THE KECHIKA YTTRIUM AND RARE-EARTH PROSPECT* (94L/11, 12 and 13)

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INTRODUCTION

A suite of alkaline igneous rocks consisting of syenites, melanocratic augite syenite dykes, an alkaline diatreme and related dykes and tuff breccias, and numerous strongly sheared and altered rocks, crops out in the Kechika Ranges of the Cassiar Mountains (RAR and REE claims). These rocks are currently being explored by Formosa Resources Corporation for their yttrium and rare-earth-element potential.

The alkaline rocks are intermittently exposed in a northwest-trending zone in excess of 20 kilometers long, the centre of which is approximately 58°42′ north and 127°30′ west (Figure 2-8-1). Elevations in the area range from 1180 to 2370 metres and there is excellent exposure above treeline. Access is by helicopter from Dease Lake, approximately 160 kilometres to the west, or from Watson Lake, Yukon, which is approximately 150 kilometres north of the property.

The area is underlain by unmetamorphosed to weakly metamorphosed Cambrian to Middle Paleozoic strata (Gabrielse, 1962). To the northeast of the area (Figure 2-8-1), thick-bedded quartzites of probable lower Cambrian age are folded in a broad open antiform with a northwest-trending axis. Along the southwestern limb of the antiform, the quartzites are in contact with a thick, southwest-dipping section of phyllites, thin-bedded marbles and massive, blocky-weathering dolostones of probable Middle and Late Cambrian and Ordovician age (Gabrielse, 1962). Chlorite, sericite, sericite-graphite and calcareous phyllites are all present within this succession. To the southwest, the phyllites are bounded by a shallow southwest-dipping fault, which juxtaposes green tuffs and cherty tuffs overlain by fossiliferous grey limestones and black quartzites with the phyllites. The limestones, which contain beds rich in rugosan corals, favosites-type corals, bryozoans and brachiopod fragments, are probably of Middle Paleozoic age (Silurian). The cherts, tuffs and limestones in the fault panel outline an overturned antiform and to the southwest are in fault contact with graphite-sericite and chlorite-sericite phyllites similar to those to the northeast. The northeastern bounding fault apparently has had normal movement along it as younger strata are present in the hangingwall; however geometry and the presence of the hangingwall anticline imply that at one time there may have been thrust motion along it. The southwestern fault is a moderate to steeply southwest-dipping thrust which places older rocks over younger. The alkaline rocks are present in the tuff-chert-limestone fault panel, between the two phyllitic units.

ALKALINE ROCKS

SYENITES

Syenites and melanocratic titanaugite syenites (malignites) are present at the south end of the property. The melanocratic syenites, which are present as large dykes or elongate stocks, are fine to medium grained, dark green to bluish grey rocks with small pyroxene and feldspar phenocrysts. They contain 40 to 60 per cent microcline, 5 to 20 per cent albite and 10 to 20 per cent titanaugite. Garnet (melanite), biotite, sodalite, cancrinite, allanite, magnetite/ilmenite, pyrite, fluorite and apatite/monazite are all present as accessory phases. Veins or segregations containing coarse calcite and dark purple fluorite ± biotite ± epidote are locally present within the malignites. In the northern part of the property, melanocratic syenites are highly sheared and chlorite-rich.

Leucocratic syenites crop out in the southern part of the property, generally as irregular zones within the melanocratic syenites. They are light grey, medium-grained, massive rocks containing 35 to 40 per cent microcline and 10 to 20 per cent albite, with fluorite, sodalite, cancrinite, sphene, biotite, pyrite and pyrochlore present in variable amounts. Crosscutting calcite-pyrite-fluorite veinlets are common. The syenites vary from massive and relatively unaltered to sheared. Sheared syenites contain potassium feldspar porphyroclasts and unrecrystallized layers in a fine-grained recrystallized and altered matrix containing abundant clay minerals, quartz, plagioclase, dolomite and muscovite.

MOTTLED PHYLLITES

Fine-grained, extremely fissile and micaceous phyllites to massive, white to buff-weathering rocks are commonly associated with other alkaline rocks in the central and northern portions of the property (Figures 2-8-1, 2-8-2). They generally occur in shallow to moderately dipping layers in excess of 25 metres thick. They have mylonitic textures and contain varying amounts of quartz, carbonate (generally dolomite, although calcite and iron-rich magnesite have also been noted), sericite, potassium feldspar, phosphates and pyrite.

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British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

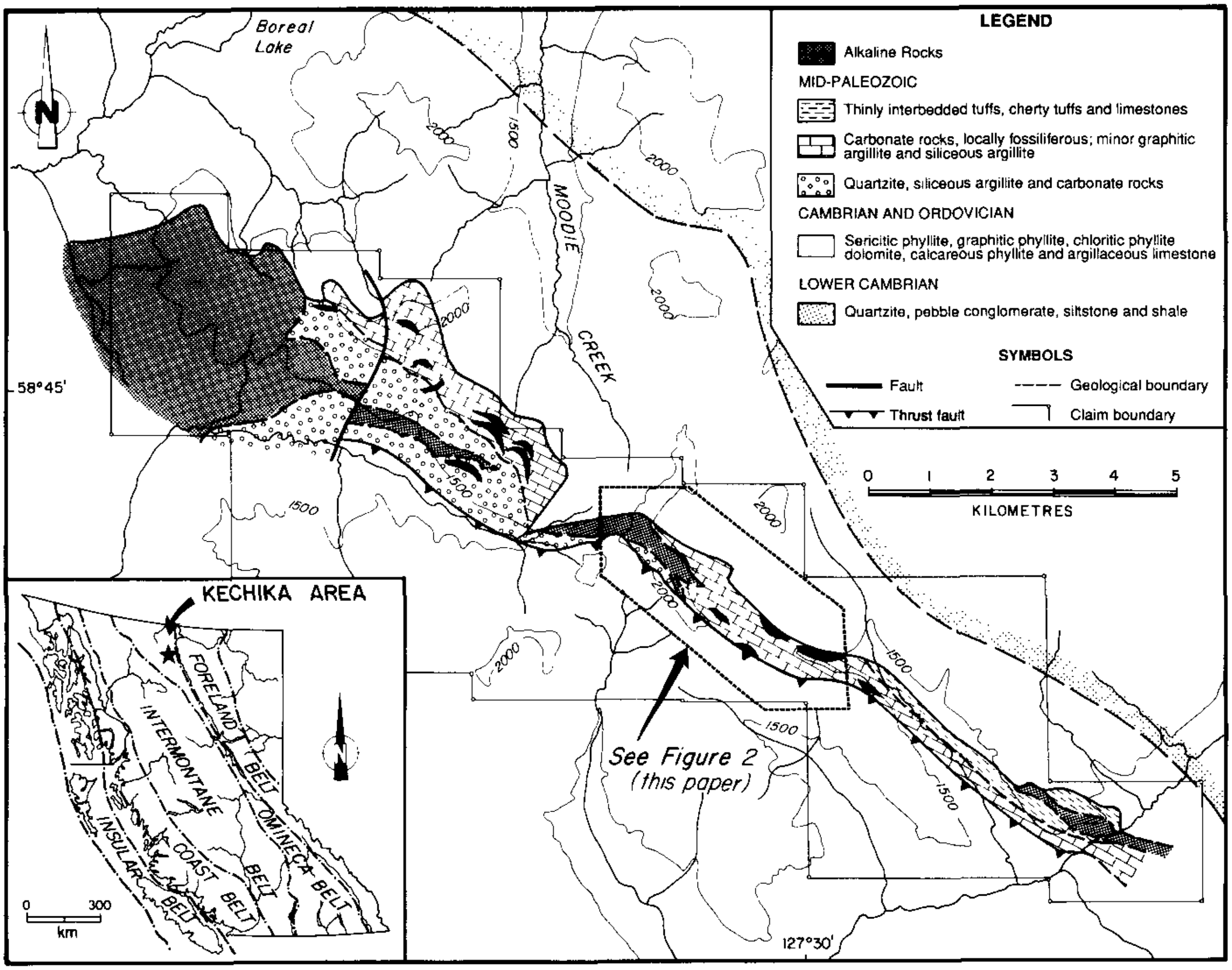

Figure 2-8-1. Geology of the Kechika Yttrium and Rare-earth prospect.

Massive varieties commonly have irregular dolomitic patches in a siliceous matrix. Some increased radioactivity is associated with certain horizons within these rocks.

Locally phosphate minerals comprise in excess of 25 per cent of the rock. In such rocks, a number of phosphate minerals may be intergrown, with apatite the most common species. Monazite (containing cerium, neodymium, lanthanum, calcium, thorium), xenotime (yttrium phosphate, with minor dysprosium, gadolinium and calcium) and an yttrium-thorium-calcium-dysprosium-gadolinium-bearing phosphate have been identified by scanning electron microscopy. Minor amounts of an iron-thorium-yttrium-calcium silicate mineral have also been noted.

In some samples, potassium feldspar porphyroclasts are preserved in a fine-grained quartz-carbonate-sericite matrix, which suggests that the mylonite had a syenitic protolith. In other cases the rocks are very fine grained and completely recrystallized; no textural evidence of the protolith remains. Field evidence indicates that these rocks are conformable to bedding in the hosting limestones and were possibly flows or tuff layers. The high degree of deformation within them compared with the other rock types may be a result of original incompetence, in which case a tuffaceous protolith is favoured. Phosphate-rich rocks are distributed in discontinuous lenses up to a few metres thick and several tens of metres long, parallel to overall layering.

DIATREME BRECCIAS, TUFF BRECCIAS AND RELATED DYKES

A complex diatreme containing a number of breccia phases, related pyroclastic tuffs and breccia dykes, crops out in the central part of the property (Figures 2-8-1, 2-8-2). These rocks weather greenish silver to rusty orange and are weakly to extremely well foliated.

The main diatreme comprises very inhomogeneous, heterolithic tuffisitic breccias with rounded to angular xenoliths up to 7 centimetres across. Quartzite and carbonate rock fragments dominate the xenolith population; some autoliths, rare syenite fragments and some black argillite clasts were also noted. Quartz xenocrysts, rare chrome spinels, juvenile and vesiculated glass lapilli, and altered crystal fragments (predominantly potassium feldspars) are also present. The breccia matrix consists of carbonate minerals and minor muscovite, and locally, chrome micas. In places near its outer contacts, the diatreme breccia is intensely deformed

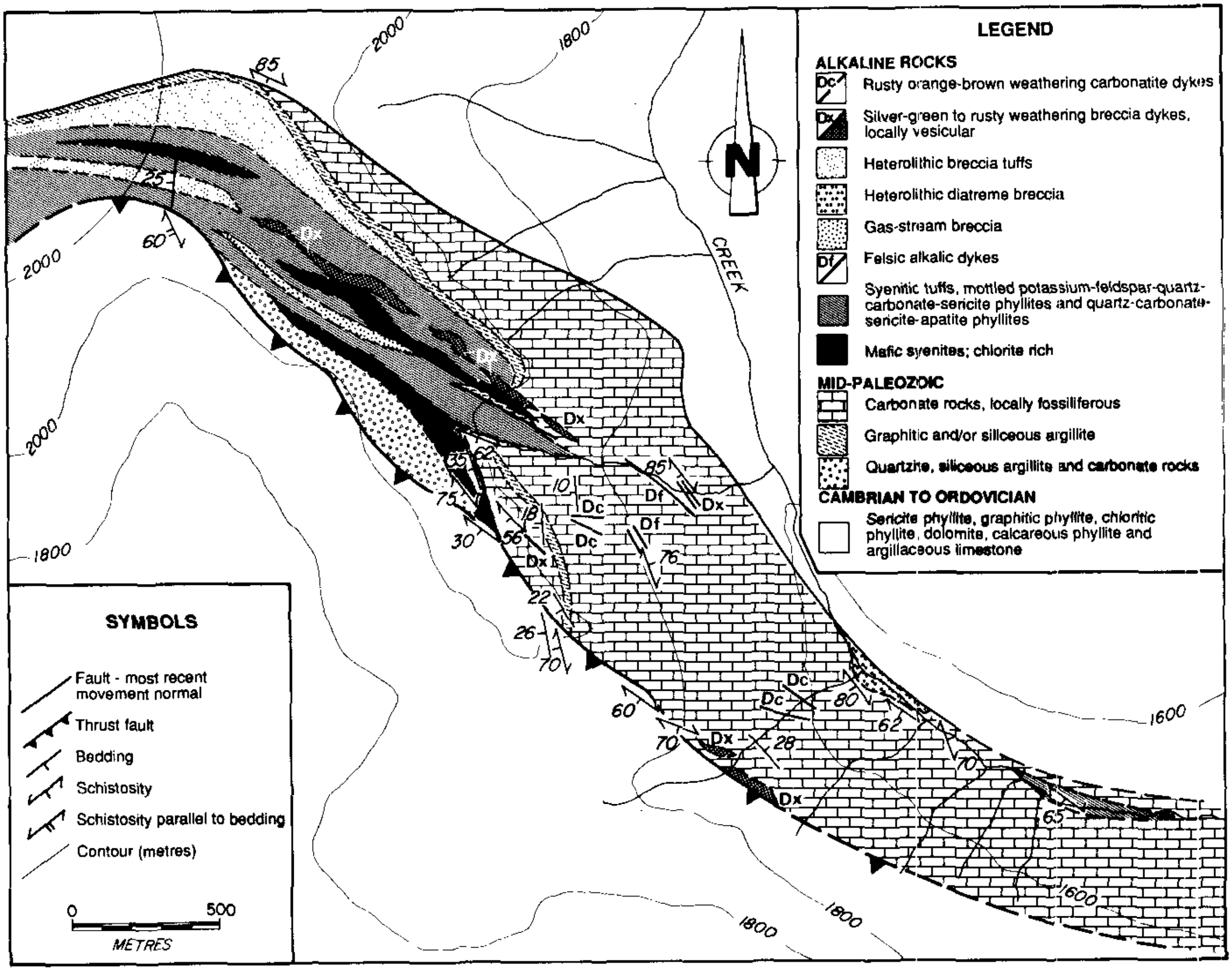

Figure 2-8-2. Detailed geology, central portion of the Kechika prospect.

and has the appearance of a stretched-pebble conglomerate. The northern and central part of the diatreme has been cut by fluorite-calcite and fluorite-calcite-pyrite stockwork veins. Similar breccias are present in the Bull River–White River area of the southern Rocky Mountains (Pell, 1987a, 1987b).

Peripheral to the main diatreme and on the ridges to the north of it (Figure 2-8-2), breccia dykes are quite common. They crosscut both the carbonate host rocks and the mottled phyllites. The dykes, in general, are extremely well foliated and average 1 to 2 metres in thickness. They are similar in composition and appearance to the matrix of the main diatreme and locally contain chrome spinels, small lithic fragments and carbonate-filled vesicles.

Lithic tuffs outcrop on ridges near the centre of the property, immediately north of the main diatreme, and at the north end of the property, south of Boreal Lake (Figures 2-8-1, 2-8-2). These pyroclastic rocks are rusty orange to silver-green weathering and very similar in appearance to the breccia dykes. They are conformable with the host carbonate succession and are interbedded with the mottled phyllites. Well-developed graded layers are present locally, with lithic fragments 1 to 3 centimetres in size at the base and fine-grained, carbonate-rich material at the top of the bed. These rocks are the presumed extrusive equivalent of the diatreme and breccia dykes.

CARBONATITES

Fine-grained igneous carbonate rocks, with a distinctive orange-brown weathering colour, are also present in the Kechika area. They occur as dykes which are generally less than 1 metre wide and crosscut both other alkaline rocks and the carbonate host rocks. Volumetrically, the carbonatites are an insignificant part of the alkaline suite.

The carbonatites are dolomite or ankerite rich (greater than 80 per cent) and contain quartz. Accessory phases include microcline, muscovite, barite, iron oxides, pyrite, fluorapatite, gorceixite, xenotime and an unidentified thorium-calcium-yttrium-iron phosphate mineral.

GEOCHEMISTRY

Only limited geochemical information is currently available for the alkaline rocks in the Kechika area. Samples have been analysed for niobium, tantalum, yttrium and rare earths (Table 2-8-1); no major element analyses have been completed. As with other alkaline suites, rocks in the Kechika

TABLE 2-8-1. RARE-EARTH, YTTRIUM, NIOBIUM & TANTALUM VALUES OF SELECTED ALKALINE ROCKS, KECHIKA AREA

	SYENITES			SYENITIC TUFFS				BRECCIAS				CARBONATITES		
	1274	1673	1676	1699	1660	1750	1691	1693	1733	1666	1734	1739	1656	1658	1662
ppm															
Nb	20	305	200	195	<5	<5	62	50	115	23	115	205	<5	11	13
Ta	<3	9	<3	13	<3	<3	<3	3	10	4	7	<3	<3	6	<3
La	218	450	133	104	142	196	86	42	626	34	140	431	39	406	472
Ce	392	738	167	162	427	616	149	77	835	96	231	557	130	508	709
Pr	<52	<80	<89	<83	<52	<98	<50	<50	<88	<50	<56	<75	<50	<54	87
Nd	225	248	46	46	402	557	62	30	204	90	75	201	140	166	293
Sm	94	24	6	6	331	505	14	5	21	39	14	57	38	37	71
Eu	45	6	1	2	138	206	3	1	5	16	4	19	16	11	20
Gd	<300	<330	<300	<300	<540	<1100	<200	<200	<380	<210	<230	<380	310	<240	<270
Tb	33	1	<1	<1	114	189	1	<1	2	14	2	8	25	3	7
Dy	223	15	3	5	755	1240	4	2	6	110	8	59	219	13	34
Ho	23	<1	<1	<1	76	100	<1	<1	<1	17	1	4	36	<1	4
Er	<100	<100	<100	<100	200	420	<100	<100	<100	<100	<100	<100	150	<110	<100
Tm	15	4	<.6	.7	39	60	.7	<.5	<.7	7	<.7	5	20	2	4
Yb	51	8	3	3	142	244	1	.8	4	50	5	21	118	4	12
Lu	5	.4	.4	.4	11	21	<.1	<.1	.2	6	.5	2	12	.4	1
Y	1100	94	41	42	3800	7100	<5	<5	27	755	65	365	1600	50	195

1274-Narrow leucocratic syenite dyke; 1673-Biotite-rich mafic syenite; 1676-Titanaugite-biotite syenite; 1699-Titanaugite syenite; 1660-Apatite-rich quartz-carbonate-sericite tuff; 1750-Apatite-rich quartz-carbonate-sericite tuff; 1691-K-feldspar-quartz-carbonate-sericite phyllitic tuff; 1693-Massive K-feldspar-quartz-carbonate tuff; 1733-Carbonate-quartz-sericite phyllitic tuff; 1666-Crystal and lapilli tuffisitic breccia; 1734-Heterolithic diatreme breccia; 1739-Lapilli tuffisitic breccia; 1656-Orange-brown weathering fine-grained finely layered carbonate of undetermined origin; 1658-Medium-grained ankeritic carbonatite dyke; 1662-Fine-grained carbonatite dyke with fluorite stockworking.

Data from Fox (1987). Nb, Ta and Y analyses by XRF, REE's by INAA.

area are generally enriched in these incompatible elements (Fox, 1987).

Chondrite-normalized rare-earth-element plots of various alkaline rock types (Figure 2-8-3) show significant rare-earth enrichment relative to average crustal abundances; total rare-earth oxides in excess of 2 per cent and yttrium values up to 7100 ppm (0.90 per cent Y_2O_3) have been reported (Fox, 1987). Malignites are generally enriched in light rare-earths and have flat to erratic heavy rare-earth patterns. The leucosyenite sample analysed has a relatively flat pattern through the light rare-earths to holmium, that is, relative abundances similar to average crust but extremely enriched, and an erratic heavy rare-earth pattern. Syenitic tuffs (mottled phyllites) have rare-earth concentrations which result in steep negatively sloping chondrite-normalized patterns that are typical of carbonatite/alkaline rock complexes. Apatite-rich syenitic tuffs produce elevated, convex upward-curving chondrite-normalized patterns indicative of significant enrichment in rare earths from samarium to thulium, patterns which are not typical of carbonatite/alkaline rock suites. These rocks are also significantly enriched in yttrium. Carbonatites and diatreme breccias give both shallow positive and shallow negative sloping chondrite-normalized patterns, indicating both slight relative light rare-earth and slight relative heavy rare-earth enrichment occurs in these rocks.

MINERALIZATION AND ECONOMIC CONSIDERATIONS

Rare-earth elements are concentrated in all alkaline rocks. Yttrium, although not a rare-earth element, is commonly grouped with them as its chemical properties are similar to

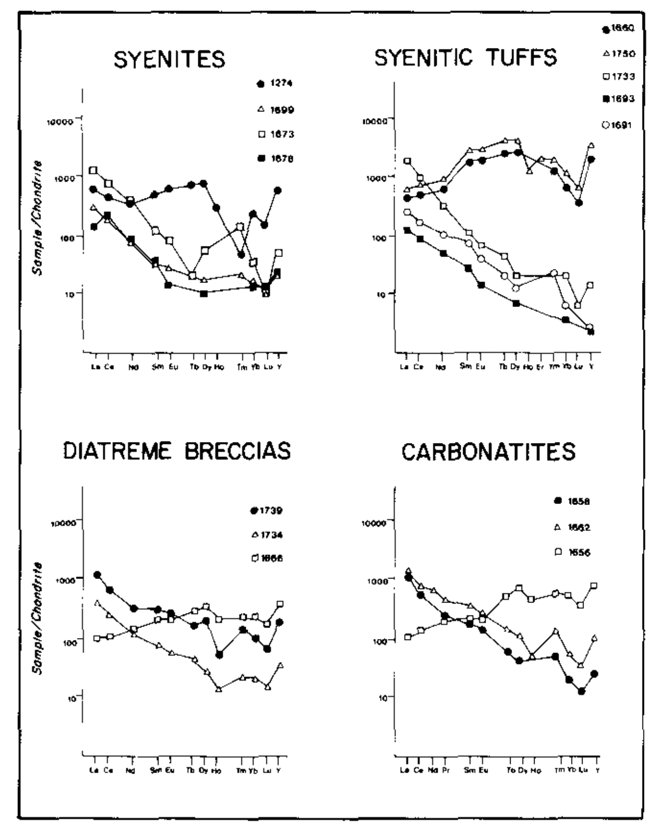

Figure 2-8-3. Chondrite normalized rare-earth element plots for selected samples, Kechika area.

the heavy rare earths. These elements are used principally in petroleum cracking catalysts, steel and metal alloying agents, glass polishing compounds and glass additives, permanent magnets and phosphors for television and lighting tubes. The rare-earths, particularly yttrium, also have important potential in the manufacture of superconductors and applications in advanced ceramics and laser technology.

The demand for light rare-earths is currently supplied by major producers such as Molycorp's Mountain Pass mine in California. In recent years, the demand for mixed rare-earth compounds has declined; however, the demand for high-purity separated rare-earths is rising (Roskill Information Services, 1986). There is a significant current demand for neodymium and praseodymium for use in specialty magnets and for less abundant rare-earth elements such as samarium, gadolinium and europium (Hedrick, 1985). Yttrium is also in demand (Roskill Information Services, 1986). Prices for rare-earth oxides as quoted by Molycorp in January, 1987 vary from a low of US$4.50 per pound for cerium oxide to US$725 per pound for europium oxide and US$1000 per pound for thulium oxide. Prices for yttrium, gadolinium and samarium oxides are all in the range of US$50 to US$55 per pound. These prices, to a certain extent, reflect costs of producing a rare-earth concentrate and processing the pure compounds and must be considered as approximate only. More current information on rare-earth oxide prices is not readily available. Current prices of rare-earth-bearing mineral concentrates, as quoted in Industrial Minerals, September 1988 are US$1.05 per pound of bastnaesite concentrates containing 70 per cent rare-earth oxides, A$700-780 per tonne of monazite concentrate with a minimum of 55 per cent rare-earth oxides, f.o.b.Australia, and US$32-33 per kilogram for yttrium mineral concentrate (xenotime) with 60 per cent yttrium oxide, f.o.b. Malaysia.

In the Kechika area, a number of alkaline rock types have been found to contain anomalously high yttrium and heavy rare-earth values (Table 2-8-1 and Fox, 1987). Of particular note are the apatite-rich zones, which contain up to 25 per cent apatite, within the mottled phyllites of possible syenitic tuff origin. These zones appear to be distributed as lenticular bodies a few metres thick by a few tens of metres in length, separated by apatite-poor zones. Yttrium and the rare earths, particularly dysprosium and gadolinium, are present in phosphate minerals such as xenotime, associated with the apatite. The origin of these zones is uncertain; apatite enrichment may be a result of primary igneous layering processes, or possibly, later metasomatism.

GEOCHRONOLOGY

No radiometric dating has been completed on the Kechika River alkaline rocks. The presence of mylonites and their distribution suggests that they were emplaced prior to orogenesis. Field relationships, in particular the presence of bedded tuff-breccias and possible syenitic tuffs, suggest that the alkaline suite is coeval with the host carbonates, that is mid-Paleozoic. This is similar to ages of 350 to 400 Ma (Pell, 1987b) for carbonatites and alkaline diatremes elsewhere in the Canadian Cordillera and suggests that the Kechika rocks were emplaced in response to major tectonic instabilities in middle Paleozoic time which also resulted in the intrusion of alkaline complexes such as Aley and Ice River.

Clear crosscutting relationships between the many alkaline phases are largely obscured by deformation and, for the most part, the sequence of emplacement cannot be established. Carbonatite dykes, which crosscut syenitic tuffs and some tuff breccias appear to be the youngest igneous rocks in the sequence.

CONCLUSIONS

In the Kechika area, a suite of rocks consisting of leucocratic and melanocratic syenites, possible syenitic tuffs, carbonatites and a diatreme breccia and related dykes and tuff breccias are intermittently exposed in a zone over 20 kilometres in length. These alkaline rocks are hosted by middle Paleozoic carbonate strata and are, at least in part, coeval with their host rocks.

Preliminary studies indicate that the igneous rocks, in particular apatite-rich syenitic tuff layers, are extremely enriched in yttrium, containing up to 0.90 per cent Y_2O_3, and heavy rare earths. More detailed mapping and mineralogical and geochemical studies are necessary to fully assess the economic potential of this suite.

ACKNOWLEDGMENTS

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REFERENCES

Fox, M. (1987): Geological and Geochemical Report, RAR 1-9, REE 1-8, and REO 1 and 2 Mineral Claims, *Golden Rule Resources Ltd.* Unpublished Company Report.

Gabrielse, H. (1962): Kechika, B.C., *Geological Survey of Canada,* Map 42-1962.

Hedrick, J.B. (1985): Rare-earth Elements and Yttrium, Mineral Facts and Problems, *United States Department of the Interior, Bureau of Mines,* Bulletin 675, pages 647-664.

Pell, J. (1987a): Alkaline Ultrabasic Diatremes in British Columbia: Petrology, Geochronology and Tectonic Significance (82G, J, N; 83C; 94B), *B.C. Ministry of Energy, Mines and Petroleum Resources,* Geological Fieldwork 1986, Paper 1987-1, pages 259-272.

——— (1987b): Alkaline Ultrabasic Rocks in British Columbia: Carbonatites, Nepheline Syenites, Kimberlites, Ultramafic Lamprophyres and Related Rocks, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Open File 1987-17, 109 pages.

Roskill Information Services Ltd. (1986): The Economics of Rare-earths and Yttrium 1986, 270 pages.

NOTES