RARE-EARTH ELEMENT- AND YTTRIUM-BEARING PEGMATITE DIKES NEAR DORA BAY, SOUTHERN PRINCE OF WALES ISLAND

By James C. Barker and Cheryl Mardock

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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
lb/yd^3	pound per cubic yard
mg	milligram
mi	mile
pct	percent
ppm	part per million
ppb	part per billion
um	micrometer, micron
st	short ton
yd^3	cubic yard

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By James C. Barker[1/] and Cheryl Mardock[2/]

ABSTRACT

Yttrium and rare-earth element pegmatite dikes are associated with a peralkaline granitic and nephelene syenite complex near Dora Bay on southern Prince of Wales Island. Mineralized dikes were mapped and sampled during USBM investigations in 1987 and 1988.

Coarse-grained pegmatite dikes, which emanated as late-stage magmatic fluids from the intrusion, further evolved into vein-dikes and ultimately silica-rich veins. The dikes can be traced up to two miles along a north-south zone. Lithophile elements exhibit a pronounced zonation in vein-dikes and veins that are distal to the Dora Bay complex with increasing values correlating with increasing distance from the complex. The pattern of mineralization suggests very late stage magmatic fluids containing the incompatable lithophile elements were injected into a preexisting north-south fracture zone.

REE mineralogy exhibit fine-grained intergrowths of principally thalenite and bastnaesite with lessor monazite and eudialyte. Euxenite contains most of the columbium values and zircon is commonly associated with the dikes.

Estimates of inferred and hypothetical resource tonnage range from 1.7 X 10^6 to 8.5 X 10^6 st for two deposits. Contained REO (including yttrium) averages 0.5 pct and ranges up to 2.0 pct. Deposits are of polymineralic composition and about half of this resource comprises the heavy yttrium subgroup.

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INTRODUCTION

Southern Prince of Wales Island, in southeast Alaska (fig. 1), is host to a trend of sodium-rich intrusive complexes and associated radioactive mineral occurrences that contain varying amounts of rare-earth elements (REE), columbium (niobium)3/, and other lithophile metals (1, 2)4/. During investigations in 1987 and 1988 by the Bureau of Mines, mineralized showings near Dora Bay were found to be among this trend of occurrences. These studies are being conducted as part of the Bureau's effort to identify and assess Alaskan reserves or resources of certain critical and strategic minerals which could be extracted during periods of prolonged national shortages. On southern Prince of Wales Island, the Bureau has recently conducted other reconnaissance investigations at Stonerock Bay, Mclean Arm, Bokan Mountain, Moira Sound, and Cholmondeley Sound.

3/The element 'Niobium' is also referred to as 'Columbium' in the context of a commercial commodity.

4/Underlined numbers in parentheses refer to the list of references preceding the appendices at the end of this report.

Columbium is used widely as a hardening alloy in high-strength, low-alloy steels. It is considered of strategic importance to the United States (U.S.) because of its application in national defense and petroleum industries, and developing uses in advanced technology. At present the country is entirely reliant on foreign sources of the metal (3).

The REE are a group of 15 chemically similar elements consisting of the lanthanide-series, atomic numbers 57 through 71. Yttrium, whose atomic number is 39, is often included with the REE because of similar chemical properties. These elements are often subdivided into two groups: 1) the light REE (cerium subgroup) consists of elements with atomic numbers 57 through 63; and 2) the heavy REE (yttrium subgroup) consists of elements with atomic numbers 39 and 64 through 71. The REE have wide and increasing applications as catalysts for the petrochemical industry, steel alloys, lighting, phosphors, glass and optics, and electronics (4). New alloy compositions for magnets utilizing certain REE have led to improved magnetic field strengths. Recent research in the fields of superconductors and metal-oxide ceramics has been dramatically advanced by the use of various REE compounds, particularly yttrium. At the present time, however, these potential new uses are still in early research and development stages and have not yet resulted in a significant increase in demand for REE. The U.S. is self-reliant in the lighter REE, however, most of the heavy REE, including yttrium are imported. Worldwide, most of the production of the heavy REE occurs as a by-product to tin and titanium placer mining.

There has been no previous documented evaluation of the REE or columbium resource potential near Dora Bay. However, of significance is the identification by Herreid and others (5) of eudialyte in zirconium mineralized dike rubble on a beach of Dora Bay. Eudialyte is a zirconium mineral often associated with REE deposits elsewhere in the world. At Dora Bay, Eberlein and others (6) further noted its occurrence in a diorite and syenite intrusion they mapped immediately southwest of Dora Bay.

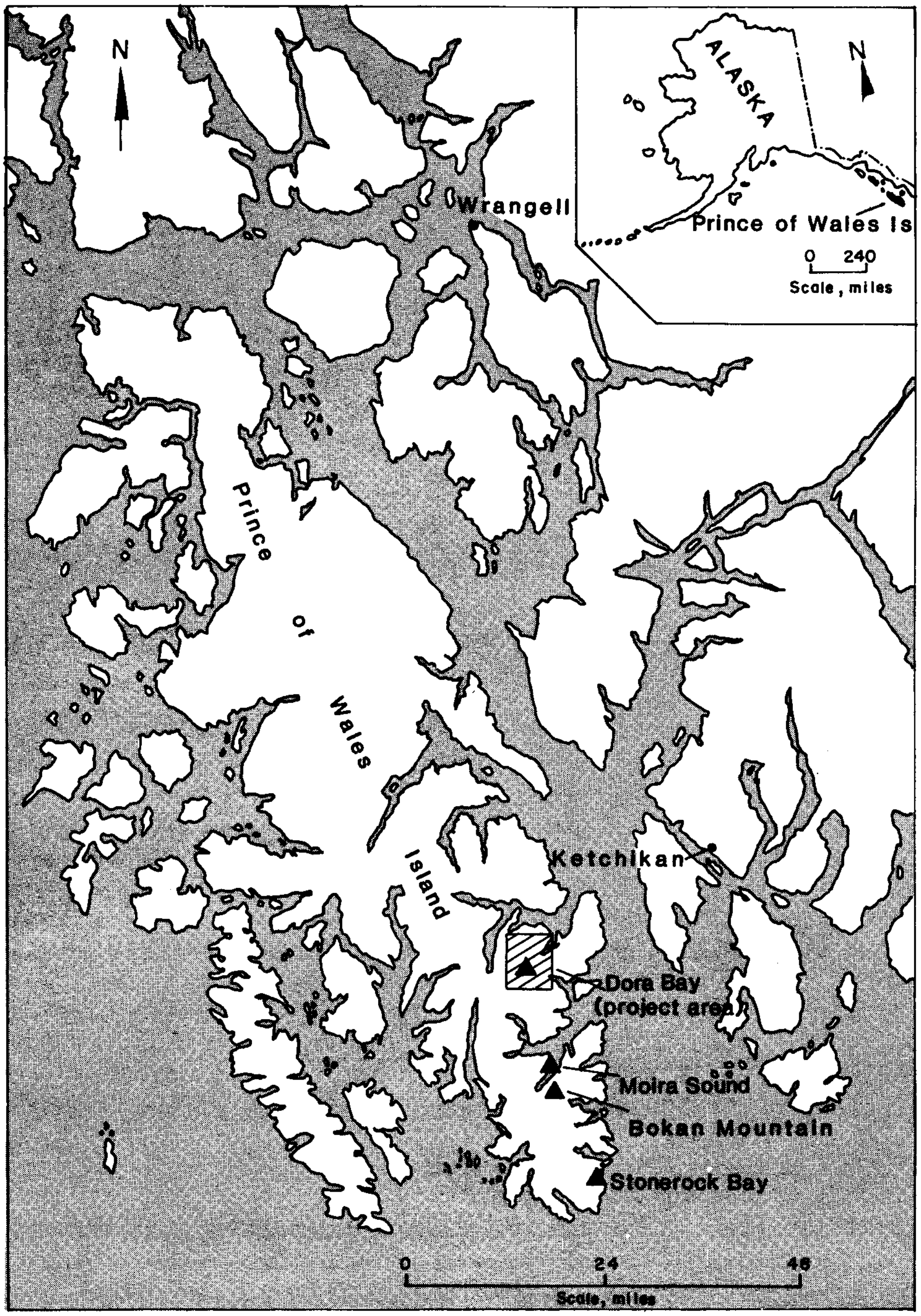


Figure 1. - Location of the Dora Bay intrusive complex on southern Prince of Wales Island.

The REE-columbium deposits near Dora Bay described in this report are not of sufficient grade to be presently economic to mine as compared to other deposits in the world. However, much of the world's REE resource potential is comprised of only the lighter REE, whereas most deposits on southern Prince of Wales Island, including those at Dora Bay, also contain the heavy yttrium subgroup. Therefore, the results of the investigation at Dora Bay are presented in the following report.

LAND STATUS AND ACCESS

The investigation area near Dora Bay lies in the Craig A-1 and A-2 quadrangles and is located in the federally managed Tongass National Forest. Certain land entitlement claims have been made in the vicinity by the SeaAlaska Native Corp. Final disposition of those claims is continuing. Elsewhere the area is designated multiple-use by the Forest Service and is open to mineral entry.

Dora Bay is a well-sheltered, relatively deep bay that is readily accessible by either boat or float planes. A foot trail leads from the head of the bay to Dora Lakes where a canoe was used during this project to gain access to areas of interest. During the field examination in 1987-88 on-going logging operations were continuing to expose additional outcrops of bedrock. Logging roads now provide access to the region immediately west of the project area.

GEOLOGIC SETTING

Regional Geology

Bedrock geology of the Dora Bay area is composed of volcaniclastic and metasedimentary rocks that have been intruded by a peralkaline granitic complex with phases of nepheline syenite, diorite, and alkaline granite. The clastic rocks have been included in the Wales Group by Eberlein and others (6), and comprise pre-Middle Ordovician to Precambrian (?), predominantly andesitic to basaltic marine volcanics, mudstones, and shales. Marble is locally interlayered in the Wales Group. Age of the Wales Group has been assigned on the basis of structural relationships with other rock units outside of the study area; no fossil record has been found.

Near Dora Bay tan-colored pelitic sediments are generally metamorphosed to greenschist. Foliation in the schist is believed to represent original bedding (6). Between Dora Bay and the South Arm of Cholmondeley Sound, intrusive bodies of eudialyte-bearing nepheline syenite and associated pegmatites have been mapped by Eberlein and others at 1:250,000 scale (6).

Intrusive Rocks

The Dora Bay peralkaline intrusive complex, informally named for this report, consists predominantly of medium-grained peralkaline (riebeckite?) granite and hornblende syenite, with alkaline granite and diorite variants. Major oxide chemistry and CIPW normative mineralogy of representative chip samples of the intrusive rock are given in table 1. The principal intrusive phases are classified on the basis of the rock chemistry and field observations. The complex has also given rise to late stage pegmatites and aplite dikes that cut both the intrusive rocks and the Wales Group metasediments.

Rubble and outcrop mapping (fig. 2) indicates that the complex is a north-south trending, 10,000-ft long, sinuous sheet-like body. The complex, as presently exposed, conforms approximately to an inferred north-south fault shown on the regional geologic map by Eberlein and others (6). The configuration of an aerial magnetic anomaly of 1,047 gamma (7) occurring about one mi west of north Dora Lake further suggests a westerly dip of the complex. Peralkaline granite boulders were found in a creek bed in this vicinity and also found at several beach localities on the east side of South Arm Cholomondeley Sound.

Geologic reconnaissance (during this project) of the region immediately west of figure 2 encompassing the aerial magnetic anomaly observed silicified, highly altered metasediments (?) that are intruded by a fine-grained diorite. It could not be ascertained whether this fine-grained diorite, which was not found to contain pegmatite or syenite phases, is in any way genetically associated with the Dora Bay complex.

Further to the west on the west side of the South Arm of Cholomondeley Sound, numerous alkaline carbonate basaltic dikes cut the Wales Group schist (table 1).

Pegmatite Dikes

Several types or phases of dikes are included under the classification of pegmatites at Dora Bay. These include:

1) coarse-grained tabular bodies, up to 13-ft thick, of quartz-albite composition with minor riebeckite, aegirine, and zircon; a halo of pyritic and chloritic alteration is generally present in the country rock;
2) vein-dikes[5/], commonly 1- to 3-ft thick, that exhibit hydrothermal alteration minerals typical of veins (e.g. quartz banding, sericite, rhodochrosite, galena, and sphalerite), but also an intrusive selvage, wallrock alteration to hornfels, and pegmatitic quartz and albite core; and
3) siliceous, manganese-stained, noticeably more radioactive veins, less than 1.2 ft thick, that appear gradational along strike from the vein-dikes.

5/For this report, a vein-dike is defined as a pegmatitic intrusion that has characteristics of both a vein and dike (7).

The coarse-grained pegmatites cut both the intrusive complex and the country rocks nearby, whereas the vein-dikes occur only in the country rock. The siliceous veins are more distal yet from the intrusion. Within the country rock, but proximal to the intrusion, a transition zone occurs where both coarse pegmatites and vein-dikes can be observed subparallel to each other in the same outcrop (see insert fig. 2), thereby indicating they are the result of somewhat chemically different and repeated phases of dike emplacement along the same structural zone. Where they cut metasediments, the pegmatite dikes tend to be long, tabular, locally bifurcating bodies whereas in the intrusion itself, they are diffuse irregular masses, generally too small to map. Locally they form minor intrusive phases commonly containing eudialyte. Further away from the intrusive complex where the dikes are more vein-like, the individual veins and vein-dikes bifurcate and splay over a widening area of at least several hundred feet (e.g. sample locations 6-11, fig. 2).

Pegmatite dikes exhibit local variations of dip and strike, but overall they form a subparallel west-dipping system of tabular bodies that strike north-south, parallel to the trend of the intrusive complex (fig. 2). The coarse-grained pegmatites feature numerous thin spur dikes that extend up to 10 ft into the hanging and footwalls. Spur dikes dip perpendicular to a principal dike yet strike subparallel to it.

MINERALOGY AND PETROGRAPHY OF THE PEGMATITE DIKES

Results of microprobe, scanning electron microscopy, and transmitted-light microscopy studies indicate that the rare-earth mineralogy of the Dora Bay complex is very similar to that of the Bokan Mountain pegmatitic and quartz-albite dike system. The predominant rare-earth minerals observed are thalenite and bastnaesite (table 2). The rare earth minerals are intricately intergrown. Figure 3 is a scanning electron backscatter (SEM) photomicrograph of a rare-earth mineral grain intergrowth containing monazite, bastnaesite, and thalenite in a matrix of quartz and calcite. Eudialyte $[Na_4(Ca,Ce)_2(Fe^{2+},Mn,Y)ZrSi_8O_{22}(OH,Cl)_2]$ was not detected in the samples examined by SEM, however, the presence of Cl, detected by microprobe, indicates that this mineral is probably also present; few other rare-earth minerals contain Cl. Locally eudialyte is abundant (3-15 pct) in restricted phases of the intrusion, however, in the field it was not observed to occur in the veins extending beyond the intrusive margins.

Table 2. - Principle REE- and Cb-bearing minerals identified at Dora Bay

Major	Minor
Thalenite	Monazite
Bastnaesite	Eudialyte
	Euxenite

Optical, radiometric, and microhardness tests indicate the presence of euxenite which likely accounts for the Cb found by geochemical analyses. Other ore minerals detected during preliminary studies include zircon, allanite, and galena. Zircon occurs as euhedral crystals and in unique quartz crystals up to 2 cm long filled with pink zircon. Zircon replaced quartz crystals were observed as selvages and center-core bands within some vein dikes near sample nos. 6-11 (fig 2). Gangue minerals of quartz, rhodochrosite, plagioclase, acmite (aegirine), riebeckite, calcite, and chlorite were identified optically. Riebeckite and aegirine are most common in the coarse grain pegmatites within or near the intrusion.

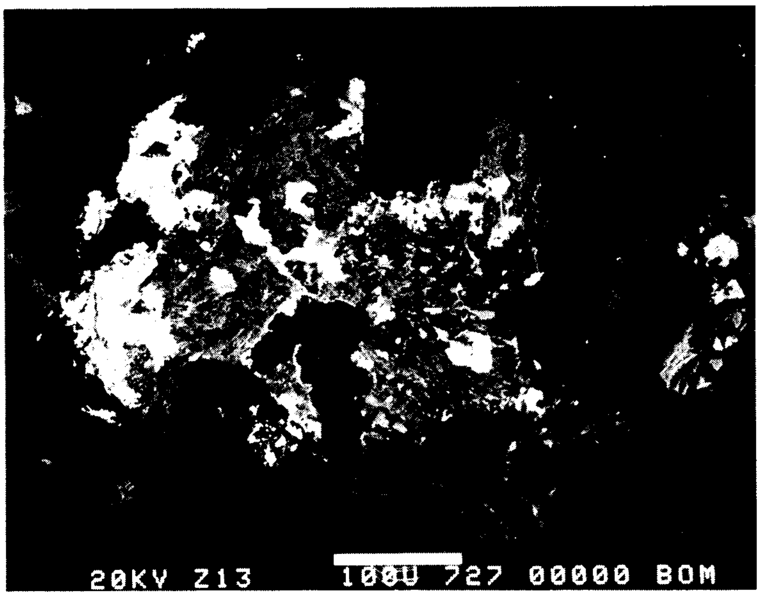


Figure 3. - SEM backscatter image of intergrown monazite (bright mineral in center) with thalenite (cream colored mineral on left) and bastnaesite (darker gray minerals) in a matrix of quartz and calcite. Magnification is 200X

SAMPLING METHODS AND ANALYTICAL TECHNIQUES

The Dora Bay area features precipitous, heavily forested slopes that lead directly down to tidewater. Although good bedrock exposure occurs at higher elevations, most of the areas of interest are associated with linear structural zones which are subject to erosion and lie at lower elevations near or within several hundred vertical feet of tidewater. Generally these lower slopes are mantled with avalanche debris and thick-tangled vegetation, thereby confining mapping and sampling to rubble supplemented with only rare outcrop. Consequently, sampling of surface exposures for the purpose of quantifying reserves or resources could not be undertaken on a routine basis.

Unless otherwise noted in the text, sampling was done as a continuous line of chips across tabular bodies exposed either in outcrop or rubble. Rock samples were analyzed at a commercial laboratory6/ for a package of 42 elements by a variety of analytical techniques listed in table 3.

6/Analyses by Nuclear Activation Services, Ann Arbor, Michigan.

Analytical results and rock sample descriptions are presented in tables 4-6. Complete analyses are listed in the appendices.

In addition to the elements listed in table 3, a representative suite of rock samples were also analyzed for Pr, Gd, Tm, Dy, Ho, and Er by an ICP/mass spectrometry procedure by the same laboratory. This permitted a determination of the total REE content in samples representative of the Dora Bay deposits.

A series of 37 heavy mineral concentrates were also collected in an attempt to detect the presence of additional mineral deposits that may be hidden by surficial cover. At each site (fig. 4) approximately one level-full 14-in gold pan of -3/8 in material was reduced by panning to a concentrate of predominantly heavy minerals. Concentrates were then weighed, pulverized, and analyzed for 34 elements7/ according to procedures listed in table 3.

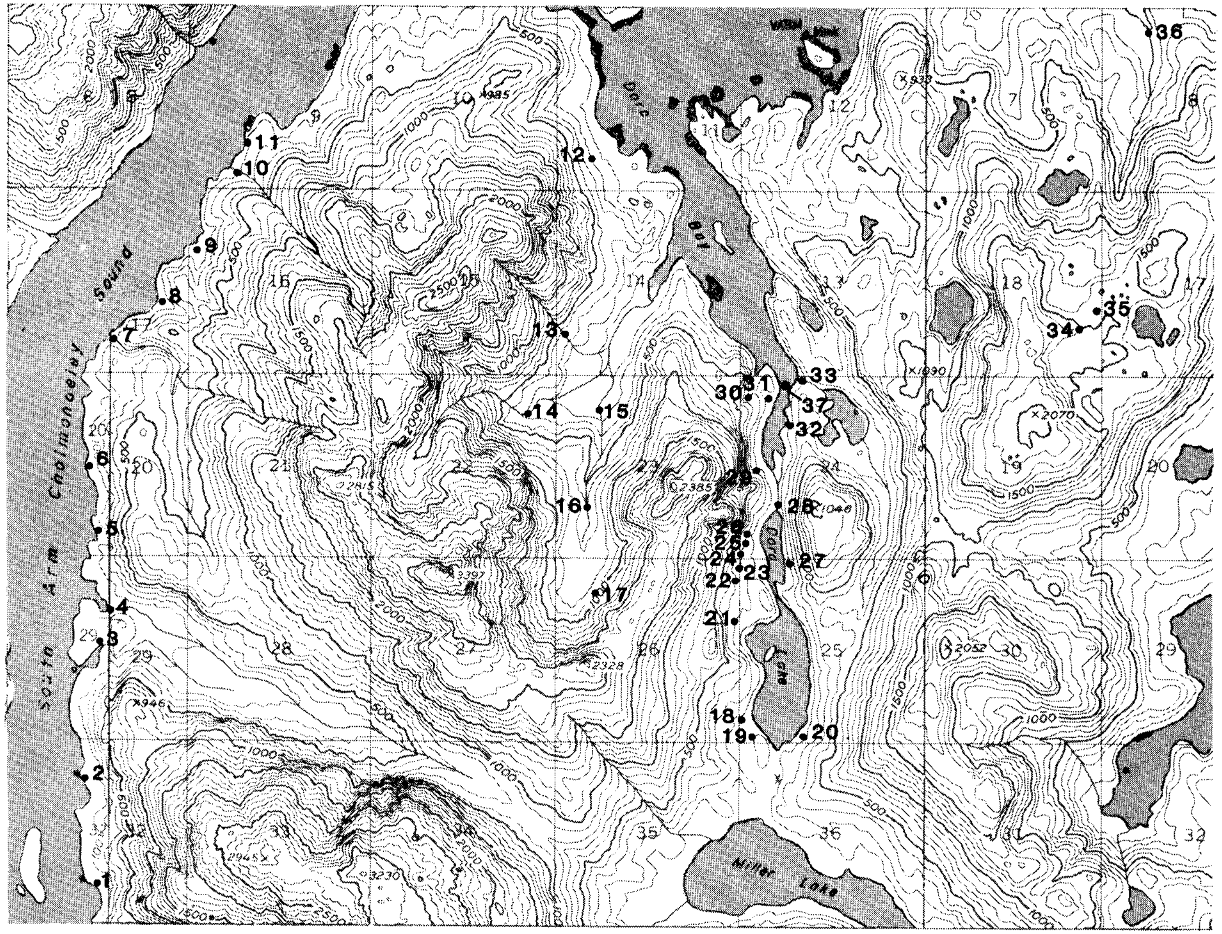
7/Analyses by Bondar-Clegg, Inc., Lakewood, Colorado.

Original sample volumes, concentrate weights, and analytical results are listed in table 7.

The heavy mineral data set was evaluated using Y as a path-finder element. Note that analytical results have been correlated by weight to the amount of recovered concentrate in mg. These normalized recovered weights of elemental Y in the original sample volumes can be compared between sample sites.

MINERALIZATION

A system of REE-Cb enriched pegmatite dikes can be traced intermittently from near the head of Dora Bay southward along the western margin of south Dora Lake (fig. 2). From the available exposures, it is apparent that there are a multitude of dikes comprising the system, the number of which



Base adapted from U.S.G.S. 1:63,360 scale Graig (A-1) quadrangle

LEGEND

46• Sample location and number

N

0 1 2
Scale, miles
Contour interval 100 feet

Figure 4. - Location of panned heavy mineral concentrates near Dora Bay.

Table 3. - Analytical methods and detection limits

ROCK SAMPLES

Element(s)	Analytical Method	Detection limit, ppm	Element(s)	Analytical Method	Detection limit, ppm
Ag	DCP	0.5	Pr	ICP-MS	0.1
As	NA	2.0	Rb	XRF	20
Au	NA	.010	Sb	NA	.2
B	DCP	100	Sc	NA	.1
Ba	XRF	10	Se	NA	3.0
Be	DCP	10.0	Sm	NA	.1
Bi	DCP	.5	Sr	XRF	20
Br	NA	1.0	Ta	NA	1.0
Cb	XRF	20	Th	NA	.5
Cd	DCP	.2	Tm	ICP-MS	0.1
Ce	NA	3.0	U	NA	.5
Co	NA	1.0	V	DCP	100
Cr	XRF	10	W	NA	3.0
Cs	NA	.5	Y	XRF	20
Cu	DCP	.5	Yb	NA	.02
Dy	ICP-MS	0.1	Zn	DCP	.5
Er	ICP-MS	0.1	Zr	XRF	20
Eu	NA	.2	Al_2O_3	XRF	100
Ga	ICP-MS	0.1	CaO	XRF	100
Ge	DCP	100	Fe_2O_3	XRF	100
Hf	NA	1.0	K_2O	XRF	100
Ho	ICP-MS	0.05	LOI	XRF	100
La	NA	.5	MgO	XRF	100
Lu	NA	.05	MnO	XRF	100
Mn	DCP	2.0	Na_2O	XRF	100
Mo	NA	5.0	P_2O_5	XRF	100
Nd	NA	5.0	SiO_2	XRF	100
Ni	DCP	1.0	TiO_2	XRF	100
Pb	DCP	2.0			

PAN CONCENTRATED SAMPLES

Element(s)	Analytical Method	Detection limit, ppm	Element(s)	Analytical Method	Detection limit, ppm
Ag	NA	5.0	Nd	NA	5.0
As	NA	2.0	Ni	NA	200
Au	NA	10	Rb	NA	20.0
Ba	NA	150	Sb	NA	0.2
Br	NA	1.0	Sc	NA	0.1
Ce	NA	3.0	Se	NA	3.0
Co	NA	1.0	Sm	NA	0.1
Cr	NA	2.0	Ta	NA	1.0
Cs	NA	0.5	Th	NA	0.5
Eu	NA	0.2	U	NA	0.5
Hf	NA	1.0	W	NA	3.0
La	NA	0.5	Y	NA	2.0
Lu	NA	0.1	Yb	NA	0.2
Mo	NA	5.0	Zn	NA	20.0
Na	NA	100			

DCP - Direct current plasma
NA - Nuclear activation
XRF - X-ray fluorescence
ICP-MS - Inductively coupled plasma followed by mass spectrometry
Samples prepared with fusion techniques

Table 4. - Pegmatite dikes and wallrock sample results, in ppm

Map No.	Field No.	Width (ft)	Cb	Th	U	Y	Zr	LIGHT REE (Cerium Subgroup) La	Ce	Pr	Nd	Sm	Eu	HEAVY REE (Yttrium Subgroup) Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Total REE
1....	26525....	1.3	620	230	22	3600	4900	581	1440	270	929	284	71	578	77	654	133	325	36	155	17	5550
2....	26432....	0.1	1300	97	77	3300	4600	1510	3090	530	1330	315	72	532	60	556	105	251	30	125	14	8520
3....	26426....	0.5	400	110	18	4600	2300	374	858	130	378	129	31	342	51	573	133	361	44	167	17	3588
4....	26527....	0.8	410	250	47	2200	3400	479	1000	---	408	108	26	---	--	---	---	---	--	130	13	----
5....	26528....	0.3	390	300	42	2700	9900	712	1380	200	590	151	35	267	44	379	88	239	31	168	21	4305
6....	26429....	1.7	190	54	20	1600	25000	179	537	61	200	58	13	117	20	206	54	179	26	188	28	1866
7....	26431....	3.0	130	39	24	1400	30000	186	578	---	224	44	10	---	16	---	---	---	--	223	34	----
9....	26428....	1.5	140	240	16	1000	4600	193	519	---	245	59	14	---	16	---	---	---	--	83	11	----
10...	26427....	1.8	270	320	36	2100	18000	552	1290	190	644	141	36	211	41	311	77	176	26	249	36	3980
11...	26531....	1.2	120	100	20	2200	21000	163	539	59	185	51	13	112	25	243	68	221	34	226	33	1972
12...	26510....	4.5	150	110	23	1900	12000	191	583	66	224	59	14	102	20	195	52	174	25	180	24	1909
13...	26421....	4.0	310	36	18	1200	6000	208	591	---	260	72	18	---	20	---	---	---	--	90	12	----
14...	26458....	2.5	130	86	31	1200	16000	105	395	---	97	33	9	---	15	---	---	---	--	137	20	----

Descriptions

1....	Sample includes four Mn-quartz dikes in a 10-ft section of schist. Dikes range from 3 to 5-in thick, other similar dikes in area; 500 cps.
2....	Siliceous Mn-stained narrow dike striking N30_W; 500 cps.
3....	Siliceous fine-grain dike with porphyritic flesh-colored (REE?) mineral. Dike strikes N5_W; 700 cps.
4....	Mn-stained siliceous dike with pegmatitic quartz core; 900 cps. Numerous similar, adjacent, thinner dikes 1 to 4-in thick.
5....	4-in thick fine-grain dike with clots of zircon.
6....	Banded hornfels, pegmatite, and fine-grain siliceous material with aegirine and needle-like pink mineral; 300 cps. Zone is wider than the 20 in exposed for sampling and has pegmatitic quartz core.
7....	Wider zone in outcrop similar to above.
9....	Banded dike as above with pegmatite center core; 600 cps.
10...	Banded silica and pegmatite quartz with 3 bands of unidentified needle-like zirconium minerals; 600 cps. Hornfels adjacent to selvage.
11...	Banded siliceous dike similar to sample 6 above, with accessory galena; 400 cps.
12...	Combined sample of 4 quartz dikes, 8-, 10-, 14-, and 24-in thick composed of crudely banded quartz, albite, riebeckite (?), and unidentified pink zirconium mineral, porphyritic cores.
13...	Swarm of intersecting narrow dikes 1 mm to 2 mm thick and 3 larger dikes 3- to 6-in thick cutting chloritic and pyritic schist, striking S 20_E; 300-900 cps. Dike material estimated to be 40 pct of sample. Sample is upper 4 ft of 25-ft wide outcrop of similar material.
14...	Similar to above but lower in section; 600 cps. Sample contains .64 ppm Au.

Table 4. - Pegmatite dikes and wallrock sample results, in ppm - Continued

Map No.	Field No.	Width (ft)	Cb	Th	U	Y	Zr	LIGHT REE (Cerium Subgroup) La	Ce	Pr	Nd	Sm	Eu	HEAVY REE (Yttrium Subgroup) Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Total REE
15...	26520....	2.0	570	160	30	1200	9400	537	1470	---	518	105	24	---	26	---	---	---	--	113	15	----
16...	26519....	3.0	310	110	14	1300	6100	48	370	17	53	24	8	65	18	182	47	138	18	125	16	1129
17...	26525....	2.0	110	19	16	260	2400	51	143	---	47	15	4	---	5	---	---	---	--	21	3	----
18...	26508....	6.0	80	22	24	590	13000	93	217	24	71	25	7	44	9	82	21	64	6	55	7	725
19...	26509....	3.0	30	12	4	200	800	54	123	---	45	12	3	---	3	---	---	---	--	14	2	----
20...	26518....	5.0	10	340	9	70	600	196	266	---	69	11	2	---	L	---	---	---	--	4	1	----
21...	26504....	2.5	40	22	5	220	600	40	100	---	45	10	2	---	3	---	---	---	--	10	1	----
22...	26505....	8.0	210	58	38	870	12000	283	545	75	243	55	11	78	13	110	26	79	8	65	8	1599
23...	26506....	3.0	10	6	1	50	300	24	49	---	22	6	2	---	1	---	---	---	--	6	1	----
24...	26479....	2.5	420	56	43	1200	8800	401	1140	---	478	125	26	---	25	---	---	---	--	117	13	----
25...	26480....	3.5	170	11	17	560	18000	78	198	24	58	20	4	30	6	63	17	54	5	53	7	617
26...	26548....	2.0	70	60	23	400	2100	210	397	---	148	26	6	---	5	---	---	---	--	18	2	----

Descriptions

15...	Swarm of 1/16- to 1-in thick dikes in a 2-ft exposure. At least two similar swarms occur immediately downhill; 500 to 1,000 cps. Located 80 ft uphill of sample 18.
16...	Sample across 18-in pegmatitic and fine-grain dike and 18-in of chloritic schist wallrock to either side, located 30 ft uphill of sample 18.
17...	Hanging wall to sample 18; chloritic schist with several 1/4-in or less thick black aphanitic veinlets normal to contact.
18...	6-ft thick coarse-grain pegmatite with coarse crystalline aegirine in albite, quartz, and earthy pink mineral; some clots of biotite.
19...	3-ft of adjacent footwall to sample 18; similar to sample 17.
20...	Footwall chloritic schist to pegmatite; contains numerous 1/16- to 3-in veinlets and dikes striking N-S and oriented normal to the pegmatite; 500 to 5,300 cps. Dikes include black opaques, amphibole, and bladed pink zirconium material.
21...	Hanging wall of diorite to pegmatite (sample 22) and cut by numerous sub-parallel and sub-normal black aphanitic veinlets.
22...	8-ft thick, coarse-grain albite aegirine pegmatite with a pink earthy mineral (zircon?); 500 to 2,000 cps.
23...	Footwall fine-grain gray diorite to sample 22, similar to sample 21.
24...	Hanging wall of altered chloritic schist; up to 900 cps.
25...	Variable grain texture and pegmatitic dike; 400 cps.
26...	Footwall chloritic schist to sample 25; 200 to 700 cps.

Table 4. - Pegmatite dikes and wallrock sample results, in ppm - Continued

Map No.	Field No.	Width (ft)	Cb	Th	U	Y	Zr	LIGHT REE (Cerium Subgroup) La	Ce	Pr	Nd	Sm	Eu	HEAVY REE (Yttrium Subgroup) Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Total REE
27...	26425....	Grab.	250	74	48	1200	24000	180	458	---	126	45	10	---	20	---	---	---	---	134	17	----
28...	26517....	8.0	160	45	35	650	15000	151	362	---	124	34	7	---	9	---	---	---	---	87	11	----
31...	26482....	0.7	260	45	13	1200	9900	168	507	---	208	59	14	---	18	---	---	---	---	125	18	----
32...	26483....	2.0	10	28	4	80	200	55	115	---	30	6	2	---	1	---	---	---	---	4	1	----
33...	26484....	2.0	380	240	96	1600	19000	517	1230	140	406	89	18	109	24	92	16	39	5	84	10	2779
34...	26549....	2.5	320	110	49	1500	8100	512	1180	130	390	101	21	142	25	194	42	122	14	92	11	2976
35...	26550....	2.5	490	23	21	3300	14000	227	452	320	239	58	13	407	15	499	106	279	34	40	5	2694
36...	26485....	2.7	580	51	117	700	20000	413	806	---	330	52	9	---	8	---	---	---	---	60	9	----
39...	25219....	1.5	L	610	89	400	2100	713	956	---	274	37	6	---	4	---	---	---	---	18	3	----
42...	26551....	3.0	200	13	7	550	5400	140	315	37	152	32	8	51	10	90	23	71	8	63	8	1008
43...	26487....	CR...	120	12	5	370	2900	74	282	---	72	20	5	---	6	---	---	---	---	40	5	----
44...	26423....	2.0	290	32	51	1400	27000	10	271	5	20	9	3	30	11	170	55	211	33	230	30	1088
45...	26463....	1.0	250	23	21	350	5200	25	93	---	22	6	1	---	4	---	---	---	---	43	6	----
47...	26619....	10.0	130	260	158	1400	75000	31	228	---	76	18	6	---	16	---	---	---	---	198	33	----
48...	26651....	6.7	1200	180	240	2400	5500	552	1120	---	507	131	29	---	36	---	---	---	---	121	17	----
50...	26618....	3.0	L	300	L	1000	5400	400	1000	---	400	L	L	100	--	400	L	L	700	L	---	----
51...	26257....	CR	L	200	L	2500	0.36	500	1400	---	800	L	L	400	--	500	L	300	200	200	---	----
52...	26327....	1.2	300	800	200	4900	---	2200	5600	800	2800	600	100	800		900	200	500	900	300	L	15900

L Less than detection limits. --- Not analyzed.

Descriptions

27...	Pegmatite rubble of albite, quartz, actinolite, amphibole, pink earthy mineral, and opaques; 500 to 900 cps.
28...	Similar to sample 27.
31...	Combined sample of 4-in radioactive dike and wallrock.
32...	Chloritized schist footwall to sample 34; 400 to 800 cps.
33...	Chloritized schist hanging wall to sample 34; 200 to 2,000 cps.
34...	Banded dike, with pegmatite; varies in width to 4 ft; 900 to 2,500 cps.
35...	Banded dike composed of quartz, albite, ribbons of aegirine, euhedral riebeckite and zircon, and earthy clots of zircon; to up 2,400 cps.
36...	Banded coarse zircon crystals and clots in fine-grain silica-rich matrix.
39...	Complex pegmatite, one of several pegmatite lenses that occur along margin of syenite intrusion; 1,000 to 1,500 cps.
42...	Coarse-grain riebeckite and feldspar syenite pegmatite dike; 200 to 800 cps.
43...	Random chips of pegmatite and Fe-stained syenite rubble in 20- by 50-ft size area; 200 to 400 cps.
44...	Coarse-grain syenite pegmatite with masses of zircon and euhedral riebeckite and aegirine; 200 cps.
45...	Coarse-grain Mn-stained syenite pegmatite.
47...	Coarse-grained manganese stained pegmatite with bordering finer-grained bands, outcrop poorly exposed; 500cps.
48...	Manganese-stained float boulder of vein 10 in or more wide, found in alluvial fan of small creek on South Arm; 900 cps.
50...	200 lb bulk sample from 3-ft vein dike. Assay by ICP-MS.
51...	200 lb bulk sample of vein swarm (vein material only). Veins range 1/2-to 5-in-thick cutting green-gray schist. Assay by ICP-MS.
52...	90 lb bulk sample of 14-in vein dike found in creek bed rubble. Assay by ICP-MS.

Table 5. - Eudialyte-bearing pegmatite sample results, in ppm.

Map No.	Field No.	Width (ft)	Cb	Th	U	Y	Zr	LIGHT REE (Cerium Subgroup) La	Ce	Pr	Nd	Sm	Eu	HEAVY REE (Yttrium Subgroup) Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Total REE
29...	26420....	CR...	230	5	2	1100	7800	147	539	---	220	63	14	---	22	---	---	---	--	98	12	----
30...	26455....	CR...	270	30	17	1400	11000	240	650	85	308	86	18	140	26	222	52	146	18	120	15	2126
37...	25218....	1.0	L	1400	181	720	3200	757	1100	130	346	58	9	62	10	78	18	43	3	36	6	2656
40...	25217....	CR...	300	140	37	1600	12000	496	980	---	440	106	23	---	28	---	---	---	--	105	12	----
41...	25646....	CR...	329	28	29	1500	14000	470	980	---	---	145	12	---	37	---	---	---	--	110	13	----

I Interference. CR Random chip sample. L Less than detection limits. --- Not analyzed.

Descriptions

29...	Random chips of eudialyte syenite (?) in creek bed just below contact with metavolcanics.
30...	Random chips of eudialyte nepheline dike in syenite.
37...	Radioactive pegmatite-pod in syenite containing riebeckite, plagioclase microcline, nephelene (?), eudialyte, quartz, and unidentified orange and yellow minerals; 2,200 cps.
40...	Random chip of eudialyte-bearing pegmatite that forms 1- to 2-in irregular bands in syenite. Traces of galena; up to 700 cps.
41...	Random chip of eudialyte-bearing pegmatite that forms multiple 1- to 2-in thick irregular bands in in syenite. Traces of galena; up to 700 cps.

Table 6. - Other sample results, in ppm

Map No.	Field No.	Width (ft)	Cb	Th	U	Y	Zr	LIGHT REE (Cerium Subgroup) La	Ce	Pr	Nd	Sm	Eu	HEAVY REE (Yttrium Subgroup) Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Total REE
8....	26430....	2.5	20	2	1	40	400	9	28	---	12	3	2	---	L	---	---	---	--	5	1	----
38...	25220....	CR...	50	11	3	170	1300	64	139	---	94	19	5	---	4	---	---	---	--	17	2	----
46...	26502....	CR...	90	15	6	270	1300	68	156	---	70	16	4	---	6	---	---	---	--	24	4	----

CR Random chip sample. --- Not analyzed. L Less than detection limits.

Descriptions

8....	Carbonitite (?) with central core of pegmatitic quartz cutting hornfels metasediment. Carbonate contains disseminated pyrite and weathers to limonite-clay; non-radioactive.
38...	Random chips of unaltered syenite, no eudialyte present; 170 cps.
46...	Aphanitic green rock with angular patches and clasts of fine-grain magnetic black material; non-radioactive. Exposed for 50 ft along logging road.

apparently increases with distance from the intrusion. An avalanche gully at sample locations 6-11 demonstrates the multiple nature of the dikes. At least four, and likely more, dikes are present between the lake level and 250 ft elevation, and additional vein-dike float was found above that level. At some sample sites, mineralization was also found in the chloritic wallrock (e.g. sample nos. 24 and 33).

Analytical data (table 4) clearly indicates that REE, columbium, and silica content, and to a lesser degree beryllium, manganese, and tantalum, increase with the distance away from the intrusion. This elemental zoning indicates mineralization is associated with the more highly evolved, quartz-rich, hydrothermally altered vein-dikes and particularly the distal veins. Figures 2 (inset) and 5 display the correlation of increasing total REE + yttrium values to the increasing amount of silica in the samples. The data indicates that the deposition of higher concentrations of lithophile elements, normally associated with a late-stage volatile-rich intrusive phase, occurs at distance from the Dora Bay intrusive source. Likely a late-stage hydrothermal phase of the Dora Bay intrusive complex was introduced along and controlled by a north-south fault or fracture zone at least partially aligned with bedding. The ultimate southward limit of the volatile precipitation and mineralization could not be determined due to extensive surficial cover including cemented glacial till. Similarly, if the same processes have taken place to the north of the intrusion, they could be projected to occur in the heavily forested slopes east of the bay head.

Due to the reconnaissance nature of the sampling, no available drill data, and the association of dikes with recessive topography, it was not possible to accurately determine the average grade of mineralization.

Vein-dikes and the distal veins they evolved into, contain concentrations of REE, yttrium, and columbium. The total of yttrium and REE in many of the samples approaches or exceeds 0.4 pct, which is equivalent to approximately 0.5 pct REO (rare-earth and yttrium oxide, as it is commercially traded). Grades range from 1,000 to 4,600 ppm Y, 1,000 to 15,900 ppm REE, 120 to 1300 ppm Cb, low to 7.5 pct Zr, and traces of uranium, beryllium, and tantalum. These values represent only the mineralized vein-dikes and veins for which widths range from 0.1 to 3.0 ft and does not include wallrock dilution necessary in mining or the weakly mineralized coarse-grained pegmatites. It is further noted that ICP-MS analyses of the larger samples for metallurgical testing (50-52) are significantly higher than the chip sample results which were performed by neutron activation. This may suggest REE self-shielding during activation which results in incomplete detection.

About 1,500 ft north of pan sample location 11, near the northern map border of figure 4, mineralized vein float (sample 48, table 4) from an 0.67 ft wide vein was found in the fan of a small creek. Source of the mineralized rock was not located, however the occurrence suggests additional dike(s) may be found near the South Arm of Cholmondeley Sound. A few boulders of peralkaline granite were also found nearby.

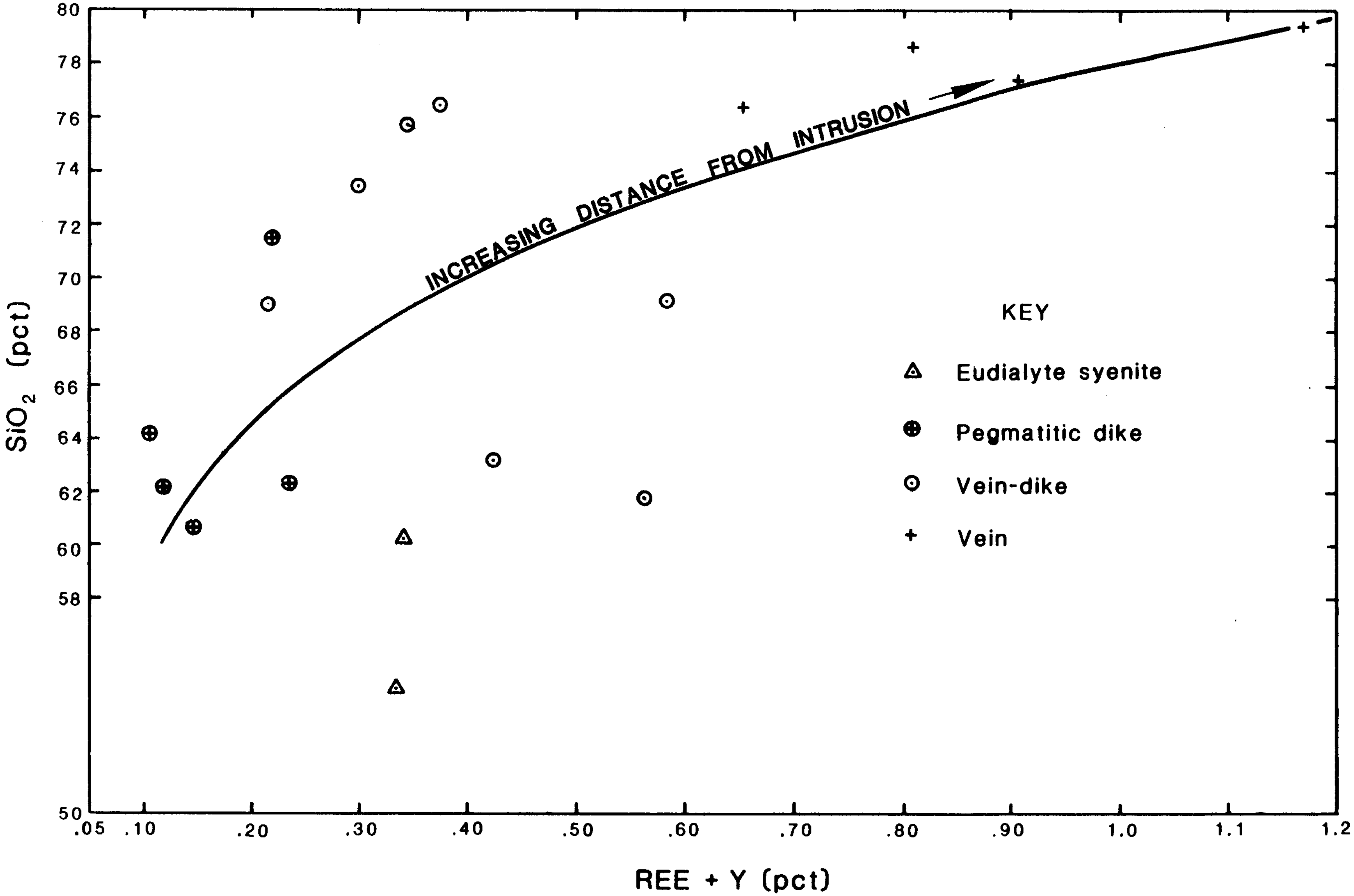


Figure 5. - Correlation of REE+Y to SiO_2 in mineralized pegmatite dikes.

RESOURCES

Classification of resource estimates in this report fall under the category of inferred subeconomic and hypothetical resources. The range of grade of the mineralized bodies is below that of producing REE deposits elsewhere in the world (3). Furthermore, metallurgical recovery of the valuable minerals at present has not been demonstrated. Inferred resource estimates are based on assumed continuity beyond the sampled locations for where there is geologic evidence. Hypothetical resources refer to the presumed existence of additional parallel mineralized vein-dikes and veins not exposed in either outcrop or rubble. Resource estimates are based on a tonnage factor of 10 cubic ft per st. Resource grade given below is tentative and based wholly on an arithmetic mean of available analyses from random sample sites (table 4).

Resource tonnage estimates are made on two areas of the dikes shown on figure 2. The first area (North Dora Lake) is represented by sample nos. 32-36, where a vein-dike having a thickness of at least 3 ft is inferred to extend eastward and outcrop at or near the 1,000 ft elevation. By calculating the intervening volume of the vein-dike, a total of 0.5 X 10^6 st is inferred. Sample values (no. 33-36, 50) average:

Cb	442 ppm
U	71 ppm
Y	1775 ppm
Zr	1.53%
REE	2816 ppm

Sample 47 suggests this zone may extend further to the north of the area for which resources are calculated. The second area (South Dora Lake) is predicated on sample nos. 1-16 and 51-52 and estimates include inferred and hypothetical tonnage along a projected strike of 4,000 ft and an assumed depth along dip of 2,000 ft. Field observations of rubble and outcrop indicate that there are a multiple of subparallel bodies present along the 4,000 ft of strike. Tonnage estimates assume an aggregated thickness of mineralized dikes ranging from a minimum of 1.5 ft to a maximum of 10 ft. By these criteria, a resource of between 1.2 X 10^6 and 8.0 X 10^6 st is estimated, of this, 2.4 X 10^6 st is considered inferred. Average sample values are:

Cb	340 ppm
U	27 ppm
Y	1969 ppm
Zr	1.08 pct
REE	3647 ppm

HEAVY MINERAL SURVEY

Panned heavy mineral concentrates were collected to evaluate the possible existence of additional mineralized bodies in the region near Dora Bay and South Arm Cholmondeley Sound (table 7).

Pan data, appendix B, shows a strong presence of sodium, which is indicative of the Na-rich amphiboles and pyroxenes derived from the Dora Bay intrusive complex. The data suggest the complex extends under surficial cover and bedrock to the west.

TABLE 7. - Volumes and weights of heavy mineral concentrates, and normalized yttrium in panned samples from the Dora Bay area

Map No.	Field No.	(-3/8 in) Sample Vol. ft^3	Concentrate Wt. g.	Analyses Yttrium ppm	Recovered Yttrium mg/pan 1/	Map No.	Field No.	(-3/8 in) Sample Vol. ft^3	Concentrate Wt. g.	Analyses Yttrium ppm	Recovered Yttrium mg/pan
1......	26547....	0.17	152.8	25	3.82	20.....	26523....	0.17	96.1	31	2.98
2......	26546....	0.17	56.6	26	1.47	21.....	26457....	0.17	46.6	47	2.19
3......	26544....	0.17	58.2	25	1.45	22.....	26456....	0.17	50.9	260	13.23
4......	26516....	0.25	114.3	33	2.56	23.....	26454....	0.17	24.2	240	5.81
5......	26515....	0.17	119.4	23	2.70	24.....	26543....	0.17	213.1	180	38.36
6......	26513....	0.17	102.8	32	3.29	25.....	26452....	0.17	71.9	230	16.54
7......	26477....	0.11	31.1	36	1.73	26.....	26419....	0.17	117.2	190	22.27
8......	26474....	0.11	39.8	32	1.96	27.....	25481....	0.17	94.2	54	5.09
9......	26473....	0.11	34.1	38	2.0	28.....	25486....	0.17	132.5	64	8.48
10.....	26471....	0.11	93.9	250	36.3	29.....	25460....	0.17	108.7	250	27.17
11.....	26472....	0.15	87.0	20	1.97	30.....	25462....	0.15	36.3	520	21.40
12.....	26464....	0.11	58.1	72	6.4	31.....	25461....	0.17	41.9	980	41.06
13.....	26459....	0.17	96.2	160	15.39	32.....	25424....	0.17	58.7	78	4.58
14.....	26466....	0.17	75.0	260	19.5	33.....	25422....	0.13	55.6	33	2.39
15.....	26503....	0.17	91.6	390	35.68	34.....	25469....	0.17	107.5	35	3.76
16.....	26501....	0.17	93.4	770	71.92	35.....	25512....	0.17	34.8	40	1.39
17.....	26467....	0.17	210.8	270	56.92	36.....	25511....	0.17	40.8	41	1.67
18.....	26526....	0.17	167.4	44	7.37	37.....	26328....	0.56	216.2	98	21.17
19.....	26524....	0.17	102.8	30	3.08						

1/Recovered Y in mg/pan is determined as $(.001)(\text{Analysis Y, ppm})\frac{(\text{conc. wt. in grams})}{(\text{no. of 14 in. pans of -3/8 in. sample})}$

Analytical results for other elements given to appendix B.

Visual examination of the rock sample data set found yttrium to be present in all mineralized samples. Therefore, yttrium was selected as a pathfinder element in the panned heavy mineral data. Analytical values in ppm Y are normalized with respect to the actual weight of recovered heavy mineral concentrate in grams from one 14 in diameter pan of fine gravel and sand. This procedure calculates the recovered elemental yttrium (in mg) in each pan at each sample site.

Data in table 7 indicates possible mineralized sources of yttrium, and therefore, REE and columbium occurrences, are located in the north-south trending valley immediately west of the mapped Dora Bay syenite/granite body shown on figure 2. Creek rubble at map location 17 (fig. 4) was noted to include aegirine syenite. The singular anomalous value at location 10 correlates with the reported anomalous yttrium and beryllium stream sediments by Herreid and others (5).

DISCUSSION AND CONCLUSIONS

The pegmatite dikes at Dora Bay, including vein-dikes and distal veins, contain concentrations of REE, yttrium, zirconium, and minor amounts of columbium. Significant values are concentrated in the vein-dikes and particularly in the more siliceous veins. Estimates of inferred and hypothetical tonnage range from 1.7 X 10^6 to 8.5 X 10^6 st for two deposits. Samples of the vein-dikes and veins commonly contain on the order of 4,000 ppm combined REE and yttrium, which is equivalent to approximately 0.5 pct REO (including yttrium). Actual REE and yttrium values may be higher than indicated due to self-shielding effects during neutron activation analyses as evidenced by assays of several bulk samples. Columbium values generally do not exceed several hundred ppm. Compared to the deposits located at nearby Bokan Mountain (1, 2), the Dora Bay dikes contain lower REE, yttrium, and zirconium values, although a higher percentage of the total REE value is contained in the heavy yttrium subgroup (fig. 6). Dora Bay occurrences contain markedly lower columbium than Bokan Mountain. In addition, unlike the Bokan Mountain deposits, there is little potential for by-product tantalum, tin, beryllium, gold, uranium, and other metals, although minor levels were detected in several Dora Bay samples, particularly the veins.

There is a pronounced zonation of the lithophile metal values in vein-dikes and veins distal to the Dora Bay alkaline complex. REE+Y values are shown to correlate positively to the degree of hydrothermal alteration as demonstrated by the increasing content of silica. This therefore suggests the incompatable lithophile elements were partioned in very late stage magmatic fluids that excaped the intrusive complex into pre-existing north-south fracture zones.

This zonation also suggests that higher grade REE and yttrium deposits, perhaps with base metals and precious metal credits, may exist along parallel striking structures or beyond the area investigated. Future exploration should initially be concentrated at a distance of several hundred- to several thousand-feet from the intrusion. The regional favorability for additional deposits is further reinforced by the anomalous yttrium heavy mineral values found in creek beds with syenite gravel 1 mi west of Dora Lakes, and the discovery of mineralized vein-dike float on the South Arm of Cholmondeley Sound.

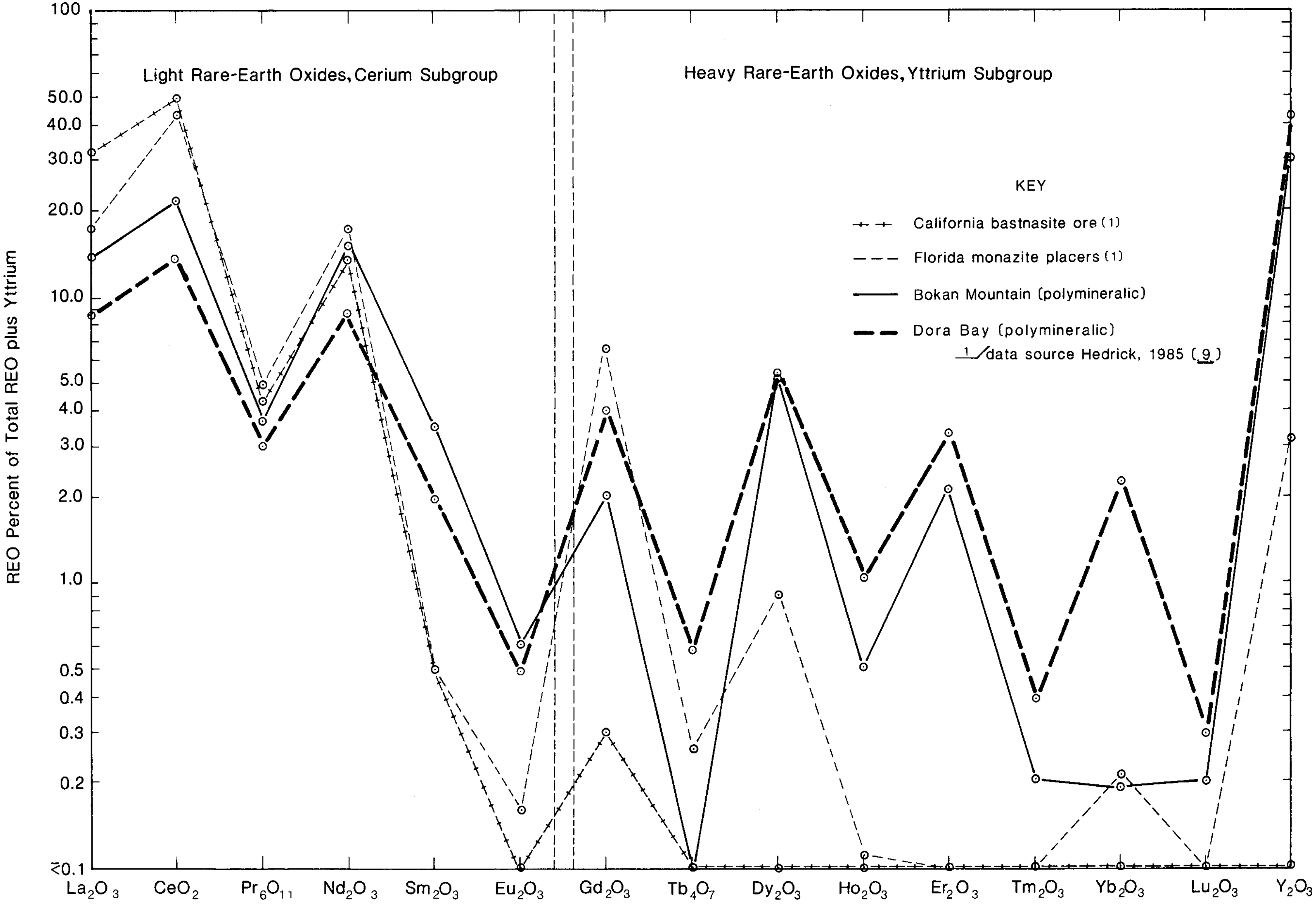


Figure 6. - Comparision of REE composition of Dora Bay pegmatite dikes to mineral deposits at Bokan Mountain and other major U.S. REE sources.

Based on the above conclusions, it should be noted that mineralized dikes evolved from the Dora Bay complex show a preferred alignment to the trace of a regional north-south fault as previously mapped (6). Subsequent erosion has reduced the area of the fault zone to the point that much of the area suspect for containing mineralized bodies now lies under glacial till, fresh water lakes, and seawater.

Also on the South Arm, and approximately four miles to the northwest of the head of Dora Bay, Herreid and others have described the Friendship Lode copper deposit occurring in chloritized and silicified Wales Group schist (5). The area is the loci of numerous alkaline basaltic dikes. Their samples from the veins showed anomalous levels of bismuth and yttrium (up to 300 ppm Y), and yttrium and beryllium were also anomalous in stream sediment samples from the immediate area to either side of the South Arm. It was suggested, therefore, that a buried intrusion with similarities to Bokan Mountain may exist at depth in the area (5). By analogy, the REE+Y zonation pattern at Dora Bay indicates future exploration of the Friendship Lode should examine the possibility of REE deposits lateral to or at depth, particularly along zones of structural weakness.

Interpretation of aerial magnetic data (7) suggests several other syenitic to dioritic bodies may occur near Dora Bay along a poorly defined regional trend that includes most REE occurrences on southern Prince of Wales Island. The likelihood of similar zoned REE+Y-bearing dikes occurring above and lateral to those buried complexes, and particularly along structural linears radiating from them, should be evaluated.

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APPENDIX A

Rock sample multi-elements analyses

ROCK SAMPLES

Element	Units	1	2	3	4	5	6
SiO_2	%	77.5	79.5	78.7	60.9	76.6	73.5
Al_2O_3	%	5.32	5.03	8.30	12.3	6.81	7.05
CaO	%	3.11	0.63	1.69	3.70	2.80	1.40
MgO	%	0.69	0.70	0.76	1.83	0.45	0.43
Na_2O	%	2.04	2.73	3.57	5.05	2.91	3.26
K_2O	%	1.62	0.82	1.74	1.82	1.58	1.27
Fe_2O_3	%	2.49	1.94	1.78	8.11	3.79	6.10
MnO	%	2.88	2.07	0.21	0.48	0.28	0.18
TiO_2	%	0.25	0.30	0.24	0.92	0.37	0.34
P_2O_5	%	0.08	0.05	0.10	0.37	0.19	0.10
LOI	%	1.77	1.46	1.16	3.69	2.46	2.15
SUM	%	99.10	96.70	99.30	100.0	100.0	99.50
Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	ppm	<2	18	4	16	23	22
Au	ppb	<10	<20	19	<15	<20	17
B	ppm	80	100	80	60	60	30
Ba	ppm	540	2200	370	240	270	150
Be	ppm	42	94	51	26	39	21
Br	ppm	<2	<4	2	<1	<1	2
Cd	ppm	2.0	2.0	1.0	<1.0	<1.0	2.0
Co	ppm	4	8	<3	15	4	3
Cr	ppm	10	20	10	10	30	10
Cs	ppm	<0.9	1.7	<2.0	1.9	<1.4	<1.4
Cu	ppm	6.0	26	4.0	8.0	13	6.0
Ge	ppm	<10	<10	<10	20	<10	<10
Hf	ppm	65	46	23	46	140	420
Mn	ppm	20000	15000	1400	3200	1700	750
Mo	ppm	<5	<5	<5	<5	<5	<5
Nb	ppm	620	1300	400	410	390	190
Ni	ppm	20	18	10	10	12	6
Pb	ppm	48	72	14	54	24	52
Rb	ppm	80	90	130	220	110	70
Sb	ppm	3.4	2.3	0.7	2.7	1.6	0.8
Sc	ppm	3.9	3.4	3.3	16.9	6.1	0.8
Se	ppm	27	43	<5	36	<5	<5
Sr	ppm	190	40	260	70	20	<10
Ta	ppm	40	33	17	28	29	12
Th	ppm	230	97	110	250	300	54
U	ppm	22.4	76.6	17.7	46.9	42.0	19.6
V	ppm	26	44	22	160	64	22
W	ppm	<3	<3	<3	<4	<4	<3
Y	ppm	3600	3300	4600	2200	2700	1600
Zn	ppm	1700	2200	190	1200	360	170
Zr	ppm	4900	4600	2300	3400	9900	25000
La	ppm	581	1510	374	479	712	179
Ce	ppm	1440	3090	958	1000	1380	537
Nd	ppm	929	1330	378	408	590	200
Sm	ppm	284	315	129	108	151	58.0
Eu	ppm	71.1	72.0	30.8	25.7	34.8	13.3
Tb	ppm	76.6	60.2	50.8	39.5	43.7	20.3
Yb	ppm	155	125	167	130	168	188
Lu	ppm	16.6	14.5	17.2	13.3	20.7	28.3

ROCK SAMPLES

Element	Units	7	8	9	10	11	12
SiO_2	%	68.5	39.6	79.0	69.1	76.5	75.7
Al_2O_3	%	6.89	14.0	6.48	6.71	7.21	7.78
CaO	%	2.16	13.1	1.36	2.40	0.87	0.38
MgO	%	0.21	2.29	0.39	0.38	0.21	0.48
Na_2O	%	2.84	2.82	2.97	4.84	3.38	4.53
K_2O	%	3.20	2.39	3.34	1.93	1.43	2.82
Fe_2O_3	%	8.00	8.98	4.49	9.87	5.80	4.91
MnO	%	0.23	0.16	0.28	0.31	0.12	0.21
TiO_2	%	0.32	1.31	0.18	0.14	0.16	0.19
P_2O_5	%	0.26	0.31	0.21	0.54	0.19	0.15
LOI	%	2.31	14.9	0.62	0.92	1.16	0.61
SUM	%	99.20	100.0	100.2	100.0	100.2	99.70
Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	ppm	8	130	2	8	4	2
Au	ppb	31	<6	18	<20	<10	<10
B	ppm	40	60	40	20	40	30
Ba	ppm	350	220	410	170	180	580
Be	ppm	19	4	19	18	16	17
Br	ppm	3	3	<1	<2	<1	2
Cd	ppm	3.0	<1.0	2.0	2.0	1.0	<1.0
Co	ppm	4	46	4	<4	4	2
Cr	ppm	10	160	10	20	20	10
Cs	ppm	<1.5	1.4	1.9	<2.0	1.5	1.0
Cu	ppm	6.5	56	15	2.5	3.5	3.5
Ge	ppm	20	<10	<10	10	<10	10
Hf	ppm	610	10	75	330	340	190
Mn	ppm	1100	1100	2000	1700	280	1200
Mo	ppm	<5	<5	<5	<5	<5	<5
Nb	ppm	130	20	140	270	120	150
Ni	ppm	9	81	8	13	9	4
Pb	ppm	86	<2	12	150	120	24
Rb	ppm	210	50	220	90	100	230
Sb	ppm	0.6	3.4	0.2	0.4	1.0	0.5
Sc	ppm	3.4	36.6	2.8	0.9	0.9	2.7
Se	ppm	<5	<5	<5	<5	20	25
Sr	ppm	<10	180	<10	150	<10	10
Ta	ppm	8	<1	9	25	9	13
Th	ppm	39	2.0	240	320	100	110
U	ppm	24.5	1.0	16.4	36.4	20.4	23.2
V	ppm	40	270	28	18	20	16
W	ppm	8	4	4	<3	3	<3
Y	ppm	1400	40	1000	2100	2200	1900
Zn	ppm	380	87	620	330	110	320
Zr	ppm	30000	390	4600	18000	21000	12000
La	ppm	186	9.3	193	552	163	191
Ce	ppm	578	28	519	1290	539	583
Nd	ppm	224	12	245	644	185	224
Sm	ppm	44.4	3.2	58.8	141	51.0	59.1
Eu	ppm	9.7	1.8	13.8	35.8	12.7	14.0
Tb	ppm	15.7	<0.5	15.6	40.8	24.6	20.0
Yb	ppm	223	5.1	82.6	249	226	180
Lu	ppm	34.3	0.72	11.3	36.2	33.0	24.1

ROCK SAMPLES

Element	Units	13	14	15	16	17	18
SiO_2	%	76.0	69.0	76.1	69.0	65.0	62.2
Al_2O_3	%	7.73	8.76	7.23	8.94	15.2	13.7
CaO	%	0.74	1.24	0.51	2.81	1.11	0.57
MgO	%	1.28	1.68	0.33	1.23	1.61	0.13
Na_2O	%	4.76	3.51	5.12	5.28	5.40	8.35
K_2O	%	1.57	2.93	2.39	2.51	4.22	3.45
Fe_2O_3	%	5.20	7.00	4.25	7.56	5.39	8.10
MnO	%	0.26	0.25	0.52	0.34	0.22	0.25
TiO_2	%	0.29	0.57	0.16	0.43	0.45	0.34
P_2O_5	%	0.14	0.16	0.11	0.13	0.09	0.04
LOI	%	1.00	2.00	1.08	0.93	1.31	0.92
SUM	%	100.1	99.50	99.40	100.3	100.5	99.90
Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	ppm	2	9	3	10	31	2
Au	ppb	<10	640	<14	13	<7	<9
B	ppm	40	30	30	30	40	20
Ba	ppm	660	260	440	480	730	170
Be	ppm	14	46	18	17	12	9
Br	ppm	1	1	<1	2	2	<1
Cd	ppm	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Co	ppm	4	6	3	4	5	3
Cr	ppm	10	20	10	<10	10	<10
Cs	ppm	<1.7	1.9	2.2	1.4	2.0	<1.4
Cu	ppm	7.0	3.5	3.0	11	12	1.5
Ge	ppm	<10	<10	20	<10	30	20
Hf	ppm	94	300	150	110	39	240
Mn	ppm	1600	1400	3600	2100	1300	1500
Mo	ppm	<5	<5	<5	<5	<5	<5
Nb	ppm	310	130	570	310	110	80
Ni	ppm	4	8	9	7	11	2
Pb	ppm	20	32	44	30	24	78
Rb	ppm	100	320	170	130	130	270
Sb	ppm	0.3	1.0	0.4	1.0	0.3	0.3
Sc	ppm	4.5	8.0	1.4	7.1	14.2	1.7
Se	ppm	24	<5	23	35	<5	<5
Sr	ppm	<10	<10	10	20	20	30
Ta	ppm	12	11	36	21	5	6
Th	ppm	36	86	160	110	19	22
U	ppm	17.6	30.8	30.2	14.5	15.8	23.5
V	ppm	24	58	12	38	68	6
W	ppm	<3	5	7	5	<3	<3
Y	ppm	1200	1200	1200	1300	260	590
Zn	ppm	330	370	450	250	190	350
Zr	ppm	6000	16000	9400	6100	2400	13000
La	ppm	208	105	537	48.2	51.3	92.9
Ce	ppm	591	395	1470	370	143	217
Nd	ppm	260	97	518	53	47	71
Sm	ppm	71.8	32.8	105	23.8	15.1	25.3
Eu	ppm	17.9	8.5	23.6	8.2	3.8	6.7
Tb	ppm	19.8	15.0	25.7	17.9	4.7	9.4
Yb	ppm	89.8	137	113	125	21.2	55.3
Lu	ppm	11.7	19.3	14.9	16.1	2.80	7.07

ROCK SAMPLES

Element	Units	19	20	21	22	23	24
SiO_2	%	70.3	64.3	64.2	62.3	63.6	62.6
Al_2O_3	%	13.1	13.5	13.9	15.0	13.0	13.5
CaO	%	0.23	0.68	1.20	0.69	2.51	1.07
MgO	%	1.06	1.19	1.44	0.21	1.34	0.38
Na_2O	%	4.61	9.63	8.50	7.53	4.66	8.79
K_2O	%	3.88	1.98	2.73	3.67	6.10	2.82
Fe_2O_3	%	4.00	6.23	6.06	6.66	6.06	7.47
MnO	%	0.10	0.34	0.23	0.33	0.25	0.26
TiO_2	%	0.35	1.32	0.63	0.37	0.59	0.45
P_2O_5	%	0.07	0.32	0.17	0.09	0.13	0.05
LOI	%	1.08	0.54	0.85	1.54	0.69	1.46
SUM	%	99.00	100.2	100.1	100.2	99.10	100.3
Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	ppm	7	57	16	10	20	<2
Au	ppb	<6	<9	14	<11	40	<10
B	ppm	40	30	30	30	30	20
Ba	ppm	900	240	410	300	630	290
Be	ppm	7	39	15	22	10	15
Br	ppm	2	<1	1	<1	1	<1
Cd	ppm	<1.0	<1.0	<1.0	1.0	<1.0	<1.0
Co	ppm	3	4	5	4	4	2
Cr	ppm	<10	10	<10	<10	<10	10
Cs	ppm	1.1	<1.6	1.8	2.3	2.3	<1.2
Cu	ppm	4.5	2.0	3.0	2.0	6.5	1.5
Ge	ppm	<10	<10	<10	<10	20	<10
Hf	ppm	18	12	11	190	8	140
Mn	ppm	650	2200	1700	2100	1900	1700
Mo	ppm	6	<5	10	<5	<5	<5
Nb	ppm	30	10	40	210	10	420
Ni	ppm	2	2	3	6	5	7
Pb	ppm	12	24	24	120	16	240
Rb	ppm	110	110	140	230	210	190
Sb	ppm	0.2	0.2	0.3	0.5	0.2	0.4
Sc	ppm	8.1	12.8	13.7	2.7	13.6	5.3
Se	ppm	<5	<5	<5	<10	<5	<5
Sr	ppm	20	50	10	80	10	50
Ta	ppm	<1	<2	<1	10	<1	23
Th	ppm	12	340	22	58	6.2	56
U	ppm	3.8	8.8	4.9	38.2	1.1	43.1
V	ppm	12	30	34	14	28	18
W	ppm	<3	<3	<3	<3	<3	<3
Y	ppm	200	70	220	870	50	1200
Zn	ppm	150	570	230	730	110	830
Zr	ppm	790	650	590	12000	330	8800
La	ppm	53.9	196	40.3	283	23.7	401
Ce	ppm	123	266	100	545	49	1140
Nd	ppm	45	69	45	243	22	478
Sm	ppm	11.8	11.1	10.0	55.4	5.9	125
Eu	ppm	3.4	2.3	2.2	11.2	1.7	26.2
Tb	ppm	2.9	<0.9	2.7	12.6	0.7	25.4
Yb	ppm	13.9	4.3	10.1	64.6	5.6	117
Lu	ppm	1.98	0.95	1.45	8.28	0.89	13.1

ROCK SAMPLES

Element	Units	25	26	27	28	29	30
SiO_2	%	64.1	65.1	61.7	62.1	58.7	60.2
Al_2O_3	%	14.2	13.3	12.9	12.9	15.6	15.0
CaO	%	0.29	1.61	0.27	0.23	1.47	1.32
MgO	%	0.03	1.19	0.03	0.07	0.03	0.08
Na_2O	%	9.66	6.78	7.33	8.39	8.16	8.15
K_2O	%	0.76	4.72	4.27	3.79	3.64	3.85
Fe_2O_3	%	7.23	5.10	8.29	8.73	8.14	7.03
MnO	%	0.15	0.21	0.17	0.15	0.28	0.26
TiO_2	%	0.22	0.62	0.37	0.29	0.20	0.23
P_2O_5	%	0.03	0.19	0.07	0.03	0.03	0.06
LOI	%	1.23	0.85	0.61	0.92	1.54	1.38
SUM	%	100.4	100.1	99.50	99.80	99.10	99.40
Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	ppm	6	2	12	4	<3	7
Au	ppb	<10	12	13	14	<10	<13
B	ppm	20	30	20	30	20	50
Ba	ppm	170	520	240	250	640	420
Be	ppm	7	19	14	20	5	24
Br	ppm	1	<1	1	3	3	<4
Cd	ppm	<1.0	<1.0	<1.0	<1.0	1.0	2.0
Co	ppm	<2	3	5	1	1	1
Cr	ppm	10	<10	10	10	<10	10
Cs	ppm	<1.5	2.8	<1.9	1.2	<1.0	2.3
Cu	ppm	0.5	4.5	1.0	1.0	1.5	1.5
Ge	ppm	10	<10	10	<10	<10	<10
Hf	ppm	280	33	410	280	170	250
Mn	ppm	590	1300	640	680	1800	1500
Mo	ppm	<5	<5	51	<5	<5	<5
Nb	ppm	170	70	250	160	230	270
Ni	ppm	3	5	3	2	4	7
Pb	ppm	36	68	180	80	10	20
Rb	ppm	60	240	310	270	80	110
Sb	ppm	0.3	0.4	0.9	0.8	<0.2	0.3
Sc	ppm	1.2	12.0	0.8	0.8	0.4	0.7
Se	ppm	<5	<5	<5	<5	<5	<5
Sr	ppm	10	20	<10	<10	150	120
Ta	ppm	4	2	14	11	17	19
Th	ppm	11	60	74	45	4.9	30
U	ppm	17.3	23.0	47.6	34.8	2.4	16.6
V	ppm	10	28	12	10	10	10
W	ppm	<3	<3	<3	9	<4	8
Y	ppm	560	400	1200	650	1100	1400
Zn	ppm	310	320	450	350	200	240
Zr	ppm	18000	2100	24000	15000	7800	11000
La	ppm	77.9	210	180	151	147	240
Ce	ppm	198	397	458	362	539	650
Nd	ppm	58	148	126	124	220	308
Sm	ppm	19.5	26.4	45.3	34.4	62.9	86.0
Eu	ppm	3.6	5.8	9.8	7.2	14.5	18.2
Tb	ppm	6.3	5.2	20.4	9.0	21.9	26.5
Yb	ppm	53.1	17.9	134	87.2	97.7	120
Lu	ppm	7.36	2.34	17.1	11.0	12.1	15.2

ROCK SAMPLES

Element	Units	31	32	33	34	35	36
SiO_2	%	68.8	64.1	63.3	63.2	61.8	62.9
Al_2O_3	%	9.55	13.9	12.7	13.8	14.1	10.7
CaO	%	1.86	1.86	1.04	0.61	1.51	0.96
MgO	%	1.51	1.82	0.57	0.21	0.23	0.16
Na_2O	%	3.86	5.01	7.20	6.77	7.94	5.64
K_2O	%	4.07	4.62	2.08	2.80	2.89	1.52
Fe_2O_3	%	6.67	5.89	6.12	7.36	5.97	10.5
MnO	%	0.29	0.21	0.42	0.41	0.47	0.30
TiO_2	%	0.27	0.64	0.50	0.35	0.65	0.54
P_2O_5	%	0.10	0.18	0.15	0.10	0.10	0.42
LOI	%	1.38	2.08	2.15	2.46	2.16	3.38
SUM	%	100.0	100.5	99.20	99.50	100.3	99.90
Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	ppm	5	10	6	<2	2	16
Au	ppb	<10	10	<14	<13	<8	<10
B	ppm	30	50	30	20	30	10
Ba	ppm	800	1300	300	260	670	190
Be	ppm	16	30	55	37	23	14
Br	ppm	1	3	1	2	<1	1
Cd	ppm	3.0	<1.0	1.0	<1.0	3.0	2.0
Co	ppm	12	12	7	3	2	3
Cr	ppm	20	<10	10	10	10	10
Cs	ppm	3.0	10.5	1.6	<1.1	<1.0	<1.0
Cu	ppm	5.0	64	3.5	7.5	5.5	3.0
Ge	ppm	<10	<10	<10	<10	20	<10
Hf	ppm	180	5	340	130	53	350
Mn	ppm	2000	1500	2900	2600	2800	1700
Mo	ppm	<5	<5	<5	<5	<5	<5
Nb	ppm	260	10	380	320	490	580
Ni	ppm	15	8	13	8	12	8
Pb	ppm	210	30	100	130	460	240
Rb	ppm	290	260	130	180	180	100
Sb	ppm	0.3	0.3	2.1	2.3	0.9	4.4
Sc	ppm	9.6	18.9	4.2	2.3	1.1	1.8
Se	ppm	39	<5	<5	12	<5	<5
Sr	ppm	50	70	<10	<10	120	20
Ta	ppm	15	<1	14	11	3	34
Th	ppm	45	28	240	110	23	51
U	ppm	13.2	3.6	96.0	49.2	21.2	117
V	ppm	72	100	34	24	24	18
W	ppm	<3	<3	5	<4	<3	<3
Y	ppm	1200	80	1600	1500	3300	700
Zn	ppm	560	230	940	820	1600	350
Zr	ppm	9900	240	19000	8100	14000	20000
La	ppm	168	54.8	517	512	227	413
Ce	ppm	507	115	1230	1180	452	806
Nd	ppm	208	30	406	390	239	330
Sm	ppm	59.0	5.7	89.0	101	58.0	52.1
Eu	ppm	14.4	1.8	17.0	20.7	13.2	9.4
Tb	ppm	17.7	0.9	23.7	24.8	14.8	8.1
Yb	ppm	125	4.0	83.7	91.7	39.6	60.4
Lu	ppm	18.2	0.64	10.1	10.5	4.70	8.91

ROCK SAMPLES

Element	Units	37	38	39	40	41	42
SiO_2	%	54.7	59.1	54.8	59.0	59.5	60.8
Al_2O_3	%	19.2	15.6	20.8	15.3	15.4	13.8
CaO	%	0.47	2.42	0.82	1.39	1.65	0.54
MgO	%	<0.01	0.20	0.33	0.07	0.08	0.03
Na_2O	%	9.42	8.34	9.69	11.5	12.10	8.44
K_2O	%	5.14	2.87	2.56	1.75	1.01	3.48
Fe_2O_3	%	3.69	9.58	1.89	6.52	7.49	10.5
MnO	%	0.31	0.28	0.27	0.52	0.47	0.24
TiO_2	%	0.23	0.53	0.11	0.26	0.25	0.34
P_2O_5	%	0.17	0.13	0.13	0.05	0.17	0.03
LOI	%	5.31	0.62	8.54	2.00	1.00	0.85
SUM	%	99.20	100.0	100.4	100.3	99.12	99.90
Ag	ppm	<0.5	<0.5	<0.5	<0.5	11.6	<0.5
As	ppm	13	6	<2	57	83	5
Au	ppb	<20	<8	<6	<20	12	<9
B	ppm	110	20	40	30	71	20
Ba	ppm	410	800	470	310	<100	240
Be	ppm	280	8	220	120	-	11
Br	ppm	<2	1	4	<2	<5	2
Cd	ppm	<1.0	<1.0	<1.0	<1.0	11	<1.0
Co	ppm	<2	5	<2	<2	<10	2
Cr	ppm	20	<10	10	10	130	<10
Cs	ppm	20.2	1.8	34.6	3.5	<1	<1.3
Cu	ppm	2.5	3.5	1.5	1.5	9	1.0
Ge	ppm	20	<10	20	20	-	<10
Hf	ppm	47	24	29	210	253	120
Mn	ppm	1800	1900	1700	3300	-	1400
Mo	ppm	<5	<5	<5	<5	<4	<5
Nb	ppm	<10	50	<10	300	*	200
Ni	ppm	6	2	4	10	<1	3
Pb	ppm	98	6	44	110	405	10
Rb	ppm	300	70	110	70	32	120
Sb	ppm	4.5	<0.2	2.1	1.1	1.8	0.3
Sc	ppm	0.2	3.0	0.1	0.6	<0.5	0.4
Se	ppm	<5	<5	<5	<5	<10	<5
Sr	ppm	10	80	100	20	200*	<10
Ta	ppm	3	4	2	11	13	10
Th	ppm	1400	11	610	140	28	13
U	ppm	181	2.9	88.6	37.4	29	7.4
V	ppm	6	8	4	8	-	8
W	ppm	<4	<3	<4	<4	<2	<3
Y	ppm	720	170	400	1600	1500*	550
Zn	ppm	1400	230	1600	840	755	360
Zr	ppm	3200	1300	2100	12000	14000	5400
La	ppm	757	64.1	713	496	470	140
Ce	ppm	1110	139	956	980	980	315
Nd	ppm	346	94	274	440	-	152
Sm	ppm	57.6	18.6	36.6	106	145	32.0
Eu	ppm	8.8	5.0	5.8	23.2	12	7.5
Tb	ppm	9.6	4.3	4.1	28.1	37	9.6
Yb	ppm	35.5	16.8	18.2	105	110	62.5
Lu	ppm	6.28	2.48	3.18	12.1	13	8.41

(-)Not analyzed
* Elemental interference noted

ROCK SAMPLES

Element	Units	43	44	45	46	47	48
SiO_2	%	61.1	71.6	62.8	71.1	69.9	75.4
Al_2O_3	%	16.2	7.30	15.7	8.96	3.90	6.99
CaO	%	0.77	0.23	0.42	0.31	0.58	0.77
MgO	%	0.08	0.03	0.02	<0.01	0.72	0.89
Na_2O	%	7.63	5.72	8.60	5.27	3.91	2.60
K_2O	%	4.47	2.39	3.56	3.21	2.11	3.05
Fe_2O_3	%	7.62	7.62	6.24	9.69	8.05	3.69
MnO	%	0.16	0.17	0.20	0.24	0.36	1.14
TiO_2	%	0.32	0.40	0.28	0.52	0.32	0.30
P_2O_5	%	0.05	0.04	0.03	0.03	0.10	0.12
LOI	%	1.23	0.92	1.23	0.23	0.81	2.62
SUM	%	100.2	100.4	99.90	99.80	101.2	98.90
Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	ppm	7	4	5	2	7	35
Au	ppb	<7	<8	7	<6	<5	<5
B	ppm	40	20	30	10	30	30
Ba	ppm	640	120	180	170	150	370
Be	ppm	8	13	10	9	10	66
Br	ppm	4	<1	2	1	2	4
Cd	ppm	<1.0	<1.0	2.0	<1.0	<1	<1
Co	ppm	3	2	4	2	5	4
Cr	ppm	<10	10	<10	<10	60	30
Cs	ppm	1.8	1.9	<1.5	<1.2	<0.9	<0.5
Cu	ppm	1.5	1.0	9.5	1.0	6.0	5.0
Ge	ppm	<10	<10	<10	<10	30	<10
Hf	ppm	67	400	100	30	1200	110
Mn	ppm	1000	650	1200	1700	1100	7300
Mo	ppm	<5	<5	<5	<5	<5	<5
Nb	ppm	120	290	250	90	130	1200
Ni	ppm	4	2	3	5	17	9
Pb	ppm	18	58	14	<2	54	88
Rb	ppm	130	110	80	80	100	150
Sb	ppm	0.2	1.2	0.3	0.8	24	17
Sc	ppm	1.1	0.2	0.5	0.2	1.6	1.6
Se	ppm	<5	60	<5	<5	<3	<3
Sr	ppm	20	<10	<10	<10	<10	70
Ta	ppm	6	11	17	4	8	24
Th	ppm	12	32	23	15	260	180
U	ppm	5.1	50.7	20.7	5.8	158	240
V	ppm	10	10	10	10	26	20
W	ppm	<3	14	<3	<3	<3	<3
Y	ppm	370	1400	350	270	1400	2400
Zn	ppm	270	320	450	230	120	4600
Zr	ppm	2900	27000	5200	1300	75000	5500
La	ppm	73.5	10.1	25.0	68.0	30.8	552
Ce	ppm	282	271	93	156	228	1120
Nd	ppm	72	20	22	70	76	507
Sm	ppm	19.6	9.2	6.2	16.0	17.7	131
Eu	ppm	4.6	2.5	1.3	3.6	6.3	29.3
Tb	ppm	5.9	11.4	4.4	6.0	15.7	35.8
Yb	ppm	39.9	230	42.8	23.5	198	121
Lu	ppm	5.22	30.1	6.21	3.71	32.6	17.2

APPENDIX B

Heavy mineral concentrates multi-element analyses

HEAVY MINERAL CONCENTRATES

Element	Units	1	2	3	4	5	6
Ag	ppm	<5	<5	<5	<5	<5	<5
As	ppm	5	10	24	9	13	6
Au	ppb	30	20	20	<10	10	10
Ba	ppm	400	200	700	200	500	300
Br	ppm	15	11	3	4	8	7
Co	ppm	32	37	34	33	27	28
Cr	ppm	180	240	210	210	170	140
Cs	ppm	0.8	1.0	1.6	<0.5	1.4	1.0
Fe	pct	8.71	7.47	8.53	8.35	5.89	6.81
Hf	ppm	4	4	3	4	3	3
Mo	ppm	<5	<5	5	6	6	5
Na	ppm	21000	17000	20000	21000	24000	27000
Ni	ppm	<200	<200	<200	<200	<200	<200
Rb	ppm	30	20	<20	20	40	30
Sb	ppm	2.7	0.7	0.9	0.4	0.5	0.4
Sc	ppm	25.9	25.7	25.8	26.5	23.7	24.1
Se	ppm	<3	<3	<3	<3	<3	<3
Sr	ppm	<500	<500	<500	<500	<500	<500
Ta	ppm	1	1	<1	1	<1	<1
Th	ppm	2.2	2.3	2.3	2.9	2.1	1.2
U	ppm	2.7	1.5	1.5	1.0	1.4	<0.5
W	ppm	<3	<3	<3	<3	<3	<3
Y	ppm	25	26	25	33	23	32
Zn	ppm	90	150	70	100	130	120
La	ppm	15.1	14.6	12.7	18.2	12.5	8.9
Ce	ppm	32	36	28	42	30	25
Nd	ppm	17	14	15	17	14	13
Sm	ppm	3.3	3.1	3.3	4.3	3.0	2.7
Eu	ppm	1.5	1.2	1.3	1.8	0.9	1.1
Yb	ppm	1.9	2.1	2.2	2.4	2.5	2.5
Lu	ppm	0.28	0.35	0.35	0.39	0.39	0.36

HEAVY MINERAL CONCENTRATES

Element	Units	7	8	9	10	11	12
Ag	ppm	<5	<5	<5	<5	<5	<5
As	ppm	32	45	34	9	5	10
Au	ppb	10	10	100	10	10	<10
Ba	ppm	600	1500	1100	300	<150	400
Br	ppm	7	4	8	4	4	3
Co	ppm	37	33	31	30	49	21
Cr	ppm	230	280	290	120	98	240
Cs	ppm	0.9	0.8	0.7	<1.0	1.9	1.1
Fe	pct	9.73	10.1	7.85	30.4	30.4	10.2
Hf	ppm	3	3	4	41	2	11
Mo	ppm	7	14	10	5	<5	12
Na	ppm	20000	13000	16000	26000	28000	16000
Ni	ppm	<200	<200	<200	<200	<200	<200
Rb	ppm	30	20	30	<20	<20	30
Sb	ppm	0.9	2.1	0.9	0.4	0.3	0.9
Sc	ppm	21.5	20.1	24.1	12.5	20.9	35.0
Se	ppm	<3	<3	<3	<3	<3	<3
Sr	ppm	<500	<500	<500	<500	<500	<500
Ta	ppm	<1	<1	<1	2	<1	1
Th	ppm	3.7	2.3	3.3	10	1.3	3.4
U	ppm	1.9	3.2	2.9	6.7	0.9	3.3
W	ppm	<3	<3	<3	<3	<3	3
Y	ppm	36	32	38	250	20	72
Zn	ppm	90	180	130	110	60	160
La	ppm	32.0	13.6	19.6	28.3	7.7	21.8
Ce	ppm	57	32	42	81	20	57
Nd	ppm	24	17	17	30	8	30
Sm	ppm	4.6	3.0	3.9	8.3	2.3	7.3
Eu	ppm	2.0	0.9	1.2	2.8	1.0	2.5
Yb	ppm	2.4	2.3	2.8	18.6	2.0	7.9
Lu	ppm	0.38	0.39	0.48	2.79	0.31	1.20

HEAVY MINERAL CONCENTRATES

Element	Units	13	14	15	16	17	18
Ag	ppm	<5	<5	<5	<5	<5	<5
As	ppm	6	19	8	12	5	19
Au	ppb	10	<10	20	20	40	<10
Ba	ppm	900	700	400	500	700	600
Br	ppm	2	3	2	1	2	9
Co	ppm	3	9	4	5	3	33
Cr	ppm	100	170	120	150	75	170
Cs	ppm	0.9	1.2	1.7	0.9	<0.9	1.0
Fe	pct	10.2	8.16	10.3	16.1	8.79	7.22
Hf	ppm	30	55	69	130	54	3
Mo	ppm	<5	<5	<5	<5	<5	<5
Na	ppm	48000	45000	44000	39000	54000	18000
Ni	ppm	<200	<200	<200	<200	<200	<200
Rb	ppm	30	70	30	30	30	20
Sb	ppm	1.3	0.8	0.4	1.0	0.6	0.7
Sc	ppm	6.3	8.4	8.1	11.4	4.4	34.5
Se	ppm	<3	<3	<3	<3	<3	<3
Sr	ppm	<500	<500	<500	<500	<500	<500
Ta	ppm	2	4	3	6	2	<1
Th	ppm	5.0	16	19	33	14	2.3
U	ppm	3.0	10.5	8.7	19.6	6.9	2.5
W	ppm	<3	<3	<3	<3	<3	<3
Y	ppm	160	260	390	770	270	44
Zn	ppm	160	170	170	290	150	190
La	ppm	46.7	43.4	63.5	70.1	46.6	16.0
Ce	ppm	122	128	148	205	132	35
Nd	ppm	66	56	83	104	66	17
Sm	ppm	15.0	11.9	18.0	25.3	15.0	4.3
Eu	ppm	4.4	4.0	5.0	6.5	4.2	1.8
Yb	ppm	18.6	24.3	32.9	64.6	26.5	3.3
Lu	ppm	3.15	3.55	5.30	9.77	4.38	0.49

HEAVY MINERAL CONCENTRATES

Element	Units	19	20	21	22	23	24
Ag	ppm	<5	<5	<5	<5	<5	<5
As	ppm	24	16	15	10	5	9
Au	ppb	10	30	10	<10	10	<10
Ba	ppm	400	400	400	500	800	900
Br	ppm	12	5	7	7	3	2
Co	ppm	25	31	25	8	5	4
Cr	ppm	140	210	240	170	200	87
Cs	ppm	1.1	1.7	1.4	1.6	1.0	0.8
Fe	pct	6.45	7.15	7.05	6.93	10.5	6.77
Hf	ppm	2	3	5	41	47	36
Mo	ppm	<5	5	<5	<5	5	<5
Na	ppm	21000	29000	28000	47000	50000	56000
Ni	ppm	<200	<200	<200	<200	<200	<200
Rb	ppm	30	20	40	60	50	50
Sb	ppm	0.4	0.2	0.4	0.3	0.3	0.4
Sc	ppm	28.6	28.0	33.4	9.7	5.8	4.3
Se	ppm	<3	<3	<3	<3	<3	<3
Sr	ppm	<500	<500	<500	<500	<500	<500
Ta	ppm	<1	<1	<1	3	2	<1
Th	ppm	2.1	1.9	2.8	10.0	5.7	7.3
U	ppm	1.6	2.3	1.7	5.6	3.0	2.6
W	ppm	<3	<3	<3	<3	<3	<3
Y	ppm	30	31	47	260	240	180
Zn	ppm	190	200	170	150	230	160
La	ppm	13.5	13.0	19.4	46.6	54.6	51.1
Ce	ppm	29	29	39	111	112	107
Nd	ppm	19	15	20	55	79	68
Sm	ppm	3.3	3.6	4.5	13.4	16.6	14.5
Eu	ppm	1.2	1.3	1.8	3.7	4.7	4.4
Yb	ppm	2.3	2.3	3.8	20.5	20.2	17.1
Lu	ppm	0.34	0.34	0.59	3.02	3.45	2.65

HEAVY MINERAL CONCENTRATES

Element	Units	25	26	27	28	29	30
Ag	ppm	<5	<5	<5	<5	<5	<5
As	ppm	7	16	6	5	9	5
Au	ppb	20	20	30	70	10	10
Ba	ppm	400	700	200	700	600	500
Br	ppm	2	4	5	4	1	5
Co	ppm	4	7	11	16	3	5
Cr	ppm	130	110	140	140	97	210
Cs	ppm	1.7	1.1	1.2	1.1	0.8	1.8
Fe	pct	8.42	9.45	4.24	6.13	15.2	12.0
Hf	ppm	43	46	4	10	82	99
Mo	ppm	<5	<5	5	7	<5	<5
Na	ppm	49000	51000	39000	36000	52000	49000
Ni	ppm	<200	<200	<200	<200	<200	<200
Rb	ppm	30	50	<20	30	30	40
Sb	ppm	0.2	0.6	0.4	1.0	0.3	0.4
Sc	ppm	6.3	7.4	17.0	20.7	7.1	5.3
Se	ppm	<3	<3	<3	<3	<3	<3
Sr	ppm	<500	<500	<500	<500	<500	<500
Ta	ppm	2	2	<1	1	2	4
Th	ppm	10	9.2	3.2	4.5	10	20
U	ppm	4.2	4.9	2.1	2.9	4.3	11.6
W	ppm	<3	<3	<3	<3	<3	<3
Y	ppm	230	190	54	64	250	520
Zn	ppm	150	270	90	270	200	200
La	ppm	45.8	49.3	21.3	26.9	79.4	57.9
Ce	ppm	116	120	47	57	180	172
Nd	ppm	52	74	26	32	110	69
Sm	ppm	13.3	14.9	5.7	5.8	23.1	18.6
Eu	ppm	3.7	4.1	1.9	1.8	5.4	5.1
Yb	ppm	21.4	18.4	4.7	6.3	30.6	45.6
Lu	ppm	3.65	2.95	0.73	1.00	5.30	6.93

HEAVY MINERAL CONCENTRATES

Element	Units	31	32	33	34	35	36	37
Ag	ppm	<5	<5	<5	<5	<5	<5	----
As	ppm	4	8	9	<2	9	110	----
Au	ppb	<10	20	<10	<10	<10	10	----
Ba	ppm	300	400	700	400	200	1000	----
Br	ppm	3	15	13	2	6	5	----
Co	ppm	5	22	37	17	31	89	----
Cr	ppm	230	230	190	130	200	220	----
Cs	ppm	1.1	1.0	<0.9	<0.7	<0.5	<0.5	----
Fe	pct	14.7	6.45	7.23	5.35	7.45	19.3	----
Hf	ppm	170	12	3	2	3	3	----
Mo	ppm	17	<5	6	5	5	14	----
Na	ppm	46000	33000	25000	27000	37000	17000	----
Ni	ppm	<200	<200	<200	<200	<200	<200	----
Rb	ppm	<20	20	<20	<20	<20	20	----
Sb	ppm	0.3	0.2	<0.2	<0.2	<0.2	2.5	----
Sc	ppm	8.0	28.7	30.5	22.5	33.8	34.2	----
Se	ppm	<3	<3	<3	<3	<3	<3	----
Sr	ppm	<500	<500	<500	<500	<500	<500	----
Ta	ppm	7	1	<1	1	<1	<1	<2
Th	ppm	35	5.4	2.5	1.3	1.1	1.8	<2
U	ppm	18.1	5.8	1.6	1.2	1.2	2.9	<2
W	ppm	<3	<3	<3	<3	<3	<3	<3
Y	ppm	980	78	33	35	40	41	98
Zn	ppm	230	140	180	110	140	240	----
La	ppm	63.3	21.9	13.9	10.5	15.2	14.2	30
Ce	ppm	231	46	33	25	33	30	83
Nd	ppm	53	22	14	11	22	17	----
Sm	ppm	23.4	4.9	3.8	3.1	4.3	4.0	----
Eu	ppm	6.1	1.4	1.2	1.1	1.8	1.5	----
Yb	ppm	83.1	7.1	3.1	2.4	2.6	2.8	----
Lu	ppm	12.1	1.05	0.52	0.38	0.38	0.44	----

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