INVESTIGATION OF RARE-EARTH AND ASSOCIATED ELEMENTS, ZANE HILLS PLUTON, NORTHWESTERN ALASKA

By James C. Barker

** Open-File Report 36-91

UNITED STATES DEPARTMENT OF THE INTERIOR

Manuel Lujan, Jr., Secretary

BUREAU OF MINES

T S Ary, Director

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter
cps	count per second
ft	foot
g	gram
in	inch
lb	pound
mi	mile
my	million years
pct	percent
ppm	part per million
yd^3	cubic yard
oz	ounce

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ABSTRACT

Unverified reports of rare earth element (REE) concentrations in gold placers and radioactive mineral prospects in the Zane Hills were investigated by the U.S. Bureau of Mines as part of the Alaska critical minerals program. REE is reported to occur in dredge concentrates at the Hogatza mine and up to 1.2 pct REE was previously analyzed in alkalic syenite (bostonite) dikes marginal to the pluton. In addition, numerous thorium-rich veins, explored for their uranium content but unevaluated for REE, occur on the western margin of the Zane Hills.

The Bureau mapped and sampled all of the reported or suspected REE occurrences. Dredge concentrates contain abundant uranothorianite, a mineral species which incorporates cerium subgroup REE. Bostonite dikes occur in conjunction with a multi-phased zoned alkalic intrusion, however, no significant REE concentrations were found. Thorium-rich veins contain nil to 0.5 pct Y but resource potential is limited by this relatively low grade, the ultimate low tonnage potential, and the lack of uranium as a major economic element.

The Zane Hills exhibit attractive exploration targets for uranium deposits, primarily in a sedimentary form. Gold may be found peripheral to the pluton in both placer and lode deposits. Resource potential of REE, however, appears limited to a placer by-product of REE-Zr-Ti that is recoverable only during large scale gold placer mining. Placer exploration of the lower Wheeler and Dakli Creeks is suggested.

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INTRODUCTION

During August 1-4, 1988, and August 4-9, 1989, personnel of the U.S. Bureau of Mines and the University of Alaska Mineral Industry Research Laboratory jointly participated in a reconnaissance of the southeast and northern-most margins of the Zane Hills pluton (fig 1). This included upper Bear and Quartz Creeks and tributaries of upper Wheeler Creek. Work was done on foot and in 1988 was based out of the Alaska Gold Company's dredge camp at Hogatza (fig 2-4). Work in 1989 was from a helicopter-accessed spike camp on upper Wheeler Creek.

The Objectives of this recon-level project were to verify verbal reports of unusual levels of radioactivity and an abundance of rare-earth minerals in concentrates produced at the Hogatza River gold dredge, and to collect samples for mineralogical characterization. Examinations of several nearby hydrothermal and intrusive related radioactive mineral prospects for possible associated rare earth elements and yttrium (REE) were also made. Concentrations of REE and zirconium have been reported in some mineralized samples from the Zane Hills uranium prospects (Gallagher and Ruzicka, 1978, DeWitt and Levy, 1980). In addition, mineralized samples were tested for Nb, Ta, Ti, Zr, and several other metals commonly associated with REE.

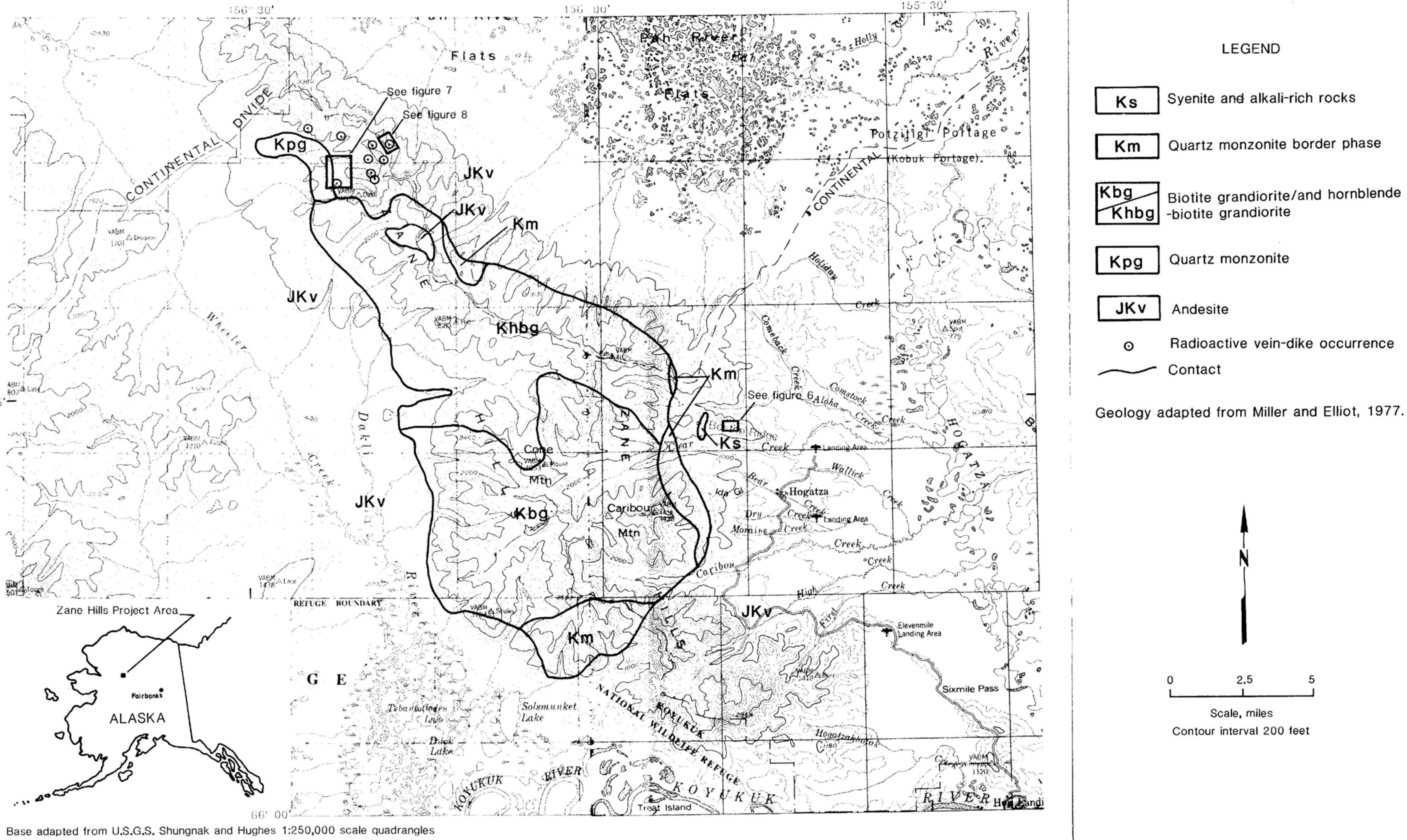

Figure 1. - Location of the Zane Hills pluton in northwestern Alaska.

Land in the vicinity of the Zane Hills is managed by the U.S. Bureau of Land Management. With the exception of valid mining claims held by Alaska Gold Company, all other land rights in the area are reserved for deficiency selection by Doyon Limited, a native corporation, established by the Alaska Native Claims Settlement Act.

This is a reconnaissance-level project of the Bureau's critical minerals program, and is not intended to provide a conclusive assessment of the area's mineral resource potential. Results of this investigation will be used to determine if further studies should be undertaken as part of the Bureau's program.

PREVIOUS WORK

There have been several previous studies of the geology and uranium potential of the Hogatza plutonic belt including the Zane Hills intrusive complex. These are listed by Eakins and Forbes (1976), who reviewed uranium potential in Alaska. In addition, and most pertinent to the area of this investigation, was geologic work by Miller and Elliott (1977), who studied uranium potential in the Zane Hills and noted anomalous radioactivity associated with bostonite dikes on the ridge north of Clear Creek.

The most detailed work on mineral prospects in the Zane Hills

has been described in a series of unpublished annual reports completed under contract to Doyon Ltd. of Fairbanks.
These are completed for the years 1976 through 1980 and 1985 and are available with permission from Doyon Ltd., attn. Dr. H. Noyes, Chief Geologist.

LOCATION AND PHYSIOGRAPHY

The area is located about 250 miles northwest of Fairbanks and is only accessible by air. Prospecting roads connect the mine camp to several sites on Clear Creek and the barge landing ramp on the Koyukuk River. A 3000 ft airstrip suitable for C-46 or similar aircraft, is also part of the camp development. The area is located in the Shungnak and Hughes 1:250,000 scale U.S.G.S. quadrangles.

Placer gold has been dredged from Bear Creek since the 1930's. A 6 cubic foot Yuba dredge is still at the site (fig. 2) and was last operated in 1983. A total of 230,000 oz of gold have been recovered from the area (Nokleberg and others, 1987).

The Zane Hills consist of exposed granitic and hornfels bedrock hills that attain elevations up to 4053 ft at Cone Mountain. The hills trend northwest and form part of the continental divide between Arctic and north Pacific watersheds. Elevation is sufficient to have given rise to valley glaciers

Figure 2. - Alaska Gold Company dredge on Bear Creek, tributary to Hogatza River.

Figure 3. - Clear Creek valley with view of the Hogatza dredge mine in the distance. This is typical wooded terrain of the eastern Zane Hills. Note development of the fluvial floodplain within a U-shaped valley of Clear Creek valley.

during Pleistocene ice advances. To the east and south the surrounding terrain consists of low rolling hills with unbroken forest cover and underlying permafrost (fig. 3). On the north and west the terrain is wind-swept tundra (fig. 4). Below elevations of 1500 ft soil cover is extensive and bedrock outcrop is exceedingly rare.

GEOLOGY

The Zane Hills pluton is part of the alkaline Hogatza plutonic belt that extends east-west across northwestern Alaska. The pluton is a multi-phased intrusion comprising biotite quartz monzonite to monzonite, granodiorite, syenite, alaskite, and aplite. Additionally, a gneissic biotite monzonite unit occurs on the southeast border of the pluton, however its relationship to the other intrusive phases is unclear. Miller and Elliott (1977), include the gneissic monzonite in the monzonite border phase of the pluton.

Representative chip samples were collected from various phases of intrusive rock. Major oxide content and calculated CIPW norms for these rocks are given in table 1. Sample locations are shown on figure 5.

The pluton is dated at 81 my by K-Ar methods on hornblende from monzonite on the southern margin of the pluton (Miller and

Figure 4. - Headwaters of Wheeler Creek. Typical glaciated valley and cirque (upper right) northwestern Zane Hills. Photo taken from a prospect on the Santa Maria Trend.

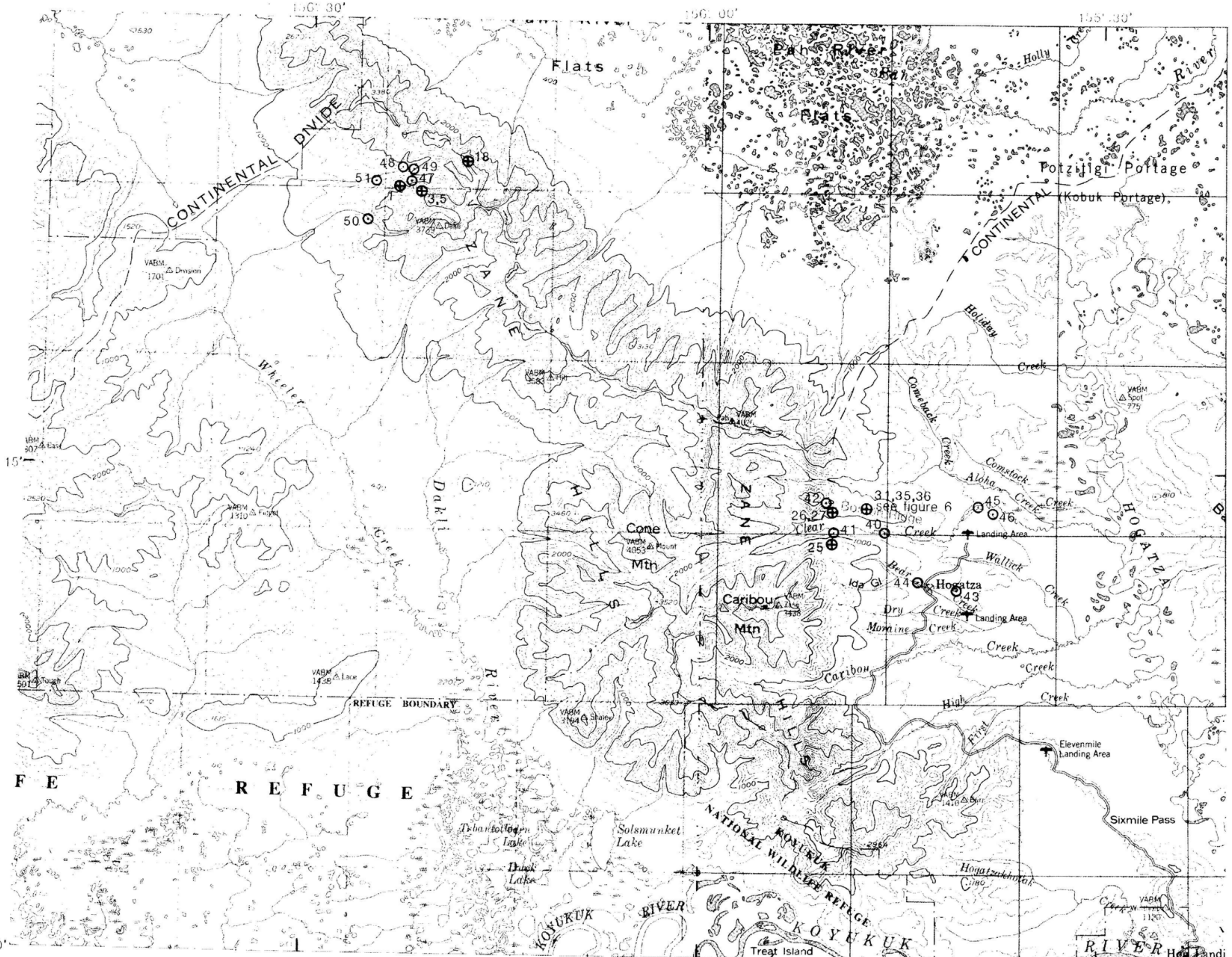

Figure 5. - Location of representative whole rock samples for major oxide analyses and panned concentrate samples.

LEGEND

⊙ Location and map number of pan concentrate sample

⊕ Location and map number of representative whole rock sample for major oxide analyses

N

0 2.5 5

Scale, miles

Contour interval 200 feet

TABLE 1. - Major oxide analyses and normative mineralogy (in wt pct) of whole rock samples from the Zane Hills pluton.

Major Oxides	1	3	5	18	25	26	27	31	35	36
SiO_2	62.79	70.96	60.32	71.02	60.50	59.50	63.10	57.10	57.08	64.28
Al_2O_3	16.08	14.26	16.44	14.09	19.30	19.50	19.60	19.56	17.90	18.90
CaO	4.87	2.09	4.40	2.01	2.76	2.12	0.35	3.55	3.25	1.06
MgO	3.09	0.50	2.62	0.62	0.87	0.52	0.57	1.51	2.80	0.20
Na_2O	4.33	3.98	4.21	3.89	4.80	4.83	5.63	4.00	4.35	6.81
K_2O	3.13	4.23	3.25	4.31	6.84	6.89	4.58	7.15	6.19	6.11
Fe_2O_3	4.48	2.06	4.73	2.04	2.85	2.19	1.85	4.53	5.17	2.16
MnO	0.07	0.04	0.08	0.06	0.10	0.05	0.05	0.11	0.08	0.10
TiO_2	0.60	0.26	0.66	0.25	0.30	0.27	0.25	0.41	0.54	0.23
P_2O_5	0.50	0.26	0.62	0.23	0.13	0.07	0.70	0.37	0.34	0.21
LOI	0.75	2.31	3.30	2.44	---	---	---	1.47	2.73	0.63
Normative Minerals										
Quartz	12.66	27.54	11.77	27.79	--	--	11.90	--	--	--
Orthoclase	18.55	25.35	19.78	25.86	41.10	42.46	28.18	43.10	37.56	36.10
Albite	36.75	34.15	36.70	33.42	41.30	42.62	49.60	30.88	37.09	56.66
Anorthite	15.24	8.67	16.86	8.38	11.10	10.49	1.33	14.59	11.33	2.96
Nepheline	--	--	--	--	--	--	--	1.97	0.38	0.52
Diopside	4.53	0.09	1.16	0.17	1.53	--	--	--	2.37	0.72
Hypersthene	6.92	1.22	7.74	1.49	1.43	1.08	1.48	0.74	--	--
Olivine	--	--	--	--	0.05	0.19	--	4.22	6.37	0.11
Magnetite	3.05	0.25	3.23	0.32	2.54	0.62	--	2.83	3.04	0.91
Ilmenite	1.14	0.50	1.29	0.48	0.58	0.54	0.31	0.79	1.05	0.44
Apatite	1.16	0.61	1.48	0.54	0.31	0.17	0.17	0.87	0.81	0.49

Map Numbers	Descriptions
1	Coarse-grained biotite-hornblende granodiorite.
3	Medium-grained K-spar porphyry dacite dike, accessory magnetite and amphibole, striking N60°E and 30 ft wide.
5	High Ca-dacitic feldspar porphyry dike about 50 ft wide.
18	Subalkaline, high Ca-rhyolite dike with porphyritic feldspar and quartz eyes. Weathers blocky, 300-350 cps.
25	Radioactive gneissic biotite monzonite in sidehill float, 700 cps.
26	Brick-red fine-grained alkali syenite (trachyte) dike rubble, cutting andesite, up to 600 cps.
27	Radioactive fine-grained alkali rhyolite to trachyte dike several ft thick, up to 700 cps.
31	Gray fine-grained monzonite (tristanite) with porphyritic hornblende (to 3 cm). Contains xenoliths of syenite and is cut by altered hematitic syenite.
35	Variably textured gray-greenish monzonite (tristanite) with interstitial magnetite, and phenocrysts of plagioclase. Rare flakes of biotite. Rock-type forms plug-like stocks about 200 ft in diameter.
36	Fine-to medium- grained equigranular syenite (trachyte), minor magnetite and amphibole.

others, 1966), suggesting a Late Cretaceous age. The igneous rocks have intruded Early Cretaceous volcanic andesites and contact relations are sharp (Patton and Miller, 1966). Locally the andesites are noticeably metamorphosed to hornfels up to a mile from the igneous contact.

The andesite ridge north of Clear Creek and east of the pluton (Boston Ridge) is cut by a complex of narrow syenite to sub-volcanic trachyte dikes and small stocks of syenite and monzonite (tristanite). The red-weathering fine-grained alkali syenitic dikes have been previously termed "bostonite" by Miller and Elliot (1977). Radiometric measurements over these dikes typically register moderate to anomalously high gamma-ray radiation (500-1200 cps). Dike widths range from a few inches to about 100 ft and are distinctly magnetic.

MINERALIZATION

There are numerous prospects and mineral occurrences in the Zane Hills, most of which contain uranium and thorium, as well as, accessory sulfide minerals (Dashevsky and Cleveland, 1985). Other occurrences include veins containing molybdenum-tungsten and gold-base metal mineralization. During this project only known radioactive mineral occurrences were specifically investigated for associated REE. This included the reported Boston Ridge prospect and thorium-uranium veins on upper Wheeler Creek. Previous workers

(Dashevsky and Cleveland, 1985) have all cited the apparent potential for sedimentary sandstone-type uranium deposits in the basinal areas flanking the Zane Hills pluton. Because of the extensive water saturated surficial cover, little is known of these basins and no further relative work was done during this study.

Boston Ridge

Miller and Elliot (1977), reported that altered bostonite dikes at the prospect contain up to 400 ppm U and 550 ppm Th. They tentatively identified betafite, an uraniferous niobate mineral, and allanite. DeWitt and Levy (1980), reported that bostonite dikes contained 0.25 to 1.51% total REE and interpreted the mineralization to be unrelated to carbonatitic magmatism. The reported prospect is misplotted by Miller and Elliot (1977), and is actually located about 1.5 m to the east where an area of anomalously high radiometric readings (up to 1200 cps) and abundant bostonite and other alkaline dikes and stocks were observed. The locality is indicated on figure 1 and shown in detail on figure 6. Evidence of campsites and prospect sampling by previous investigators confirmed the location of this prospect.

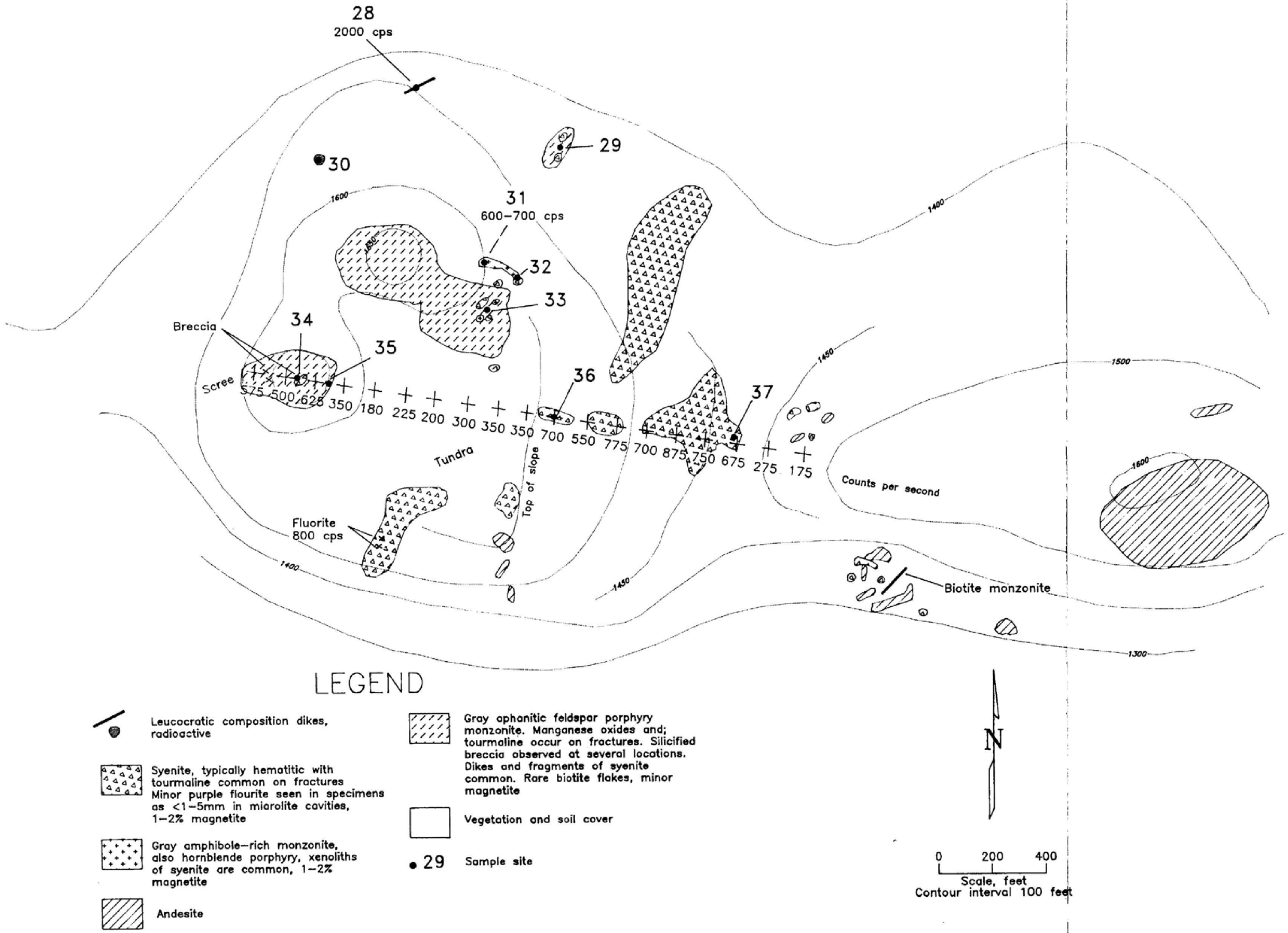

Figure 6. - Site map of the Boston Ridge prospect.

The Boston Ridge prospect consists of a multi-phased intrusive complex occupying an area about 2000 ft in diameter on Boston Ridge. At the center of the complex several small monzonite stocks are composed of gray to green, fine-grained, amphibole-rich hornblende porphyry. This textural phase appears to grade to, or is cored by a gray aphanitic feldspar porphyry of similar composition which forms the core of two distinct topographic knobs on the portion of Boston Ridge shown in figure 6. Major oxide analyses of sample 31 and 35 suggest the composition to be of an undersaturated intermediate sub-volcanic rock termed tristanite. Within the porphyry phases, inclusion of syenitic xenoliths and cross-cutting syenite or trachyte dikes indicate at least two widely spaced events of either syenite or monzonite intrusion. Either two phases of syenite intrusion took place, one predating and the other post dating the monzonite, or two phases of monzonite, predate and postdate the syenite. Additionally, other dike phases include a leucocratic amphibole dacite and a biotite monzonite, both of which cut the stocks and andesite country rock.

Only minor mineralization was observed at the prospect. Trace amounts of fluorite occur in syenite. Radiometric readings over syenite range to 2000 cps (map location 28, fig. 6) but contained no visible mineralization. Several thin syenite dikes were observed elsewhere along the ridge of andesite, however the radiometric levels are minimal and they also were unmineralized.

Table 2. - Sample Results from Boston Ridge prospect, in parts per million (ppm).

Map	RARE EARTH ELEMENTS			RADIOACTIVES		OTHER		
Numbers	La	Ce	Y	U	Th	Nb	Zr	Au
28	139	199	69	62.8	191	56	--	<.005
29	--	--	--	--	--	--	--	--
30	121	177	51	26.5	178	50	--	<.005
31	--	--	--	--	--	--	--	--
32	167	211	76	188.0	499	165	--	<.005
33	108	89	65	89.9	350	155	--	.015
34	97	145	43	32.7	121	43	--	<.005
35	--	--	--	--	--	--	--	--
36	--	--	--	--	--	--	--	--
37	111	134	40	32.9	120	80	1400	<.005

	Descriptions
28	Radioactive (up to 2000 cps) leucocratic amphibole alkali dike about 6 ft wide, cutting the gray-green monzonite porphyry.
29	(mineral specimen only)
30	Manganese stained syenite float rock in tundra area.
31	(see table 1)
32	Similar to above but coarser grained, from brick-red, 6 in wide dike cutting fine-grained amphibole-rich alkali intrusive rock with manganese and tourmaline on fracture surfaces.
33	Float similar to above from radioactive tundra area (to 1500 cps).
34	Narrow hematitic syenite dikes cutting gray aphanitic porphyry, slightly radioactive (to 700 cps) compared to background of 500 cps.
35	(see table 1)
36	(see table 1)
37	Radioactive (to 1200 cps) boulders of hematitic, fine-grained feldspathic rock, trace pyrite.

-- not analyzed.

NOTE: Analytical procedures by neutron activation for La, Ce, Th, U; by x-ray fluorescence for Nb, Zr and Y; and by fire-assay atomic absorption for Au. Analyses by Chemex Labs, Inc. Sparks, NV.

Analytical results listed in table 2 are of representative composited chip samples from the most radioactive rock types at the Boston Ridge prospect. Sample results indicate similar U and Th values as reported by Miller and Elliot (1977). Values of La, Ce, and Y are, however, near normal background levels, and there is no suggestion of elevated REE values as reported by DeWitt and Levy (1980). Higher grade REE mineralization, if it occurs, is not sufficiently widespread so as to be readily relocated.

Upper Wheeler Creek - Santa Maria Trend and Potato Saddle

A swarm of distinctly radioactive, northeast to northwest-trending veins, cut hornfels (andesite) at the head of Wheeler Creek. Many consist of only single exposures; due to the lack of outcrop they could not be traced along strike. The most continuous of these vein systems are known as the Santa Maria trend and Potato Saddle prospects (fig. 7 and 8). Previous exploration by industry (Gallagher and Ruzicka, 1978, Dashevsky and Cleveland, 1985), consisting of foot traverses with scintillation counters and prospect trenching, have located at least nine separate vein occurrences or clusters of veins (fig. 1). Limited efforts to evaluate these prospects with airborne radiometrics, track-etch cups, and shallow drill holes, were also made but were largely unsuccessful as methods for tracing mineralization under thick surficial cover. Sample results and descriptions of specific prospects are listed in tables 3 and 4.

Table 3. - Sample Results from Santa Maria prospects, in parts per million (ppm).

Map Numbers	La	Ce	Y	U	Th	Nb	Zr	Au
1	--	--	--	--	--	--	--	--
2	49	89	300	139.0	3281	26	--	.010
3	--	--	--	--	--	--	--	--
4	52	160	900	54.7	1161	285	--	<.005
5	--	--	--	--	--	--	--	--
6	9	72	280	955.0	374	67	--	<.005
7	99	199	300	176.0	5073	77	--	.005
8	64	174	1760	23.3	746	53	--	<.005
9	76	125	142	27.4	531	49	--	.025
10a	85	184	230	59.8	1619	85	--	<.005
10b	56	114	145	17.1	429	66	--	<.005
10c	69	140	125	25.0	766	52	--	<.005
11a	123	246	220	51.9	1574	58	--	.005
11b	294	370	880	674.0	>10000	49	--	<.005
12	70	124	370	56.3	637	275	--	.070
13	147	75	4100	419.0	>10000	<5	--	<.005
14	160	424	410	217.0	3821	89	--	<.005

Descriptions

1	(see table 1).
2	Radioactive (to 2000 cps) vein rubble of black silica with calcite, hematite and magnetite, no outcrop found.
3	(see table 1).
4	Radioactive (to 3000 cps) vein rubble of banded black silica with magnetite and hematite. Pieces 1- to 2-ft-thick. Sample is random chips of mineralized float. Another concentration of similar float 200 ft to ESE.
5	(see table 1).
6	Pink aphanitic feldspar, quartz veins, and laminae of carbonate, epidote, and chlorite. Radioactive (to 2000 cps) float locally abundant.
7	Abundant radioactive (to 3500 cps) float in vicinity of and filling shallow prospect pit. Sample is random chips of radioactive float.
8	High grade sample of green aphanitic and hematitic silica banding up to several inches thick. Measured 1500 cps.
9	Banded quartz and magnetic black aphanitic mineralogy, vein is 4-in-thick and found in rubble only.
10a	5.5 ft continuous chip sample of southern portion of trench wall. Banded green chlorite, fine-grained pink feldspar, and hematitic silica with bands of fine-grain magnetic amphibole. All cut by web-like chlorite-silica-hematite veinlets and 4-to 8-in-wide altered granitic dikes. Radiometric readings of 7000-12000 cps over banding and 6000 cps over dikes.
10b	5.0 ft continuous chip sample of northern portion of trench wall described above.
10c	Banded chlorite, carbonate, magnetic amphibole, and silica; (see fig. 11).
11a	Radioactive (to 1000 cps) hornfels, silicified with rare coarse-grained amphibole-epidote-chlorite. Zone is several ft wide.
11b	Float, 6-in-thick, of radioactive (3600 cps) pink quartz vein.
12	High grade sample of radioactive (to 2000 cps) veined hornfels and pink felsic schleiren. Zone of rubble is 40 ft across but could not be traced downhill.
13	Not shown on figure 7, sample from pit at most westerly location on figure 1. Random chips of radioactive (to 17000 cps) rubble in and near prospect pit. Vein rubble does not exceed 5 inches in width. Multiple of veins present. Mottled texture of carbonate amphibole, chlorite, epidote, feldspar, and quartz veining.
14	Not shown on figure 7, sample from pit at most easterly location on figure 1. Radioactive (to 3500 cps) 8-in-wide vein float of fine-grain gray mineralogy and black veinlets. Exhibits partially resorbed breccia.

-- Not analyzed.

NOTE: Analytical procedures by neutron activation for La, Ce, Th, U; by x-ray fluorescence for Nb, Zr and Y; and by fire-assay atomic absorption for Au. Analyses by Chemex Labs, Inc. Sparks, NV.

Table 4. - Sample results from Potato Saddle prospect, in parts per million (ppm).

Map	RARE EARTH ELEMENTS			RADIOACTIVES			OTHER	
Numbers	La	Ce	Y	U	Th	Nb	Zr	Au
18	--	--	--	--	--	--	--	--
19	86	210	67	52.4	1804	37	--	<.005
20	151	551	440	147.0	4741	155	--	<.005
21	161	498	195	167.0	4032	68	--	<.005
22	118	370	500	224	5201	36	--	<.005
23	82	146	26	5.9	25	10	--	.005
24	40	110	3100	87.8	2078	78	--	<.005

	Descriptions
18	(see table 1).
19	Rubble of random oriented quartz veining and feldspar. Trace galena and chalcopyrite. Zone of radioactive (to 1000 cps) rubble traced for 150 ft, no outcrop.
20	Radioactive (to 2500 cps) vein float of mottled pink feldspar in a black aphanitic matrix with magnetite.
21	Radioactive (>20000 cps) vein in trench wall, 8-in-thick striking 170° and near vertical. Similar texture to above.
22	Radioactive (to 5000 cps) banded vein rubble 8-in-thick, traced for 250 ft. Includes minor parallel radioactive (to 1000 cps) veinlets exposed in outcrop.
23	Pyritized andesite with about 2% pyrite.
24	Vein rubble, up to 5-in-thick, radioactive to 2000 cps on individual pieces.

Table 5. - Sample results from border zone monzonite prospect, in parts per million (ppm).

Map	RARE EARTH ELEMENTS			RADIOACTIVES		OTHER		
Numbers	La	Ce	Y	U	Th	Nb	Zr	Au
25	129	188	30	55.8	140	20	760	<.005

NOTE: Analytical procedures by neutron activation for La, Ce, Th, U; by x-ray fluorescence for Nb, Zr and Y; and by fire-assay atomic absorption for Au. Analyses by Chemex Labs, Inc. Sparks, NV.

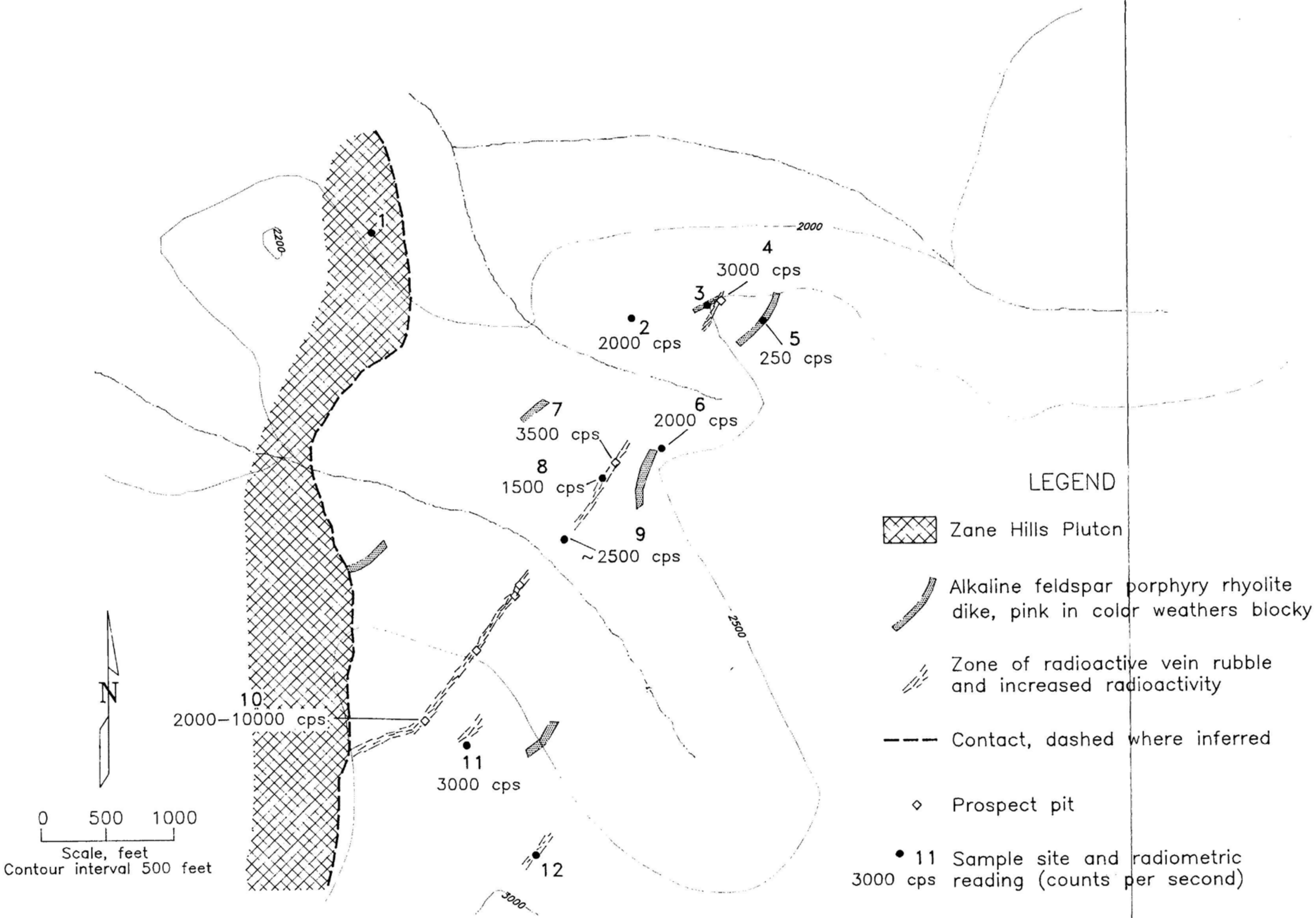

Figure 7. - Site map of the Santa Maria trend prospect.

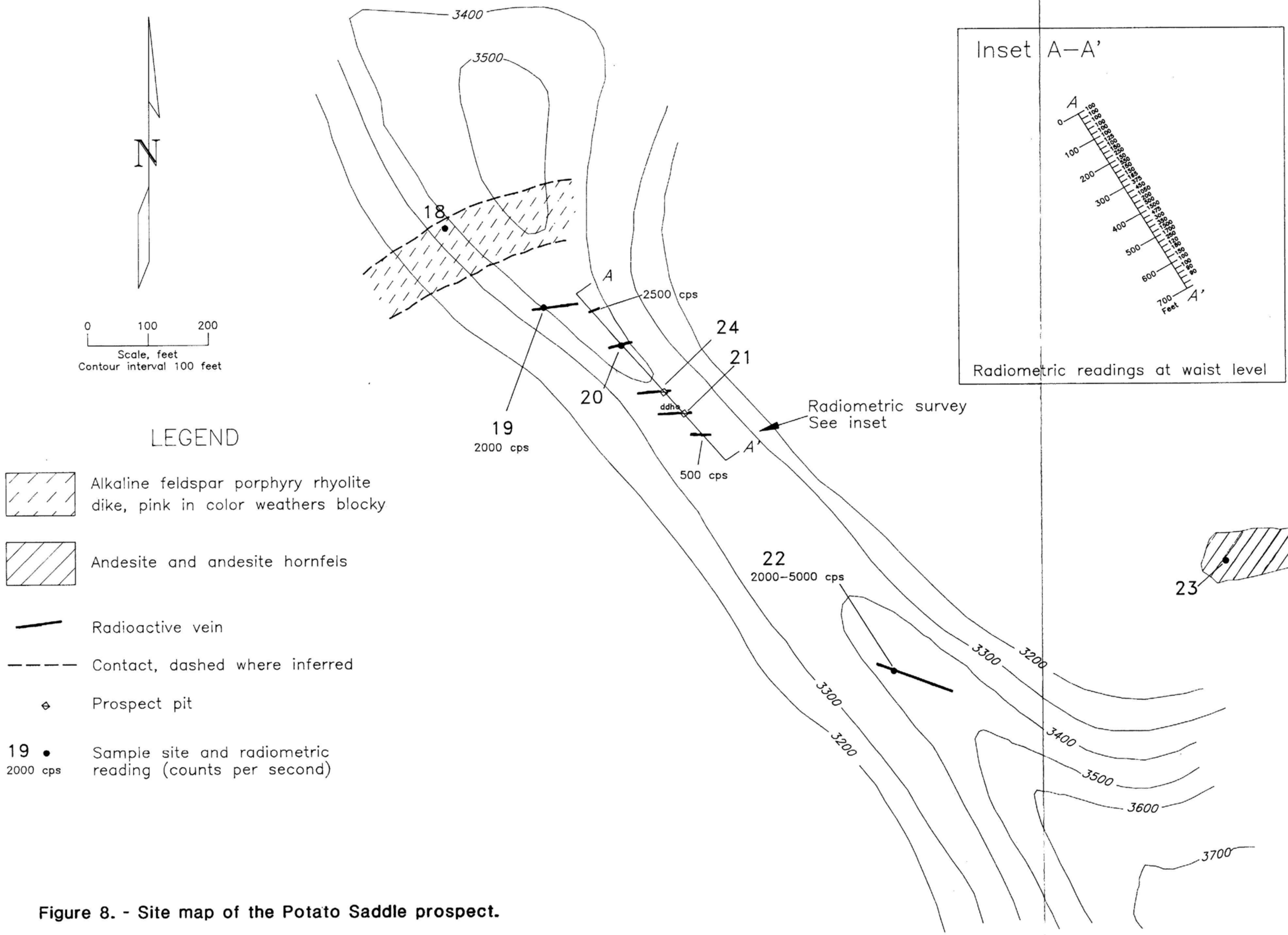

Figure 8. - Site map of the Potato Saddle prospect.

Veins occur in multiple subparallel groups or sets that are separated by wider zones of barren bedrock. Along the Santa Maria trend (fig. 7) prospect pits have exposed up to 40 ft of irregularly mineralized bedrock, and similar, although thinner (<1 ft) mineralized veins cut bedrock as much as several hundred feet to either side. Mineralization in the wider central zone is confined to tabular pods and bands, 0.1-to 2-ft-thick, and altered granitic dikes several feet thick. Similarly, the Potato Saddle prospect (fig. 8) also exhibits the habit of these veins to occur in subparallel swarms. Float rock and prospect pits at Potato Saddle indicate mineralization occurs in multiple veins one inch to about one foot wide within a zone about 400-ft-wide.

Veins cut the andesitic country rocks and vein selvages exhibit glassy banding and recrystallization with secondary magnetite. Thermal alteration of the andesite extends outward variable distances from the contacts. Highly altered and partially silica resorbed leucocratic granitic dikes are incorporated within or adjacent to the larger veins. It is likely that both the veins and incorporated granitic dikes are emplaced along pre-existing fracture zones.

Origin of the veins is unclear, however, at the southern-most extent of the Santa Maria trend, the veins are wider and can be seen cutting plutonic rocks. The veins are a combined product of the leucocratic dike intrusion and repeated pulses of hydrothermal

Figure 9. - Flow-type banding of chlorite, calcite, quartz, amphibole, and magnetite in radioactive vein, sample 10c Santa Maria trend.

fluids as evidenced by the complex, cross-cutting features and overprint of sericitic, chloritic, and carbonate alteration. It is likely the veins represent very late stage lithophile-rich (eg. Zr, REE, Th) and highly fractionated magmatic fluids emanating from the Zane Hills pluton into existing fractures where rapid transition occurred to early-stage hydrothermal fluids.

Compositions and texture are extremely variable with predominating green and black banded aphanitic silica, calcite, and amphibole. Near the plutonic margin on the south end of the Santa Maria trend, the banded mineralogy exhibits a schleiren or flow-type appearance (fig. 9). Additionally, irregular zones with a fine-grained pink feldspathic groundmass feature mottled aggregations of sericite, epidote, carbonate, and chlorite. Zircon occurs as irregular bands, however, its abundance is difficult to estimate due to color masking by hematitic staining of aphanitic feldspar. These larger scale textural features are cut by sets of anastomosing and web-like veinlets of silica, magnetite, hematite, and amphibole. Calcite and specular hematite occur along fracture surfaces. Rare grains of galena and chalcopyrite were also noted. Areas of resilicified breccia are locally abundant and are discernable in outcrop (fig. 10). Further to the north and away from the plutonic margin the degree of silicification appears to increase and the compositional banding is more orderly. There also is an apparent northward increase in radiometric readings over the veins. The general lack of outcrop, however prevented

Figure 10. - Partially resorbed and silicified breccia forming core of vein occurrences at southern end of the Santa Maria trend.

investigation of lateral zonation.

Continuity along strike of individual veins is difficult to predict. Where the mineralization occurs at or near the surface, either in outcrop or rubble, it is readily detected by radiometric methods (1000-3000 cps cf. 60 to 100 cps background). However, solifluction and slope creep processes generally limit bedrock exposure to the tops of ridges, whereas lower side slopes are deeply covered with scree (fig 11). Mineralized float rock which tends to be softer and more readily weathered can generally be traced no more than several hundred feet. Only the Santa Maria trend exhibited indications of continuity because it could be found cutting the tops of three closely spaced knife-like ridges for a strike length of about one mile.

Border Phase Monzonite

A border phase of monzonite was recognized by Miller and Elliott (1977), to contain abnormally high levels of uranium and thorium (avg. 30 ppm U and 125 ppm Th). The radioactive elements are concentrated in disseminated grains of uranothorianite, thorite, betafite, allanite, zircon, and sphene. DeWitt and Levy (1980) analyzed samples of the monzonite and gneissic monzonite but found no unusual concentrations of REE.

Float rock of radioactive gneissic monzonite (sample location 25, fig. 5) was found on the south slope of Clear Creek valley. Although the rock contains elevated U and Th, the REE values are only slightly elevated over the range of normal crustal abundance levels for igneous rocks (table 5). This rock type is relatively widespread on the eastern margin of the Zane Hills pluton and represents potential source rock for both placer REE and sedimentary uranium.

Figure 11. - Prospect pit at Potato Saddle prospect. See map enlargement on figure 8. Frost action causes downslope creep of fractured rock generally obscuring bedrock and mineralization below the ridge.

HEAVY MINERAL PANNED CONCENTRATES

Results of the heavy mineral survey indicate anomalously high levels of uranium and thorium persist in most stream drainages, probably due to minerals uranothorianite and allanite. The REE values also reflect a regional widespread source, however, values are far below concentrations of possible economic interest. Data presented in table 6 readily demonstrates that the higher REE values are found in gravel from lower drainages where the gravel is more highly reworked. Consequently, sample values from high gradient headwaters draining cirques above Wheeler Creek are relatively low, whereas the highest values are found in the lower floodplain gravel of Clear Creek.

A total of 12 panned concentrates were collected. REE values are predominantly composed of the lighter cerium subgroup that are contained in allanite and monazite (visually identified). The multi-element analysis of placer (map no. 44) and panned concentrates further indicate only low levels of Sn, Nb, Ta, and W (tables 6 and 7). Evaluation of the contained quantity of heavy mineral values per equivalent quantities of original gravel should consider that the gravel sampled was mostly loose surface gravel, sorted annually by floods, and containing very minor percentages by volume of fine-grained sediment fractions. Gravel at depth would reasonably be expected to contain relatively greater volumes of finer-sized material including heavy minerals.

The indication that REE values increase with sediment transport and reconcentration suggest at least low grade, although widespread, REE enrichment of downstream alluvial gravel has occurred. For this reason the mid- to lower valleys of Wheeler, Dakli, and Clear Creeks should be drill-evaluated for a combined gold - REE placer deposition. Ilmenite and zircon may also be recoverable.

Barrels of highly concentrated heavy minerals stockpiled from dredge operations on Bear Creek were sampled to determine their REE content (table 7). Although the La, Ce, and Y values were relatively low for a dredge concentrate, the unusually high Nd value is unexpected and worthy of note, but was not reevaluated. Other heavy mineral panned concentrates were not analyzed for Nd. It is possible a Nd-rich mineral occurs in bedrock sources. A Nd-rich bastnaesite, for instance, has been noted in mineralized thorium-rich hydrothermal shear zones in syenite of the Mt. Prindle-Roy Creek prospect north of Fairbanks, (Burton, 1981).

Table 6 - Analytical results of heavy mineral panned concentrates, in parts per million (ppm).

			Analyses[1]											
Map No.	Vol (ft^3)	Conc (g)	U	Th	La	Ce	Y	Calculated[2] lb-(La,Ce,Y)/yd^3	Nb	Sn	Ta	W	Ti	Zr
40	0.52	69.1	481	850	635	816	54	.012	92	12	<2	30	17000	17000
41	0.39	89.2	254	590	666	885	42	.022	56	19	<2	22	21000	6500
42	0.02	18.0	101	290	162	344	43	.023	100	<2	<2	250	4200	1100
43	0.98	187.5	195	390	512	659	51	.014	71	12	<2	4	10000	5900
44	NA		20200	29000	>5000	I	100	--	<2	<2	<2	530	5500	5400
45	2.12	384.2	142	470	848	1130	84	.022	100	8	<2	43	23000	5600
46	0.26	42.4	116	220	379	492	30	.008	56	19	<2	110	17000	4600
47	0.52	52.53	--	23	72	100	--	.001	--	--	--	--	--	--
48	0.39	56.43	--	9	60	230	--	.002	--	--	--	--	--	--
49	0.26	25.42	--	9	80	160	--	.001	--	--	--	--	--	--
50	0.78	184.75	--	38	165	355	--	.007	--	--	--	--	--	--
51	0.65	262.45	--	79	335	600	--	.024	--	--	--	--	--	--

Descriptions

40 Clear Creek, fast-flowing and 40 ft wide.
41 Loose, coarse gravel from stream bar, Clear Creek.
42 Panned soil below bostonite dike north of Clear Creek.
43 Hand panned concentrate from same site as above.
44 50 lb composited sample from 10 drums of radioactive dredge concentrate from the Bear Creek Mine. This is an analysis of a second split of sample listed in Table 7.
45 Very coarse gravel w/ little contained silt/sand fraction; Clear Creek.
46 Loose, coarse gravel exposed at out flow of beaver dam, slough of lower Clear Creek.
47 Streambed of rounded coarse gravel and small boulders.
48 Streambed of rounded coarse gravel and small boulders, much magnetite.
49 Rounded gravel, few boulders.
50 Coarse gravel and boulders near granite outcrop.
51 Coarse rounded gravel with few boulders.

1 Analyses by x-ray fluorescence (XRF) methods, Nuclear Activation Services, Ann Arbor, Michigan.
I Interference
-- Not analyzed.
2 lb - (La, Ce, Y) calculated as follows $\frac{27}{\text{Volume}(ft^3)}$ X H.M. conc(g) X $\frac{\text{La, Ce, Y (pct)}}{454}$ = lb - $\frac{\text{(La, Ce, Y)}}{yd^3}$

Table 7 - Analyses (in pct) of placer concentrate[1] from Bear Creek.

						Analyses[2]					
Map No.	Nb	Ta	Sn	U	Th	La	Ce	Nd	Pr	Gd	Y
44	L	L	L	2.97	4.38	0.060	0.21	1.73	0.05	0.01	0.02

L - less than 0.01%.
1 Sample was composited from barrels of concentrate from past dredge mining.
2 Analyses by ICP-mass spectrometry method, Albany Research Center, U.S. Bureau of Mines, Albany, Oregon.

CONCLUSION AND RECOMMENDATIONS

Although the Zane Hills, and particularly the sedimentary basins that flank the hills, represent attractive exploration targets for uranium deposits (i.e. sedimentary deposits), the data from limited rock and heavy mineral sampling failed to suggest the presence of significant rare earth element mineralization in bedrock sources. Although up to 0.5% Y was detected in the Wheeler Creek veins and could be of by-product interest, the associated uranium contents (0.01 to 0.1% U) are far too low to be economic. Consequently, recovery of minor by-product REE from narrow veins is impractical.

Placer REE occurs throughout the Zane Hills, but likewise sampling to date suggests that grade is too low unless it can be recovered as a by-product of large scale gold placer mining. Highly concentrated dredge concentrates stored at the Alaska Gold Company's camp did contain several percent of rare-earth elements primarily composed of the light cerium subgroup, particularly neodymium. Ilmenite and zircon may also be placer mineral by-products. Placer gold in the area is derived from near, or within, the southeast contact aureole of the pluton (Bear, Clear, Dry, and Caribou Creeks), whereas, REE minerals are weathered from granitic bedrock and dike systems. Therefore, placer REE enrichment will not directly coincide with that of gold. The data, however, indicate fluvial REE is increasingly concentrated downstream. Consequently the mid- to lower valleys of Wheeler, Dakli, and Clear

Creeks, below the contact aureole may host significant gold placers with by-product REE, ilmenite, and zircon. The placer REE occurs primarily in monazite, uranithorianite, and allanite(?) which if recovered would require disposal of a highly radioactive thorium waste.

The Boston Ridge prospect was found to comprise a highly complex alkaline intrusion, however, mineralization is negligible. It was not possible to duplicate the previously reported analytical values of REE exceeding 1.0%.

REFERENCES

1. Burton, P.J., Radioactive Mineral Occurrences, Mount Prindle Area, Yukon-Tanana Uplands, Alaska. MS Thesis on file with, The University of Alaska Fairbanks Library, Sept. 1981, 72pp.

2. Dashevsky, S.S. and Cleveland, G.C., Examinations on Doyon Ltd. Regional Deficiency Selections, 1985. Written communications from H. Noyes, June 1988, 7 pp.

3. DeWitt, D.B. and Levy, A.S. Purcell Mountains - Zane Hills Project, Alaska. 1980 Progress Report by Union Energy Mining Division, Molycorp., to Doyon Ltd. Written communication from H. Noyes, June 1988, 8 pp.

4. Eakins, G.R. and Forbes, R.B., Investigation of Alaska's Uranium Potential. AK Div. of Geol. and Geophys. Surv. Spec. Rpt. 12, 1976, 331 pp.

5. Gallagher, J. and Foss, T., Zane Hills - Purcell Mountains Annual Report, 1979. Unpublished report for Doyon Ltd. from H. Noyes, June 1988, 32 pp.

6. Gallagher, J. and Ruzicka, J., Zane Hills Purcell Mountain Uranium Annual Report, 1978. Unpublished report for Doyon Ltd. Written communication from H. Noyes, June 1988. 51 pp.

7. Miller, T.P. and Elliott, R.L., Progress Report on Uranium Investigations in the Zane Hills Area, West-Central Alaska. U.S. Geol. Surv. Open file 77-428, 1977, 11 pp.

8. Miller, T.P. and Ferrians, O.J., Suggested Areas for Prospecting in the Central Koyukuk River Region, Alaska. U.S.G.S. Cir. 570, 1968, 12 pp.

9. Miller, T.P., Patton, W.W., Jr., and Lanphere M.A., 1966 Preliminary report on a plutonic belt in west central Alaska. in U.S. Geol. Surv. Research 1966: U.S.G.S. Prof. Paper 550-D p. D158-D162.

10. Nokleberg, W.J. and others, Significant Metalliferous Lode Deposits and Placer Districts of Alaska. U.S. Geol. Surv. Bull. 1786, 1987, 104 pp.

11. Patton, W.W., Jr. and Miller, T.P., 1966 Regional geologic map of the Hughes Quadrangle, Alaska U.S. Geol. Surv. Misc. Geol Inv. Map I-459 scale 1:250,000.

EXPLANATION

Ks	Syenite and alkali-rich rocks
Km	Quartz monzonite border phase
Kbg/Khbg	Biotite grandodiorite/and hornblende-biotite granodiorite
Kpg	Quartz monzonite
JKv	Andesite
	Radioactive vein-dike occurrence

Contour interval is 1000 ft.

Geology adapted from Miller and Elliot, 1977.

Appendix A.

Field Sample Numbers

Versus Map Numbers

Sample Number	Map Number
SS27586	1
SS27585	2
SS27608	3
SS27584	4
SS27583	5
SS27540	6
SS27541	7
SS27570	8
SS27607	9
SS27581	10a
SS27606	10b
SS27582	10c
SS27544	11a
SS27545	11b
SS27543	12
SS27571	13
SS27580	14
SS27575	18
SS27577	19
SS27578	20
SS27603	21
SS27579	22
SS27604	23
SS27576	24
SS24603	25
SS24595	26
SS24594	27
SS27611	28
SS27612	29
SS27610	30
SS27588	31
SS27587	32
SS27590	33
SS27589	34
SS27613	35
SS27614	36
SS24593	37
SS24600	39
SS24592	40
SS24596	41
SS24597	42
SS24599	43
SS24600	44
SS24601	45
SS24602	46
SS27601	47
SS27546	48
SS27547	49
SS27572	50
SS27573	51