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GEOLOGICAL SURVEY

The potential for uranium deposits in the Tertiary Kootznahoo Formation of the southern part of the Admiralty trough, southeastern Alaska

By

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INTRODUCTION

Geologic evidence suggests that the lower Tertiary Kootznahoo Formation in the southern part of the Admiralty trough in southeastern Alaska may be favorable for uranium. The area of this study includes the outcrop belt along the southwestern side of Zarembo Island, a small area east of Point Nesbit along the southwest coast of Zarembo Island, and another small area in California Bay on the north coast of Prince of Wales Island (figs. 1 and 2). Uranium was investigated in the Zarembo Island area by Eakins (1975) who reported only 2 ppm uranium and attributed a slight radioactive anomaly to thorium or potassium. Radioactive veins of hematitic carbonatite are present near the entrance to Salmon Bay on the northwest coast of Prince of Wales Island. The radioactivity in these veins, hosted by Silurian graywacke, seems to result mostly from thorium bearing accessory minerals (Houston and others, 1958).

Samples were collected from outcrops of the Kootznahoo Formation and the overlying volcanic rock. These samples were analyzed for uranium and thorium by the delayed-neutron method (Millard, 1976) and for other elements by semi-quantitative spectroscopy. Chemical analyses were carried out in the analytical laboratories of the U.S. Geological Survey in Denver, Colorado. Mineralogical analyses were by whole-rock X-ray diffraction and by thin section examination. Clay minerals were determined by X-ray diffraction before and after heating, glycolation, and acidization (Dixon and Weed, 1977). Sandstone grains were identified, counted, and measured in thin sections of a few samples. Petrographic descriptions are given in table 1.

GEOLOGIC SETTING

Tertiary continental sedimentary rock from several separate areas in the Admiralty trough was described by Buddington and Chapin (1929). The Kootznahoo Formation was named by Lathram, Pomeroy, Berg, and Loney (1965) from exposures in the Kootznahoo Inlet area on the west side of Admiralty Island. Similar and apparently correlative sequences have been described in the Pybus-Gambier area of southern Admiralty Island (Loney, 1964) and in the Keku Strait area of Kuiu and Kuperanof Islands by Muffler (1967) (fig. 1). The Kootznahoo Formation was uplifted and eroded, and only remnants of a previously continuous unit are exposed, but it was probably originally deposited throughout the Admiralty trough (fig. 1). The Kootznahoo contains fossils ranging from Paleocene through Miocene in age (Wolf in Lathram and others, 1965, p. 30-31). In the California Bay area the Kootznahoo overlies Paleozoic sedimentary rock, predominantly the Silurian Heceta Limestone, and in the eastern and southwestern Zarembo Island areas it is overlain by volcanic flows and agglomerates that range in composition from basalt to rhyolite (fig. 2). The Zarembo Island outcrops of the Kootznahoo are penetrated by numerous felsic and mafic sills and steeply dipping dikes that

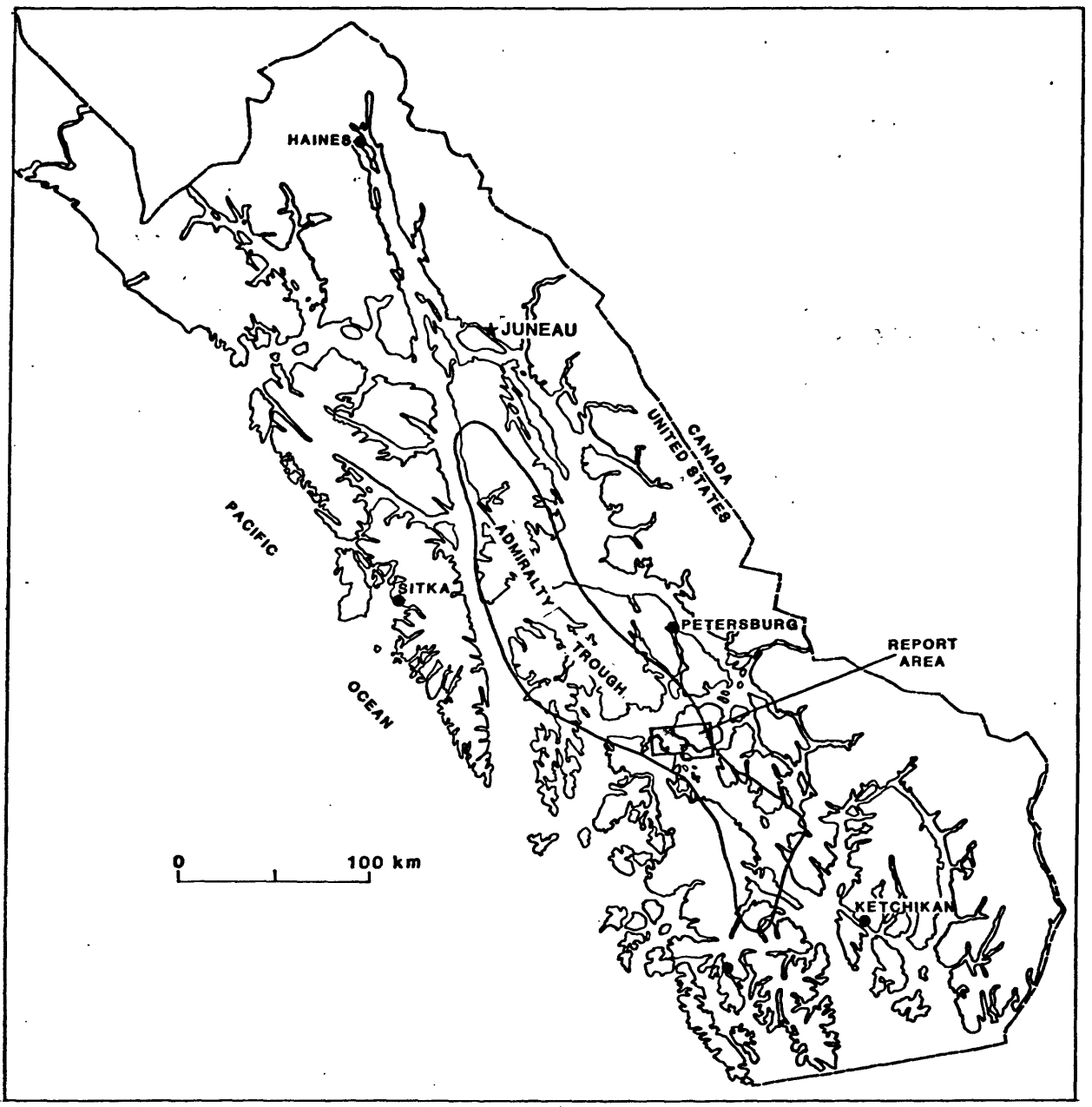
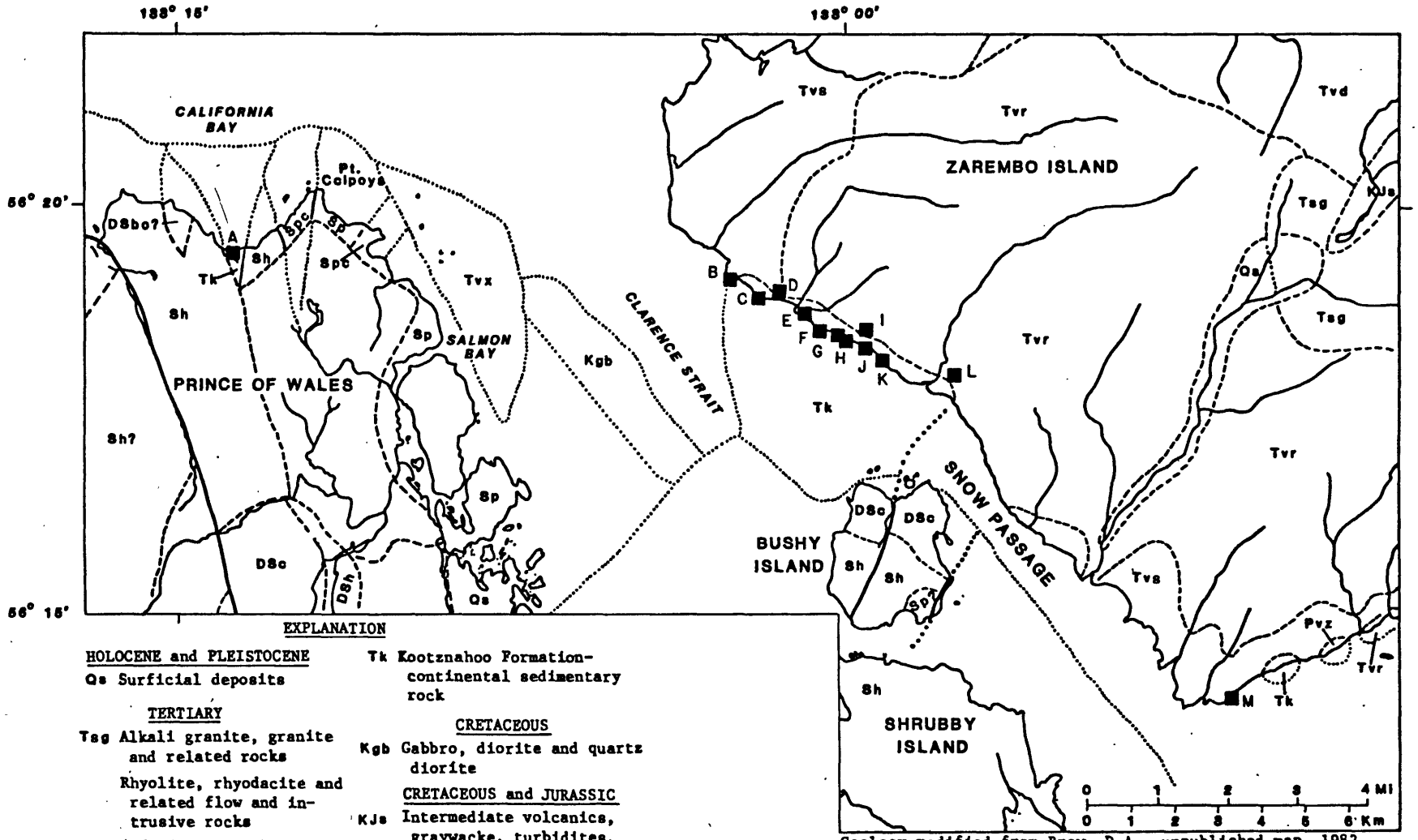


Figure 1.--Southeastern Alaska showing Admiralty Trough (Don J. Miller and others, 1959, fig. 8-12) and the area of the present report.



EXPLANATION

HOLOCENE and PLEISTOCENE

Qs Surficial deposits

TERTIARY

Tsg Alkali granite, granite and related rocks

Rhyolite, rhyodacite and related flow and intrusive rocks

Tva Andesite and other intermediate flow rocks

Tvd Complex of flows, dikes, and sills ranging from rhyolite to basalt

Tvx Volcanic breccia and agglomerate

Tk Kootznahoo Formation-continental sedimentary rock

CRETACEOUS

Kgb Gabbro, diorite and quartz diorite

CRETACEOUS and JURASSIC

KJs Intermediate volcanics, graywacke, turbidites, and melange undifferentiated

DEVONIAN-SILURIAN

DSc Polymictic conglomerate

DSbo Oligostrome Heceta Limestone in blocks of turbidite matrix

SILURIAN

Sh Heceta Limestone

PALEOZOIC(?)

Pzv Agglomerate and volcanic breccia

Geology modified from Brew, D.A., unpublished map, 1982

■A Sample locality

Formation boundary, dashed where approximate, dotted where covered

Fault, dashed where approximate, dotted where covered

Figure 2.--Geology and sample localities of report area.

range in thickness from less than a meter to several meters. The felsic bodies are younger than the mafic bodies. The mafic dikes are composed of microgabbro and the felsic dikes are rhyolite or quartz dacite. Mafic dikes are also found in the California Bay area on northern Prince of Wales Island. These dikes are probably younger than the Kootznahoo but their age relative to the Kootznahoo at that locality was not determined with certainty.

The Admiralty trough is an elongate basin that extends from Central Admiralty Island southeastward to central Prince of Wales Island (fig. 1). The structure of the area is discussed in greater detail by Miller, Payne, and Gryc (1959). The trough is about 320 km long and 50 km wide.

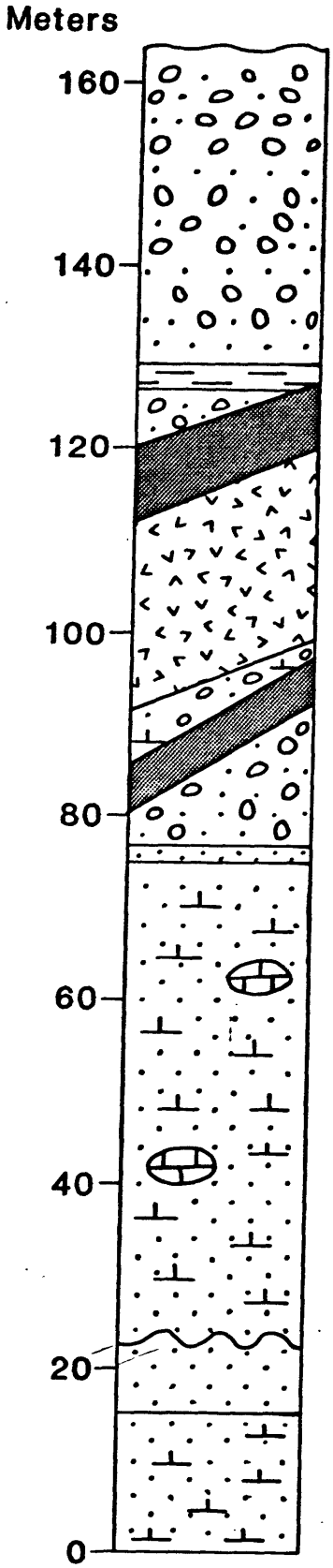
POTENTIAL URANIUM HOST ROCKS

The Tertiary continental sedimentary beds along the west and southwest coasts of Zarembo Island and on the north end of Prince of Wales Island are apparently part of the Kootznahoo Formation. For the most part, they were deposited in fluvial environments and may be favorable host rocks for uranium deposits. The Kootznahoo contains carbonaceous material and pyrite that may aid in the precipitation of uranium. Samples contain as much as 27.7 ppm uranium. This content of uranium although far from commercial grade is considerably more than is generally found in sandstone, and at least a minor amount of epigenetic enrichment is suggested.

About 50 m of the Kootznahoo Formation is exposed along the west side of Zarembo Island. In this area the Kootznahoo strikes about N 50 W, nearly parallel to the coast and dips at about 30^{0} to the N.E. These beds probably represent only a small part of the Kootznahoo because the formation is about 410 m thick in the Port Camden area to the north (Buddington and Chapin, 1929). On Zarembo Island the Kootznahoo consists mostly of conglomerate and sandstone, but it also contains some shale and siltstone (fig. 3). The base of the formation is covered and the top of the formation is overlain by volcanic conglomerate and lava flows.

Approximately 40 meters of the Kootznahoo Formation crops out about 2 to 3 km east of Point Nesbit at the southern tip of Zarembo Island. The sequence there is very similar to that on the southwest coast of Zarembo. The rock is mostly medium- to coarse-grained brown arkosic sandstone, sandy arkosic conglomerate and dark-gray shale. Dark gray slate and white chert are the most common clasts in the conglomerate. Two samples of conglomerate averaged 9.2 ppm uranium and one shale sample contained 6.5 ppm uranium (table 1). Dikes contain inclusions of the sedimentary country rock. The sedimentary sequence is overlain by altered dark gray volcanic conglomerate and lava flow. Clasts of sandstone are contained within the volcanic rock.

Only about 20 meters of the Kootznahoo Formation is present at the California Bay locality where it overlies Silurian limestone (fig. 2). This Tertiary sequence consists of sandstone, coal, mudstone, and shale. The sandstone is light brown, poorly sorted and cross-bedded, the coal is pyritic, the mudstone is light brown and conglomeratic, and the shale is black and



Conglomerate and conglomeratic sandstone, gray and brown, medium-bedded; conglomerate clasts consist of white quartz, gray slate, igneous rock and a trace of vitreous coal (35-40cps)

Shale, dark-gray, flakey, non-calcareous, sandy at top

Conglomerate, brown with black varnish, sandy, non-calcareous (35cps)

Basalt, dark-gray and black, hard

Rhyolite, light-brown, porphyritic, contains weathered phenocrysts (60cps)

Conglomerate, brown, sandy

Basalt, black, dense; contains casts of small phenocrysts; resistant to weathering (30cps)

Conglomerate, dark-gray and brown, poorly sorted, calcareous; clasts consist of white quartz, basalt and slate (25cps)

Sandstone, brown, hard, calcareous, thin wavy bedded

Sandstone, brown, medium-grained, calcareous; bedding is massive; contains calcareous concretions and veins, scattered cavities, but no carbonaceous material (30-45cps)

Sandstone, gray and brown, fine-grained, slightly calcareous; upper surface is contorted with 1/2 m relief (40cps)

Sandstone, brown, fine-grained, calcareous; displays indistinct cross-bedding; contains no carbonaceous material (40cps)

Figure 3.--Section of Tertiary rocks in the intratidal zone on the southwest coast of Zarembo Island, Alaska (near east center of NW 1/4 of section 29, T64S, R80E)

Table 1.--Uranium and thorium data, together with lithology and mineralogy of samples of Kooznahoo Formation and related igneous rock.

Sample Number	Map* Location	Uranium ppm	Thorium ppm	Th/ U	Lithology	General Mineralogy
					Intrusive and extrusive rock	
88802	K	9.0	22.8	2.5	rhyolite dike, light red brown	quartz, plagioclase, microcline, kaolinite, illite
R-4	L	9.0	18.0	2.0	dacite volcanic agglomerate, light gray quartz	quartz, plagioclase, K-feldspar, chlorite, illite
87806	F	8.2	18.9	2.3	quartz dacite flow?, light gray mottled	quartz, plagioclase, K-feldspar, calcite, siderite
87802	C	6.6	8.0	1.2	quartz dacite flow, medium gray	quartz, plagioclase, chlorite, calcite
R-2	D	5.6	9.3	1.7	quartz dacite flow, mottled gray	plagioclase, quartz, chlorite, calcite
89803	G	3.9	4.0	1.0	dark gray microgabbro dike	plagioclase, K-feldspar, augite, ilmenite, smectite, illite
87804	E	3.7	<2.4	<0.7	quartz dacite dike, medium gray	plagioclase quartz, kaolinite, smectite?
87801	B	3.5	<2.3	<0.7	dacite flow rock, gray quartz	plagioclase quartz, kaolinite calcite
R-3	I	3.3	5.6	1.6	quartz dacite flow rock, medium gray	plagioclase, quartz, chlorite, illite to smectite
89802	G	3.0	<2.0	<0.7	micro basaltic dike, medium gray	plagioclase, chlorite augite quartz, magnetite, smectite
88803	K	2.2	2.2	1.0	microgabbro dike, dark gray	plagioclase, augite, chlorite, kaolinite, magnetite, ilmenite
Average		5.3	<8.7	<1.4		
					sedimentary rock	
812803	A	27.7	28.5	1.0	coal, pyritic	pyrite, dolomite
88804	J	17.7	<5.1	<0.3	sandstone, gray fine grained carbonaceous	calcite quartz, plagioclase, K-feldspar, pyrite, chlorite, smectite
88805	H	15.2	86.3	5.7	conglomerate, gray lithic, arkosic	quartz, plagioclase, K-feldspar, chlorite, illite, pyrite, magnetite
NP2-2	M	10.5	20.8	2.0	conglomerate, gray lithic, arkosic	quartz, plagioclase, chlorite, illite
NP2-3	M	8.2	22.9	2.8	conglomerate, gray lithic, arkosic	quartz, plagioclase, chlorite, mica, calcite
89804	G	7.0	10.0	1.4	shale, medium gray, hard, platy, silty	quartz, plagioclase, chlorite, illite, kaolinite?
NP2-1	M	6.5	7.6	1.2	mudstone, medium gray, dense	quartz, mica, chlorite, plagioclase
87803	C	6.5	9.1	1.4	conglomerate, carbonaceous fragments, pyrite	quartz, plagioclase, chlorite, illite, pyrite, siderite?
812801	A	6.2	7.2	1.2	sandstone, brown, coarse grained, poorly sorted	quartz, plagioclase, K-feldspar pyrite, kaolinite
89805	K	4.7	7.3	1.3	shale, dark brown, laminated silty, mica	quartz, plagioclase, calcite, chlorite, muscovite
88801	K	3.5	11.6	3.3	sandstone, brown, medium-grained	quartz, plagioclase, K-feldspar, chlorite, illite, kaolinite?
812802	A	3.3	3.6	1.1	sandstone, brown coarse-grained, crossbedded	quartz, plagioclase, K-feldspar, kaolinite, calcite, dolomite
89806	K	2.8	3.6	1.7	sandstone, brown, medium grained crossbedded	quartz, plagioclase, K-feldspar, chlorite, muscovite
87805	E	2.5	7.1	2.9	sandstone, light brown, to medium grained, contains carbonaceous fragments	quartz, plagioclase, K-feldspar, muscovite, chlorite
Average		7.4	16.5	2.0		

*See fig. 2

fissile. A slight radioactive anomaly (about 2 to 3 times that of most of the other rock) is located at the base of the sandstone bed and at the top of the coal bed. The coal contains 27.7 ppm uranium (table 1).

Grains of the Kootznahoo sandstone and conglomerate generally consist of quartz, plagioclase, K-feldspar, mica, and chlorite. The total amount of feldspar exceeds that of quartz and the rock is mostly classified as arkose or arkosic (fig. 4). Kaolinite (?), smectite, calcite, siderite, and magnetite together with minor amounts of various accessory minerals are found in some of the samples. The sandstone is partly cross-bedded and partly massive. The conglomerate clasts are fragments of plutonic igneous rocks, metamorphic rocks and white chert. The mudstone is laminated at various intervals. The predominant clay mineral at the Zarembo Island localities is chlorite, although others are present; the predominant clay mineral at the California Bay locality is kaolinite.

The Kootznahoo Formation was deposited in a non-marine basin in a predominantly fluvial environment. Lacustrine environments may also have been present as indicated by the laminated mudstone, but they were probably local ephemeral lakes on a flood plain. Lacustrine fossils were not found, although an adequate search was not made. The narrowness of the Admiralty trough suggests that true distal sediments were not deposited, but the sedimentary rock at California Bay, which contains coal, is probably more distal than that at Zarembo Island. The chlorite deposited in the sedimentary rock on Zarembo Island was probably derived from erosion of metamorphic rocks. The kaolinite in the California Bay samples may have been winnowed and carried to the center of the basin or it may have been derived diagenetically in a more acidic environment associated with the coal swamps.

The average uranium content of the sedimentary rock samples analyzed for this report is 7.4 ppm. This is nearly three times the average found in Tertiary continental sedimentary rocks from south central Alaska (Dickinson and Campbell, 1978). These uranium values are probably related to the amount of resistate minerals, such as sphene and zircon and to epigenetic enrichment. The correlation coefficient between uranium and zirconium contents is +0.11 which is insignificant for 13 samples (tables 2, 3). If, however, only samples with less than 10 ppm uranium are considered, the correlation coefficient is +0.77 which is significant at the 98 percent confidence level for 10 samples. A similar relation exists between uranium and titanium; the correlation is insignificant if all 13 samples are compared but the correlation in samples with less than 10 ppm uranium is +0.69 which is significant at the 95 percent confidence level for 10 samples (table 2). In the samples with less than 10 ppm uranium most of the uranium apparently is in resistate minerals and in the samples with more than 10 ppm some of the uranium is from other sources, possibly epigenetic enrichment. This relationship is also shown on a scatter diagram of uranium versus titanium (fig. 5). One sample, the coal sample (table 1, number 812803), was not included in this analysis because of its different origin although it contains 27.7 ppm uranium, the highest for the sedimentary rocks. The uranium in this sample could have been absorbed from uraniferous ground water by carbonaceous material, but the sample also contained about 10 times more zirconium than any

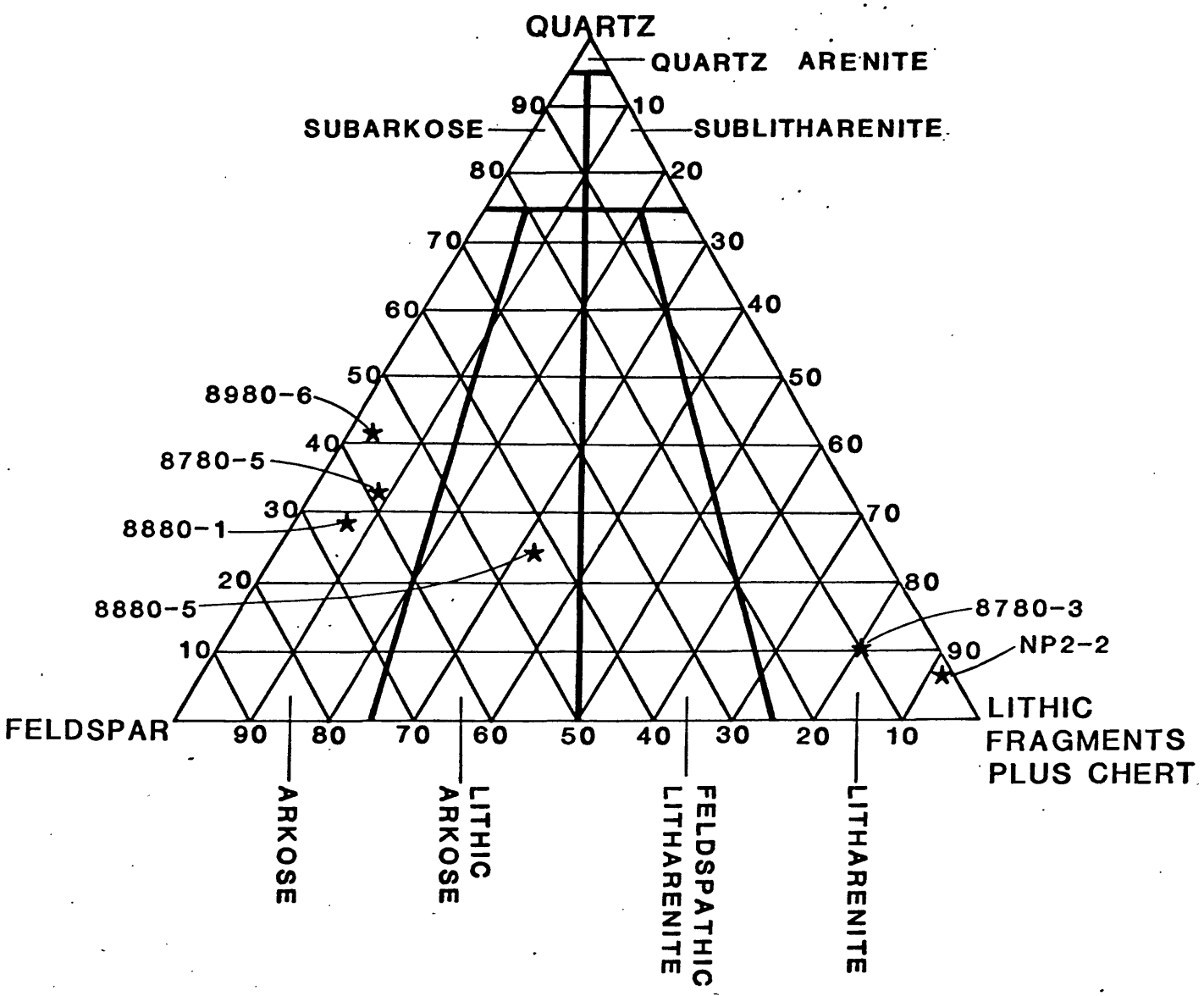


Figure 4.-- Samples of sandstone and conglomerate from the Kootznahoo Formation classified according to a modified version of Folk's (1974) sandstone classification.

Table 2.--Correlation coefficients between uranium and various elements.

	Zr	La	Sr	V	Ti
All sedimentary rocks (less coal)	+.11(13)	+.24(13)	+.22(13)	+.24(13)	-0.15(13)
Sedimentary rocks with less than 10 ppm uranium	+.77(10)***	+.4(10)	-.38(10)	+.29(10)	+.69(10)**
Igneous rocks	+.26(11)	+.64(11)**	-.50(11)	-.54(11)	-.51(11)*

*Significant at 90% confidence level
**Significant at 95% confidence level
***Significant at 98% confidence level

Table 3.--Semiquantitative 6-step spectrographic analyses of sedimentary rocks. Elements listed below table were either not detected or were below limits of detection in all samples. N equals not detected or below limits of detection. L equals detected, but below limit of determination. G equals greater than 10 percent. (Detection limits are given in Table 5.)

	812803*	88804	88805	NP2-2	NP2-3	89804	NP2-1	87803	812801	89805	88801	812802	89806	87805
Fe%	G	1.5	5.0	3.0	2.0	3.0	3.0	3.0	7.0	3.0	3.0	1.5	1.5	1.5
Mg%	0.1	0.7	0.7	1.5	1.0	3.0	1.5	1.5	.07	2.0	0.7	0.7	0.7	0.7
Ca%	0.3	7.0	0.7	1.0	1.5	0.7	0.15	1.5	0.15	1.5	2.0	3.0	3.0	1.5
Ti%	0.15	0.15	0.15	0.15	0.3	0.3	0.3	0.3	0.15	0.3	0.15	0.15	0.15	0.15
Mn (ppm)	150.0	1000.0	700.0	700.0	700.0	700.0	300.0	1000.0	30.0	700.0	700.0	300.0	500.0	300.0
B	700.0	N	N	20.0	N	N	30.0	N	N	N	N	N	N	N
Ba	700.0	700.0	700.0	300.0	500.0	1500.0	700.0	300.0	500.0	1000.0	1000.0	700.0	1000.0	1000.0
Be	15.0	N	N	N	N	1.0	N	1.0	N	N	N	N		N
Co	30.0	F	F	F	5.0	15.0	15.0	7.0	7.0	15.0	7.0	N	L	L
Cr	30.0	20.0	30.0	30.0	30.0	70.0	70.0	70.0	30.0	30.0	15.0	15.0	7.0	15.0
Cu	100.0	15.0	15.0	15.0	7.0	70.0	50.0	30.0	15.0	30.0	7.0	7.0	5.0	3.0
La	N	N	30.0	30.0	30.0	30.0	30.0	N	N	30.0	30.0	N	N	N
Mo	30.0	N	N	N	N	N	N	N	7.0	N	N	N	N	N
Nb	20.0	N	N	N	N	N	N	L	N	N	N	N	N	N
Ni	150.0	7.0	7.0	15.0	10.0	30.0	30.0	15.0	15.0	20.0	3.0	3.0	3.0	3.0
Pb	70.0	10.0	N	N	N	20.0	10.0	10.0	20.0	70.0	10.0	N	10.0	N
Sc	30.0	7.0	7.0	15.0	15.0	15.0	20.0	15.0	N	15.0	7.0	7.0	7.0	7.0
Sr	300.0	700.0	300.0	150.0	700.0	300.0	150.0	200.0	150.0	300.0	700.0	300.0	300.0	300.0
V	150.0	70.0	150.0	150.0	70.0	150.0	150.0	100.0	70.0	70.0	150.0	30.0	70.0	70.0
W	300.0	N	N	N	N	N	N	N	N	N	N	N	N	N
Y	100.0	30.0	15.0	15.0	15.0	20.0	30.0	30.0	N	20.0	20.0	15.0	10.0	10.0
Zr	1500.0	70.0	100.0	70.0	150.0	150.0	150.0	150.0	70.0	100.0	70.0	70.0	30.0	70.0
Si%	3.0	10.0	G	G	G	10.0	G	G	G	G	G	G	G	G
Al	3.0	7.0	5.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Na	0.3	3.0	1.5	1.5	0.7	3.0	0.7	2.0	1.5	1.5	3.0	1.5	2.0	3.0
K	N	3.0	1.5	1.5	1.5	3.0	3.0	1.5	1.5	3.0	1.5	1.5	2.0	1.5
Ce (ppm)	N	N	N	N	150.0	N	N	N	N	N	N	N	N	N
Ga	150.0	15.0	15.0	15.0	10.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	10.0	10.0
Ge	300.0	N	N	N	N	N	N	N	N	N	N	N	N	N
Yb	7.0	3.0	1.5	2.0	1.5	3.0	3.0	3.0	N	2.0	2.0	1.5	1.0	1.0

Ag, As, An, Ba, Be, Bi, Cd, Pd, Pt, Sb, Sn, Te, U, Zn, P, Hf, In, Li, Re, Ta, Th, Tl

*coal sample ashed before analysis

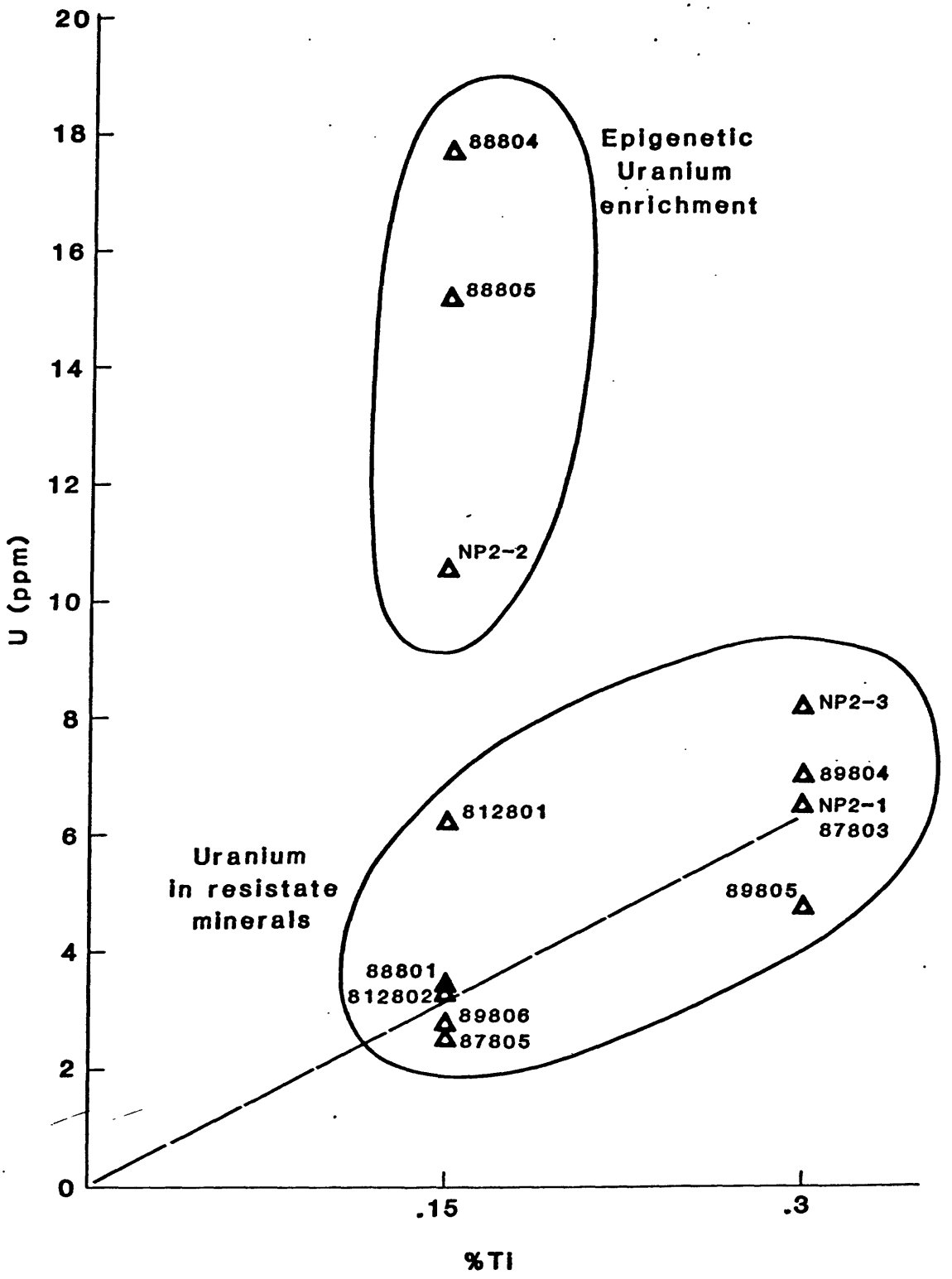


Figure 5.--Scatter diagram of uranium versus titanium from sedimentary rock samples of the Kootznahoo Formation.

of the other samples, and if this zirconium is from zircon, the uranium could also have been contained in a concentration of zircon. Such a concentration in a coal without noticeable detrital minerals seems unlikely, however.

The brown color of the sandstone may have been caused by surface oxidation of iron and by downward percolating oxidizing surface water. This water may have removed uranium from near surface rock. If a zone of unoxidized sandstone is present at depth, uranium deposits may be present there. Only drilling would answer this question. The average annual rainfall at Ketchikan is nearly five meters. Preservation of surface uranium deposits except in very impermeable rock in such a wet climate seems unlikely.

POTENTIAL URANIUM SOURCE ROCK

There are several potential uranium source rocks in the southern part of Admiralty trough. These include Tertiary volcanic and intrusive rocks on the west side of Zarembo Island and in the southern half of Kupreanof Island to the north, and Tertiary alkali granite in the southeastern part of Zarembo Island and in much of Etolin Island to the southeast (D. A. Brew, unpublished map, 1981). Although a complete study of these rocks is beyond the scope of this paper, limited studies of the volcanic rock directly overlying the potential host rock and intrusive rock penetrating it were carried out. In addition, pertinent information was acquired from stream sediment studies by John Cathrall (unpublished data, 1981).

The volcanic rock is commonly altered at the surface and identification was mostly from X-ray diffraction data. It weathers to light and medium gray. Judging from the whole rock X-ray patterns, plagioclase is the most abundant mineral in all the volcanic rock samples except for one in which quartz is the most abundant (table 1). Some, if not most of the quartz is secondary and it forms thin veins or replacements in the rock. The volcanic rocks contain much calcite believed to be predominantly secondary and some siderite. Clay alteration products in the volcanic rock include chlorite, illite, and a trace of smectite.

The mineral composition of the intrusive rock is very similar to the extrusive rock except that more kaolinite and smectite are found in the intrusive rocks and the more mafic intrusive rock contains augite, magnetite, and ilmenite. There is a gradationally increasing amount of quartz present in the samples from the more mafic rock, which contains little or none, to the more felsic rock in which quartz may be the most common mineral. There is also a similar gradual increase in the amount of uranium within this rock (table 1). The gamma-ray response over the younger felsic dikes is nearly twice that over the mafic dikes.

Data are too few for a thorough analysis of the volcanic and intrusive rocks as potential uranium source rocks (table 1). The data do suggest, however, that the rocks are relatively high in uranium and low in thorium, and that they probably have not been leached of uranium. The 11 samples of igneous rock contained an average of 5.3 ppm uranium and less than 8.7 ppm thorium. Compared to the averages, 3.5 ppm for uranium and 11.0 ppm for

thorium, for the upper continental crust (Wedepohl, 1971), uranium is high in these samples and thorium is low. The data can be divided into two groups on the basis of uranium content and Th/U ratios. The first group of samples, which includes two of quartz dacite and one of rhyolite, averages 8.7 ppm uranium and 19.9 ppm thorium giving an average Th/U ratio of 2.3. Average Th/U ratios for vitreous (unleached) groups of samples of felsic volcanic rocks from the western conterminous United States ranges from 2.9 to 3.5 (Zielinski, 1982). Average uranium content of 1,352 silic volcanic samples, also from the western conterminous United States is about 6.5 ppm (Wenrich, 1982). The first group of samples studied here is, based on these comparisons, high in uranium, but with a slightly lower than normal Th/U ratios, and, although they contain ample uranium to be a source rock, apparently they have not lost uranium by leaching. The second group of samples studied here, which includes 5 of quartz dacite, 2 of microgabbro, and one of basalt, averaged about 4 ppm uranium and less than 4.5 ppm Th. The Th/U ratio ranged from less than 0.7 to 1.7 and averaged less than 1.1. The low Th/U ratios could indicate slight uranium enrichment, but the very low thorium content suggests loss of thorium. The method of thorium loss is not known, but, again the data does not suggest uranium leaching.

John Cathrall (unpublished data, 1982) analyzed stream sediments from areas of Tertiary rhyolitic volcanic areas from the southern part of Kupreanof Island (fig. 1). Seven of these samples averaged 6.7 ppm uranium and 17 ppm thorium. These stream sediment values are similar to values for felsic or vitreous tuffs (Wenrich, 1982; Zielinski, 1982) and probably are representative of the volcanic area from which they were derived. Three samples of rhyolitic agglomerate and flow from near Kah Sheets Lake in this same general area contained an average of 10.9 ppm uranium and 30 ppm thorium (K. A. Dickinson, unpublished data, 1979). One of these samples contained 16.4 ppm uranium and 40 ppm thorium. These figures also suggest that some of the rhyolitic rock contains ample uranium for epigenetic mineralization, but the Th/U ratios of around 3 or less, which is typical of unleached felsic tuffs, suggest that uranium loss by leaching has not occurred.

Tertiary alkali granite that represents a potential source of uranium crops out in southeastern Zarembo Island and in much of Etolin Island to the southeast. No uranium and thorium analyses of this rock are available, but stream sediment samples from the Etolin area have been analyzed (John Cathrall, unpublished data, 1982). Seven samples from streams crossing alkali granite terrane averaged 13.2 ppm U and 17.7 Th. The thorium value is more or less average and the uranium value is about twice that generally in granitic rocks (Rogers and Adams, 1978). Again, the low Th/U ratio does not suggest that the alkali granite has lost uranium.

A significant negative correlation between uranium and vanadium and between uranium and titanium and a significant positive correlation between uranium and lanthanum was found in the igneous rock samples (table 2, 4). A strong positive correlation probably also exists between uranium and thorium but it was not calculated because some of the thorium values are only upper limits. The correlation between uranium and lanthanum is common in igneous rocks because both elements tend to be excluded from early mineral phases during differentiation and concentrated in the latest magmatic stages. The

Table 4.--Semiquantitative 6-step spectrographic analyses of igneous rocks. Elements listed below table were either not detected or were below limits of detection in all samples. N equals not detected or below limits of detection. L equals detected, but below limits of determination. G equals greater than 10 percent. (Detection limits are given in Table 5.)

	88802	R-4	87806	87802	R-2	89803	87804	87801	R-3	89802	88803
Fe%	1.5	1.5	1.5	3.0	3.0	7.0	3.0	7.0	3.0	3.0	7.0
Mg%	0.15	0.3	0.3	0.7	0.7	3.0	0.7	1.5	0.7	3.0	3.0
Ca%	0.15	0.7	1.0	3.0	3.0	5.0	3.0	3.0	0.7	3.0	5.0
Ti%	0.15	0.15	0.15	0.3	0.7	1.5	0.3	0.7	0.3	0.3	0.7
Mn (ppm)	150.0	300.0	300.0	700.0	700.0	1500.0	700.0	700.0	700.0	1500.00	1500.0
Be	1.0	1.0	1.0	1.0	N	N	N	1.0	N	N	N
Co	N	L	5.0	15.0	10.0	30.0	7.0	20.0	7.0	15.0	30.0
Cr	3.0	3.0	7.0	30.0	7.0	70.0	1.5	30.0	1.0	70.0	70.0
Cu	2.0	3.0	7.0	15.0	30.0	0.15	7.0	30.0	5.0	30.0	30.0
La	N	30.0	L	N	30.0	30.0	N	N	N	N	N
Mo	N	N	N	7.0	N	N	N	5.0	N	N	N
Nb	N	N	L	N	L	N	N	N	N	N	N
Ni	2.0	3.0	5.0	15.0	7.0	15.0	N	7.0	N	30.0	30.0
Pb	10.0	10.0	10.0	10.0	N	N	N	N	N	N	N
Sc	N	7.0	7.0	15.0	15.0	50.0	7.0	30.0	7.0	15.0	30.0
Sr	150.0	150.0	150.0	300.0	300.0	300.0	300.0	150.0	300.0	700.0	300.0
V	15.0	30.0	30.0	70.0	150.0	300.0	70.0	150.0	70.0	70.0	200.0
Y	30.0	30.0	30.0	30.0	30.0	30.0	15.0	50.0	20.0	15.0	30.0
Zr	100.0	150.0	150.0	150.0	150.0	100.0	150.0	150.0	150.0	70.0	100.0
Si%	G	G	G	G	G	G	G	G	G	G	G
Al%	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Na%	3.0	1.5	2.0	1.5	3.0	1.5	2.0	3.0	3.0	2.0	1.5
K%	3.0	2.0	3.0	1.5	3.0	1.5	1.5	1.5	1.5	N	0.17
Ga	15.0	15.0	15.0	10.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Yb	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.5	3.0	2.0	3.0

Ag, As, An, 8, Bi, Cd, Pd, Pt, Sb, Sn, Te, U, W, Zn, P, Ce, Ge, Hf, In, Li, Re, Ta, Th, Tl

Table 5.--Approximate lower limits of visual determination for the elements analyzed by the 6-step spectrographic method at the Denver Laboratory* (Myers and others, 1961).

Element	%	Element	%
Fe	0.001	Si	0.002
Mg	0.002	Al	0.01†
Ca	0.002	Na	0.05
Ti	0.0002	K	0.7
		P	0.2
	ppm		ppm
Mn	1	Ce	200
Ag	0.5	Ga	5
As	1000	Ge	10
Au	20	Hf	100
B	20	In	10
Ba	2	Li	100
Be	1.5	Re	50
Bi	10	Ta	500
Cd	50	Th	200
Co	5	Tl	50
Cr	1	Yb	1
Cu	1	Pr	100
La	50	Nd	70
Mo	3	Sm	100
Nb	10	Eu	100
Ni	5	Gd	50
Pb	10	Tb	300
Pd	2	Dy	50
Pt	50	Ho	20
Sb	200	Er	50
Sc	5	Tm	20
Sn	10	Lu	30
Sr	5	Ir	50
Te	2000	Os	50
U	500	Rh	2
V	7	Ru	10
W	100		
Y	10		
Zn	300		
Zr	10		

*Some combinations of elements affect the limits of determination. In favorable materials, values lower than above may be detected. In unfavorable materials, these limits of determination may not be attained.

negative correlations between uranium and titanium and between uranium and vanadium are probably explained by the same general process; the titanium and vanadium having been concentrated in early mineral phases.

RADIOMETRIC MEASUREMENTS

Radiometric measurements from this and other studies show no apparently significant anomalies in the Tertiary sedimentary or volcanic rock in this study area (Eakins, 1975; Susan Karl, unpublished map, 1981). Some of the conglomerates from southern and western Zarembo Island and the top of the coal bed at California Bay exhibited gamma-ray measurements of about two to three times that of the surrounding rock. Not surprisingly, the rhyolitic dikes on western Zarembo Island produced scintillometer readings of about two to three times that of the basasltic dikes. No significant anomalies were observed where an airborne radiometric survey crossed the southern tip of the Kootznahoo outcrop area (LKB Resources, Inc., 1979).

SUMMARY

The Kootznahoo Formation is potentially an excellent host rock for uranium. It includes permeable sandstone and conglomerate beds together with suitable reductants. Carbonaceous fragments are common in some of the sandstone and conglomerate beds and pyrite is present in a coal bed. Slight epigenetic uranium enrichment is present in some of the conglomerate and sandstone beds and possibly in the coal bed. Surface oxidation would probably have destroyed any surficial uranium deposits, but deposits could be found in subsurface reduced zones. The Kootznahoo is overlain by volcanic rock that includes dacite and rhyolite that have abnormally high uranium content in some places. The Th/U ratio of the few samples analyzed, however, suggests that these potential source rocks have not lost uranium by leaching. A potential for uranium deposits cannot be ruled out, however, because uranium leaching may have occurred from the same rock in other areas or from other rocks and because there must have been a source of uranium for the occurrence found in the northern part of the Admiralty trough (Dickinson, 1979).

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