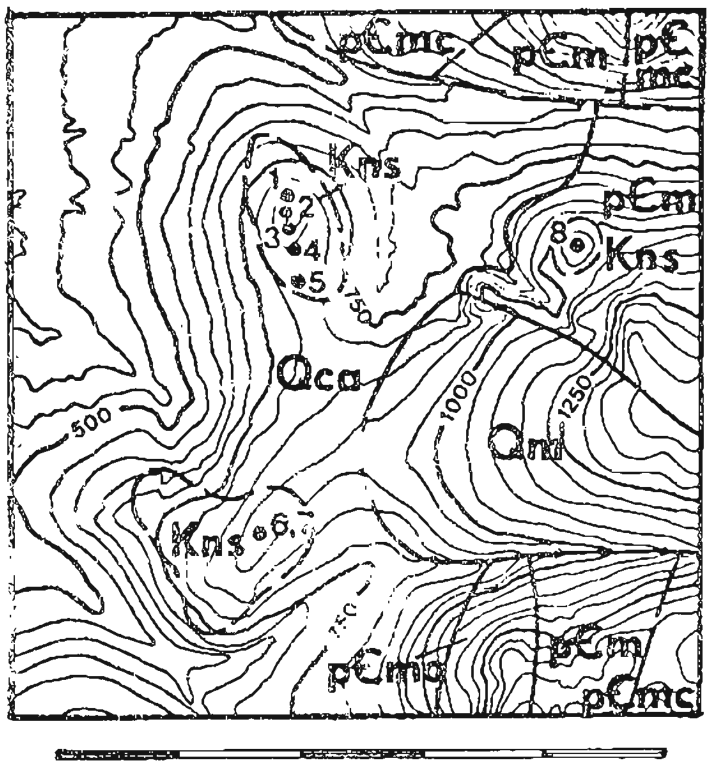
Oxides	Wt. %
SiO_2	61.1
Al_2O_3	19.0
Fe_2O_3	1.7
FeO	1.6
MgO	0.8
CaO	2.8
Na_2O	5.3
K_2O	6.3
H_2O^-	0.06
H_2O^+	0.67
TiO_2	0.39
P_2O_5	0.16
MnO	0.07
CO_2	0.05
Total	100.00

Total alkalies = 11.6, which is greater than 1/6 SiO_2. According to our classification (after Shand, 1922), this is an alkaline rock. The difference in classification schemes extends the belt of alkaline rocks 170 km east of the margin described by Miller (1972).

The Dry Canyon Creek Stock

Located on the west side of the Darby Pluton on the eastern Seward Peninsula, the Dry Canyon Creek Stock is described by Miller and others (1972) as a leucocratic to trachytoid foyaite (Figure 14). The stock is cut by blue-gray pulaskite dikes and has been tentatively assigned a mid-Cretaceous age based on a K-Ar age of 105 ± 3 m.y. (M.A. Lanphere, written communication in Miller and others, 1972).

Modes of 17 rocks determined from examination of stained thin sections and rock slabs are shown in Figure 15. The predominant rock type is a hornblende-biotite nepheline syenite, but other more mafic phases, such as hornblende-aegerine-augite alkali gabbro were also found. One sample of syenite containing less than one percent quartz was found in rubble crop.



Cretaceous
Kns--Nepheline Syenite and Alkali Gabbro.

Quaternary
Qm---Morainal Deposit
Qca--Colluvium and Alluvium.

Precambrian
pCmc-Metamorphic Complex
pCm--Marble

Figure 14. Geologic and sample locality map of the Dry Canyon Creek Stock, as modified from Miller and others (1972).

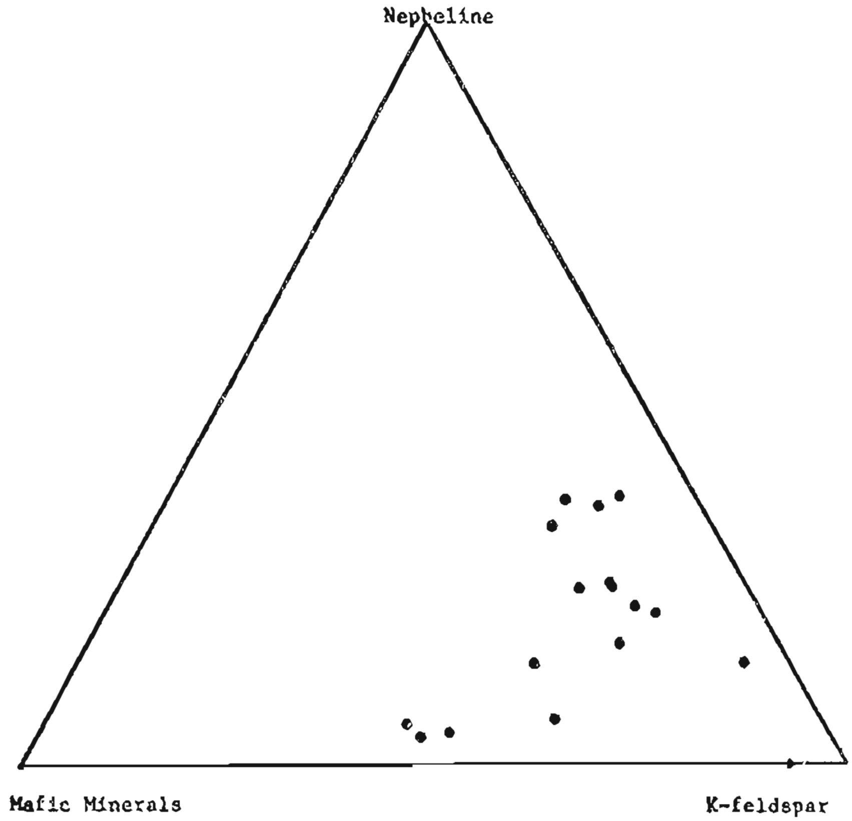


Figure 15. Modes of rocks from the Dry Canyon Creek Stock.

The potassium feldspar is anorthoclase which occurs as subhedral grains, often showing a mottled scotch plain twinning, distinctively different from that found in microcline. The maximum size of the anorthoclase crystals is 5 mm. Nepheline, which makes up as much as 35% of the rock, is in interstitial crystals, which have been largely altered to cancrinite. Often the anorthoclase and nepheline show evidence of exsolution structures including graphic and myrmekitic intergrowths, and what Bowen (1928) described as a fingerprint texture.

Plagioclase occurs as a minor constituent in some of the samples, and a major rock forming mineral in one case where it makes up 14.7% of the rock.

Biotite, hornblende, and pyroxene are found in varying proportions. Biotite is the major mineral in the leucocratic varieties where its habit is glomeroporphyritic or in bands and streaks.

The pyroxene is most common in the alkali gabbros where it is distinctively zoned, showing sodium enrichment towards the rim and a stronger augite component towards the center. The pyroxene makes up as much as 25% of some of the rocks sampled.

Brownish hornblende is found in both the leucocratic and mesocratic varieties, sometimes as reaction rims around the pyroxene, and in other cases rimmed by biotite. Hornblende and biotite are interstitial to the felsic minerals whereas the pyroxenes are subhedral and appear to have formed prior to crystallization of the light colored minerals.

The predominant texture is one that appears to be glomeroporphyritic, but is actually a relict texture resulting from the exsolution of large subhedral leucite crystals, in a matrix of mafic minerals, predominantly biotite. The texture appears as circular aggregates of nepheline and anorthoclase, surrounded by bands of biotite and hornblende. Upon careful examination some of the round cross sections appear to have eight sides, a relict of the original crystallization history. Flow banding or perhaps a minor shearing of the rock during the latest stages of crystallization have caused some distortion and elongation of the pseudoleucite cross-sections. This period of deformation could not have been very severe because little evidence of cataclastic deformation is evident along grain boundaries.

Much of the biotite has experienced severe radiation damage. There are abundant pleochroic haloes which are the result of uranium and thorium in zircon and apatite crystals. The apatite appears to contain a much higher concentration of uranium and thorium than in other rocks examined in this study, as evidenced by the width of the haloes. In one sample, the margins of the biotite crystals are black. These crystal margins looked quite similar to the pleochroic haloes caused by the radioactive accessories incorporated within the biotite. This distortion of the pleochroism along grain margins suggests that the adjacent minerals, in this case hornblende, nepheline and anorthoclase, are high in uranium and thorium.

A light colored garnet, perhaps andradite, is present in substantial amounts (4%) in some of the samples. The garnet occurs as anhedral grains in roughly circular swarms, suggesting that a number of these small equant grains are part of a much larger garnet crystal.

Melilite, characterized by high relief, low birefringence, a uniaxial negative sign and light yellowish color, is seen in three of the samples, making up as much as 5.6% of the rock The mineral occurs as small interstitial grains, and occasionally as elongate subhedral crystals up to 1 mm in length.

Carbonate is found in all of the samples in minor or accessory amounts. It is difficult to tell whether the carbonate is the result of remobilization of calcite or dolomite from the nearby metamorphic terrain, or if it is primary. The carbonate grains are very small, usually 0.1 mm in size. They are anhedral but do not appear to be restricted to vein areas, nor do they appear to be replacing other minerals.

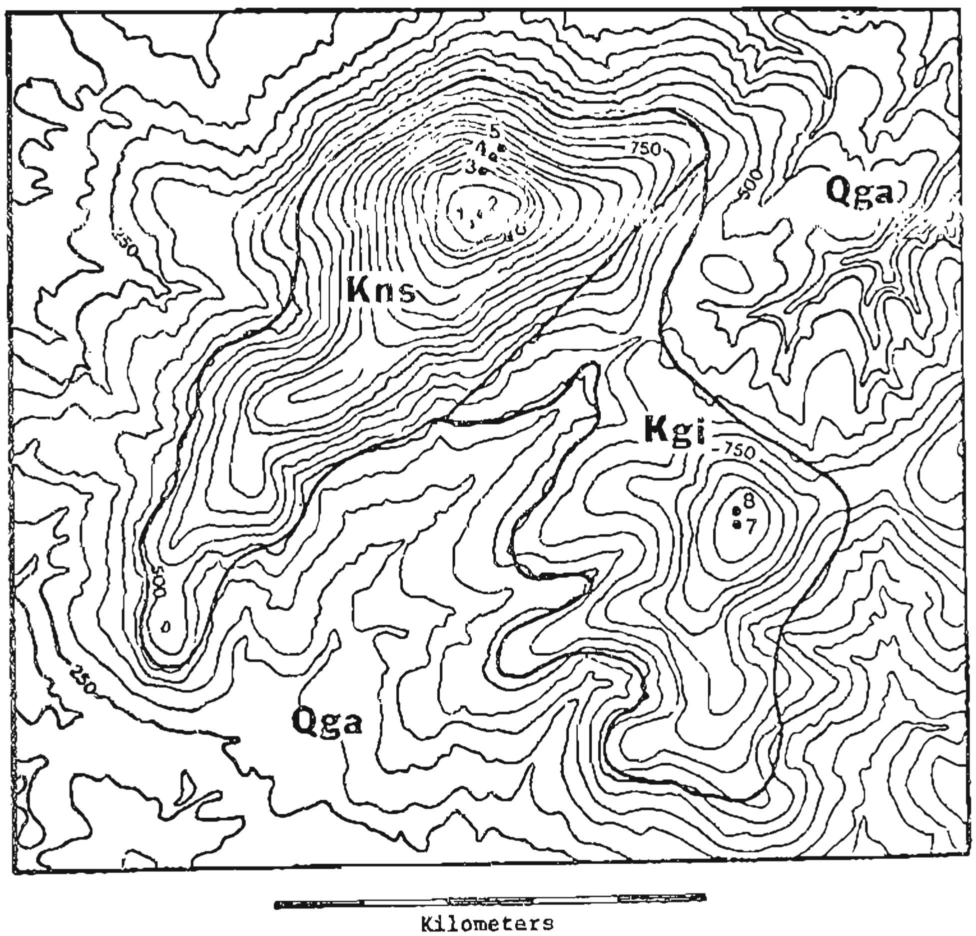
The fact that the carbonate minerals are found in so many of the sections as disseminated grains, and the coexistence of melilite in these rocks strongly supports a primary origin. The occurrence of carbonate-bearing vein rocks of primary origin in the Selawik Hills (Eakins and others, in press) also supports this conclusion.

Quartz occurs as an accessory mineral in one syenite sample. Other accessory minerals include sphene, apatite, and zircon.

Selawik Lake Complex

The Selawik Lake Complex is a small (18 sq. km in area) alkaline pluton located on the south shore of Selawik Lake in western Alaska. The northern half of the complex is composed of massive leucocratic juvite (Miller, 1972). Melanite garnet is abundant, constituting as much as 15 percent of the rock. The southern half of the pluton is poorly exposed and consists of perthosite and malignite. The alkaline stock is in fault contact with a syenite that contains minor amounts of quartz (Miller 1972).

Modes of 10 rock samples from the Selawik Lake Complex are shown in Figure 17. A location and geologic map is shown in Figure 16. Sample localities are restricted to the north side of the pluton because outcrops are virtually absent in the southern half. Of particular interest are samples AP-6A, B, and C, taken from a zone of dike intrusion and alteration that contains uranium values as high as 92 ppm.



Explanation

Cretaceous
Kns-Nepheline Syenite
Kgi-Syenite and Monzonite

Quaternary
Qga-Undifferentiated Glacial Drift

Figure 16. Location and geologic map of the Selawik Lake Complex.

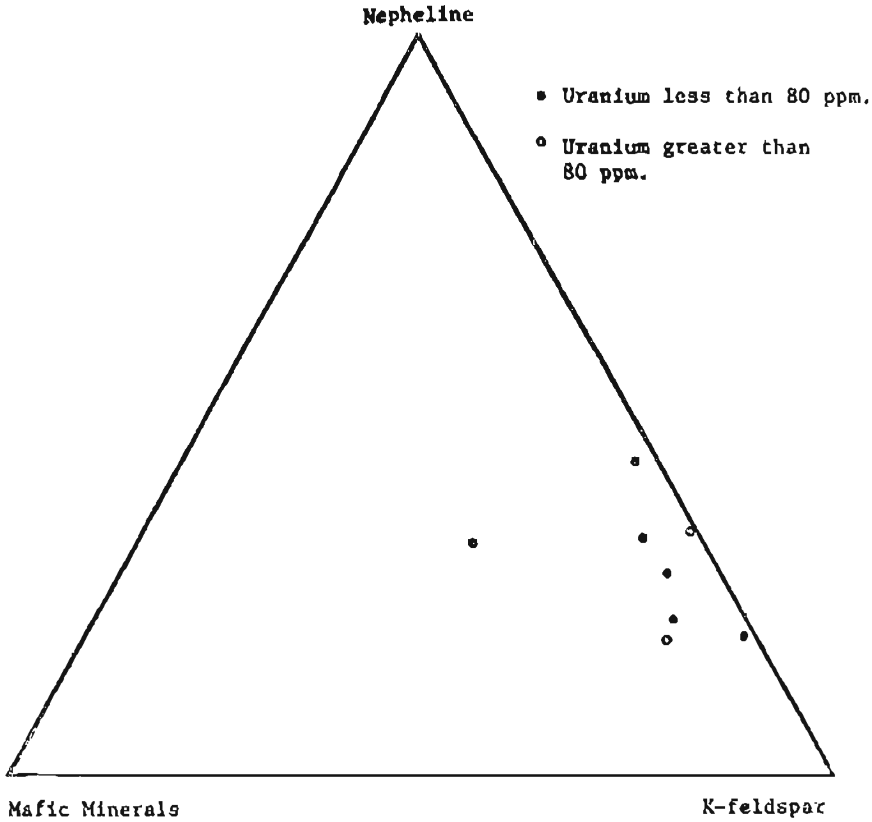


Figure 17. Modes of rocks from the Selawik Lake Complex.

The major rock type found in the samples collected during the 1975 field season is a garnet and aegerine-bearing biotite nepheline syenite. The major minerals include orthoclase, nepheline, cancrinite, aegerine, biotite, and melanite garnet. Kalsilite has also been identified (Miller, 1972).

The predominant textures found in these samples are complex intergrowths that are the result of exsolution. A fine-grained fingerprint intergrowth is found in most samples studied and less commonly, a medium-grained graphic exsolution texture. The complexity of the exsolution made the determination of the modes difficult and a large error is associated. Petrographic analysis was aided by the use of a methylene blue nepheline stain (see Appendix 4). The stain clearly defined the nepheline in the fingerprint intergrowths. A number of intergrown crystals were first point counted separately at closely spaced intervals to determine the average ratio of nepheline to K-feldspar within the intergrowths. After the percentage was determined the intergrown crystals could then be counted as one phase and the proper proportions of the two felsic minerals determined after counting was completed.

The habit of the nepheline and K-feldspar crystals seen in these rocks is the result of these exsolution textures. K-feldspar is orthoclase, which sometimes occurs as very large crystals, up to 10 cm in size.In hand specimen the feldspar is often rose colored. Nepheline is anhedral, in smaller grains that are sometimes altered to cancrinite. Plagioclase was not found in any of the sections studied.

Mafic minerals are commonly found in glomeroporphyritic crystals and in bands. Biotite, the most common mafic mineral, is a dark brown variety often showing distinct pleochroic haloes, as the result of radiation damage from included apatite and zircon crystals. The pyroxene is a deep green aegerine, sometimes rimmed by biotite, in subhedral grains approximately 1 mm in size. Melanite garnet is intimately associated with the pyroxene in some sections, suggesting a genetic relationship. It appears that the garnet has exsolved from the pyroxene. This could occur if an aluminous pyroxene had crystallized initially at considerable depth and then had exsolved the Al^{++} ion as the result of a decrease in pressure. The aluminum could then go into the formation of garnet, a melanite form of andradite if enough Ti^{4+} was present. Sphene is also found in some of the glomeroporphyritic crystals, suggesting that titanium was abundant.

A dark reddish-brown amphibole occurs as a minor mineral. The accessory minerals include apatite, zircon, fluorite, and pyrochlore, a thorium-bearing mineral associated with nepheline syenite.

Two rock samples from the adjacent syenite were analysed for their uranium and thorium content and their modes determined by petrographic analysis. The syenite is medium-grained, with a gneissic texture, and contains less than 1% quartz. Whereas plagioclase is absent in the alkaline stock to the west, in the syenite unit it makes up 6-8% of the rock.

Aegerine-augite and an amphibole are the mafic minerals, making up as much as 15% of the rock. The amphibole has a striking blue-green component to its pleochroic scheme, suggesting a high Na concentration.

As noted in the discussion of the monzonite at Granite Mountain, and in the monzonite in the Zane Hills, the classification as alkaline by Shand (1922) would probably include this rock type. Although quartz is present in minor amounts, the presence of quartz is probably the result of abundant calcium, magnesium, and iron, which allowed the early formation of sodium-bearing amphiboles and pyroxenes. The incorporation of sodium in these minerals depleted the melt in this component during later stages of crystallization. As a result, nepheline did not form, and the percentage of SiO_2 in the rock was sufficient to allow the crystallization of quartz. Although there is a distinction between the syenite and the nepheline syenite in terms of their bulk chemistry, this difference is enhanced mineralogically because of the abundance of iron, calcium, and magnesium in the syenite which removed the alkalies from the melt and did not allow the formation of nepheline as a late state crystallization product.

This is an interesting conclusion because it suggests an additional model for the formation of complexes that contain both alkaline and calc-alkaline rocks. Perhaps the mechanism for the formation of zoned intrusives is based on the fractionation and distribution of the mafic elements, which in turn control the crystallization and distribution of the alkali elements.

GEOCHEMISTRY OF URANIUM AND THORIUM

Igneous Rocks

During most of the magmatic cycle, uranium and thorium are in the tetravalent state and the crystallization paths of the two elements are quite similar because of their similar ionic radii. The ionic radius of uranium is approximately 0.97A in sixfold coordination and 1.01A in eight-fold coordination; that of thorium is 1.02A in 6 fold, and 1.06A in eight-fold coordination. Plus 4 is the only stable valence state of the thorium atom, whereas uranium, under oxidizing conditions, readily changes from +4 to a +6 valence state decreasing its ionic radius to .8A. This property causes uranium and thorium to follow strikingly different paths during the latest stages of crystallization, and during the weathering cycle.

During crystallization, when the water content of the melt is very low, part of the U^{4+} and Th^{4+} present enter host minerals, proxying for Zr in zircon, and Ca in apatite and sphene. Coordination requirements prevent uranium and thorium from substituting for calcium in plagioclase.

Almost all compounds of U^{4+} and Th^{4+} are known to be highly insoluble in aqueous solutions in the laboratory. Late in the differentiation of a magma, water may so reduce the solubility of both uranium and thorium that sporadic precipitation of actual uranium and thorium minerals may occur (Larsen and Phair, 1954).

At a very late magmatic stage, uranium is commonly oxidized to the U^{+6} valence state, and forms a number of soluble compounds particularly with $CO_2^=$ and $SO_4^=$ anions. Thorium has only one stable valence state and it is not affected by the shift to oxidizing conditions.

Uranium is associated with alkaline igneous rocks, and particularly with the agpaitic or peralkaline group of alkaline rocks. Such rocks contain more total alkalies than aluminum. Although the rocks examined in this report are highly potassic, because of their high aluminum content none of them would fall in the agpaitic or peralkaline category of alkaline rocks.

On the whole uranium concentrations in volcanic rocks appear to be slightly higher than concentrations in their plutonic equivalents. In addition to uranium concentrated in accessory minerals, the glass phase often is enriched (Adams, 1954). In the glass phase uranium is easily leached whereas only a small percentage of the uranium in the common accessories can be mobilized during weathering processes.

Sedimentary Rocks

By far the greatest quantity of uranium is found in sandstone-uranium-vanadium-copper deposits (Stanton, 1972). The greatest development of these ore bodies occurs in the western and southwestern United States where they are believed to have formed in an arid or semi-arid environment.

The usual host rocks of these "sandstone" deposits are conglomerates, sandstone, and siltstones. Within these rocks, the deposits are related to a variety of sedimentary features: contacts of coarse sediment with mudstone, thickness of the coarse unit, paleostream channels, and plant remains.

It is generally agreed that these deposits are epigenetic, but the source of the uranium-bearing fluids is unknown. The uranium deposits are the result of the reduction of uranium compounds, such as $U(SO_4)_3$ and $U(CO_2)_3$. The deposits occur in uranium rolls, at the boundary between oxidized and reduced rock. The reducing environment is produced by anaerobic bacterial decay and the formation of H_2S from the breakdown of plant remains.

Thorium is not a major constituent in these deposits. It is not easily mobilized by the weathering processes, and is not transported by oxidizing telethermal solutions.

Sea Water and Ocean Basins

Uranium will combine in sea water with sulfate and carbonate ions to form soluble compounds. As in the sedimentary deposits, it requires reduction in order for precipitation to occur. Such an environment is possible in peat bogs and in lagoons and closed basins where circulation of the water does not occur.

In Alaska, where peat bogs are abundant and where sizeable fluctuations in sea level have occurred, particularly during Pleistocene time, offshore submerged peat deposits and associated uranium concentrations deserve consideration.

Thorium would tend to concentrate in placer deposits offshore because it is left behind during weathering processes in heavy accessory minerals.

DISCUSSION OF URANIUM AND THORIUM DATA

Introduction

One hundred eight rock samples were analysed for uranium, thorium and potassium during the course of this study. The results of the analysis plus tabulated mineralogical data are located in Appendix 1. A discussion of the methods used for analysis is given in Appendix 4.

Average values and standard deviations for the analytical data are given in Table 5. Histograms of the relative abundances of uranium and thorium are shown in Figure 18. With the exception of a few extreme values, the uranium distribution closely approximates a straight line when plotted on log probability paper, reflecting a log normal distribution (Figure 19).

Table 5

Means, Standard Deviations, Maxima, and Minima for Uranium and Thorium Data for Five Plutons in Western Alaska.

Pluton	Uranium			
	Mean	Std. Dev.	Maximum	Minimum
Granite Mountain	2.9	1.6	6.8	0.8
Darby	5.9	3.4	14.5	1.3
Zane Hills	5.2	9.1	49.0	0.3

Table 5 (Cont.)

Pluton	Uranium			
	Mean	Std. Dev.	Maximum	Minimum
Dry Canyon	7.3	3.9	20.3	3.9
Selawik Lake	12.9	25.8	92.0	1.0
Total	5.8	9.6	92.0	0.3

Pluton	Thorium				Observations
	Mean	Std. Dev.	Maximum	Minimum	
Granite Mountain	32.8	17.6	67.7	8.9	28
Darby	37.1	15.3	64.3	13.5	22
Zane Hills	25.4	20.1	74.0	3.1	32
Dry Canyon	55.9	14.8	76.0	31.5	16
Selawik Lake	34.2	18.9	70.3	8.3	10
Total	35.0	19.9	76.0	3.1	108

Major Uranium Anomalies

As shown in Figure 18, seven samples lie distinctively above the clustering of uranium concentrations. These anomalies are briefly discussed below.

Selawik Lake Complex

Uranium values as high as 86 and 92 ppm were detected from an area of dike intrusion along the east side of the Selawik Lake Complex (samples AP-6a and c, Figure 16). The dike strikes approximately east-west, and is composed of 71% K-feldspar, 18.6% nepheline, 8.6% biotite, 0.6% pyroxene, and 1.8% accessories. The accessory minerals include fluorite, pyrochlore, sphene, and apatite, and at least one other minor mineral that could not be identified using x-ray techniques. High concentrations of uranium are not restricted to the dike phase alone. One sample of the adjacent pluton contained 92 ppm uranium.

Zane Hills Augen Gneiss

Within the area of the Zane Hills augen gneiss unit, two pegmatite dikes were found to contain uranium concentrations up to 49. ppm. The highest value was determined from a pegmatite having the composition of a quartz monzonite. The augen gneiss zone is characterized by abundant veining, and additional aplitic vein rocks were analysed. These, however, did not show high concentrations of uranium. The fact that the pegmatite and aplite dikes are in large part restricted to the augen gneiss unit suggests that they are genetically interrelated to the augen gneiss or that the zone is an area of structural weakness and that the dikes fill fractures within the unit.

Dry Canyon Creek Stock

A sample of hornblende-biotite-nepheline syenite, containing abundant accessory minerals was found to contain 20.3 ppm uranium in a sample from the Dry Canyon Creek Stock.

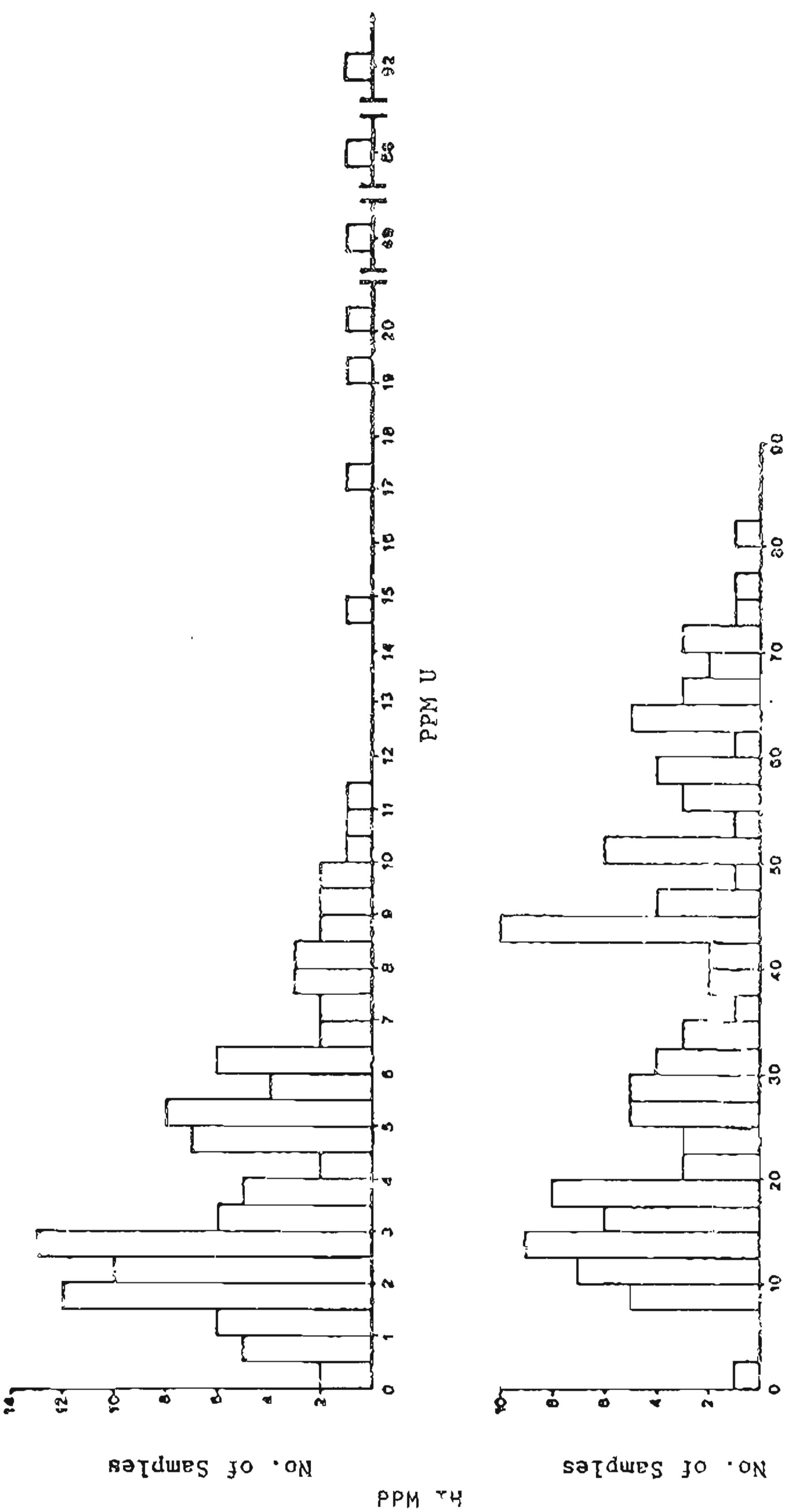


Figure 18. Relative abundance of uranium and thorium within the study area.

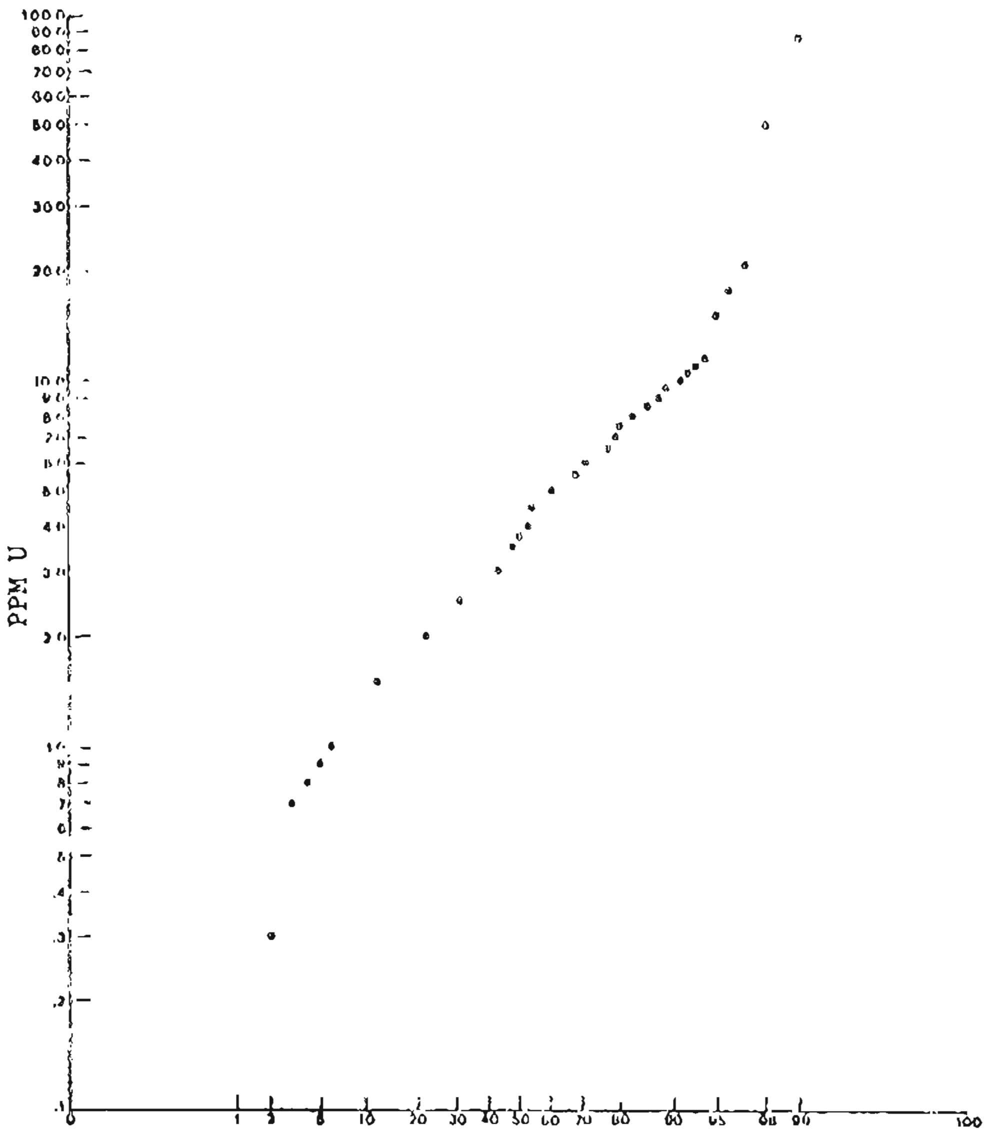


Figure 19. Log-normal probability plot of uranium concentrations.

Darby Mountains

A uranium concentration of 14.5 ppm was detected in a quartz monzonite from the Darby Mountains. Although this value is high in terms of this study, Miller and Bunker (1975a) have analysed a number of samples from the Darby Mountains showing similar concentrations.

Assessment of Uranium Anomalies

The above areas, particularly the locations in the Zane Hills and the Selawik Lake Complex are of economic interest and serve as good target areas for future exploration. Both areas drain into basins that may contain Tertiary sediments beneath the tundra cover. Recent uranium analyses from the monzonite unit in the Zane Hills by Staatz and Miller (1976) have yielded uranium concentrations as high as 130 ppm.

A uranium concentration of 100 ppm is not uncommon in alkaline rocks in the rest of the world. In the Illimaussaq intrusive, at Greenland, the average uranium concentration is greater than 200 ppm. In Alaska the Bokan Mountain alkali granite contains a range of 20-200 ppm uranium disseminated throughout the pluton.

The price of U_3O_8 is negotiable and as a result is highly variable. Today's average cost is about $20.00/lb. Price is dependent on the location of the mine, and the nature of the deposit. The current minimum ore grade is 0.[illegible]% U_3O_8 although one mine in West Africa, where labor costs are exceedingly low, consists of a 0.05% deposit, in pegmatites.

Because of the high transportation costs, the minimum current ore grade in Alaska is about 0.2% U_3O_8. Although 100 ppm is far from ore grade, the abundance of plutons containing leachable uranium in the Selawik Basin and Seward Peninsula, provide ample source areas for secondary Colorado-type uranium deposits in the adjacent Tertiary Basins. In addition, with the rapid growth in the cost of uranium, the United States will soon begin exploiting some of the lower grade deposits.

Uranium Analyses of Mineral Separates

Individual minerals were separated from five rock samples and analysed for their uranium concentrations. The results of these analyses are presented in Table 6. Uranium is highly concentrated in sphene, apatite, and allanite. The highest concentration was detected in a small sample that appeared to contain a few minute crystals of uranothorite.

Table 6

Uranium Concentrations in Mineral Separates and Estimation of the Contribution of Individual Mineral Phases to the Whole Rock Uranium Content

	Granite Mountain			Zane Hills		
Mineral	U-ppm	% of rock	U-ppm x % of rock	U-ppm	% of rock	U-ppm x % of rock
Quartz + feldspar	-3	90.5	?	12.	86.4	10.32
Amphibole	-3	2.5	?	7.	7.5	.53
Pyroxene	-3	5.6	?	46.	0.6	0.28
Biotite	-	-	-	23.	1.1	0.25
Sphene	234	1.0	2.34	1520*	1.4	21.28*
Apatite	612*	0.4	2.45*	1146*	0.4	4.58*
Allanite	-	-	-	-	-	-
Urano-thorite)	-	-	-	1780.	0.1	1.78

Table 6 (Cont.)

	Granite Mountain	Zane Hills
Whole rock analysis	1.2	17.2 ppm
Total due to rock forming minerals	?	11.4 ppm
Total due to accessory minerals	4.8 ppm*	27.6 ppm*

Darby Mountains

Mineral	U-ppm	% of rock	U-ppm x % of rock
Quartz + feldspar	-3	97.6	?
Amphibole	-	-	-
Pyroxene	-	-	-
Biotite	29.	2.1	0.61
Sphene	1512.	0.1	1.51
Apatite	646.*	0.1	0.65*
Allanite	948.	0.1	0.95
Urano-thorite[1]	-	-	-

Darby Mountains

Whole rock analysis	2.8 ppm
Total due to rock forming minerals	.6 ppm
Total due to accessory minerals	3.1 ppm*

	Dry Canyon Creek Stock			Selawik Lake Complex		
Mineral	U-ppm	% of rock	U-ppm x % of rock	U-ppm	% of rock	U-ppm x % of rock
Nepheline + feldspar	-3	49.8	?	21.	89.2	18.7
Amphibole	11.	23.8	2.6	-	-	-
Pyroxene	16.	27.2	4.5	-	-	-
Biotite	-	-	-	80.	8.6	6.9
Sphene	259.	0.4	1.04	363.	1.8	6.5
Apatite	623.	0.2	1.25	-	-	-
Fluorite	-	-	-	160.	0.1	1.6
Sphene + Unknown	-	-	-	519	0.1	5.2

	Dry Canyon Creek Stock	Selawik Lake Complex
Whole rock analysis	10.0 ppm	86.0 ppm
Total due to rock forming minerals	7.1 ppm	25.6 ppm
Total due to accessory minerals	2.3 ppm	13.3 ppm

* = minimum value due to incomplete dissolution with HF/HNO_3.

-3 = Uranium concentration below detection limit

1 = also contained sphene and apatite.

? = value cannot be determined due to low concentration of uranium.

\- = mineral not present in rock sample.

An attempt was made to determine the contribution of each of the mineral phases to the total concentration of uranium in the whole rock sample. The percentage of the mineral was multiplied by the concentration of uranium in that mineral. The results of this calculation do not always closely approximate the uranium concentration as determined from the analysis of the entire sample.

There are a number of errors that must be considered. Contamination of the rock sample during mineral separation is a strong possibility although every precaution was taken in the laboratory to produce clean separates. The samples, particularly those containing the accessory minerals, were often very small which reduces the accuracy of the analysis. The point counting technique used in this study is good to approximately ±2.0% (see Appendix 4). Some of the concentrations of the minerals fall below this limit.

The possibility of an error in the detected uranium value of a highly uraniferous accessory mineral is much less than the possibility of an error in the uranium concentration of the felsic minerals. The inclusion of 1 grain of sphene for example, to every 100 grains of feldspar, would cause a tremendous error in the calculated contribution of the felsic minerals to the concentration in the whole sample.

One or two grains of quartz or feldspar in a sphene or apatite sample would have little effect on the analysed concentration of these minerals. If we have some confidence in the uranium concentrations determined in the accessory minerals we can draw an interesting conclusion. Assuming that the percentage of these minerals in the individual rock samples is approximately correct as determined by point count analysis, we can account for all of the uranium in the samples from Granite Mountain, the Zane Hills, and the Darby Mountains, by the accessory minerals alone. However, in the two nepheline-bearing rocks, if we make the same assumption we can only account for a fraction of the total uranium concentration from the accessory minerals.

Our conclusion is that either the uranium is concentrated in the felsic phases, in the latter two samples, or there are additional phases that make up very minor proportions of the rock that contain very high concentrations of uranium and are partly included in the rock-forming minerals.

Correlations: U-Th-K-Mineralogy-CPS

A step-wise multiple linear regression analysis was performed on the mineralogical and chemical data for the 108 rock samples in this study. The objective of this analysis was to see if there is some systematic variation between the uranium and thorium concentrations, and the mineralogy of the samples. The Honeywell program called SMLRP, was used. The program relates a number of independent variables, in this case, potassium, quartz, plagioclase, K-feldspar, amphibole, pyroxene, biotite, nepheline, garnet, accessory minerals, and counts per second (CPS from a scintillometer), to either uranium or thorium as the dependent variable.

In addition to performing the step-wise regression on the entire data set, the program was also performed on individual plutons. This analysis provides excellent mineralogical guides for the prospector, within individual plutons, and illustrates the wide variety of rock types that contain anomalous concentrations of uranium and thorium.

Analysis of Total Sample Set

The correlation matrix for all of the samples analysed is shown in Figure 20. A correlation of 1.000 represents a perfect correlation, i.e., all of the variance of one variable can be explained by the variance of another. A correlation of 0.000 represents no linear relationship between the variables. Graphical examples of correlation coefficients are shown in Appendix 3. If a relationship between uranium and one of the variables existed and was of the form of a higher order polynomial equation, the correlation coefficient would not necessarily reflect this relationship. Based on the correlation coefficients, the regression builds a linear equation that explains how Y (uranium or thorium) is related to X (mineralogy or potassium). What we wish to determine is: How much of the variability of Y can we explain in terms of a number of independent variables, $X_1, X_2, X_3, \ldots X_{12}$.

In Figure 20 columns one and two are of the greatest interest economically. Uranium does not correlate well with any of the minerals in the study area. The highest correlation coefficient is a negative relationship with plagioclase, but a coefficient of -0.283, although significant with this number of samples at the 90% confidence level, shows only a weak relationship. In terms of the regression equation, plagioclase is the first variable considered: R^2 is 0.0803.[1] The addition of four other variables, thorium, K-feldspar, quartz, and total accessories only increases the R^2 value to 0.1468. We can say that there is very little correlation between any of the mineralogical constituents measured and the uranium content of the rock, and that we can explain very little of the variability of uranium in terms of the mineralogical data. This is not a surprising result. As noted earlier, a wide variety of rocks in the thesis area are known to contain anomalous concentrations of radioactive elements. The regression reflects this observation.

The correlations between thorium and mineralogy are only slightly better. After five variables have been added to the regression, we are only able to describe 30% of the variance of Th in terms of the other variables. The wide range in rock types in which high concentrations of radioactive elements are found throughout the thesis area is reflected by the regression equation for both uranium and thorium.

On a regional scale, in terms of the data available, the uranium and thorium concentrations cannot be precicted in terms of mineralogy. We cannot assist the prospecting geologist by suggesting rock types in

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[1] R^2 = goodness to fit of the linear equation

$$= \frac{\text{sum of squares due to regression}}{\text{total sum of squares}} \qquad \begin{matrix} 1 = \text{perfect fit} \\ 0 = \text{no fit} \end{matrix}$$

	U	Th	K	Qtz	Plag	Kfeld	Amph	Px	Bi	Ne	Gar	Acc	Cps
U	1.000												
Th	0.224	1.000											
K	0.198	0.302	1.000										
Qtz	-0.028	-0.420*	-0.586	1.000									
Plag	-0.283	-0.383	-0.797	0.446	1.000								
Kfeld	0.253	0.399	0.712	-0.639	-0.765	1.000							
Amph	-0.061	0.327	-0.010	-0.479	-0.065	0.114	1.000						
Px	-0.032	0.256	-0.002	-0.405	-0.204	0.113	0.524	1.000					
Bi	0.076	0.114	0.185	-0.122	-0.231	-0.030	-0.203	-0.003	1.000				
Ne	0.116	0.167	0.808	-0.458	-0.704	0.397	-0.084	-0.051	0.221	1.000			
Gar	0.005	0.082	0.244	-0.222	-0.341	0.164	-0.155	0.125	0.122	0.330	1.000		
Acc	0.097	0.229	0.098	-0.382	-0.110	0.209	0.237	0.197	0.131	-0.021	-0.051	1.000	
Cps	0.287	0.615	0.276	-0.127	-0.341	0.377	0.168	-0.099	0.049	0.133	-0.261	0.039	1.000

Figure 20. Correlation matrix for 108 samples analyzed in this study. *Underlined values are significant correlations with uranium and thorium at a 90% confidence level.

the thesis area upon which he should concentrate his investigations. We can suggest, from these data, that all of the plutons in the area, and not only the alkaline varieties, should be studied in some detail.

We can look at the uranium and thorium data in a different way by considering the means, standard deviations, and maxima and minima for each rock type as listed in Table 7.

Table 7

Means, Standard Deviations, and Maxima and Minima of Uranium and Thorium Data, By Rock Type

Rock Type	Uranium			
	Mean	Std. Dev.	Maximum	Minimum
Nepheline Syenite	12.83	23.24	92.0	1.0
Alkali Gabbro	8.77	1.37	10.0	7.3
Syenite	5.87	4.64	17.2	1.6
Monzonite	3.03	1.98	8.4	0.8
Quartz Monzonite	5.47	8.10	49.0	-0.3
Granite	10.38	6.23	19.4	5.1
Granodiorite	2.19	1.14	4.8	0.7

Rock Type	Thorium				Observations
	Mean	Std. Dev.	Maximum	Minimum	
Nepheline Syenite	46.15	19.9	82.3	8.33	25
Alkali Gabbro	66.3	8.97	76.0	53.3	3
Syenite	42.01	14.06	62.5	24.5	10
Monzonite	40.94	21.45	74.0	9.11	19
Quartz Monzonite	28.71	16.65	64.3	8.85	36
Granite	32.3	13.3	51.0	21.3	4
Granodiorite	17.5	12.38	44.8	2.1	14

An analysis of variance was performed on these data to determine if there is a significant difference between the means of the individual groups. The results of this analysis are listed in Table 8.

The analysis determined that at $\alpha = .05$ there is no significant difference in the means of the uranium values. The F value = 1.78, whereas the critical F at this confidence level is 2.20.

In accordance with the observation made earlier, that there were significant correlations between thorium and mineralogy, the analysis of variance determined that there is a very significant difference between the mean thorium concentrations of individual rock types. This reflects the more predictable behavior of thorium during the differentiation process. Calculated F at a 95% confidence level is 7.72, with the critical F remaining the same value as above, 2.20.

Table 8

Summary Table for the Analysis of Variance-Uranium

Source of Variation	dF	Sum of Squares	Mean Squares
Between rock types	6	1,624	270.7
Within rock types	103	15,649	151.93
Total	109	17,273	– –

$F = \frac{270.7}{151.93} = 1.78$ dF = 6, 103   Critical F = 2.20

Summary Table for the Analysis of Variance-Thorium

Source of Variation	dF	Sum of Squares	Mean Squares
Between rock types	6	14,363	2,393
Within rock types	103	31,996	310
Total	111	46,359	- -

$F = \frac{2,393}{310} = 7.7.$ dF = 6, 103   Critical F = 2.20

The Scintillation Counter as a Prospecting Tool

The hand-held scintillometer is standard prospecting equipment for uranium. We can comment on the reliability of this device for recording uranium values by computing the correlation coefficients (Figure 20).

The correlation between uranium and counts per second is 0.287. The correlation coefficient for thorium and counts per second is 0.615, which is highly significant. In most cases the scintillometer does not reflect the uranium content of the rock. Thorium is much more abundant in most of the rocks and the gamma radiation produced by the uranium is overshadowed by that produced from thorium. The scintillometer fails to register minor fluctuations in uranium content in an area predominantly enriched in thorium. These minor fluctuations are of little interest to the exploration geologist.

The standard deviation of an individual scintillometer reading is equal to $\sqrt{n}$, where n = counting rate. The square root of 450 is 21. Therefore the counting rate of 500 deviates significantly from 450 at the 95% confidence level. 475 is not significant at this confidence level. Therefore a considerable amount of variability in the counting rate can be attributed to statistical variation within the counter.

The mean and standard deviation for all the scintillometer data = 414 CPS and 168 CPS, respectively. A reading greater than 582 is significant at the 1σ level, and a reading greater than 750 is significant at the 2σ

level. Individual scintillometer readings are listed in Appendix 1. The only readings that exceed the 2 alpha limit are from the uraniferous rocks of the Selawik Lake Complex, and the radioactive rocks of the alkaline monzonite zone in the Zane Hills. When one considers individual readings in terms of their variability from the mean, it is possible to discriminate the more significant anomalies.

Admittedly the statistical information obtained is based on a relatively small sample size. Additional data in the Selawik Basin and eastern Seward Peninsula will aid in defining the overall background and variability of the scintillations.

Although there is little correlation between the radioactivity and mineralogy in the total sample set, examination of data for individual plutons revealed significant relationships that should aid the prospector.

Granite Mountain

Means, standard deviations, minima, and maxima for uranium and thorium analyses of 32 samples from the Granite Mountain pluton are shown in Table 5. The correlation matrix for Granite Mountain is shown in Figure 21. Good correlations are apparent between uranium and potassium, r = 0.647, uranium and nepheline, r = 0.742, and uranium and garnet, r = 0.697. The regression determines that 55% of the variance of uranium can be explained by the single variable nepheline. 65% of the variance can be explained by the variables nepheline and thorium, and 70% of the variance of uranium can be explained by nepheline, thorium, and pyroxene.

Thorium does not correlate as well with any of the mineralogical variables. In the regression, 22% of the variability of thorium can be described by the variance of uranium. The combination of thorium and total accessories explains 34% of the variance of Th. The addition of other variables does not appreciably improve the regression equation.

The variation in uranium, thorium, potassium, and CPS across the zones of the Granite Mountain intrusive is shown graphically in Figure 22. There is virtually no correlation at all between uranium and CPS. Thorium has a distinct effect on the CPS reading, whereas potassium has no effect. It seems unlikely that the rest of the variability in CPS could be the result of the general background produced by cosmic radiation. Another possibility is that there is a great deal of within outcrop variability. Therefore the scintillations, recorded over an area of about 25 square feet, do not correlate well with individual samples, which vary a great deal across short distances. However, within outcrop variability was determined to be small at Granite Mountain (Figure 22). The poor correlation between thorium and counts per second is probably the result of a number of variables including cosmic radiation, analytical error, within outcrop variability, weathering variations, and the effect of potassium, i.e. variability in background.

Darby Pluton

The average uranium content of the Darby Pluton is 11 ppm (Miller, 1975a). Along the traverse the value was significantly lower, averaging 5.9 ppm for 22 observations (see Table 5). Thorium averages 37.1 ppm.

	U	Th	K	Qtz	Plag	Kfeld	Amph	Px	Bi	Ne	Gar	Acc	Cps
U	1.000												
Th	0.464 *	1.000											
K	0.547	0.408	1.000										
Qtz	-0.040	-0.284	-0.515	1.000									
Plag	-0.420	-0.187	-0.741	0.515	1.000								
Kfeld	0.152	0.153	0.628	-0.638	-0.739	1.000							
Amph	-0.361	-0.098	-0.204	-0.216	0.102	-0.045	1.000						
Px	-0.155	0.184	0.051	-0.539	-0.306	0.042	0.032	1.000					
Bi	0.014	0.016	0.151	-0.154	-0.476	0.050	-0.279	0.660	1.000				
Ne	0.742	0.206	0.745	-0.230	-0.689	0.324	-0.360	0.010	0.154	1.000			
Gar	0.697	0.204	0.743	-0.231	-0.691	0.288	-0.365	0.058	0.254	0.896	1.000		
Acc	-0.067	0.324	0.097	-0.329	-0.127	0.104	0.402	0.384	0.133	-0.208	-0.178	1.000	
Cps	-0.108	0.521	-0.119	-0.152	0.267	0.105	0.245	-0.019	-0.213	-0.510	-0.495	0.335	1.000

Figure 21. Correlation matrix for 32 samples from the Granite Mountain Pluton. *Underlined values are significant correlations with uranium and thorium at a 90% confidence level.

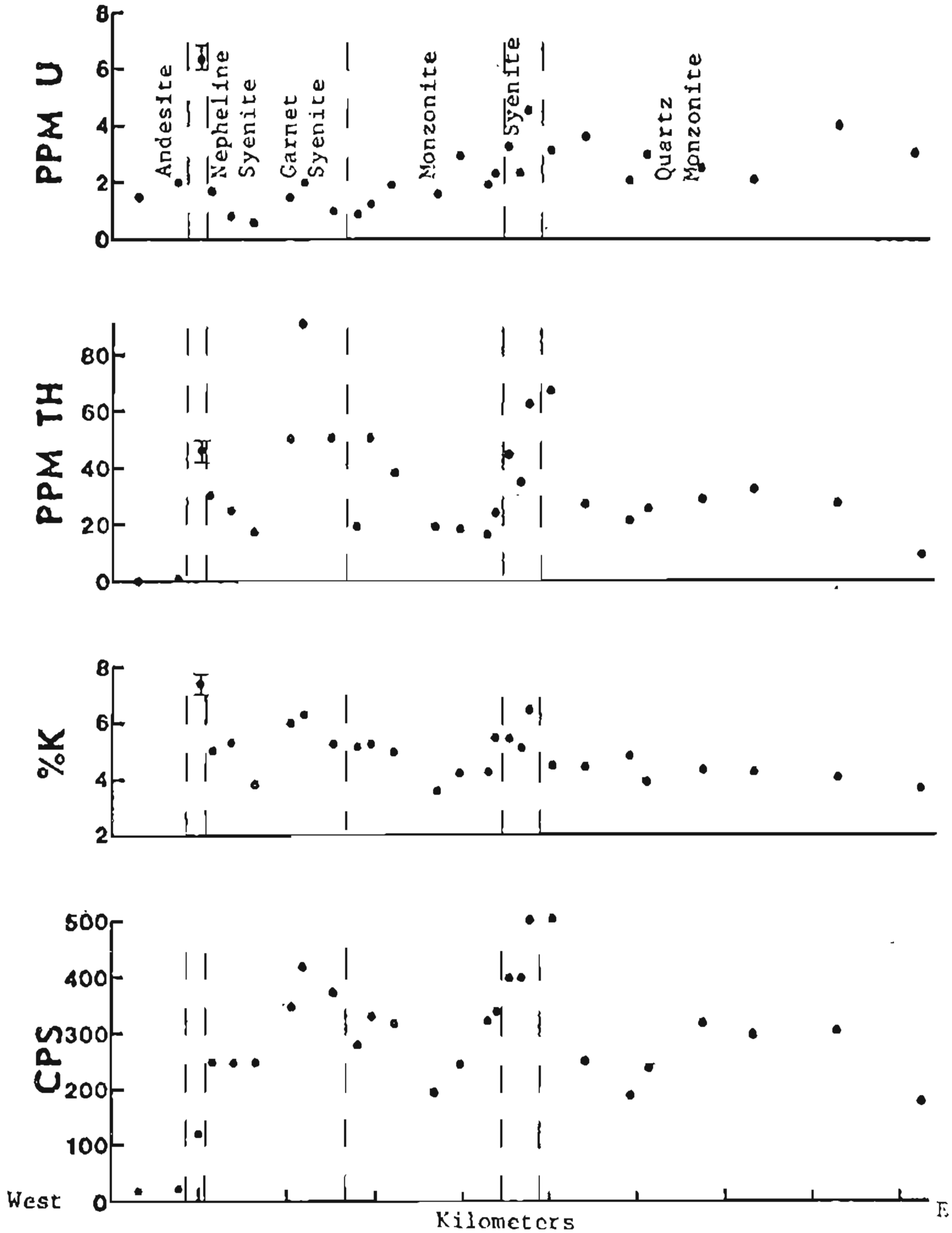

Figure 22. Variation in uranium, thorium, potassium, and counts per second across the Granite Mountain Pluton. Error bars indicate total within outcrop variability as determined from 3 samples.

The correlation matrix for mineralogical and chemical data from the Darby Mountains is shown in Figure 23. Uranium is weakly correlative with the presence of quartz, the absence of plagioclase, and the absence of biotite. The regression shows that 33% of the variability in uranium can be described by biotite and accessory minerals. Additional variables do not improve the goodness of fit of the regression equation.

Thorium does not show significant correlation with any of the variables at the 90% confidence level. In the regression, 8 variables account for only 35% of the variability of thorium.

Uranium, thorium, potassium, and counts per second are graphically represented in Figure 24. Data collected in the field with the use of a scintillometer suggested uranium and thorium enrichment towards the west margin of the pluton. From Figure 24 it is apparent that this enrichment does not include uranium. The increased CPS reflects a general increase in thorium. The potassium content is roughly constant across the pluton.

The number of dikes present, and the number of samples displaying the peculiar porphyritic texture described earlier, increase towards the west edge of the pluton. These observations suggest that the western edge of the Darby Pluton was an area enriched in volatiles or was more extensively fractured. The west contact of the pluton was mapped by Miller and others (1972) as an intrusive contact, whereas the eastern margin is fault bounded. Therefore the western zone represents the crystalline edge of the Darby Pluton in agreement with the expected increase in concentration of volatiles.

Zane Hills Pluton

Means, standard deviations, minima, and maxima for uranium and thorium analyses from 32 samples from the Zane Hills are listed in Table 5. The correlation matrix for the Zane Hills is shown in Figure 25. Of particular interest, are the correlations between thorium and quartz, amphibole, and K-feldspar. The relationship between thorium and quartz is shown graphically in Figure 26.

Variation in quartz accounts for 62% of the variance of thorium. Quartz, and plagioclase account for 66% of the variance of thorium, and quartz, plagioclase, and amphibole account for 68%. The addition of pyroxene and biotite to the regression improves the approximation of the linear fit to 72%. The addition of other variables does not appreciably improve the regression equation. Figure 26 and Figure 13 show that the good correlation between quartz and thorium is not a linear relationship, but two populations; one containing little quartz and abundant thorium, and another containing abundant quartz, which is thorium-poor.

Correlation between uranium and mineralogy are not as marked. Uranium correlates with plagioclase, K-feldspar, and potassium.

The poor correlation between uranium and mineralogy is largely the result of two samples which contain high concentrations of uranium in granophyric dike rocks associated with the augen gneiss unit (Figure 27). In addition, the alkali monzonite unit, although high in thorium, does not show uranium enrichment within the samples analysed.

	U	Th	K	Qtz	Plag	Kfeld	Amph	Px	Bi	Ne	Gar	Ace	Cps
U	1.000												
Th	-0.178	1.000											
K	0.045	-0.181	1.000										
Qtz	0.446*	-0.207	-0.347	1.000									
Plag	-0.394	0.265	-0.057	-0.680	1.000								
Kfeld	0.152	-0.175	0.472	-0.108	-0.636	1.000							
Amph	-0.261	-0.151	0.178	-0.177	0.036	0.026	1.000						
Px	-0.236	-0.212	-0.105	-0.288	0.199	-0.036	0.023	1.000					
Bi	-0.451	0.237	-0.194	-0.356	0.318	-0.233	-0.053	0.555	1.000				
Sa	-0.236	-0.212	-0.105	-0.288	0.199	-0.036	0.023	1.000[1]	0.585	1.000			
Gar	-0.236	-0.212	-0.105	-0.288	0.199	-0.036	0.023	1.000[1]	0.585	1.000[1]	1.000		
Acc	-0.349	0.006	0.379	-0.444	0.244	0.066	0.661	-0.042	0.024	-0.042	-0.042	1.000	
Cps	0.032	0.366	0.211	0.133	-0.119	0.052	-0.472	-0.521	-0.086	-0.521	-0.521	-0.266	1.000

Figure 23. Correlation matrix for 22 samples from the Darby Pluton. *Underlined values are significant correlations with uranium and thorium at a 90% confidence level.

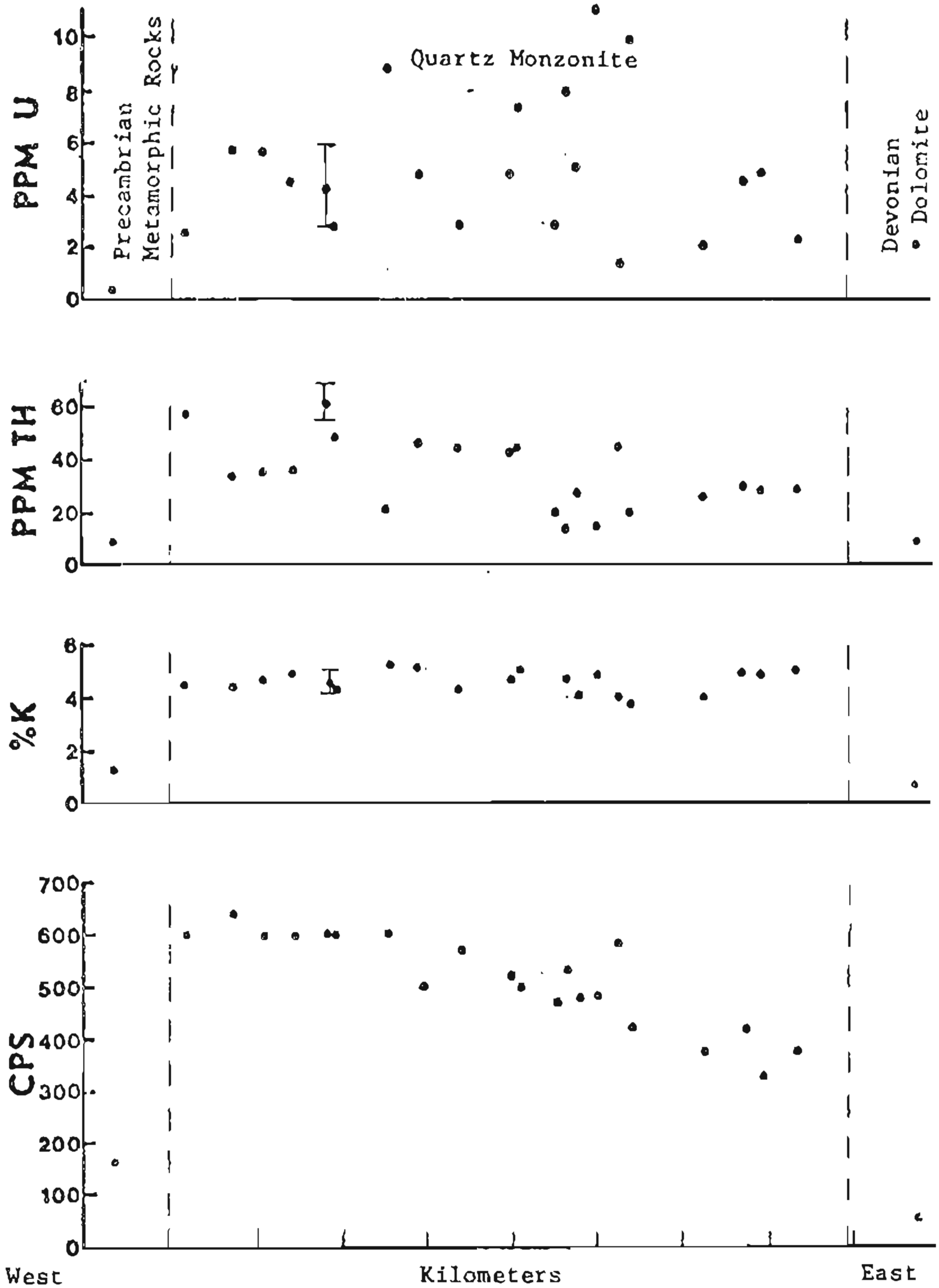

Figure 24. Variation in uranium, thorium, potassium, and counts per second across the Darby Pluton. Error bars indicate total within outcrop variability as determined from 2 samples.

	U	Th	K	Qtz	Plag	Kfeld	Amph	Px	Bl	Na	Gar	Acc	Cps
U	1.000												
Th	0.070	1.000											
K	0.414*	0.597	1.000										
Qtz	0.018	-0.789	-0.559	1.000									
Plag	-0.556	-0.302	-0.742	0.130	1.000								
Kfeld	0.453	0.639	0.919	-0.613	-0.824	1.000							
Amph	-0.089	0.705	0.444	-0.799	-0.059	0.459	1.000						
Px	0.065	0.437	0.518	-0.573	-0.368	0.560	0.488	1.000					
Bl	-0.283	0.025	-0.265	-0.133	0.445	-0.342	-0.171	0.110	1.000				
Ne	0.064	0.232	0.197	-0.260	-0.151	0.180	-0.142	-0.023	0.492	1.000			
Gar	0.064	0.232	0.197	-0.260	-0.151	0.180	-0.142	-0.023	0.492	1.000	1.000		
Acc	-0.048	0.308	0.094	-0.519	0.154	0.101	0.360	0.399	0.256	0.052	0.052	1.000	
Cps	0.176	0.723	0.881	-0.722	-0.576	0.879	0.595	0.634	-0.248	0.099	0.099	0.228	1.000

Figure 25. Correlation matrix for 32 samples from the Zane Hills Pluton. *Underlined values are significant correlations with uranium and thorium at a 90% confidence level.

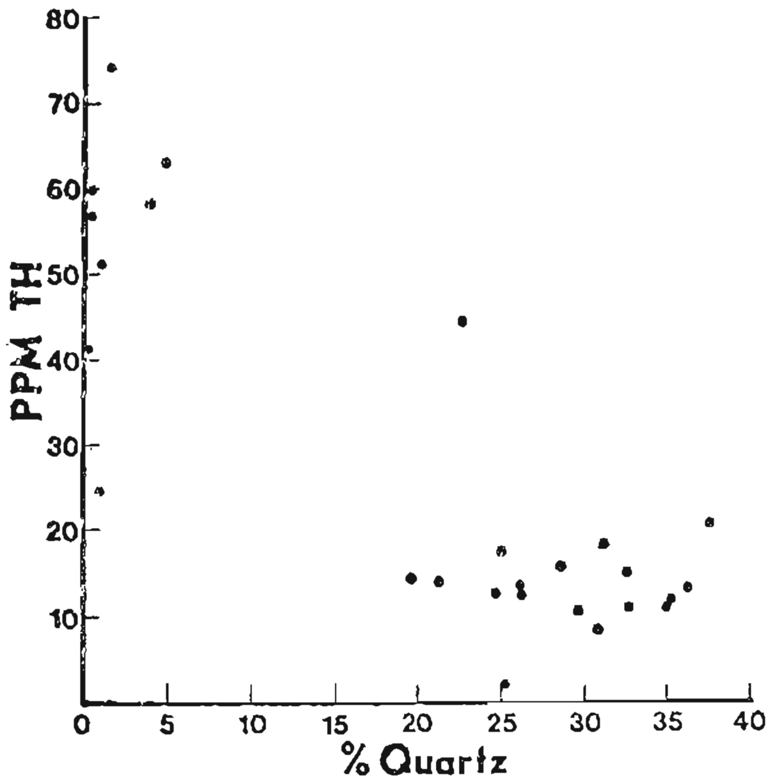

Figure 26. Plot of quartz against thorium concentrations from the Zane Hills Pluton.

Uranium, thorium, potassium, and CPS are shown graphically in Figure 27. Notice the strong correlation between thorium and potassium, and CPS with thorium and potassium. The scintillometer closely reflects the thorium concentrations in the Zane Hills rocks. Uranium correlates poorly with the scintillometer values. Although a few high concentrations of uranium were found, they occurred in thin dike rocks that would have little effect on a scintillometer held at waist level. The thorium appears to be disseminated through the rock, contained in large part in minute grains of uranothorite, monazite, apatite, and sphene.

The Dry Canyon Creek Stock

Means, standard deviations, minima, and maxima are given in Table 5 for uranium and thorium analyses for 16 samples collecced from the Dry Canyon Creek Stock.

Thorium is particularly high at the Dry Canyon Creek Stock. Uranium is slightly anomalous. Scintillometer readings from this stock were quite high, up to 800 CPS.

The correlation matrix for the Dry Canyon Creek Stock is shown in Figure 28. Uranium correlates well with the percent accessory minerals. Uranium is largely concentrated in the accessory minerals. Thorium does not show this same relationship. Although the data are not conclusive, it is possible that the thorium is concentrated predominantly in other mineral phases, or that the uranium originally located in the more abundant and more easily weathered rock-forming minerals, has been leached. The more resistant thorium compounds in the rock-forming minerals would remain behind.

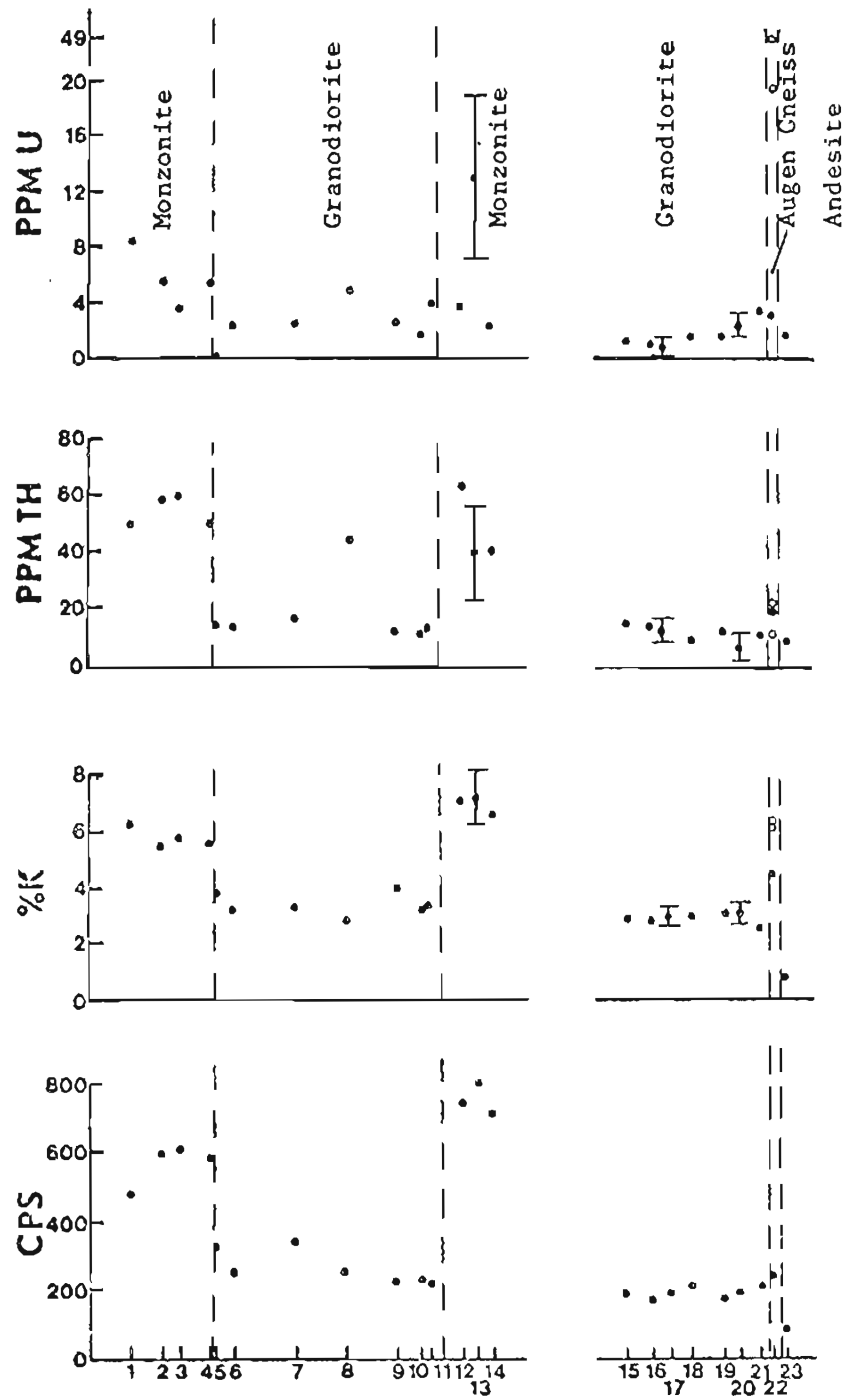

Figure 27. Variation in uranium, thorium, potassium, and counts per second along two traverses in the Zane Hills Pluton. Error bars indicate total within outcrop variability, from two samples.

	U	Th	K	Qtz	Plag	Kfeld	Amph	Px	Bi	Ne	Gar	Acc	Cps
U	1.000												
Th	0.221	1.000											
K	-0.124	-0.383	1.000										
Qtz	0.117	-0.201	0.184	1.000									
Plag	-0.109	0.436 *	-0.561	-0.153	1.000								
Kfeld	-0.094	-0.016	0.520	0.684	-0.169	1.000							
Amph	0.293	0.411	-0.889	-0.155	0.473	-0.411	1.000						
Px	0.188	0.393	-0.907	-0.131	0.524	-0.380	0.812	1.000					
Bi	0.179	-0.160	0.707	-0.183	-0.232	0.095	-0.707	-0.622	1.000				
Ne	-0.469	-0.496	0.344	-0.362	-0.349	-0.449	-0.430	-0.498	0.202	1.000			
Gar	-0.031	-0.241	0.081	-0.085	-0.172	-0.156	-0.294	-0.167	0.201	0.239	1.000		
Acc	0.674	0.209	0.252	-0.194	-0.340	-0.164	-0.158	-0.249	0.524	-0.005	-0.085	1.000	
Cps	0.288	0.125	0.343	-0.005	-0.070	0.071	-0.222	-0.547	0.417	0.132	0.154	0.597	1.000

Figure 28. Correlation matrix for 16 samples from the Dry Canyon Creek Stock. *Underlined values are significant correlations with uranium and thorium at a 90% confidence level.

Both uranium and thorium show a moderate negative correlation with nepheline. The distribution of uranium and thorium during crystallization of a magma usually shows a correlation between increase in alkalies and increase in radioactivity. Perhaps the relationship between nepheline and uranium can be explained by the oxidation of U^{4+} during the latest stage of crystallization of the stock. This would remove the uranium from the intrusive into hydrothermal solutions, during the period when nepheline was crystallizing.

In the regression analysis, we are able to explain 45% of the variance of uranium in terms of the percent of accessories. Sixty-seven percent of the variance is explained in terms of accessories and nepheline, 72% in terms of accessories, nepheline, and amphibole. The addition of thorium explains 79% of the variance, and finally the addition of quartz explains 85% of the variance. Additional variables do not appreciably improve the regression equation.

Uranium concentrations in the Dry Canyon Creek Stock can be explained quite well in terms of five variables, by far the most significant of which is the % of total accessories. Uranium appears to be substituting for Ca^{2+} in the accessory minerals sphene and apatite.

The relationships between thorium and the mineralogical variables are not as clear. Nepheline and quartz (two mutually exclusive variables) account for 41% of the total variance of thorium.

The scintillometer readings do not vary a great deal at the Dry Canyon Creek Stock, and it is not surprising that there is almost no correlation among uranium, thorium and total counts per second.

Selawik Lake Complex

Means, standard deviations, and minima and maxima for uranium and thorium analyses from 10 samples from the Selawik Lake Complex are shown in Table 5.

The correlation matrix for 13 variables is shown in Figure 29. Uranium correlates rather strongly with biotite, thorium, and counts per second. The correlation with the scintillometer reading is a result of much higher concentrations of uranium, which allow the gamma radiation emitted from the uranium to exceed that of thorium and cause a noticeable fluctuation in the counting rate. In addition uranium and thorium are correlative, and the gamma radiation that they emit is compounded in the scintillometer reading. The combination of gamma ray emissions from both elements reduces the effect of cosmic radiation and the correlations with the scintillometer are much improved.

The mineralized zone in the Selawik Lake Complex is not confined to a dike rock but extends into the country rock for a few meters on either side of the intruded area. This broad concentration of uranium allows for a larger area of radioactive rock to affect the counter. This is distinctively different than the Zane Hills occurrence where the high concentrations of uranium were restricted to thin dike rocks.

	U	Th	K	Qtz	Plag	Kfeld	Amph	Px	Bi	Mo	Gar	Acc	Cps
U	1.000												
Th	0.693 *	1.000											
K	-0.262	-0.444	1.000										
Qtz	-0.142	0.282	-0.835	1.000									
Plag	-0.141	0.285	-0.810	0.986	1.000								
Kfeld	0.134	0.060	-0.435	0.382	0.365	1.000							
Amph	-0.150	0.304	-0.815	0.956	0.904	0.256	1.000						
Px	-0.152	0.375	-0.516	0.619	0.589	-0.235	0.755	1.000					
Bi	0.639	0.584	0.195	-0.433	-0.427	-0.487	-0.314	0.171	1.000				
Mo	-0.111	-0.472	0.762	-0.846	-0.834	-0.651	-0.794	-0.515	0.211	1.000			
Gar	-0.187	0.149	0.437	-0.302	-0.298	-0.749	-0.168	0.326	0.448	0.377	1.000		
Acc	0.124	0.445	-0.754	0.855	0.911	0.227	0.732	0.526	-0.162	-0.738	-0.285	1.000	
Cps	0.858	0.518	-0.469	0.008	0.019	0.020	-0.016	-0.081	0.467	-0.047	-0.291	0.262	1.000

Figure 29. Correlation matrix for 10 samples from the Selawik Lake Complex. *Underlined values are significant correlations with uranium and thorium at a 90% confidence level.

Approximately 41% of the variance of uranium is explained by variations in the biotite content. The addition of garnet to the equation increases the R^2 value to 0.69. Ninety-three percent of the variance of uranium can be described by the variables potassium, garnet, biotite, K-feldspar, and amphibole. For this regression, the thorium variable (because it could not be determined in the field) was not included.

We can describe the distribution of uranium sufficiently in terms of four mineralogical variables and potassium.

Seventy-two percent of the variance of thorium is explained by the variation in biotite and nepheline in the regression equation. There are no other significant variables with the exception of uraniun which was not included in the regression.

Certainly the distribution of the radioactive elements in the Selawik Lake Complex follows a much more systematic distribution than is observed in other plutons in this study.

CONCLUSIONS

The calculation of correlation coefficients and the step-wise multiple linear regression breaks down a very complicated data set into a more concise form. The apparent result of the step-wise analysis for all of the samples within the thesis area, was that there was virtually no correlation between mineralogy, and the uranium and thorium concentrations. This is a misleading conclusion. The analysis of individual plutons shows that there are strong correlations between mineralogy and radioactivity, but that the independent variable that describes the greatest amount of variance of uranium or thorium changes from one pluton to the next. Therefore when one considers the entire picture, the correlations in the individual plutons cancel each other and we are left with the apparently random distribution of uranium and thorium within the province.

The correlations suggest that there is some relationship between the crystallization history of the rocks and the distribution of uranium and thorium within individual plutons. The lack of correlation on a regional scale is indicative of multiple origins for the plutons. This is not surprising, because the age of the intrusives span a period of 20 million years, and they vary in composition from highly oversaturated granodiorite and quartz monzonite to highly alkaline nepheline syenite.

The results of this investigation are in some ways discouraging for the exploration geologist who hopes to discover a uranium ore body based on regional mineralogical associations. Had there been a strong correlation on the broad scale between radioactivity and certain rock types, perhaps the area of exploration in the Yukon-Koyukuk Basin and eastern Seward Peninsula could be greatly reduced, and individual target areas selected. The broad variation of rock type in which high concentrations of uranium are found does not allow the exploration geologist to leave any plutons unexplored in this area.

The poor correlation between uranium and counts per second registered on the hand-held scintillometer is not as discouraging as it may seem. When high concentrations of uranium are present, as in the vein deposits and associated mineralized zones of the Selawik Lake Complex, scintillometer counts represent the concentrations of uranium very well. It fails to register the small granophyre dikes of the Zane Hills, but the fact that they are small makes them a much less significant deposit than the Selawik Lake occurrence. What the scintillometer fails to record, appears to be minor variations in uranium concentration in rocks that are predominantly thorium-rich. These minor variations are not of primary interest to economic geologists, and therefore the failure of the scintillometer to register them is not a hindrance to exploration.

Uranium prospecting is in a state of infancy in Alaska when compared to the rest of the United States. The discovery of uranium concentrations up to 92 ppm in the Selawik Lake Complex and additional high concentrations in a mineralized granophyric dike zone in the Zane Hills encourages the identification of this area as a uranium and thorium province. The existence of high concentrations of the radioactive elements in accessory minerals, such as sphene and apatite, where they can be leached by weathering processes, makes possible the deposition of large quantities of uranium in the Tertiary basins believed to exist adjacent to the investigated plutons.

Recent work by the State of Alaska Geological and Geophysical Surveys in cooperation with the Los Alamos laboratory indicates that the concentration of uranium in surface water samples is exceedingly low. Although this is discouraging, the paleo-environments of Alaska have changed significantly through the Cenozoic Era, since the emplacement of these plutons during Cretaceous time. Colorado-Plateau type conditions have been described from other localities throughout the world, lying at relatively high latitudes (Meyerhoff, 1972). It is a possibility that the appropriate environment for leaching, distribution and precipitation of uranium was present in the Yukon-Koyukuk Basin and the eastern Seward Peninsula at some time since the emplacement of the Cretaceous Plutons.

Mineralogical Guidelines for Future Uranium Investigations

Granite Mountain

Concentrate investigations on rocks containing abundant nepheline, and garnet, and little plagioclase and amphibole.

Darby Mountains

Explore the west margin of the Darby Pluton. It appears to be a zone of abundant dike intrusion and is a likely area for uranium mineralization.

Zane Hills

Concentrate investigations within the Augen Gneiss Unit, and determine if it is continuous along the east margin of the pluton. Within the Monzonite Unit select samples that contain little plagioclase.

Dry Canyon Creek Stock

Select samples that contain abundant accessory minerals, and that contain little nepheline.

Selawik Lake Complex

Select samples containing abundant biotite. Use the scintillometer to outline target areas. Because of the association of biotite with uranium, magnetometer surveys of the pluton should be a useful exploration tool.

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APPENDIX 1

Mineralogical and Chemical Data

Granite Mountain Pluton

	U	Th	K_2O	Qtz	Plag	K-feld	Am	Px	Bio	Ne	Gar	Acc	CPS
GM-3-1	06.2	41.1	07.00	00.0	00.0	58.7	00.0	07.1	04.9	21.2	07.5	0.5	150.0
GM-3-2	06.2	45.8	07.71	00.0	00.0	52.8	00.0	05.3	04.6	18.2	18.3	0.2	150.0
GM-3-3	06.8	42.7	07.50	00.0	00.0	57.5	00.0	04.3	03.6	16.6	17.2	0.7	150.0
GM-4	01.7	30.2	05.07	00.8	05.0	41.6	00.0	23.2	32.7	00.0	03.0	1.9	250.0
GM-5	00.8	22.6	05.32	02.5	30.7	47.1	11.7	08.3	00.0	00.0	00.0	1.4	250.0
GM-10	00.9	19.8	05.17	00.0	38.8	49.2	03.1	07.1	00.0	00.0	00.0	1.2	280.0
GM-11	01.2	50.0	05.19	00.4	32.7	57.6	02.5	05.6	00.0	00.0	00.0	1.4	330.0
GM-12	01.9	38.0	04.94	00.0	42.4	44.0	03.0	08.0	00.0	00.0	00.0	1.6	320.0
GM-13	01.6	19.2	03.57	01.3	45.8	34.3	08.4	08.6	00.0	00.0	00.0	1.0	195.0
GM-15	01.9	16.1	04.25	00.6	37.2	45.7	09.5	06.4	00.0	00.0	00.0	0.4	320.0
GM-16	02.4	09.1	05.45	00.4	38.5	42.5	13.4	04.8	00.0	00.0	00.0	0.3	250.0
GM-16A	02.5	10.4	05.37	00.6	35.3	48.0	12.9	03.2	00.0	00.0	00.0	0.6	250.0
GM-17	03.5	56.3	05.57	00.4	55.8	33.4	02.6	03.1	00.0	00.0	00.0	0.9	425.0
GM-18	00.9	15.0	05.37	00.5	33.8	49.6	11.6	02.2	00.0	00.0	00.0	1.3	400.0
GM-14	02.9	18.4	04.20	02.9	54.3	23.4	03.1	13.9	00.0	00.0	00.0	1.3	245.0
GM-18A	03.2	44.8	05.42	00.2	20.6	46.7	21.0	06.7	00.0	00.0	00.0	4.8	400.0
GM-19-1	01.9	52.1	04.62	00.0	33.8	40.4	08.7	14.6	00.0	00.0	00.0	1.1	400.0
GM-19-2	02.7	17.6	05.59	00.0	07.9	91.1	00.1	00.4	00.0	00.0	00.0	0.2	400.0
GM-20	05.4	67.7	05.95	02.6	50.2	40.3	00.0	05.3	00.0	00.0	00.0	1.7	600.0
GM-20A	04.5	62.5	06.42	00.0	22.4	61.4	06.8	06.6	00.0	00.0	00.0	2.4	400.0
GM-21	03.1	66.7	04.53	02.5	34.0	41.7	14.1	07.1	00.0	00.0	00.0	0.4	500.0
GM-22	03.6	27.1	04.45	13.0	44.9	26.3	06.2	00.0	00.0	00.0	00.0	0.2	250.0
GM-23	02.1	20.8	04.87	16.0	51.5	29.1	02.0	00.4	00.0	00.0	00.0	0.3	190.0
GM-24	02.9	25.5	03.98	15.8	49.3	30.1	01.6	00.7	00.0	00.0	00.0	0.6	240.0
GM-25	02.5	28.6	04.36	17.3	48.1	28.6	04.5	00.0	00.0	00.0	00.0	0.2	320.0
GM-26	02.1	32.3	04.23	18.5	46.6	30.3	03.8	00.0	00.0	00.0	00.0	0.5	300.0
GM-27	04.0	27.6	04.05	17.8	48.1	28.0	02.6	01.8	00.0	00.0	00.0	1.1	300.0
GM-28	03.0	08.9	03.69	21.4	49.0	24.8	03.6	00.3	00.2	00.0	00.0	0.4	280.0

		U	Th	K_2O	Qtz	Plag	K-feld	Am	Px	Bio	Ne	Gar	Acc	CPS
Dry Canyon Creek Stock	DC-1	07.5	67.7	10.65	00.0	00.0	51.8	00.0	00.0	14.4	[illegible]	00.0	2.6	570.0
	DC-2-1	04.8	71.4	10.35	00.0	02.2	62.0	10.3	[illegible]	[illegible]	14.6	[illegible]	[illegible]	[illegible]
	DC-2-3	20.3	66.1	10.77	00.0	00.0	53.5	13.3	00.0	15.3	05.3	[illegible]	3.5	[illegible]
	DC-3-1	07.4	46.9	10.34	00.0	00.0	47.7	00.7	00.0	10.2	31.6	03.3	0.7	600.0
	DC-3-2	05.4	41.1	10.55	00.0	00.3	55.4	00.4	00.0	17.8	24.8	01.2	0.1	600.0
	DC-4	09.0	44.8	11.18	00.5	00.0	93.0	03.1	00.0	03.2	00.0	00.0	0.1	570.0
	DC-5-1	05.4	72.4	09.21	00.0	00.0	47.9	11.8	03.2	00.0	32.1	00.0	0.4	580.0
	DC-5-2	04.5	31.5	09.16	00.0	00.0	47.3	14.3	03.5	00.0	35.9	00.0	0.4	560.0
	DC-6-1	04.3	62.5	10.47	00.0	01.8	57.3	03.6	00.0	13.4	24.5	00.0	0.8	580.0
	DC-6-2	05.9	34.9	11.13	00.0	00.0	36.2	00.4	00.0	09.2	54.3	00.0	1.2	580.0
	DC-6-3	03.9	66.1	11.33	00.0	00.0	79.8	00.0	00.0	05.7	13.7	00.0	0.9	580.0
	DC-7-1	09.0	76.0	06.53	00.0	02.7	45.2	17.8	28.7	00.0	03.7	00.0	0.2	500.0
	DC-7-2	10.0	64.6	07.09	00.0	00.0	44.5	23.8	27.2	00.4	05.3	00.0	0.6	500.0
	DC-7-3	07.3	58.3	06.97	00.0	02.6	47.4	[illegible]	21.5	00.0	04.6	00.0	0.2	500.0
	DC-8-1	06.4	34.9	12.04	00.0	00.0	66.3	00.0	00.0	15.0	21.3	00.0	0.4	500.0
	DC-8-2	05.4	56.3	11.92	00.0	00.0	66.8	04.2	00.0	09.0	20.2	00.0	0.6	500.0
Selawik Lake Complex	AP-1-1	01.0	16.1	17.05	00.0	00.0	69.4	00.0	00.6	08.0	21.4	00.0	0.6	240.0
	AP-1-2	01.5	27.1	16.49	00.0	00.0	60.6	00.0	05.5	01.1	32.2	05.2	0.3	240.0
	AP-2	02.2	26.0	13.50	00.0	00.0	79.8	00.0	01.6	00.9	19.0	00.0	0.2	250.0
	AP-3	06.6	44.8	14.84	00.0	00.0	65.8	00.0	00.0	03.2	27.8	03.2	0.2	340.0
	AP-4	07.8	44.8	14.36	00.0	00.0	40.6	01.6	08.2	08.8	31.8	08.2	1.0	360.0
	AP-5	02.7	15.6	14.75	00.0	00.0	54.9	00.0	00.0	00.8	43.6	00.0	1.0	390.0
	AP-6A	86.0	70.3	10.65	00.0	00.0	70.6	00.0	00.6	08.6	18.6	00.0	1.8	700.0
	AP-6B	09.6	08.3	11.67	00.0	00.0	66.0	00.0	00.0	01.0	33.6	00.0	0.3	500.0
	AP-6C	92.0	37.0	11.13	00.0	00.0	67.4	00.0	00.5	07.7	22.2	01.2	1.0	800.0
	AP-7	06.4	42.7	06.48	01.0	06.0	75.3	08.2	07.0	00.0	00.0	00.0	2.5	340.0
	AP-8	05.6	45.8	07.77	01.0	08.1	72.0	05.3	05.2	00.0	00.0	00.0	5.3	400.0
	ZH-1	08.4	51.0	06.19	02.0	31.0	45.2	00.0	00.0	14.8	00.0	00.0	0.7	475.0
Zane Hills Pluton	ZH-2	05.4	58.3	05.52	04.1	32.3	43.2	14.6	01.2	06.0	00.0	00.0	0.5	600.0
	ZH-3	03.7	59.9	05.85	00.6	32.6	48.0	12.3	01.3	07.2	00.0	00.0	1.3	610.0
	ZH-4A	05.4	51.0	05.52	01.2	40.7	38.3	15.5	00.0	01.6	00.0	00.0	1.2	500.0
	ZH-4B	00.3	11.5	06.13	35.0	29.5	35.2	00.1	00.0	00.0	00.0	00.0	0.0	580.0
	ZH-5	00.3	14.1	03.82	28.6	48.4	16.2	00.0	00.0	05.4	00.0	00.0	0.6	330.0
	ZH-5A	02.3	74.0	05.68	03.2	37.6	41.2	13.8	00.0	02.8	00.0	00.0	0.8	500.0

Pluton	Sample	U	Th	K_2O	Qtz	Plag	K-feld	Am	Px	Bio	Ne	Gar	Acc	CPS
Zane Hills Pluton	ZH-6	02.4	13.5	03.21	36.4	44.0	15.9	00.0	00.0	04.5	00.0	00.0	0.4	250.0
	ZH-6A	01.7	13.5	03.35	49.2	41.6	19.3	00.0	00.0	05.3	00.0	00.0	0.2	250.0
	ZH-7	02.5	18.8	03.41	31.3	35.4	30.1	00.0	00.0	03.5	00.0	00.0	0.2	360.0
	ZH-8	04.8	44.8	02.60	22.6	48.8	17.3	00.0	00.0	10.9	00.0	00.0	0.3	260.0
	ZH-9	02.5	12.0	04.03	33.7	24.4	37.4	00.0	00.0	03.7	00.0	00.0	0.2	230.0
	ZH-10	01.7	11.4	03.27	32.7	39.9	22.0	00.0	00.0	03.3	00.0	00.0	0.4	240.0
	ZH-11	01.5	15.1	03.37	32.5	40.5	24.0	00.0	00.0	02.7	00.0	00.0	0.2	230.0
	ZH-11A	06.5	11.4	04.50	29.6	35.9	34.4	00.0	00.0	00.1	00.0	00.0	0.0	230.0
	ZH-12	03.6	63.0	07.15	05.0	34.8	52.7	07.6	00.0	02.4	00.0	00.0	0.1	750.0
	ZH-13	05.8	24.5	08.15	01.0	25.9	60.4	06.5	01.4	07.1	00.0	00.0	1.0	800.0
	ZH-13A	17.2	56.7	06.45	00.5	28.2	57.5	07.5	00.6	01.1	00.0	00.0	1.8	800.0
	ZH-14	02.1	40.6	06.61	00.5	30.5	54.2	12.8	00.2	00.0	00.0	00.0	0.2	720.0
	ZH-15	01.2	14.6	02.97	19.6	53.2	14.4	00.0	00.0	09.8	00.0	00.0	1.2	200.0
	ZH-16	00.9	14.0	02.80	21.2	42.3	14.7	02.4	00.0	05.3	00.0	00.0	0.7	180.0
	ZH-17	00.7	12.5	02.99	24.8	43.8	16.6	01.4	00.0	07.6	00.0	00.0	1.4	200.0
	ZH-17A	01.2	11.0	03.27	26.3	50.0	13.0	05.5	00.0	02.7	00.0	00.0	0.7	200.0
	ZH-18	01.4	07.4	03.04	30.8	37.6	24.0	00.4	00.0	06.8	00.0	00.0	0.4	220.0
	ZH-19	01.6	12.5	03.15	26.2	46.4	15.0	04.4	00.0	06.6	00.0	00.0	0.4	180.0
	ZH-20	01.6	02.1	03.14	25.2	47.6	16.8	03.8	00.0	05.4	00.0	00.0	0.8	200.0
	ZH-20A	02.8	08.9	03.21	25.4	45.6	17.3	05.4	00.0	05.1	00.0	00.0	0.7	200.0
	ZH-21	03.2	11.3	02.53	12.0	55.7	17.9	07.0	00.0	07.2	00.0	00.0	0.4	220.0
	ZH-22A-1	03.4	17.7	04.85	29.8	48.8	13.0	05.0	00.0	11.4	00.0	00.0	0.6	250.0
	ZH-22B-2	19.4	21.3	06.15	37.6	18.2	43.4	00.0	00.0	00.0	00.0	00.0	0.4	350.0
	ZH-22A-2	02.3	20.3	04.44	25.7	42.3	20.2	02.7	00.0	08.5	00.0	00.0	0.5	250.0
	ZH-22B-1	45.0	13.5	06.25	32.4	21.5	48.7	00.0	00.0	00.4	00.0	00.0	0.1	350.0
Darby Pluton	DA-1	02.1	[illegible]	04.01	25.8	31.7	33.1	00.0	00.0	06.1	00.0	00.0	0.2	375.0
	DA-2	01.8	28.6	04.8[illegible]	[illegible]	34.4	37.4	00.0	00.0	02.5	00.0	00.0	0.4	420.0
	DA-3	02.3	[illegible]	04.96	27.0	37.2	36.7	01.5	00.0	01.4	00.0	00.0	1.7	375.0
	DA-4	09.8	[illegible]	03.76	38.[illegible]	23.4	37.8	00.0	00.0	00.2	00.0	00.0	0.2	400.0
	DA-5-1	14.5	53.1	04.33	35.[illegible]	33.9	30.2	00.0	00.0	01.9	00.0	00.0	0.0	520.0
	DA-5-2	05.1	32.3	05.16	[illegible]	22.6	50.2	00.0	00.0	01.4	00.0	00.0	0.2	520.0
	DA-6-1	08.2	60.9	04.34	30.8	[illegible]	33.4	00.0	00.0	01.9	00.0	00.0	0.1	500.0
	DA-6-2	02.9	44.3	04.41	[illegible]	[illegible]	32.0	00.0	00.0	02.0	00.0	00.0	0.1	500.0

Darby Pluton

	U	Th	K_2O	Qtz	Plag	K-feld	Am	Px	Bio	Ne	Gar	Acc	CPS
DA-7	10.9	14.6	04.86	39.7	25.5	33.9	00.0	00.0	00.5	00.0	00.0	0.1	480.0
DA-8	01.3	44.8	04.07	37.8	29.7	28.3	00.0	00.0	03.2	00.0	00.0	0.4	580.0
DA-9	04.5	35.9	04.94	26.8	33.1	38.8	00.0	00.0	03.4	00.0	00.0	0.4	595.0
DA-10	02.8	48.4	04.45	39.9	24.7	32.7	00.0	00.0	01.6	00.0	00.0	0.3	600.0
DA-11	05.0	27.6	04.04	36.1	26.6	35.8	00.0	00.0	01.5	00.0	00.0	0.1	475.0
DA-12	07.9	13.5	04.71	38.5	20.9	38.2	00.0	00.0	01.8	00.0	00.0	0.2	530.0
DA-13	05.7	43.3	04.43	27.0	39.0	31.2	00.0	00.0	01.7	00.0	00.0	0.3	640.0
DA-14-1	08.2	51.0	04.37	39.2	13.6	45.6	00.0	00.0	02.0	00.0	00.0	0.1	580.0
DA-15-1	05.8	64.3	04.42	34.3	27.0	34.5	00.0	00.0	02.8	00.0	00.0	0.4	600.0
DA-15-2	02.7	57.8	04.92	22.1	36.2	36.9	00.0	00.0	03.3	00.0	00.0	0.3	600.0
DA-16-1	09.8	24.5	05.39	35.3	20.3	44.1	00.0	00.0	00.3	00.0	00.0	0.1	600.0
DA-16-2	08.8	16.6	05.08	35.6	27.3	35.0	00.0	00.0	01.8	00.0	00.0	0.4	600.0
DA-17	04.8	46.3	05.17	19.7	37.8	37.9	00.0	00.0	02.0	00.0	00.0	1.7	500.0
DA-18	02.9	41.2	04.32	24.7	37.0	37.4	00.0	00.0	00.8	00.0	00.0	0.2	560.0

There is no mineralogical data available for the following samples

GM-1	1.5	0.7	0.6
GM-2	1.8	0.8	0.02
GM-6	0.6	17.4	3.8
GM-7	1.6	50.5	6.0
GM-8	2.0	88.5	6.3
GM-9	1.0	50.1	5.2
DA-6	4.8	28.6	4.8
DA-19	2.6	56.7	4.5
DA-20	-0.3	12.0	1.3
DA-21	2.2	7.6	6.0

APPENDIX 2

Alkaline Igneous Rocks

The term alkaline has not been used consistently in the past. Sorensen (1974) summarizes the differing uses of this term.

1. Igneous rocks of Atlantic or Alkaline series (branch, group, facies).
2. Igneous rocks with alkali feldspar as the predominant feldspar, that is with more alkalies than average for their clans.
3. Igneous rocks containing feldspathoids.
4. Igneous rocks with an alkali-lime index less than 51.
5. Igneous rocks containing feldspathoids, and/or soda-Pyroxenes and/or amphiboles.

We have accepted Shand's definition of alkaline rocks. Noting that alkalies are chiefly contained in feldspar, he suggested the following: If the ratio of alkalies to alumina, or the ratio of alkalies to silica in the bulk composition exceeded the ratio found in K-feldspar or albite, the rock is to be considered alkaline.

APPENDIX 3

Examples of Correlation Coefficients, as taken from Davis (1973).

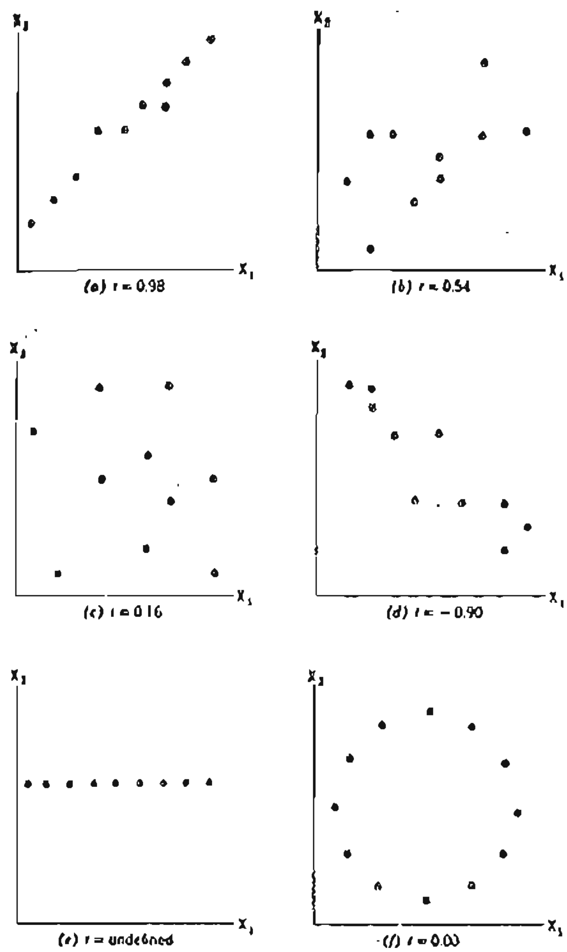


Figure 30. Correlation coefficients.

APPENDIX 4

Analytical Techniques

Uranium Determination

A 1.0g sample is digested in concentrated HF/HNO_3, and uranyl salts are formed. 10 ml of this solution are extracted into ethyl acetate using a saturated aluminum nitrate solution.

0.1 ml of the ethyl acetate layer is extracted and placed on a mixed carbonate-fluoride pellet in a platinum crucible. The ethyl acetate is evaporated under a quartz heat lamp.

The pellets and ethyl acetate residue are then fused at a temperature of 650°C for exactly 15 minutes.

The resulting fluorescence of the fused pellet is determined using a Turner model 110 fluorometer.

Thorium Determinations (Korkisch and Dimitriadis, 1973)

Thorium is separated from all matrix elements by means of anion exchange using the strongly basic anion exchanger Dowex 1, X8 (100-200 mesh; chloride form). After elution thorium is determined spectrophotometrically by using arsenazo III.

Ion exchange separation

The sorption solution is passed through the ion-exchange column containing 10 g of resin in the chloride form. The resin is washed, in portions, with a total of 100 ml of 8 M nitric acid in order to remove all elements accompanying the thorium, including those which are weakly retained by the resin. The absorbed thorium is then eluted with 100 ml of 6 M hydrochloric acid and the eluate is evaporated to dryness on a hot plate. To the residue, 5 ml each of 1 M hydrochloric acid and 2% potassium permanganate solution are added and the solution is evaporated on the hot plate to destroy organic matter. The residue (which may contain manganese dioxide) is taken up in 10 ml of concentrated hydrochloric acid and the solution is evaporated to dryness on the hot plate. Ten ml of hydrochloric acid plus 5 drops of formic acid are added to eliminate all nitrates and the solution is evaporated again.

Arsenazo method

The residue containing manganese (II) chloride and the thorium is dissolved in 5 ml of concentrated hydrochloric acid and after the addition of 1 ml of 0.2% arsenazo the solution is diluted with water to 10 ml in a standard flask. The thorium content is obtained by measuring the resulting color of the solution using a Beckman 25 spectrophotometer.

Potassium Determination

Potassium concentrations were determined using the atomic absorption method subsequent to fusion with $LiBO_2$.

Reproducibility of uranium analyses

To determine the variability in the uranium analyses performed by Resource Associates of Alaska, six splits of the same sample were submitted. These results are shown below.

Table 9

Replicate Analyses of DC-5-1

Trial	U-ppm
1	5.4
2	6.6
3	5.4
4	6.1
5	7.2
6	5.1

The reproducibility for this batch of check samples was quite good. However, the results of random check samples occasionally produced drastic differences in the analysed values. Some examples are listed below:

Table 10

Replicate Analyses of Mineral Separates

	Sample	Trial	U-ppm
Darby Mtns.	Felsic minerals	1	34
		2	-3.*
	Biotite	1	29.
		2	17.
Dry Canyon	Felsic minerals	1	19.
		2	-3.*
	Pyroxene	1	40.
		2	16.

*Uranium concentration is below the detection limit

The above samples were mineral separates. One would expect a larger error associated with these samples. However some of the results indicate a serious technical error. The unrealistically high values are believed to have been caused by contamination of the sample from the previous analysis. This presents a problem that must be considered when working with the uranium analyses in this report. A uranium analysis succeeding a high value may sometimes show a concentration of uranium where this concentration is the result of contamination.

The highest uranium values reported in this paper were resubmitted to the laboratory to check the validity of these results.

Point Counting Techniques

Modes were determined for 108 rock samples using point counting techniques. One thousand points were counted for each rock sample. Rock slabs were counted by placing a grid system, on transparent acetate, directly onto the rock slab. The counting interval was approximately equal to the largest crystal diameter, except in the highly porphyritic rocks.

Standard 1,000 mm^2 thin sections were counted using a J. Swift and Sons automatic mechanical stage. Two-inch by three-inch sections, equal to 3,000 mm^2 in area were counted using a hand operated mechanical stage.

According to Chayes (1956), the accuracy of the point counting analysis can be estimated in terms of the grain size and the area of the rock that is counted. Grain size is measured in this determination as "the number of major mineral identity changes along a unit length of line". The unit length is 40 mm. This analysis yields a number that is called the IC number.

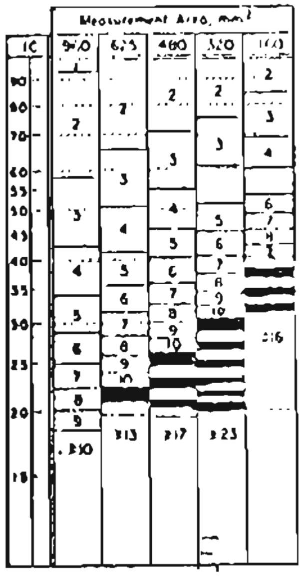
Figure 31 shows the number of thin sections required for maintaining average major mineral analytical error $\leq$1.4%, 2.0% and 2.5%. Based on the determination of IC numbers of a number of rock samples in this study, the analytical error is approximately $\leq$2.0%.

Staining Techniques

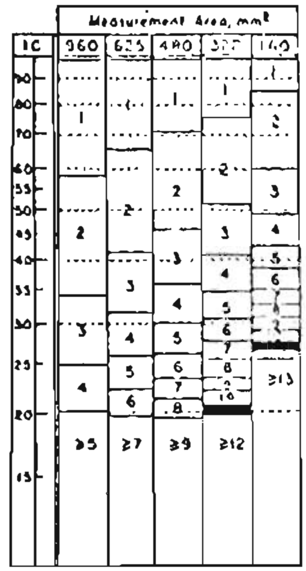
To aid in modal determinations, rock slabs, and thin sections were stained for potassium feldspar, plagioclase feldspar, and nepheline.

Potassium feldspar was stained with sodium cobaltinitrite after etching in concentrated HF (Norman II, 1974). Rock slabs were immersed in hydrofluoric acid, whereas the thin sections were etched with HF vapor at room temperature. If there was some difficulty in discriminating plagioclase from quartz, the sample was then dipped in a saturated $BaCl_2$ solution, which gives the plagioclase a powdery white appearance. Amaranth was not used because the color produced on the etched plagioclase was quite similar to the color of quartz in many of the samples.

Nepheline was stained using methylene blue and concentrated phosphoric acid, after Shand (1939). The syrupy phosphoric acid is spread onto the thin section or rock slab using a glass rod. After about one minute the sample is gently dipped in water. A silica gel is formed as a result of the decomposition of the nepheline by the acid. When dipped in a weak methylene blue solution (0.25%) the silica gel is stained deep blue. Preserving the stain is rather difficult. If the sample is allowed to dry the gel contracts and is easily removed in small dry flakes. A drop of water-soluble glue placed on the wet surface and covered with a coverglass will permanently preserve the stain.



1.41



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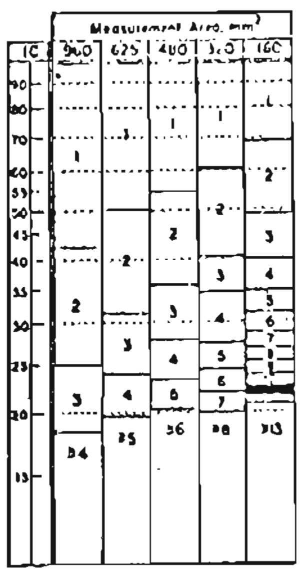

2.5

Figure 31. Number of thin sections required to maintain major mineral analytical error less than 1.41%, 2.0%, and 2.5%, based on the area of the thin section and the IC number, after Chayes (1956).