RA No. 49

RECLASSIFICATION AUTHORIZATION

In accordance with the authority delegated to me by memorandum from the General Manager, dated December 6, 1948, subject "Security Procedures and Policies relating to the Domestic Raw Materials Program" and based on the criteria for determining classification, as outlined in Appendix A attached thereto, the documents listed below are reclassified as indicated.

Document	Present Classification	Revised Classification
USGS - Trace Elements Investigation Report No. 39 - In the Serpentine-Kougarok Area Seward Peninsula, Alaska, by R. M. Moxham and W. S. West, dated November, 1949.	OFFICIAL USE ONLY	UNCLASSIFIED

June 10, 1950

Date

P. M.

Jesse C. Johnson

Manager
Raw Materials Operations

9/12/50 - by
N. B Patterson

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D.C.

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AEC-266/0

Dr. Phillip L. Merritt, Assistant Manager
Raw Materials Operations
U. S. Atomic Energy Commission
P. O. Box 30, Ansonia Station
New York 23, New York

Dear Phil:

Enclosed are copies 2, 4, and 5 of Trace Elements Investigations Report No. 39, "Trace elements investigations in the Serpentine-Kougarok area, Seward Peninsula, Alaska", by R. M. Moxham and W. S. West, November 1949.

Sincerely yours,

Thomas B. Nolan

Assistant Director

Enclosures 3

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATIONS IN THE SERPENTINE-KOUGAROK AREA, SEWARD PENINSULA ALASKA

By

R. M. Moxham and W. S. West

November 1949

Trace Elements Investigations Report 39

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D.C.

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(In pocket)

TRACE ELEMENTS INVESTIGATION IN THE SERPENTINE-KOUGAROK AREA, SEWARD PENINSULA, ALASKA

By Robert M. Moxham and Walter S. West

ABSTRACT

Three factors were responsible for seeking radioactive materials in the Serpentine-Kougarok area of the Seward Peninsula:

1) The known radioactivity of one of two placer samples available from the area.

2) The association of other radioactive material with a body of granite 45 miles west of the Serpentine Hot Springs granite.

3) The lack of other samples available for radioactivity tests from this important mining area.

Radioactive material in quantities detectable with a field Geiger-Mueller counter was found to be restricted to the bedrock and to the gravel within the outcrop area of granite at the head of Serpentine River.

Tests of radioactivity at outcrops of the granite indicate a small amount of active material is disseminated throughout the mass. Four variants of the normal granite have been recognized, including early and late differentiates, and pegmatitic and fine-grained facies. All variants except the early differentiates show

activity in excess of the normal granite. The average equivalent uranium content of 29 samples of the granitic variants is 0.008 percent. The heavy mineral portions of these samples average 0.034 percent equivalent uranium.

It is estimated the placer deposits in the area of granitic intrusion amount to about 200,000 cubic yards of material containing 0.00014 percent equivalent uranium. The gravel would yield approximately 400 short tons of heavy concentrate (with a specific gravity greater than 2.89) containing .072 percent equivalent uranium. The normal granite has millions of tons of material containing about 0.005 percent equivalent uranium. The more radioactive facies of the normal granite were not found in minable quantities.

The activity of the placer material and bedrock is attributed to three thorium-bearing accessory minerals and two secondary pegmatite minerals carrying small amounts of uranium.

INTRODUCTION

Purpose of investigation

Trace elements investigation in the Serpentine-Kougarok area on the Seward Peninsula, Alaska, in 1946, was made specifically to search for lode and placer deposits of radioactive materials. Three factors were responsible for the selection of this particular area for examination:

1) Two samples from the upper Kougarok area in the Alaskan placer collection were tested for radioactivity in the winter of 1944-45. One sample (labelled Harris Creek, a tributary of the

North Fork) showed 1.335 percent equivalent uranium and was among the more highly radioactive samples from all of Alaska. _/

_/ Harder, J. O., and Reed, J. C., Preliminary report on radioactivity of some Alaskan placer samples: U. S. Geol. Survey, Trace Elements Investigations Report 6, pp. 5, 14, unpublished, 1945.

2) Investigations in 1945 at Ear Mountain, 45 miles west of the Serpentine-Kougarok area, exposed a small radioactive lode deposit associated with a granitic intrusive and suggested the possibility of similar deposits in the granite area at the head of the Serpentine River.

3) Two placer samples, one from Mascot Gulch and one from Harris Creek, were the only samples from the Kougarok area available for prior testing. They were entirely inadequate to represent this important mining district.

The Kougarok district ranked second in gold production on the Seward Peninsula during the pre-war period, surpassed only by the Nome district. _/ Dredges accounted for the largest output, but

_/ Smith, P. S., The mineral industry of Alaska in 1939: U. S. Geol. Survey Bull. 926, p. 59, 1941.

many smaller hydraulic workings also contributed to it. Gold mining was at a standstill during the war owing to the ban on all but very small operations. In the summer of 1946, the first season after the lifting of restrictions, the miners attempted only preparatory work for future operations. They were hampered by the high cost of labor and shortage of machinery.

Mining in the upper Kougarok Valley has centered around Taylor, where a number of bulldozer-hydraulic operations were active during the pre-war period. Most of the other workings were within a short distance of Taylor on the main stream, but many of the upper tributaries have been worked sporadically in the past, some nearly to their sources. In 1946, the operations in the upper Kougarok Valley, above the mouth of North Fork, were as follows: John Kanari, six miles north of Taylor; the Kougarok Consolidated Placers Inc., Keenan's camp, four miles north of Taylor, where dredging had not yet been resumed, but drilling was in progress; Jim Carroll at Taylor; Sam Godfrey at the mouth of Henry Creek, two miles south of Taylor; and the North Fork Dredging Co., operating a dredge at the mouth of Harris Creek. In the upper Serpentine Valley, George Bodis was working near the mouth of Dick Creek, 12 miles northwest of Taylor. Near the mouth of Budd Creek, a tributary of American River, Dodson had resumed mining, but his camp was not visited. Mining had not yet been resumed at the Walsh camp on Humboldt Creek, about eight miles east of Serpentine Hot Springs.

Personnel and acknowledgments

The field party consisted of Robert M. Moxham and Walter S. West, geologists; Arthur E. Nessett, cook; and John J. Otoyuk and John E. Kemek, camphands.

Acknowledgment is gratefully made to Messrs. Sam Godfrey and M. J. Walsh of Nome, and the personnel of Wien Alaska Airlines, Inc. for their assistance and cooperation in the field.

GEOGRAPHY

Location and extent of area

The Serpentine-Kougarok area, in the north-central part of the Seward Peninsula in western Alaska, straddles the divide along the east-west axis of the Peninsula. Figure 1 shows the location of the Serpentine-Kougarok area on the Seward Peninsula. The portion of greater interest is outlined in the northeastern part of figure 1 and is shown on a larger scale in figure 2.

The Serpentine River, on the north side of the divide, is formed by the junction of Bryan, Schlitz, and Hot Springs Creeks and flows northwestward into Shishmaref Inlet, an indentation of the coast of the Arctic Ocean in the northwestern part of the Peninsula. The Kougarok River flows south from the divide into the Kuzitrin River which enters Bering Sea on the west side of the Peninsula via the inlets (Salt Lake, Grantley Harbor, and Port Clarence) in the vicinity of the settlement of Teller. The northeastern part of the area includes the headwaters of Humboldt Creek and the Fish River. Humboldt Creek is the main western tributary of the Goodhope River which drains into Kotzebue Sound on the northeastern coast of the Peninsula. The Fish River lies north of Humboldt Creek and flows directly into Kotzebue Sound. South of the divide and east of the Kougarok, the American River flows southward into the Agiapuk River which in turn enters Salt Lake, east of Teller. The Kougarok Mountains form the divide between the American and Kougarok basins. They have an average relief of about 1500 feet.

Settlements, accessibility, and sources of supply

The city of Nome, on the south coast of the Seward Peninsula and about 80 miles south of the center of the area investigated, is the principal source of supplies and the main base for small planes, which are the only convenient means of transportation into the Serpentine-Kougarok area.

The two more prominent landing fields in the Serpentine-Kougarok area are at Taylor in the upper part of the Kougarok Valley at the mouth of Taylor Creek and on Hot Springs Creek at the head of the Serpentine River. At the time of this report the Serpentine Hot Springs field was generally considered hazardous because of its short length (about 1,000 feet), rough surface, and the prevalence of crosswinds and downdrafts. The Taylor field was the most frequently used for routine service. Airstrips are also in use at most of the active mining camps, including Keenan's and John Kanari's camps, four and six miles, respectively, north of Taylor on the Kougarok; George Bodis' camp on Dick Creek in the Serpentine basin, about 12 miles northwest of Taylor; and at the North Fork Dredging Company's camp on North Fork, five miles east of the Kougarok River.

Taylor, formerly an active placer-mining camp and center of population in the Serpentine-Kougarok area, was almost completely abandoned during the last years of the war owing to the ban on gold mining. Only one man was working there during the summer of 1946. Taylor can be reached by road from Shelton in the lower Kougarok

Valley, the terminus of a narrow-gauge railway from Nome. Freight for the Kougarok area is also brought in by barge from Teller to Davidson's Landing, 25 miles south of the area of the map, and then hauled by tractor to the various mining camps.

Serpentine Hot Springs, about 14 miles north of Taylor, can be reached from Taylor either by tractor trail or plane. There are no permanent residents in the immediate vicinity of the hot springs.

Physical conditions in the area

The greater part of the Serpentine-Kougarok area has a rolling, tundra-covered surface above which rise a few ridges of rather low relief with local steep and rugged peaks. The tundra extends up the flanks of the hills until the steepness of the slope affords some drainage. Above this level the rocks are generally bare of vegetation and usually disintegrated into a deep talus mantle by severe frost action. The area is treeless, except for a few small stunted willows in some creek bottoms, and hence all fuel must be shipped into the area.

GEOLOGY

Published and unpublished information on the general geology and mineral resources of the Serpentine-Kougarok area is very scant. The earlier reconnaissance investigations in 1900, 1901, and 1906 were summarized by Brooks in 1908. _/ Brief statements have been

_/ Brooks, A. H., The Kougarok region: in, The gold placers of parts of Seward Peninsula, Alaska, by A. J. Collier, et al.: U. S. Geol. Survey Bull. 328, pp. 294-328, 1908.

published on some of the lode prospects. _/ Comments on the

_/ Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: U. S. Geol. Survey Bull. 345, p. 244, 1908.

Martin, J. B., Jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, pp. 440-442, 1918.

Brooks, A. H., (Brief statement on Ward copper prospect), Mineral resources of Alaska, 1920: U. S. Geol. Survey Bull. 722, p. 65, 1922.

placer-mining activities are made in a water-supply paper and in many of the Survey's annual reports on the mining industry. _/ The

_/ Henshaw, F. F., and Covert, C. C., The Kougarok region: in, Water-supply investigations in Alaska, 1906-1907: U. S. Geol. Survey Water-supply Paper 218, pp. 77-98, 1908.

Brooks, A. H., and Smith, P. S., (In the various annual summary reports between 1905 and 1942 on the mining or mineral industry in Alaska): U. S. Geol. Survey Bulls. The numbers of the yearly bulletins may be obtained from "Publications of the Geological Survey".

placers of the upper Kougarok were described in an unpublished report in 1941. _/

_/ Shallit, A. B., The placer deposits in the upper Kougarok, Seward Peninsula, Alaska: unpublished manuscript presented at the University of Alaska for degree of Engineer of Mines, 1941.

<u>Rock formations</u>

Three types of bedrock are recognized in the Serpentine-Kougarok area. These are:

1) Two "members" of the Nome group of altered sedimentary rocks of Ordovician and Silurian age.

a) Undifferentiated limestones, slates, and schists.

b) The Port Clarence limestone, probably mostly Silurian in age.

2) Greenstones of Paleozoic or younger age.

3) Granite and other acidic intrusives of Mesozoic or, in part, perhaps of Tertiary age.

Quaternary unconsolidated sands and gravels occur as fill of variable depth in the valley bottoms.

Undifferentiated limestones, slates, and schists

In general, the undifferentiated limestones, slates, and schists of the Nome group are exposed in the valley basins; whereas the Port Clarence limestone forms the ridges between the basins. Exceptions to this generalization include parts of Kougarok Mountain and Midnight Mountain and the nearby hills, which are composed of schist. The schists normally consist of quartz and chlorite or muscovite but are locally graphitic. Graphite is well developed at one outcrop, two miles north of Serpentine Hot Springs in the bank of a small tributary of Rock Creek.

Port Clarence limestone

The Port Clarence limestone is a massive crystalline marble in most places. Some localities near the limestone-schist contact show considerable contortion. Traces of fossils have been retained in a few localities despite the intense changes, and those collected by Collier on Harris Creek were considered to be Niagaran or Middle Silurian in age. /

/ Collier, A. J., et al., The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 76, 1908.

Greenstones

Intensely altered basic intrusives, classified as greenstones by Collier, occur on Washington and Henry Creeks, tributaries of the upper Kougarok River, and in the valley of the Kougarok south of Coarse Gold Creek. The greenstones on Henry Creek contain crystals of actinolite and garnet but lack the schistose characteristic of this rock type in other localities.

Serpentine Hot Springs granite and other acidic intrusives

The major rock mass of Mesozoic or Tertiary age is a granitic stock that is exposed over a roughly oval area (fig. 1). The long axis of this oval is about six miles in length and strikes east. Serpentine Hot Springs is slightly west of the center of the granite area, of which the larger part is within the headwater drainage of Hot Springs and Humboldt Creeks, and the Fish River. The outcrop of the granite is made conspicuous by the abundance of pinnacles formed by weathering along well-developed joint systems.

Rhyolitic intrusives of smaller size occur on the summit of Kougarok Mountain as well as on its southwest flank. The rhyolite on the summit was not found in place, but the amount and alignment of float suggests that the material is not far removed from its bedrock source. Several such areas of float were seen on a traverse along the crest of the Mountain.

The normal granite is a coarse, light-colored rock composed chiefly of quartz, orthoclase, and biotite.

Locally the granite exhibits rounded or globular masses, containing a much greater proportion of biotite. The maximum diameter of these masses is about 1 foot. They probably represent partly assimilated inclusions of an early basic magmatic differentiate or border phase.

The stock has been transected by three types of intrusive material or differentiates of the granite:

1) Pegmatitic quartz-muscovite veins.

2) Fine-grained, acidic veins similar to the granite in composition.

3) Dark-colored, tabular, dike-like masses similar in composition to the earler basic differentiates.

Probably all of the three types listed above are related in time of emplacement and magmatic source and represent phases in consolidation of the magmatic sequence. The veins are generally very irregular and difficult to trace for any distance. The margins may be either sharp or gradational. Few of the veins exceed several inches in thickness, and the thicker portions are generally lens-shaped. Vugs are present in some of the pegmatite veins and are lined with quartz, mica, and tourmaline crystals.

Although these granitic variants are present in many parts of the area, the greater number occur in the pinnacles on the flanks and summit of the low hill on the northeast side of the south fork of Hot Springs Creek. Vugs and irregular banding are well developed in a vein that transects a pinnacle near the summit of the hill at the locality where samples 86-88 were collected (see fig. 2). The vein consists of a central zone up to 4 inches in width composed of quartz, muscovite, and tourmaline, and irregular zones on both sides composed of layers of fine-grained, acidic material a few inches in width. A biotite-rich zone, about 5 feet in length and several inches wide, occurs in the normal granite along one margin of the vein. In a second pinnacle, 30 feet distant, the probable continuation of the same vein contains a vug 2 feet in diameter lined with quartz crystals up to 2 inches in length and books of mica.

MINERALIZATION, LODE PROSPECTS, AND PLACER GOLD MINING

Tin, tungsten, mercury, copper, and gold have been found in the Serpentine-Kougarok area.

A small amount of placer cassiterite occurs in the gravels of Humboldt Creek and has been reported from Mascot Gulch, a headwater tributary of the Kougarok, and from Dick Creek, a tributary of the Serpentine. An unverified report suggests cassiterite may occur also in Budd and Windy Creeks, tributaries to American River. Scheelite, said to have been obtained from Homestake Creek, a tributary entering the Kougarok from the west at Taylor, was shown to the writers by a prospector. Cinnabar has been recognized in some gravels of the lower Kougarok Valley, and a small amount was seen in semi-concentrates from a shallow gully in the south side of the eastern fork of Hot Springs Creek.

Several copper prospects have been staked in the vicinity of Kougarok Mountain, but evidence of development work was seen only at the Ward property between Bismark and Star Creeks, 2 miles north of the northern end of Kougarok Mountain. Several trenches have been dug at the Ward prospect, and an adit, now caved a short distance from the portal, reveals a few veins of malachite and azurite about 2 inches thick near a limestone-schist contact.

Gold-quartz lodes have been exposed by placer mining at the headwaters of the Kougarok River, although none have been worked commercially.

Placer-gold deposits have been found in many parts of the drainage basins of the area. The placers have been mined on Dick Creek, Humboldt Creek, some tributaries of the American River, and in the Kougarok basin. The major part of the production has been from the Kougarok and its tributaries.

Placer deposits in the Kougarok Valley occur both in the gravels of the present streams and in those on benches at two or more levels. The more conspicuous benches are at altitudes of 25 and 50 feet above the present stream. The benches are discontinuous and somewhat difficult to recognize because of erosion and soil creep. The bench gravels average 10 to 20 feet in thickness. Drilling at the dredge site of the Kougarok Consolidated Placers Inc., in 1946, showed the stream gravels to be 18 feet thick. All of the gravels are characteristically barren of gold except in the few inches above bedrock.

RADIOACTIVE MINERAL INVESTIGATIONS

Methods and procedures

Field procedures

Utilization of the Geiger-Mueller counter in trace elements reconnaissance work has been discussed in detail by Stead. _/

_/ Stead, F. W., Preliminary report on field measurement of radioactivity: U. S. Geol. Survey, Trace Elements Investigations Report 13, pp. 1-5, unpublished, 1945.

Approximate quantitative measurements of samples were made by comparison with a standard containing a known percentage of equivalent uranium. Bedrock samples were crushed to approximately 20-mesh size, and a quantity sufficient to fill a container identical with the standard in shape and volume (25 cubic inches) was used for radioactivity determinations. The 20-mesh size was selected arbitrarily for convenience in later laboratory work.

Samples of stream gravels were panned only to semi-concentrates of sufficient bulk for comparison with the standard because of the excessive time involved in obtaining the necessary amount of clean heavy concentrate. The samples represent surface gravel only, except those obtained from placer mines. Care was taken, however, to remove the uppermost well-washed gravel and to take samples at such depths that the sands and clays formed a tight matrix between the pebbles and retarded the downward movement of the heavy minerals.

Laboratory studies

Bedrock and placer samples were further concentrated in the laboratory for mineralogical study and for determining to what degree the radioactive material could be concentrated. The small quantity of material which would not pass through a 20-mesh sieve was rejected after scanning for radioactive mineral fragments, for only grains under that size would pass through the separatory funnels used in heavy-liquid separations. Samples were split into fractions of greater and less than 2.89 specific gravity by use of the heavy-liquid bromoform. From some selected samples the minerals heavier than 3.3 specific gravity were removed with methylene iodide. The bromoform heavy fractions, which approximate the character of sluice-box concentrates, were tested for radioactivity with a laboratory beta counter.

Distribution of radioactive material

Radioactive material was found in quantities detectable with a field Geiger-Mueller counter in gravel or bedrock only in the area of intrusive granitic rock outcropping in the vicinity of Hot Springs Creek at the head of the Serpentine River and adjacent east-flowing drainage.

Data concerning the gravel samples are given in appendix 1, and the data on the crushed bedrock samples are listed in appendix 2.

Surface samples of the placer deposits of Budd and Eldorado Creeks (eastern tributaries of American River), the upper Kougarok River and its tributaries, and the headwater tributaries of the

Serpentine River, excluding Hot Springs Creek, did not show sufficient activity to be detected with a field counter, although a few of the heavy-mineral fractions of these samples display a slight amount of radioactivity. However, the investigation was not carried far enough into the American and Goodhope River basins to entirely eliminate these placer areas; likewise, no work was done on the Kougarok River or its tributaries downstream from North Fork.

One dredge concentrate was collected from the Kougarok Consolidated Placers, Inc. The material was derived from gravel on the left limit of the Kougarok River between the mouths of Taylor and Homestake Creeks. No appreciable activity was noted.

The reconnaissance of Harris Creek failed to reveal any placer material along the creek's course comparable in radioactivity to that shown by the older sample from the Alaskan placer collection. Unfortunately, all of this original sample from Harris Creek was used in chemical analysis, and mineralogical comparison with samples taken in 1946 is impossible. The original sample may represent an extremely high local concentration or a sluice concentrate from gravel immediately above bedrock at one of the older placer workings, or the sample may have been incorrectly labeled and actually taken at another locality.

Both "members" of the Nome Group were examined in a number of localities with no activity being apparent. The greenstone was tested at the outcrop area on Kougarok Mountain. The results were negative.

As stated above, the acid dikes on Kougarok Mountain were not found in place. Placer samples from the drainage basin in which the dikes are located failed to show significant activity, which would indicate the intrusives are lacking in radioactive constituents in commercial quantities.

No radioactive minerals were found at the Ward copper prospect located on the north flank of Kougarok Mountain. Laboratory tests of the ore taken a few feet from the portal were negative.

The locations of all samples collected in the Serpentine Hot Springs area are shown in figure 2. In the symbols, e. g., 93 .023, used for sample localities on figure 2, the figures preceding the decimal points are the field collection numbers of the samples, and the figures including and following the decimal points represent equivalent uranium, hereafter referred to as E. U., in the heavy-mineral fractions. Data relating to samples 118 through 184 have been omitted from figure1 and the appendix as a result of their insignificant activity.

Radioactive material in the gravels

The radioactivity of most of the semi-concentrates panned from the gravel in the Serpentine Hot Springs area is sufficient to be readily recognizable with a field counter. The content of active material in these semi-concentrates ranges from 0.000 to 0.017 percent E. U. As the degree of concentration obtained by panning is purely arbitrary and differs for each sample, the percent E. U. of the semi-concentrates is not given in appendix 1.

Further concentration of these samples in bromoform yielded heavy-mineral fractions containing 0.003 to 0.84 percent E. U. The average content of the heavy fractions of the 74 samples is 0.064 percent E. U. The increase in tenor of radioactive material effected by heavy-liquid separations in the laboratory indicates roughly the amount of beneficiation of the original gravel that might be obtained by the most efficient gravity methods under ideal conditions. The concentration ratio, that is, the weight of the original gravel to that of the heavy-mineral fraction, gives a rough estimate of the amount of heavy minerals in the gravel that might be recovered at each sample locality. The concentration ratio averages 758 to 1. Assuming 1 cubic yard of gravel weighs 3,100 pounds, the heavy-mineral content averages 4 pounds per cubic yard of gravel.

The amount of radioactive material in the unconcentrated gravel is too low to be determined with a counter, but may be computed from the concentration ratios and the E. U. content of the heavy-mineral fractions. (See appendix 1.) The numerical average of all samples is 0.00014 percent E. U. The highest content of radioactive material in the unconcentrated gravel was found at two sites represented by samples 73 and 37 (see fig. 2), which contain approximately 0.0012 and 0.0019 percent E. U., respectively. The maximum recovery possible by gravity concentration would be approximately 4.3 pounds per cubic yard of material which would contain 0.84 percent E. U. (sample locality 73), and 22.6 pounds per cubic yard of material which would contain 0.26 percent E. U. (sample locality 37).

Bedrock deposits of radioactive material

The normal granite in much of the Serpentine Hot Springs area probably contains disseminated accessory minerals which are slightly radioactive, for gamma counts on all outcrops are above the average background count. Four samples of the granite from widely separated localities averaged 0.005 percent E. U. in the unconcentrated form. The crushed material was treated with methylene iodide, and a very small quantity of heavy minerals was obtained. The small amount of heavy residue prevented the determination of the E. U. content, but qualitative radiation tests indicate slight activity. A sample of disintegrated granitic material collected from a sidehill wash, concentrated by the removal of the lighter minerals through creep action, contained 0.004 percent E. U. as determined in the field. The heavy-mineral fraction of this sample contains 0.06 percent E. U.

As stated above, four variants of the normal granite have been recognized. Samples of three, the pegmatitic, fine-grained acidic, and late basic differentiates, all show activity in excess of the normal granite, whereas outcrop tests of the early differentiates failed to indicate any concentration of active minerals. The most active unconcentrated sample (no. 82) of lode material is of the pegmatitic variety and contains 0.032 percent E. U., or about 10 ounces of material equivalent in activity to uranium per short ton of rock. The average E. U. content of 20 samples of the pegmatitic facies of the normal granite indicates that this facies contains slightly less than 3 ounces of E. U. per short ton.

The sample of fine-grained acidic intrusive (no. 86) containing the greatest quantity of E. U. would yield approximately 5 ounces per short ton. This sample was taken from the vein described on page 12. The average content of the three samples of acidic dikes is 0.009 percent E. U., or 3 ounces per short ton. The most radioactive sample of the basic dike material (no. 105) contains 0.011 percent E. U., or about 3½ ounces per ton. The average of the three sites sampled is 0.008 percent E. U., or about 2½ ounces per ton.

Radioactive minerals

Radioactivity in the gravel and bedrock originates from active elements associated with the following minerals: zircon ($ZrSiO_4$), titanite ($CaTiSiO_4$), allanite (an hydrous silicate of Ca, Fe, Al, Ce, La, and Di), hydrogoethite ($3Fe_2O_3 \cdot 4H_2O$), and two unidentified secondary minerals.

The small size of the zircon crystals prevented hand picking sufficient material for a quantitative analysis of its activity. However, a magnetic separation of sample 18 yielded a nearly pure zircon fraction which was tested semi-quantitatively with a laboratory beta counter and showed approximately 0.15 percent E. U.

Sodium-fluoride flux tests for uranium _/ on this fraction were

_/ Northrup, M. A., Fluorescent bead test for uranium in minerals: Ind. Eng. and Chem., Anal. Ed., vol. 17, pp. 664-670, Oct. 1945.

negative so that the activity is thought to be due to thorium, although fluorescence in this instance may have been inhibited by the relatively high percentage of zirconium.

Spectrographic analyses of hand-picked samples of allanite and titanite show 0.1 and 0.03 percent thorium, respectively. These figures are approximate, as they are close to the limit of sensitivity for the method used. Uranium was not detected spectrographically, and sodium-fluoride flux tests on these two minerals were also negative.

The three secondary minerals, hydrogoethite and two unidentified, react positively for uranium in sodium-fluoride flux. Spectrographic analysis indicates a content of somewhat less than 1 percent.

Mineralogical studies of the placer samples indicate the activity is due principally to zircon and allanite, both of which are present in all of the concentrates. Allanite is present in many of the samples, and hydrogoethite and the two unidentified secondary minerals occur in a somewhat smaller percentage of the concentrates. Although these minerals usually constitute a minor portion of the heavy minerals in comparison to the zircon and titanite, they doubtless add considerably to the activity in many samples.

Field outcrop tests, as well as the laboratory studies, of the normal granite indicate the presence of minor amounts of active minerals rather evenly distributed throughout the mass. The widespread occurrence of zircon and titanite in the streams draining the outcrop area of the intrusive supports this conclusion. Allanite, which is less common and present in smaller amounts, is probably also an accessory mineral in the normal granite, although perhaps more irregularly disseminated.

The activity of the pegmatitic facies of the granite is due primarily to hydrogoethite and two other secondary minerals as yet unidentified. X-ray and spectrographic studies of these two minerals were inconclusive in suggesting the nature of the primary minerals from which they may have been derived. The major constituent elements of one of the secondary minerals are Cu, Ag, and Pb; traces of Be and Fe are present. The other mineral consists mainly of Al, Ca, Fe, Ag, Cu, Pb, and Si. The hydrogoethite contains traces of Cu, Ag, Be, and Si, in addition to the major constituent, Fe. The radioactive part of the heavy-mineral fraction of the fine-grained acidic intrusives is composed chiefly of zircon and titanite with lesser amounts of allanite, whereas the active heavy portion of the biotitic variant is composed primarily of allanite with only a few grains of zircon.

Thorium-uranium content

The relative amounts of thorium and uranium in the gravel and bedrock deposits are dependent upon the nature of the mineral constituents. As shown above, the activity of the placer deposits is primarily due to thorium-bearing zircon, titanite, and allanite, and to a lesser extent to secondary minerals containing uranium. The activity of the normal granite, the fine-grained acidic intrusives, and the biotite-rich material is also due to the presence of thorium-bearing minerals. The secondary minerals of the pegmatitic facies contain uranium but it is not known whether thorium is also present.

Inferred reserves

As no mining has been done in the Serpentine Hot Springs area, data are lacking on the depth of the gravel and the degree of increase of tenor toward bedrock. The gravel is undoubtedly shallow, and an estimate of 6 feet in depth may be close to the average along the main channels of all branches of Hot Springs Creek and the headwater tributaries of Humboldt Creek and the Fish River. The width of the gravel could not be determined specifically because the places where the stream deposits coalesce with slope wash are mostly covered by tundra. The low content of heavy minerals in the gravel did not warrant line sampling across the course of the streams to determine variation in content of radioactive material over a definite width of gravel. Approximately 15 miles of creek bottom were sampled. Assuming the gravel deposits are 4 yards wide and 2 yards deep as a fair overall estimate of the ground containing radioactive material, there are about 200,000 cubic yards of gravel in the drainage basins of Hot Springs Creek and the headwaters of Humboldt Creek and the Fish River. The gravel contains approximately 400 short tons of heavy concentrate having an average E. U. content of .072 percent.

Although the number of samples taken of the normal granite can hardly be considered representative, the slight activity indicated by numerous outcrop tests at widely scattered localities supports the inference that the average content of the samples collected, 0.005 percent E. U., approximates the tenor of the normal granite. The outcrop of this rock is more than 24 square miles in extent and represents a mass of millions of tons. The vein material is narrow and irregular, seldom exceeding a few inches in width and a few feet in length. There did not appear to be a minable quantity at any of the sites sampled.

Conclusions

The investigations in the Serpentine-Kougarok area failed to reveal either placer or bedrock deposits of radioactive material in quantities of commercial interest. Although the field studies were necessarily restricted in their scope, the results do not indicate further work to be warranted.

APPENDIX I

Data on gravel samples, Serpentine Hot Springs granite area

Sample locality number	Heavy-mineral concentrate (bromoform separation) E. U. content (percent)	Heavy-mineral concentrate (bromoform separation) Weight (grams)	Weight original gravel sample (pounds)	Concentration ratio (weight original gravels to heavy-mineral fraction)	E. U. content natural gravels (percent)
		Hot Springs Creek and tributaries (all samples in order downstream)			
		Main right-limit tributary of north fork			
60	.041	36.0	30	378:1	.00011
59	.058	71.2	60	382:1	.00015
58	.036	60.7	60	448:1	.00008
57	.047	65.7	60	414:1	.00011
56	.050	42.6	80	852:1	.00006
55	.046	60.0	70	529:1	.00009
26	.052	40.8	30	334:1	.00016
		Northeast headwater branch of the north fork			
25	.016	15.2	30	895:1	.00002
24	.015	21.1	30	645:1	.00002
23	.035	19.3	30	705:1	.00005
22	.044	20.2	30	674:1	.00007
21	.053	23.2	30	587:1	.00009
20	.054	4.0	30	3400:1	.00002
37	.260	99.3	30	137:1	.00190
19	.017	10.8	30	1260:1	.00001

APPENDIX I (continued)

Data on gravel samples, Serpentine Hot Springs granite area

Sample locality number	Heavy-mineral concentrate (bromoform separation) E. U. content (percent)	Heavy-mineral concentrate (bromoform separation) Weight (grams)	Weight original gravel sample (pounds)	Concentration ratio (weight original gravels to heavy-mineral fraction)	E. U. content natural gravels (percent)
		Southeast headwater branch of the north fork			
42	.041	33.7	30	404:1	.00010
41	.008	26.5	30	514:1	.00002
40	.018	10.1	30	1350:1	.00001
39	.040	13.2	30	1031:1	.00004
91	.173	19.4	50	1169:1	.00015
38	.015	45.6	40	398:1	.00004
		Minor tributary gulches near junction NE and SE headwater branches of north fork			
73	.840	31.9	50	711:1	.00118
70	.463	35.7	50	635:1	.00072
71	.039	43.8	43	445:1	.00009
		North fork below junction of headwater branches to main right-limit tributary			
18	.070	21.6	30	630:1	.00011
72	.100	24.4	50	929:1	.00011
17	.028	34.8	30	391:1	.00007
16	.070	14.3	30	952:1	.00007

APPENDIX I (continued)

Data on gravel samples, Serpentine Hot Springs granite area

Sample locality number	Heavy-mineral concentrate (bromoform separation) E. U. content (percent)	Weight (grams)	Weight original gravel sample (pounds)	Concentration ratio (weight original gravels to heavy-mineral fraction)	E. U. content natural gravels (percent)
	North fork below junction of headwater branches to main right-limit tributary (continued)				
15	.052	11.1	30	1226:1	.00004
69	.006	32.3	30	421:1	.00001
14	.036	15.9	30	856:1	.00004
68	.112	35.7	40	508:1	.00022
67	.103	51.6	30	264:1	.00039
	South fork Hot Springs Creek				
35	.069	15.4	50	1473:1	.00005
36	.031	11.1	30	1226:1	.00003
32	.032	9.5	30	1432:1	.00002
34	.003	18.7	30	728:1	.00000
33	.005	16.3	30	835:1	.00000
31	.050	20.3	30	670:1	.00008
30	.012	29.2	35	544:1	.00002
29	.064	60.4	30	225:1	.00028
63	.038	27.1	30	502:1	.00008
62	.034	36.3	30	375:1	.00009
61	.036	25.0	30	544:1	.00007
28	.062	69.2	40	262:1	.00024
27	.036	24.2	40	750:1	.00005
48	.052	34.7	30	392:1	.00013

APPENDIX I (continued)

Data on gravel samples, Serpentine Hot Springs granite area

Sample locality number	Heavy-mineral concentrate (bromoform separation) E. U. content (percent)	Heavy-mineral concentrate (bromoform separation) Weight (grams)	Weight original gravel sample (pounds)	Concentration ratio (weight original gravels to heavy-mineral fraction)	E. U. content natural gravels (percent)
		South fork Hot Springs Creek (continued)			
46	.044	16.9	30	805:1	.00006
47	.018	22.2	30	613:1	.00003
		Left-limit gully of Hot Springs Creek below forks			
45	.015	5.4	30	2520:1	.00000
		Downstream from junction of main right-limit tributary and north fork			
66	.086	44.4	40	409:1	.00021
13	.108	57.6	30	236:1	.00046
12	.062	44.2	55	564:1	.00011
11	.082	44.2	30	308:1	.00027
10	.060	32.4	30	420:1	.00014
9	.079	31.8	30	428:1	.00018
7	.068	31.9	30	427:1	.00016
6	.030	15.7	30	867:1	.00004
5	.037	27.5	30	495:1	.00008
4	.030	18.4	30	740:1	.00004
3	.040	52.5	30	259:1	.00015
2	.041	68.5	40	265:1	.00015

APPENDIX I (continued)

Data on gravel samples, Serpentine Hot Springs granite area

Sample locality number	Heavy-mineral concentrate (bromoform separation) E. U. content (percent)	Heavy-mineral concentrate (bromoform separation) Weight (grams)	Weight original gravel sample (pounds)	Concentration ratio (weight original gravels to heavy-mineral fraction)	E. U. content natural gravels (percent)
		Downstream from junction of main right-limit tributary and north fork (continued)			
1	.044	48.9	30	278:1	.00016
43	.027	17.3	30	787:1	.00003
44	.050	20.4	30	667:1	.00007
		Fish River and tributaries			
92	.020	11.7	50	1940:1	.00001
109	.031	8.8	55	2835:1	.00001
101	.008	32.3	50	702:1	.00001
		Humboldt Creek and tributaries			
95	.038	18.8	45	1086:1	.00004
94	.057	62.7	63	456:1	.00012
100	.037	35.6	50	637:1	.00006
99	.016	15.5	69	2021:1	.00000
97	.009	39.3	40	462:1	.00002
98	.010	54.9	53	438:1	.00002

APPENDIX II

Data on bedrock samples, Serpentine Hot Springs granite area

Sample locality number	E. U. content of crushed sample (percent)	E. U. content heavy-mineral concentrates (percent)	Concentration ratio (weight of the original sample to heavy minerals)	Type of material
74	.016	.034	2.0	Quartz-muscovite-tourmaline vein
75	.019	.057	3.3	Same vein as #74; 8 feet distant
76	.008	.033	5.6	Quartz-muscovite-tourmaline vein
77	.006	.017	2.3	Quartz-muscovite vein
78	.004	.018	5.0	Quartz-muscovite vein
79	.016	.024	2.7	Quartz-muscovite vein
80	.005	.011	3.4	Quartz-muscovite tourmaline vein
81	.007	.085	19.5	Quartz-muscovite vein
82	.032	.096	9.5	Quartz-muscovite vein
83	.004	.039	17.9	Quartz-muscovite vein
84	.004	.020	4.5	Biotite-rich granitic differentiate
85	.009	.021	1.9	Biotite-rich granitic differentiate
86	.015	.071	150.5	Fine-grained acidic vein
87	.004	.070	42.0	Fine-grained acidic vein
88	.004	.036	4.6	Quartz-muscovite-tourmaline vein
90	.007	.021	110.0	Fine-grained acidic vein
93	.012	.023	6.9	Quartz-muscovite vein
96	.000	.009	2.3	Quartz-muscovite vein
102	.002	.060	214.0	Disintegrated granite from sidehill wash
103	.004	.022	16.4	Quartz-muscovite vein

APPENDIX II (continued)

Data on bedrock samples, Serpentine Hot Springs granite area

Sample locality number	E. U. content of crushed sample (percent)	E. U. content heavy-mineral concentrates (percent)	Concentration ratio (weight of the original sample to heavy minerals)	Type of material
104	.000	.023	8.5	Iron-stained zone in granite
105	.011	.033	4.4	Biotite-rich granitic differentiate
106	.004	.040	15.4	Quartz-muscovite-tourmaline vein
107	.012	.044	7.5	Quartz-muscovite vein
108	.000	.021	7.0	Iron-stained zone in granite
110	.007	.040	14.7	Iron-stained quartz vein in granite
111	.008	.035	6.8	Quartz-muscovite vein
112	.009	.034	9.6	Quartz-muscovite vein
113	.008	.018	16.5	Quartz-muscovite vein