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URANIUM AND THORIUM CONTENT OF SOME TERTIARY GRANITIC ROCKS IN THE SOUTHERN ALASKA RANGE

By

Bruce L. Reed and Thomas P. Miller

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Introduction

A reconnaissance study of background radioactivity and uranium and thorium content of seven early and middle Tertiary granitic plutons in the southern Alaska Range (McGrath and Lime Hills 1:250,000 quadrangles, fig. 1) was conducted in 1979. Modal analyses, chemical data, a brief petrographic description, and a discussion of the radioactivity and uranium-thorium content of some of the plutons sampled are given in this report. Two areas of anomalous uranium concentration and a uranium- and thorium-rich peralkaline granite suggest the possibility of disseminated uranium deposits or hydrothermal uranium enrichment.

Windy Fork Pluton

The elongate Windy Fork pluton underlies an area about 55 km^2 (figs. 1 and 2) and is composed chiefly of hornblende peralkaline granite with lesser amounts of hornblende-biotite granite. Biotite and hornblende from two samples of the pluton yield potassium-argon ages of 30.1 and 29.0 m.y. respectively (Reed and Lanphere, 1973). A pyroxene alkali-feldspar syenite and hornblende-biotite granite (samples 11 and 12, fig. 1) from an intrusive complex northwest of the Windy Fork pluton may belong to the same plutonic event. Both plutons lie northwest of the Alaska-Aleutian Range batholith, are post-tectonic and intrude a terrane consisting of sandstone, phyllite, and limestone of probable Paleozoic age.

Modal analyses for the ten samples collected are given in table 1 and shown on the modal diagram in figure 3. Uranium and thorium analyses are given in table 2. Seven of the ten samples are hornblende granite and plot in the alkali-feldspar granite field. The remaining three samples contain 7 to 16 volume percent albite, more yellow-brown biotite than hornblende, and plot in the granite field. The age and contact relations of the two rock types are not known.

The hornblende granite is medium-grained hypidiomorphic granular with sub- to euhedral crystals of perthite that lie in a seriate matrix of grey quartz. Perthite locally displays schiller effects. Albite, as discrete finely albite-twinned crystals, makes up less than 3 percent of the rock, and ferromagnesian minerals comprise about 7 percent. Soda- and iron-rich hornblende is optically negative, has a 2V less than 30°, and displays varied pleochroism: X is generally dark blue to black, Y is bluish-grey to greenish-brown, and Z ranges from pale yellow to yellowish-brown. Minor amounts of reddish-brown biotite are generally present. Opaque minerals cluster near or within hornblende. Interstitial pale violet fluorite is the most abundant accessory mineral and is commonly observed in hand specimen. Other accessory non-opaque minerals include ubiquitous non-metamict zircon and lesser amounts of apatite, interstitial calcite, and rare allanite. Eudialite, a zirconium- and rare-earth-bearing silicate, that is commonly found in silica-under-saturated rocks, is an abundant mineral in quartz-amphibole-K-feldspar pegmatite veins that cut the granite and adjacent sedimentary rocks near the north end of the pluton. The sample from a eudialyte-bearing dike (no. 1A, table 3) contains 33 ppm uranium.

The average and range of ten chemical analyses collected (table 4) illustrate the alkaline character of the pluton. Five of the seven hornblende granite samples are peralkaline granites, that is, they have a peralkaline index (mol. amts. K_2O+Na_2O/Al_2O_3) $\geq$ 1 and are acmite normative. The fluorine content of the samples averages about 0.22 percent (table 2).

Background radioactivity, determined by a hand-held scintillometer, of the hornblende granite averages about 300 cps (counts per second) with a range from 225 to 375 cps. The average uranium content of the ten background samples collected is 9.2 ppm; the range is 5.63 to 12.1 ppm. Thorium averages 33.6 ppm and has a range of 22.9 to 45.1 ppm (table 2). The average Th/U ratio for the samples is 3.71.

Rogers and Adams (1969) give an average uranium content of 4 ppm for granites world-wide, which is considerably below the 9 ppm average uranium content of the Windy Fork pluton. Many granitic bodies, however, contain an average uranium content of 10 ppm or more (Nishimori and others, 1977), and these are commonly alkaline or alkali-rich varieties. The average uranium content for the Windy Fork pluton, therefore, while high for granites in general, is not necessarily unusual for a peralkaline granite.

An area of above-average radioactivity was noted while flying over talus boulders in a 300 m wide cirque near the northern border of the pluton (locality 3, fig. 2). On-the-ground total radioactivity of over 500 cps was measured with as much as 2500 cps recorded locally on individual boulders. The uranium content of five anomalously radioactive grab samples (3A, 3C-F, table 3) of peralkaline granite from this area averages 25.5 ppm with a range of 19.9-29.1 ppm. The average thorium content is 295 ppm, with a range from 169-404 ppm; this compares to a range of 10-20 ppm Th for most granites (Rodgers and Adams, 1969). Uranium and thorium content of a typical sample from this area are 12.1 and 45.1 respectively (no. 3, table 2). The anomalously radiogenic samples show about a three-fold increase in uranium and an eightfold increase in thorium over the ten background samples (table 2) for the Windy Fork pluton. In addition, the average Th/U ratio is 11.4, or about three times that of the background samples.

The radiogenic samples show no apparent megascopic difference in composition or texture compared to peralkaline granite elsewhere in the pluton. In thin section, the mafic minerals appear to be more altered with development of deuteric biotite and muscovite. It is assumed from thin section study that the uranium and thorium in these rocks and in the Windy Fork pluton in general is related to the accessory mineralogy. In addition to fluorite, other ubiquitous accessory minerals in the radioactive samples are zircon and opaque minerals. Point counts were therefore made on thin sections (2000 points counted in each thin section) to determine if the abundance of zircon or opaque minerals in this more radiogenic part of the pluton differed from the rest of the body. No obvious correlation exists between the abundance of zircon or opaque minerals and the uranium content (fig. 4), with the possible exception of sample 3B (not shown on fig. 4) which contains 5.5 percent zircon. The limited data suggests that the higher uranium content of the radioactive samples is not due to an increase in zircon, nor is the wide range (0.5 to 4.95 volume percent) in the opaque mineral content of the radioactive samples convincingly related to their uranium content.

The increased uranium and thorium content in the more radiogenic samples appears due to scattered subhedral to euhedral crystals of a yellow-green, isotropic (metamict?) mineral present in all thin-sections of the radioactive samples. Iron-stained radiation(?) fractures extend away from the mineral. The mineral was found only in the radioactive rocks and not in thin sections from the remainder of the pluton. The high Th/U ratio (11.4) of the radiogenic rocks together with the optical characteristics of the unknown mineral suggest that it may be uranothorite or thorianite.

The strongest radioactivity (2500 cps) was noted along an iron-stained feldspar-rich face of a large talus block. An analysis of this material (sample 3B, table 3) yielded 490 ppm uranium and less than 150 ppm thorium. A thin section of the granite taken perpendicular to this face shows an abundance (5.5 percent) of large euhedral zircon crystals and at least ten grains of the aforementioned yellow-green mineral. The high uranium content and corresponding low Th/U ratio, however, suggest that at least some uranium has been mobilized and redeposited along joint surfaces. It is possible that deuteric alteration released uranium from uranium-bearing accessory minerals such as uranothorite(?), thorianite(?) or zircon.

It is apparent that the peralkaline granite here differs from the rest of the pluton examined in the following ways: (1) uranium and thorium have both been enriched, at least locally; (2) thorium has been considerably more enriched than uranium; and (3) uranium has been mobilized and redeposited along joint surfaces. The reason for the anomalous concentration of uranium and particularly thorium (> 10 times the normal Th content of granites) in this part of the pluton is unknown pending more detailed mapping.

Uraniferous peralkaline granite, hematite iron-staining, purple fluorite (noted in float of fluorite-rich skarn in the cirque) and a post-tectonic setting is a common association in plutonic rocks containing either disseminated or hydrothermal uranium deposits (Rodgers and others, 1978). The occurrance of an apparent primary uranium- and thorium-bearing mineral (uranothorite?) and at least some uranium enrichment near the northern margin of the pluton suggests that uranium deposits of either a disseminated or a hydrothermal character, possibly similar to those at the Bokan Mountain alkaline stock in southeastern Alaska (MacKevett, 1963), could occur in the Windy Fork pluton.

Styx River pluton

Biotite granite forms the northern part of the Styx River batholith (Reed and Elliott, 1970), part of the Merrill Pass sequence, which, in this area, was emplaced between 34 and 37 m.y. ago (Reed and Lanphere, 1973). At locality 25 (fig. 1) 3 km southeast of Jimmy Lake, the rocks are strongly fractured, light brownish-orange, medium-grained alkali-feldspar granite porphyry. Up to 20 percent ovoid quartz phenocrysts 0.5 to 1.5 cm across and anhedral perthite phenocrysts up to 2 cm in diameter lie in a seriate matrix of quartz and perthite. Perthite shows patchy sericitization and biotite is altered to opaque minerals, chlorite, and sericite. Purple fluorite, an abundant accessory mineral, occurs both as interstitial fillings and as a deuteric replacement of quartz and perthite. Minor zircon is present.

A representative sample of the granite at this location, contains 0.35 percent fluorine, 14.8 ppm uranium, 38.3 ppm thorium, and has a Th/U ratio of 2.6 (no. 25, table 2). High radioactivity, up to 2000 cps, was noted along N. 40° W. trending vertical joints in granite exposed along a creek. This is in contrast to background radioactivity of about 450 cps. Analysis of three grab samples (samples 25A-C, table 3) of granite with the radiogenic iron-stained joint surfaces show a strong enrichment in uranium (101-882 ppm), although no secondary uranium minerals were noted. Galena, arsenopyrite and sphalerite (?) were also noted along joint surfaces.

Jimmy Lake stock

Two float samples (nos. 23 and 24, table 2) are representative of biotite granite porphyry from the Jimmy Lake stock (fig. 1). This stock is believed to be a satellite of the Merrill Pass sequence. Sample 24 is a medium- to fine-grained granite porphyry that contains phenocrysts of smokey grey quartz (with abundant fluid inclusions) and of irregular perthite clots in a fine-grained mosaic of quartz, sericitized oligoclase, and interstitial perthite. Biotite, which makes up about 10 percent of the rock, is characterized by many small opaque pleochroic haloes. The nuclei of some haloes appear to be strongly metamict zircon. Accessory minerals include interstitial and deutric fluorite and rare allanite. This sample contains 35.4 ppm U and 42.3 ppm Th. The low Th/U ratio of 1.20 suggests uranium enrichment in at least this sample. Background radioactivity of granite talus is 350 to 400 cps.

Granite of Tired Pup and Northeast Prong

There is little megascopic difference between the granites of Tired Pup and northeast prong (fig. 1, table 1). Rocks from both plutons are biotite granite and plot in the granite field (fig. 3). Biotite granite in the northeast prong yields concordant biotite-hornblende ages of about 26 m.y. - about 30 m.y. younger than the granite of Tired Pup (Reed and Lanphere, 1973). In addition, there are differences in the chemistry and accessory mineralogy of the plutons. Granite in the northeast prong contains about 75 percent SiO_2, whereas the granite of Tired Pup contains about 72 percent. Sparse muscovite is present in the granite of Tired Pup. Greenish-brown biotite occurs in the northeast prong with rare hornblende. Biotite in the Tired Pup pluton is characteristically reddish brown. Accessory minerals in both granites are fluorite, slightly metamict zircon, apatite, and allanite. A single grain of an opaque mineral, cubic in outline and causing intense pleochroic haloes in adjacent biotite, is present in one thin section (sample 13) from the northeast prong; it may be uranothorianite.

Two samples of granite from the northeast prong average 10.9 ppm uranium and 35.1 ppm thorium - about twice the average uranium (5.65 ppm) and thorium (21.4) contents of seven samples from the granite of Tired Pup (table 2). Background radioactivity of the northeast prong averages about 350 cps. Background radioactivity of the granite of Tired Pup ranges between 150 and 350 cps and averages about 240 cps.

Summary

Limited data suggest that the uranium and thorium contents of middle Tertiary granites in the northern part of the southern Alaska Range are about twice those of a nearby early Tertiary granite. The average uranium content of 17 granite samples from four middle Tertiary plutons (Windy Fork, Styx River, Jimmy Lake stock and northeast prong) is 11.9 ppm with a range of 5.6 to 35.4 ppm; thorium averages 35.9 ppm with a range of 22.9 to 45.8 ppm. The average Th/U ratio for these samples is 3.35 with a range of 1.2 to 4.3. Background radioactivity for these plutons ranges between 300 and 450 cps. The average uranium content of the single early Tertiary granite sampled (Tired Pup pluton) is 5.65 ppm with a range of 3.0 to 9.0 ppm; thorium averages 21.4 ppm with a range of 12.3 to 36.0 ppm, and the Th/U ratio average is 3.8 with a range of 2.9 to 4.6. Background radioactivity ranges between 150 and 350 cps and averages about 250 cps.

Higher than average contents of uranium and thorium and low Th/U ratios in some samples from the peralkaline Windy Fork pluton and the northern part of the Styx River pluton suggest the possibility of disseminated uranium deposits or hydrothermal uranium enrichment in these plutons. The Windy Fork pluton is particularly interesting because the combination of peralkaline rocks, high uranium background, fluorite, and indications of remobilized uranium are considered favorable criteria for granite with associated uranium deposits. An early Tertiary post-tectonic peralkaline granite about 10 km in diameter underlies Telaquana Mountain 130 km south of the Windy Fork pluton (B. L. Reed and M. A. Lanphere, unpublished data), and other peralkaline plutons, possibly uraniferous, may be present in this part of the southern Alaska Range.

Acknowledgements

Bea Hopkins provided the modal data for Table 1 and drafted the illustrations. Julie Dumoulin provided thin section modal data which served as the basis for figure 4. Travis Hudson reviewed a draft of the manuscript.

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TABLE 1. Modal analyses (volume percent) of granitic rocks, southern Alaska Range (sample locations are shown in figures 1 & 2, modal analyses from stained rock slabs.

Sample no.	Field no.	Quartz	Alkali feldspar	Plagioclase	Mafic and opaque minerals	Unknown	Unit
1	79AR32	29.3	62.9	2.6	5.2		Windy Fork pluton
2	37	38.3	41.1	10.5	10.1		" " "
3	33	29.3	63.4	0.3	7.1		" " "
4	36	29.9	62.7	-	7.4		" " "
5	1	33.8	57.2	-	9.0		" " "
6	2	28.5	66.2	0.3	5.0		" " "
7	5	29.4	53.2	7.7	9.7		" " "
8	34	29.1	49.2	16.4	5.3		" " "
9	4	25.9	63.2	1.8	9.1		" " "
10	35	24.5	68.4	-	7.1		" " "
11	6	2.6	82.6	2.4	2.6	9.8	
12	7	24.9	43.1	20.2	11.8		
13	8	32.2	36.9	25.4	5.5		Northeast prong
14	9	40.8	39.8	16.4	3.0		" "
15	28	26.3	35.7	28.5	7.5		Granite of Tired Pup
16	27	35.2	32.0	27.3	5.5		" " " "
17	26	32.0	45.8	17.2	5.0		" " " "
18	25	39.7	36.2	18.5	5.6		" " " "
19	23	29.3	20.7	38.2	11.8		" " " "
20	24	37.3	44.8	13.0	4.9		" " " "
21	10	29.3	32.8	30.4	7.5		" " " "
22	22	22.2	16.1	42.1	19.6		
23	11	32.6	35.2	27.6	4.6		Jimmy Lake stock
24	12	34.9	38.3	23.4	3.4		" " "
25	39	35.3	60.8	12.0	2.7		Styx River pluton
26	17	28.6	49.1	17.9	4.4		" " "

TABLE 2. Uranium, thorium, fluorine and chlorine content of granitic rocks, southern Alaska Range (sample locations are shown in figures 1 and 2; modal analyses are given in table 1).

Sample no.	Field no.	Quadrangle	Latitude	Longitude	U (ppm)	CV[1/]	Th (ppm)	CV[1/]	Th/U	F (percent)	Cl (percent)	Lithology
					Windy Fork pluton							
1	79AR32	McGrath A-3	62°03'33"	154°06'29"	9.7	2	34.2	6	3.53	.26	.029	hornblende granite
2	79AR37	McGrath A-3	62°02'29"	154°08'08"	10.6	2	36.1	5	3.41	.21	.055	biotite-hornblende granite
3	79AR33	McGrath A-3	62°02'30"	154°03'56"	12.1	2	45.1	5	3.74	.29	.021	hornblende granite
4	79AR36	McGrath A-3	62°02'00"	154°01'32"	8.96	2	30.4	6	3.39	.27	.037	hornblende granite
5	79AR1	McGrath A-3	62°01'32"	154°04'01"	10.3	2	38.7	5	3.74	.24	.027	hornblende granite
6	79AR2	McGrath A-3	62°01'34"	154°04'01"	8.4	2	36.2	4	4.32	.23	.031	hornblende granite
7	79AR5	McGrath A-3	62°00'40"	154°03'45"	6.79	2	28.5	5	4.20	.24	.076	hornblende-biotite granite
8	79AR34	Lime Hills D-3	61°59'56"	154°06'47"	10.7	2	33.7	6	3.15	.12	.047	biotite granite
9	79AR4	Lime Hills D-3	61°39'27"	154°04'23"	8.46	2	30.5	5	3.61	.21	.076	biotite-hornblende granite
10	79AR35	Lime Hills D-3	61°57'15"	154°05'31"	5.63	3	22.9	4	4.08	.16	.049	hornblende granite
11	79AR6	McGrath A-3	62°03'59"	154°21'16"	3.02	3	8.74	11	2.89	.07	.008	pyroxene alkali-feldspar syenite
12	79AR7	McGrath A-3	62°05'09"	154°20'43"	12.9	2	41.6	5	3.22	.09	.058	hornblende-biotite granite
					Northeast prong							
13	79AR8	Lime Hills D-2	61°52'34"	153°42'50"	10.8	2	37.8	5	3.49	.08	.014	biotite granite
14	79AR9	Lime Hills D-3	61°54'13"	153°45'34"	11.1	2	32.4	6	2.92	.12	.016	biotite granite
					Granite of Tired Pup							
15	79AR28	Lime Hills C-4	61°44'53"	154°11'04"	3.42	3	13.4	8	3.93	.08	.014	biotite granite
16	79AR27	Lime Hills C-4	61°37'19"	154°14'52"	6.55	2	25.9	5	3.96	.11	.008	biotite granite
17	79AR26	Lime Hills C-4	61°34'24"	154°16'18"	6.36	2	21.6	6	3.39	.15	.007	biotite granite
18	79AR25	Lime Hills C-4	61°31'48"	154°13'53"	9.05	2	36.0	5	3.97	.16	.005	biotite granite
19	79AR23	Lime Hills C-3	61°31'34"	154°00'29"	3.03	4	13.8	7	4.57	.05	.010	biotite granite
20	79AR24	Lime Hills B-4	61°26'40"	154°15'06"	6.88	2	26.7	6	3.89	.15	.004	biotite granite
21	79AR10	Lime Hills B-3	61°25'52"	153°53'04"	4.24	3	12.3	9	2.90	.05	.013	biotite granite
22	79AR22	McGrath A-1	62°00'42"	153°28'01"	3.23	3	7.11	14	2.20	.04	.015	hornblende-biotite granodiorite
					Jimmy Lake stock							
23	79AR11	Lime Hills C-1	61°44'20"	153°11'47"	15.1	2	45.8	5	3.04	.21	.001	biotite granite porphyry
24	79AR12	Lime Hills C-1	61°44'20"	153°11'47"	35.4	1	42.3	3	1.20	.23	<.001	biotite granite porphyry
					Styx River pluton							
25	79AR39	Lime Hills C-1	61°41'48"	153°12'20"	14.3	2	38.3	6	2.59	.35	<.001	sericitized alkali feldspar granite porphyry
26	79AR17	Lime Hills C-1	61°39'49"	153°08'52"	10.6	2	35.7	5	3.38	.24	.040	biotite granite

Delayed neutron uranium and thorium analyses by H. T. Millard Jr., M. Coughlin, R. B. Vaughn, M. Schneider, S. V. Laster, B. A. Keaten and W. Stang. Chemical analyses of fluorine and chloride by J. Riviello and V. McDaniel.

[1/] CV = coefficient of variation = one standard deviation, based on counting statistics, expressed as percent of concentration.

TABLE 3. Delayed neutron uranium and thorium analyses of radioactive samples from the Windy Fork and Styx River plutons (sample locations are shown in figures 1 and 2).

Sample no.	Field no.	Quadrangle	Latitude	Longitude	U (ppm)	Th	Th/U	Lithology
1A	79AMm201	McGrath A-3			33.3	46.3	1.39	Eudialyte bearing dike; grab sample
3A	79AMm215A	McGrath A-3	62°02'30"	153°03'56"	25.5	404	15.8	Radioactive hornblende granite grab sample
3B	215B	McGrath A-3	62°02'30"	153°03'56"	490	<150	-	Strongly radioactive hematite + quartz + feldspar joint-filling material; composite grab sample
3C	215C	McGrath A-3	62°02'30"	153°03'56"	27.7	337	12.2	Radioactive hornblende granite grab sample
3D	215D	McGrath A-3	62°02'30"	153°03'56"	25.2	189	7.5	Radioactive hornblende granite grab sample
3E	215E	McGrath A-3	62°02'30"	153°03'56"	29.1	376	12.9	Radioactive hornblende granite grab sample
3F	215F	McGrath A-3	62°02'30"	153°03'56"	19.9	169	8.5	Radioactive hornblende granite grab sample
25A	79AMm220A	Lime Hills C-1	61°41'48"	153°12'20"	727	<200	-	Radioactive hornblende granite grab sample
25B	220B	Lime Hills C-1	61°41'48"	153°12'20"	882	<240	-	Radioactive hornblende granite grab sample
25C	220C	Lime Hills C-1	61°41'48"	153°12'20"	101	<37	-	Radioactive hornblende granite grab sample

Analysts: H. T. Millard, Jr., R. B. Vaughn, S. W. Lasater, B. A. Keaten.

TABLE 4. Average and range of ten chemical analyses of the Windy Fork pluton.

Oxides (weight percent)	Average	Range	CIPW norms (weight percent)	Average	Range
SiO_2	73.5	70.9 -74.7	Q	27.28	21.26-30.15
Al_2O_3	12.65	11.8 -13.5	C	0.02	0.00 -0.19
Fe_2O_3	1.36	0.65 -2.1	or	29.05	26.66-32.85
FeO	1.61	1.2 -2.3	ab	35.93	30.40-40.72
MgO	0.18	0.06 -0.31	an	0.92	0.00 -4.42
CaO	0.84	0.59 -1.3	ac	1.23	0.00 -6.14
Na_2O	4.44	3.7 -4.8	ns	0.07	0.00 -0.66
K_2O	4.91	4.5 -5.5	wo	1.11	0.00 -2.45
H_2O+	0.29	0.17 -0.41	en	0.44	0.15 -0.77
TiO_2	0.23	0.15 -0.29	fs	1.93	0.78 -2.99
P_2O_5	0.05	0.02 -0.09	mt	1.36	0.00 -2.26
MnO	0.07	0.03 -0.12	il	0.44	0.29 -0.55
CO_2	0.04	0.03 -0.08	ap	0.11	0.05 -0.21
			cc	0.10	0.07 -0.18

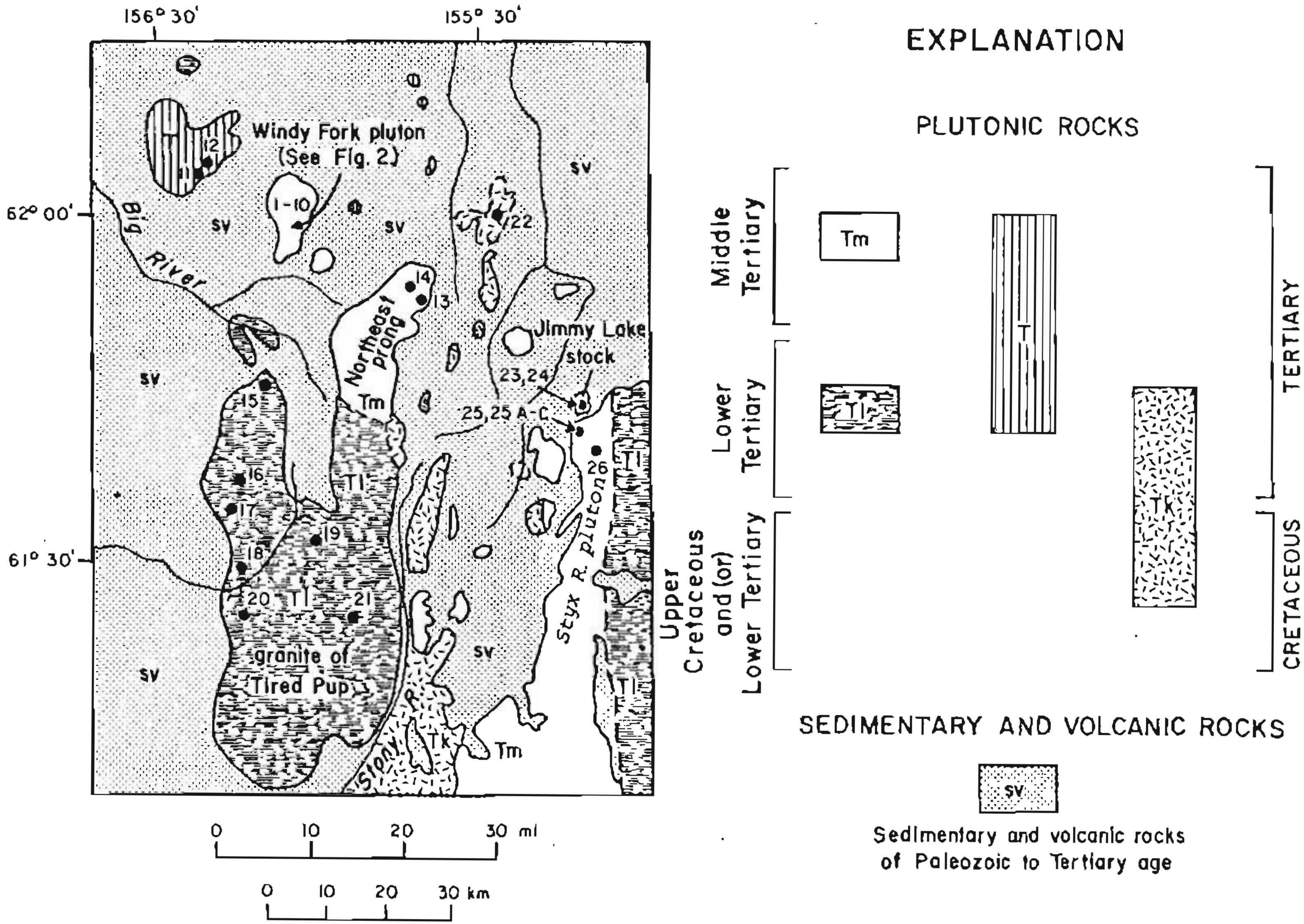

Figure 1.--Generalized geologic map of part of the southern Alaska Range showing location of samples collected. Geology modified from Reed and Lanphere (1973) and Reed and Elliot (1970).

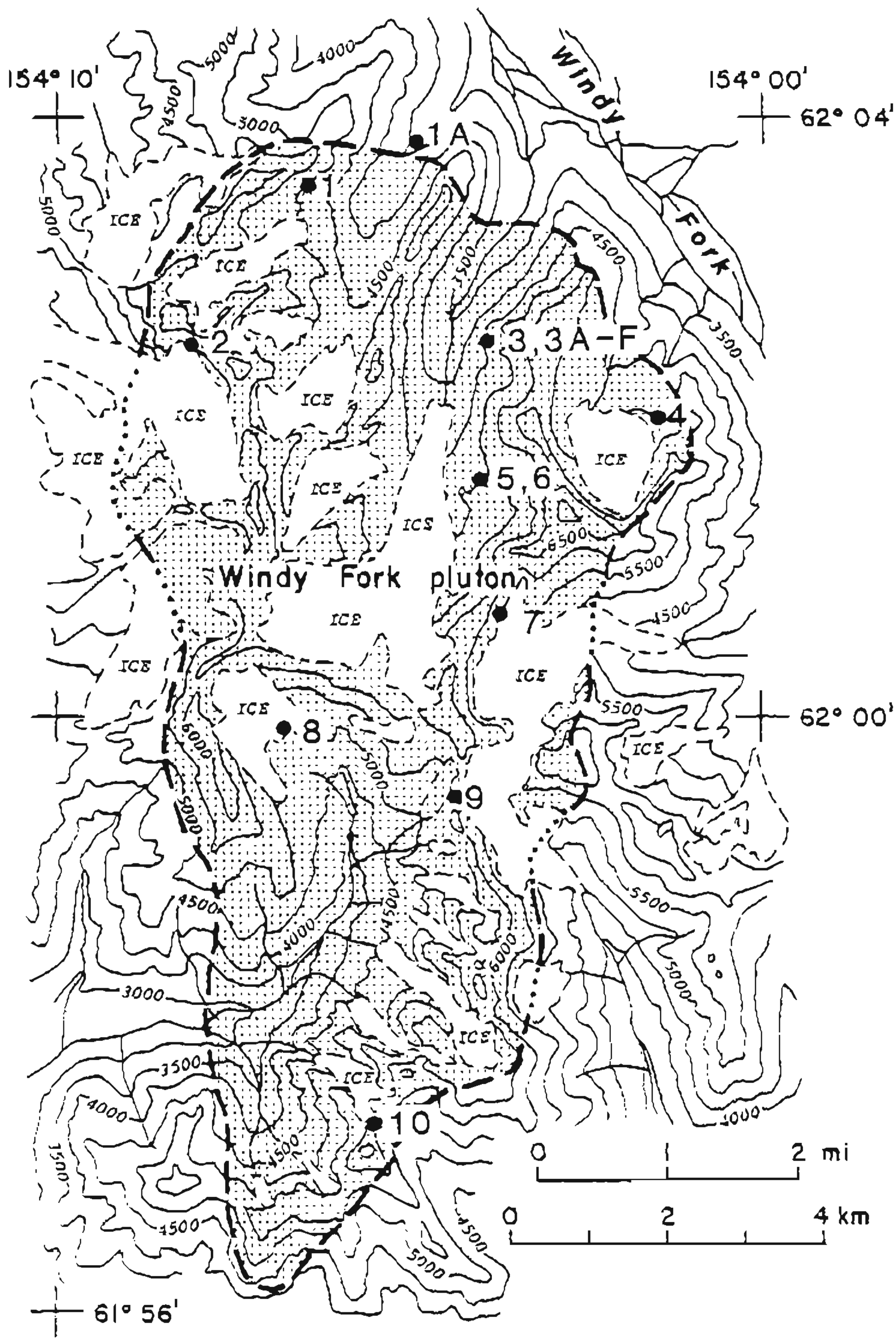

Figure 2.--Outline of Windy Fork pluton showing location of samples collected.

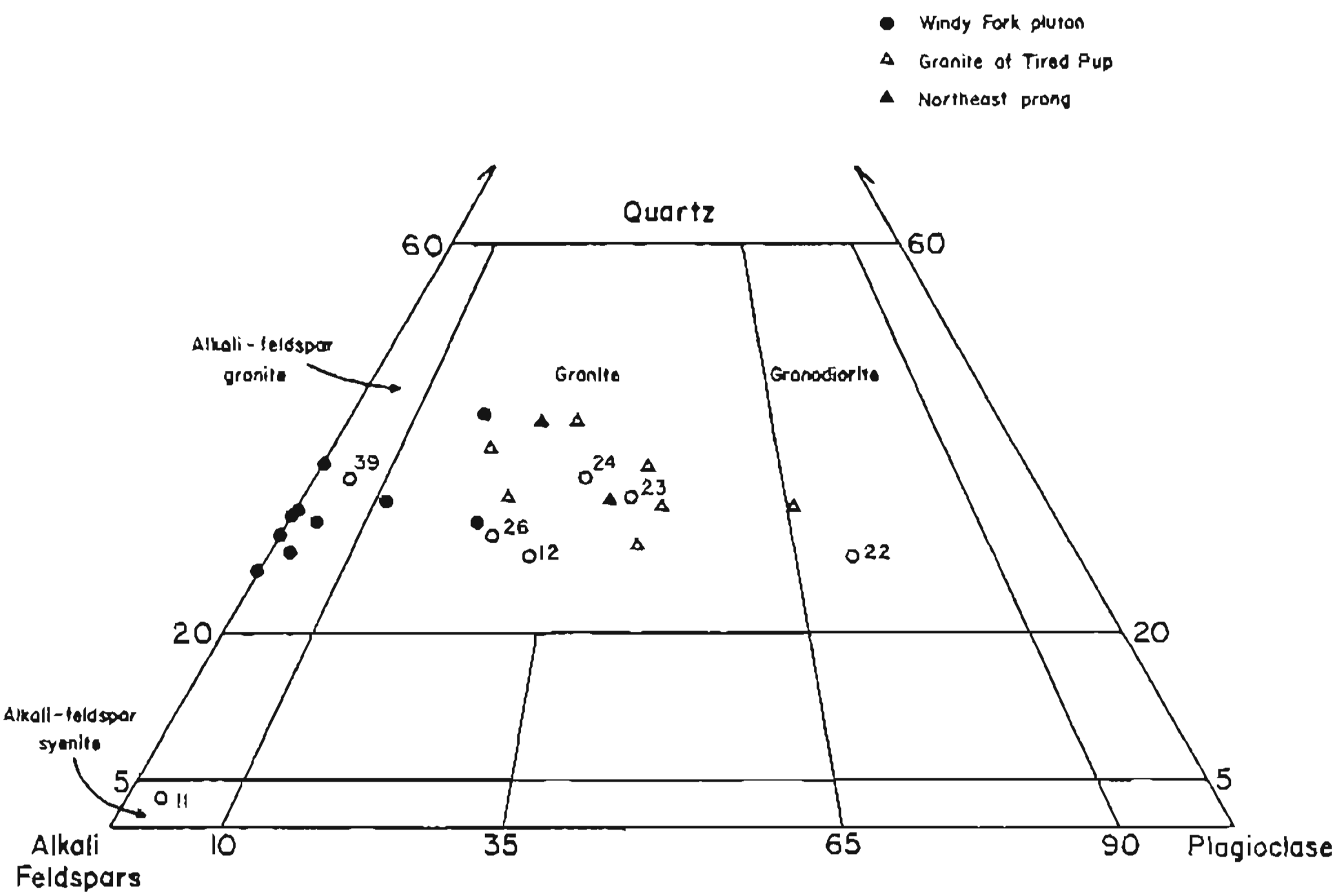

Figure 3.— Modal diagram of the granitic samples given in table 1. Numbers adjacent to open circles refer to sample locations shown on figure 1 and listed in table 1. Classification system is that of the IUGS (Streckeisen, 1973).

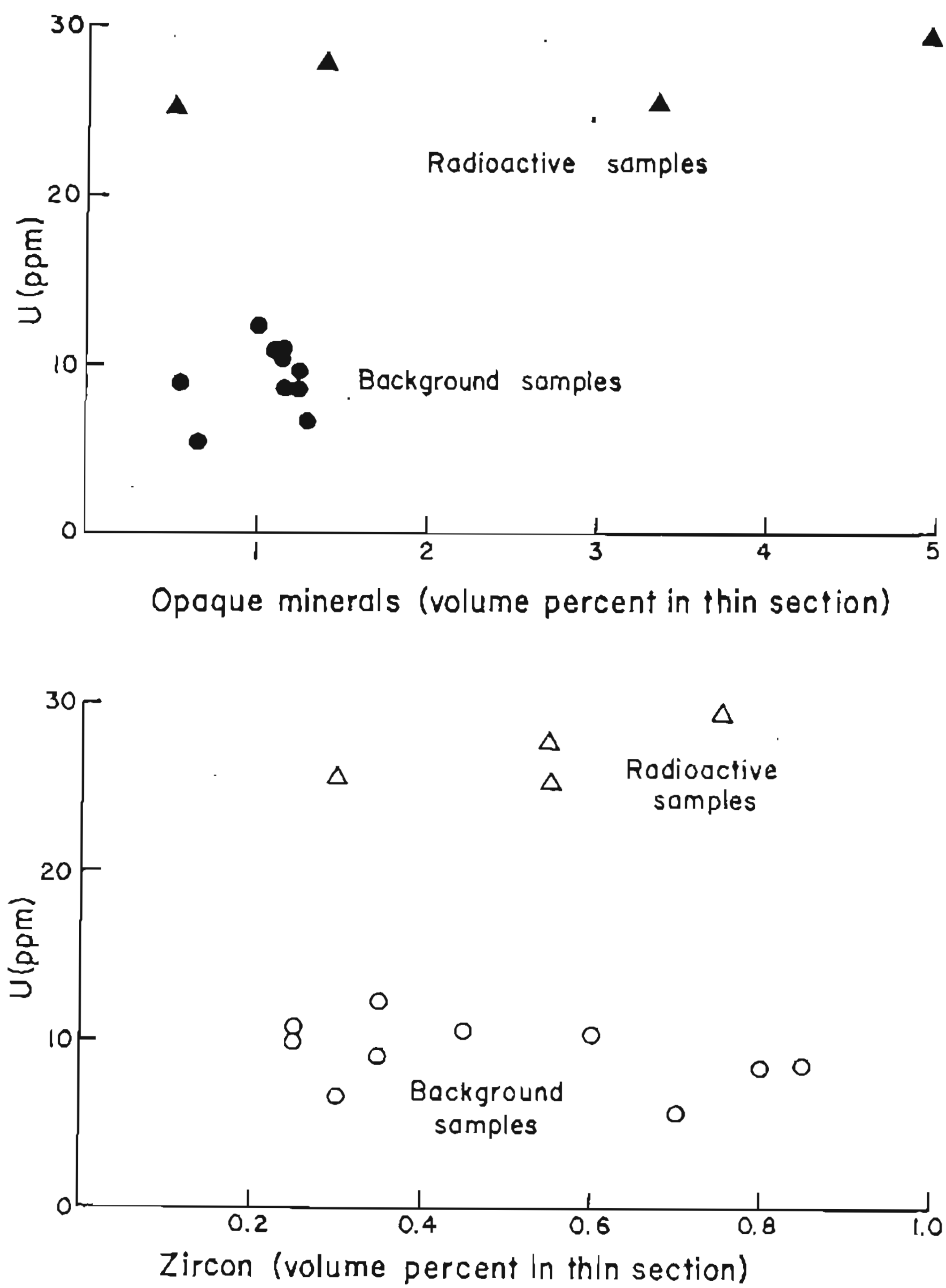

Figure 4.--Plots of zircon and opaque minerals (volume percent) against uranium for background and radioactive samples of the Windy Fork pluton.