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RARE-METAL MINERALIZATION IN THE NUIKLAVIK VOLCANIC ROCKS OF THE FLOWERS RIVER IGNEOUS SUITE

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ABSTRACT

The Nuiklavik felsic volcanic rocks of the Flowers River Igneous Suite in north-central Labrador have been identified as an excellent target for rare-metal mineralization (Y, Zr, REE). A program of mapping, sampling and laboratory studies has been ongoing since 1991 to evaluate this rare-metal potential.

The stratigraphy of the Nuiklavik felsic volcanic rocks has been divided into the following units: Basal Tuff Unit, Amphibole-bearing porphyritic Unit, Lower Crystal-rich ash-flow Unit, Crystal-poor and quartz-phyric ash-flow Unit and Upper ash-flow Unit. Each unit can be subdivided into several smaller subunits (or rock types). Most units and subunits are ash-flow tuffs or lithic breccias that exhibit various degrees of welding and compaction.

Rare-metal mineralization has been identified in the Crystal-poor and quartz-phyric ash-flow Unit, where it is associated with ash-flow tuffs and ash-flow lithic breccias. The Y values range from 400 to 1900 ppm, with values over 900 ppm being locally common. These rare-metal showings are currently open for claim staking.

INTRODUCTION

Several occurrences of rare-metal mineralization were previously observed by Hill (1981, 1982) in the granites and volcanic rocks of the Flowers River Igneous Suite. A compilation of rare-metal analyses from potential rare-metal targets in Labrador (Miller, 1988) indicated that the highest potential for rare-metal mineralization in this suite occurs in the volcanic rocks. This report, which is part of an ongoing four-year project, briefly documents the volcanic stratigraphy and the occurrence of rare-metal mineralization, chiefly Y and Zr, in these rocks.

The Nuiklavik felsic volcanic rocks of the Flowers River Igneous Suite were first mentioned by Beavan (1954), who named them the Nuiklavik volcanic suite. Subsequent work was carried out on these rocks and the Flowers River granites, the intrusive members of the Flowers River Igneous Suite, by several workers, including Hill (1981, 1982, 1991), Hill and Miller (1991; see Miller (1992a) for additional references).

The Nuiklavik felsic volcanic rocks are 7 km west of the Labrador coast and 70 km south of Nain (Figure 1). These rocks are preserved in a cauldron structure (14 km radius), which occurs within a peralkaline granite ring. Figure 2 illustrates the general geology of the Flowers River cauldron complex and surrounding rocks.

STRATIGRAPHY

A preliminary version of the stratigraphy of the Nuiklavik felsic volcanic rocks was first proposed in earlier reports (Miller, 1992a, and Miller and Abdel-Rahman, 1992). Subsequent mapping and petrographic work has resulted in several revisions to the stratigraphy and a further refining of subunits.

Recent field work has expanded the stratigraphic section (Figure 3). It has also confirmed the occurrence of locally crosscutting porphyritic peralkaline granite sills and dykes in the lower part of the volcanic section. These sills and dykes are probably closely related to the sub-volcanic microgranites that underlie the volcanic rocks.

Petrographic work indicates that most, if not all, of the felsic rocks in this sequence, including the columnar-jointed porphyries and aphyric rocks, are ash-flow tuffs or lithic breccias (ignimbrites). This conclusion is supported by the abundance of shards and broken phenocrysts and the occurrence of many ash-flow textures in the groundmass of these rocks. Aphyric amoeboid-shaped fragments, commonly less than 1 cm wide, are also more abundant than previously thought. Some ash-flow units exhibit obvious ignimbritic

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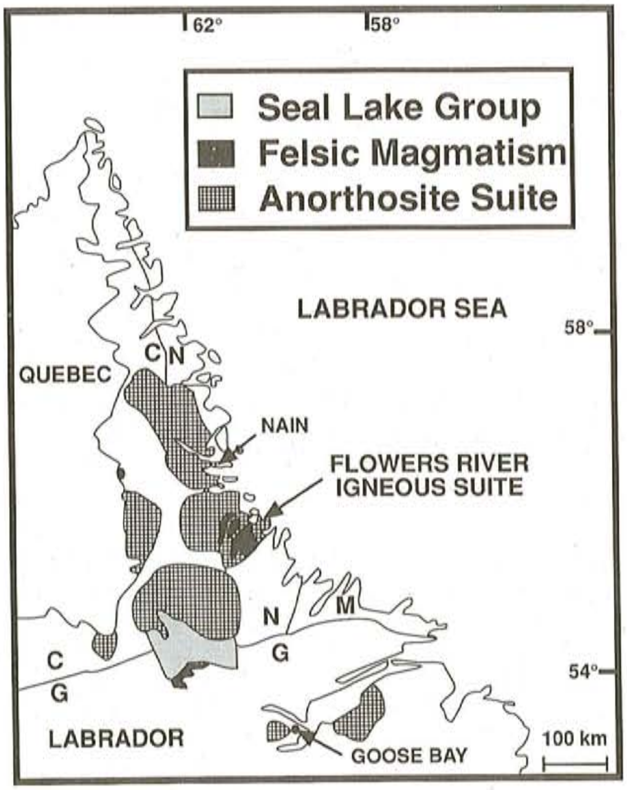

Figure 1. *Location map of the Flowers River Igneous Suite and the Nuiklavik felsic volcanic rocks, Labrador. Structural provinces: C = Churchill, N = Nain, G = Grenville, M = Makkovik.*

structures on weathered surfaces, such as lithic fragments, fiammé and laminations.

Many ash-flow tuffs have been strongly welded and compacted. These processes have obliterated many ash-flow textures and resulted in the formation of columnar joints and rheo-ignimbritic flow textures.

The Nuiklavik stratigraphic section (Figure 3), which is approximately 340 m thick, is now divided into five major units, based upon the general characteristics of the rocks, and can be further subdivided into many subunits. These five major units and the closely related Flowers River granites are briefly described below.

FLOWERS RIVER GRANITES

These amphibole–pyroxene-bearing granites are mostly peralkaline but some examples of transitional, olivine-bearing granites have also been observed. The peralkaline granites have been subdivided into coarse granites and microgranites. The coarse granites are characterized by a grain size of between 3 and 10 mm, hypersolvus feldspars and a hypidiomorphic texture. The microgranites occur with either porphyritic, aplitic or granophyric textures and commonly contain grains less than 2 mm. Microgranites occur structurally above the coarse-grained granites and are in intrusive contact with the volcanic rocks (Figure 2) or occur as sills and dykes in the lower part of the volcanic section.

NUIKLAVIK VOLCANIC ROCKS

Basal Tuff (Unit 1)

This unit is characterized by well-bedded waterlain (?) aphanitic to very fine-grained tuffs and massive to faintly bedded siliceous units. One occurrence of limestone (?), up to 6 m thick, is interbedded with the volcanic units. A gabbro sill, which crosscuts the volcanic units locally, also occurs in this unit. Intermediate feldspar porphyry and aphyric flows (?) and minor felsic quartz-feldspar porphyry are also found. Observed thicknesses are up to 25 m but estimates suggest that this unit may be up to 40 m thick. Microgranite cuts the lower portions of this unit.

Amphibole-Bearing Porphyry (Unit 2)

This unit consists of a basal dark-coloured feldspar–quartz ± amphibole porphyry, a mid-unit amphibole–feldspar–quartz porphyry and an upper amphibole-bearing ignimbrite. The lower subunit is locally columnar-jointed and is up to 20 m thick. The middle subunit commonly contains a fine-grained to very fine-grained matrix and inclusions of underlying feldspar–quartz ± amphibole porphyry, feldspar porphyry and monzonite, which may indicate that this subunit occurs as intrusive sills and dykes rather than extrusive rocks; this subunit ranges from 5 to 40 m thick. The amphibole ignimbrite subunit commonly contains rare quartz or feldspar phenocrysts and is usually less than 10 m thick. The lower and upper subunits appear to be strongly welded ash-flow tuffs. The middle unit appears to be made up of both high-level sills and dykes and ash-flow tuffs.

Lower Crystal-Rich Ash-Flow (Unit 3)

This unit is dominated by columnar-jointed feldspar–quartz and quartz-mafic (altered feldspar?) porphyries, which are up to 100 m thick. Feldspar–quartz porphyry commonly occurs at the base of this unit, whereas quartz-mafic porphyry occurs in the middle. Thin (less than 10 m) quartz porphyry and quartz-porphyry breccia locally occur at the top of this unit. Columnar-jointing and massive textures in outcrop indicate that this unit represents strongly welded ash-flow tuffs.

Crystal-Poor And Quartz-Phyric Ash-Flow (Unit 4)

This unit consists of a basal aphyric aphanitic subunit and a series of aphyric, phenocryst-poor and quartz-bearing ash-flow tuffs and lithic breccias. The basal aphyric subunit rarely contains ignimbritic textures but more usually exhibits no textures other than columnar-jointing; it ranges from between 10 and 40 m thick. Locally occurring, the next subunit is a feldspar + quartz-poor ignimbrite, which ranges up to 40 m thick. The middle subunits consist of aphyric and quartz-poor lithic ash-flow breccia, highly compacted and

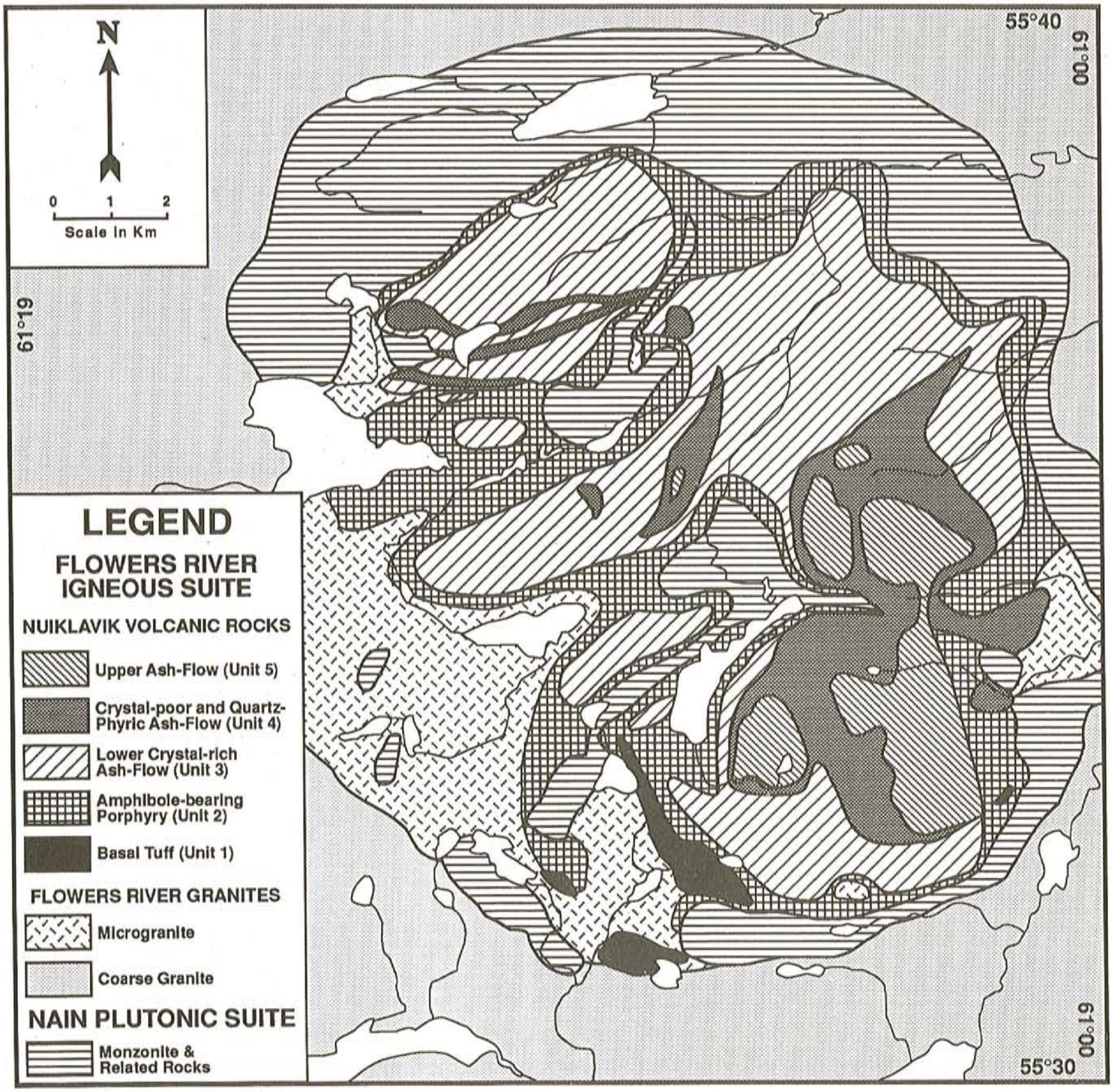

Figure 2. *General geology of the Nuiklavik felsic volcanic rocks of the Flowers River Igneous Suite and the surrounding host rocks.*

welded ash-flow tuff and rare poorly compacted ash-flow tuff. Lithic fragments are commonly from the underlying aphyric, quartz-poor ash-flow and aphyric ash-flow subunits; rare feldspar–quartz porphyry fragments are also observed. Each of these subunits is not observed in every exposure of this unit as it appears that they commonly represent different facies of the same ash-flow sheet; for example, the lithic ash-flow breccia would represent the near vent equivalent of a fragment-poor ash-flow tuff. Individual subunit sheets range from 4 to 10 m thick, whereas the entire package of sheets is up to 40 m thick. The upper subunit is a locally occurring quartz ash-flow tuff to breccia unit, which is up to 10 m thick. The basal aphyric aphanitic subunit may represent lava flows, a vent plugging magma or a highly welded and compacted ash-flow as it commonly exhibits no ash-flow textures and is the most abundant fragment type in the near vent lithic breccias.

Upper Ash-Flow (Unit 5)

The base of the upper ash-flow unit is defined by the occurrence of a crystal-rich feldspar–quartz ash-flow tuff,

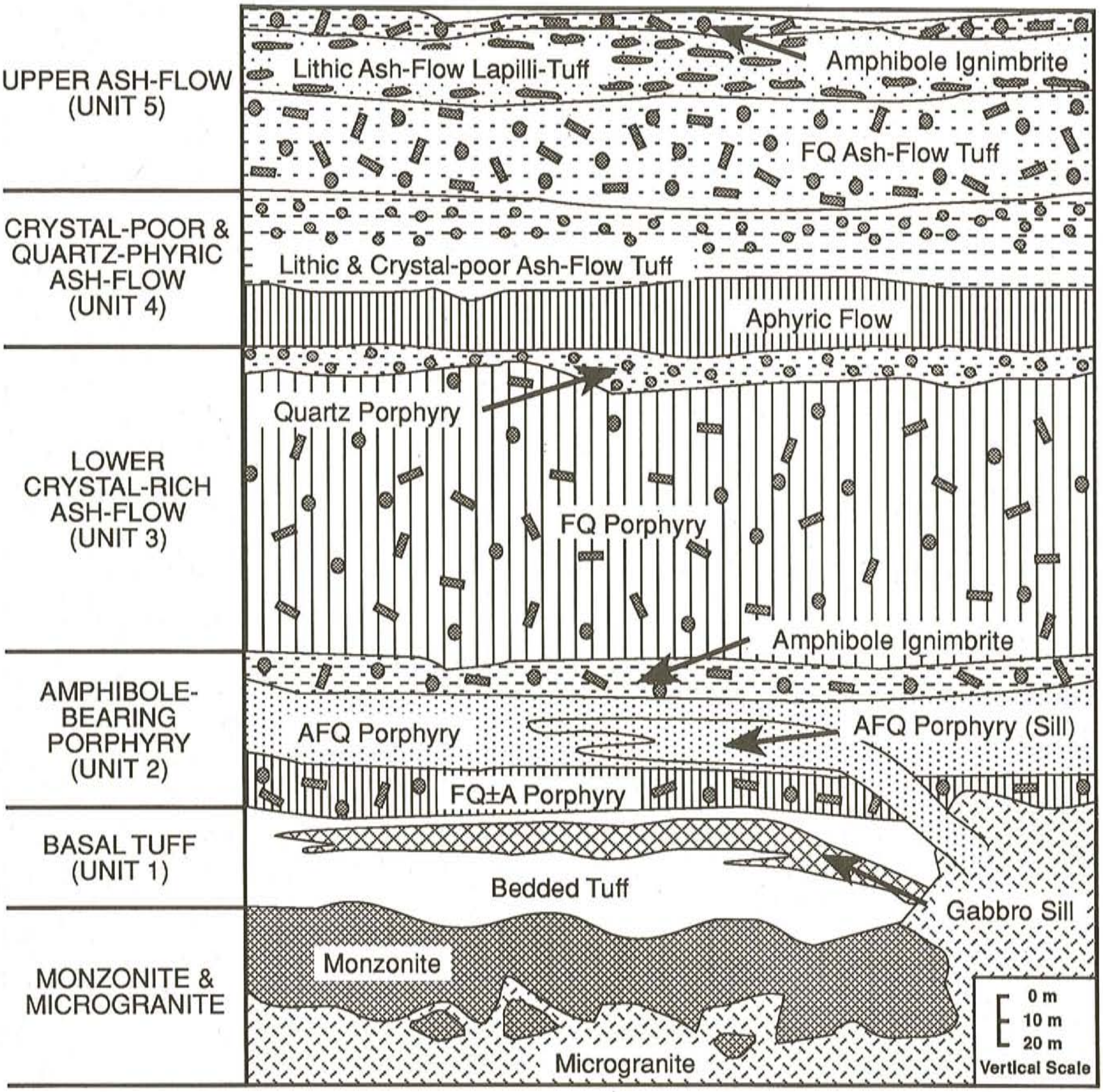

Figure 3. *Generalized stratigraphic section of the Nuiklavik felsic volcanic rocks.*

which is locally columnar-jointed and always contains abundant broken phenocrysts and shards; thickness ranges from 10 to 60 m. The next subunit is an aphyric to phenocryst-poor ash-flow lithic lapilli tuff that contains abundant aphyric and quartz-phyric fragments; thickness ranges from 20 to 25 m. The subunit uppermost in this unit and uppermost in the entire stratigraphic section consists of amphibole-feldspar ignimbrite and amphibole ignimbrite similar to that described in the Amphibole-bearing porphyritic Unit (Unit 2); minimum thickness of this subunit is 10 m.

MINERALIZATION

A large number of radioactive showings were identified in the 1991 field season in the Flowers River cauldron complex (Figure 4; Miller, 1992b). These showings were considered to be rare-metal showings based on the correlation between radioactivity and rare-metal contents observed at the Strange Lake deposit and the Letitia Lake rare-metal showings (Miller, 1986, 1987, 1988, 1992a, b). Subsequent rare-metal analyses (see Miller, 1992b, for analyses, and Table 1 for the most anomalous values) confirm that the highest rare-metal

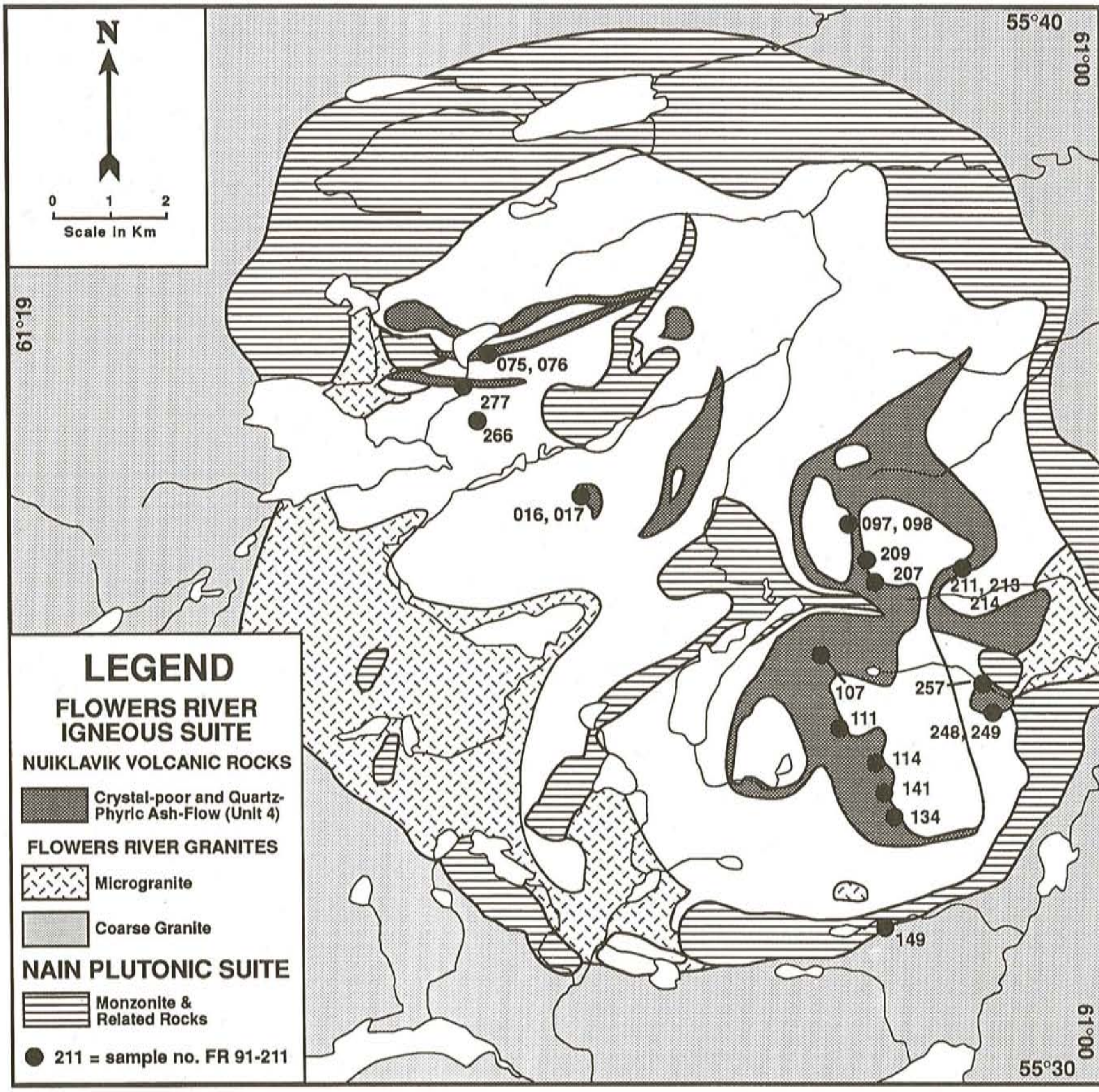

Figure 4. *Location of samples with highly anomalous Y values in the Nuiklavik felsic volcanic rocks and location of the Crystal-poor and quartz-phyric ash-flow Unit (Unit 4), which has a high potential for rare-metal mineralization; 214 = location of detailed section used in Figure 5.*

values correlate very well with the highest radioactivity measurements.

Interest was initially focussed on the Nuiklavik felsic volcanic rocks by the anomalous values for Y observed in some of these rocks. Statistical analysis of Y values in just over 200 chemical analyses (from samples collected in 1991) yield the results found in Table 2. These averages, tabulated by subunit, indicate, with only a few exceptions, that the Flowers River granites (microgranite = 96 ppm and coarse granite = 50 ppm), the Basal Unit (31 ppm; Unit 1), the Amphibole-bearing porphyritic Unit (78 and 136 ppm; Unit 2) and the Lower crystal-rich ash-flow Unit (72 to 103 ppm; Unit 3), which collectively make up approximately two thirds of the volcanic stratigraphy, contain low, uneconomic concentrations of Y and other rare-metals. The exceptions, a granite aplite (432 ppm) and the amphibole ignimbrite subunit (318 ppm) of the Amphibole-bearing porphyritic Unit

Table 1. Highly anomalous rare-metal analyses from the Nuiklavik felsic volcanic rocks

Field No.	Rock Type	Nb	Zr	Th	Y	La	Ce	Be	Coordinates N	Coordinates E	Spectr.
FR-91-075	Aphyric Ash-Flow Tuff (Unit 4)	338	4912	79	492	392	1081	19.7	6164775	614305	1000
FR-91-076	Aphyric Ash-Flow Tuff (Unit 4)	350	5185	82	499	359	1006	18.9	6164710	614315	760
FR-91-149	Quartz-poor Ash-Flow Tuff (Unit 4)	328	6622	86	499	551	1416	13.9	6156605	622605	940
FR-91-257	Aphyric Flow (Unit 4)	382	4999	104	501	340	1130	10.4	6159180	622750	980
FR-91-277	Quartz-poor Ash-Flow Tuff (Unit 4)	205	4578	91	502	363	922	14.2	6164010	613730	800
FR-91-248	Aphyric Ash-Flow Tuff (Unit 4)	365	4937	92	525	364	689	8.8	6158845	623005	970
FR-91-266	Quartz-poor Ash-Flow Tuff (Unit 4)	153	3905	57	529	923	1867	26.5	6163630	614070	560
FR-91-207	Aphyric Ash-Flow Breccia (Unit 4)	324	4151	86	533	338	929	30.9	6160785	620955	810
FR-91-249	Quartz Ash-Flow Breccia (Unit 4)	361	5118	94	537	480	1067	9.1	6158840	623025	880
FR-91-209	Amphibole Ignimbrite (Unit 5)	327	4286	82	546	107	558	16.8	6161050	621020	750
FR-91-111	Quartz Ash-Flow Tuff (Unit 4)	357	6195	113	552	437	1180	50.5	6158390	620255	1050
FR-91-213	Aphyric Ash-Flow Tuff (Unit 4; fragment)	375	6277	118	553	399	1178	25.3	6161030	622495	2220
FR-91-097	Quartz-poor Ash-Flow Tuff (Unit 4)	365	4702	94	584	45	452	14.6	6161905	620610	850
FR-91-098	Aphyric Ash-Flow Tuff (Unit 4)	405	5300	107	587	289	1062	28.9	6161840	620590	900
FR-91-016	Quartz-poor Ash-Flow Tuff (Unit 4)	429	5838	116	640	410	1237	28.3	6162585	616090	1000
FR-91-017	Aphyric Ash-Flow Breccia (Unit 4)	473	7085	116	692	59	593	12.7	6162615	616075	1120
FR-91-211	Quartz Ash-Flow Tuff (Unit 4)	521	8094	164	792	534	1542	40.9	6161080	622435	1150
FR-91-10	Aphyric Ash-Flow Breccia (Unit 4)	616	10519	211	910	845	2278	19.5	6159700	620200	2050
FR-91-214	Aphyric Ash-Flow Breccia (Unit 4)	646	11162	222	1024	596	1876	33.6	6161010	622570	2000
FR-91-114	Quartz-poor Ash-Flow Tuff (Unit 4)	647	9382	202	1039	809	2151	16.9	6157690	620985	1500
FR-91-134	Quartz-poor Ash-Flow Tuff (Unit 4)	766	11569	247	1161	766	2237	13.1	6156950	621205	1750
FR-91-141	Quartz Ash-Flow Tuff (Unit 4)	1414	21104	403	1888	604	2518	54.5	6157160	621125	3000

Chemical analyses by I.C.P. analysis; values in p.p.m.
Spectr. = cps reading from an EDA GRS-500 spectrometer set for total counts (TC1)

(Unit 2), contain anomalous Y values but they are minor in extent.

The highest values of Y were obtained from the Crystal-poor and quartz-phyric ash-flow Unit (Unit 4), which has average values, for all but one of its subunits, from 300 to 600 ppm and contains all samples, but one, which have values over 490 ppm Y (Table 1). The aphyric or basal subunit has an average of 130 ppm Y, which is similar to that of the units which occur below it.

The Upper ash-flow Unit (Unit 5) exhibits Y values that increase upward from 189 ppm for the feldspar–quartz ash-flow tuff, through 373 ppm for the ash-flow lapilli tuff and

Table 2. Rare-metal values and averages for stratigraphic units in the Nuiklavik felsic volcanic rocks

	Nb	Zr	Th	Y	La	Ce	Be	Spectr.
Upper Ash-Flow Unit (#5)								
Amphibole Ignimbrite	329	4502	94	462	310	808	13	840
Amphibole Ignimbrite	327	4286	82	546	107	558	17	750
Ash-Flow Lapilli Tuff	325	2100	44	373	140	410	17	520
Feldspar-Quartz Ash-Flow Tuff–Average (7)	134	2115	28	189	234	513	11	464
Crystal-poor and Quartz-phyric Ash-Flow Unit (#4)								
Quartz Ash-Flow Tuff–Average (6)	307	5586	90	480	302	878	27	816
Quartz Ash-Flow Breccia–Average (4)	218	3548	57	308	331	662	11	690
Quartz Ash-Flow Tuff (non-compacted)	1414	21104	403	1888	604	2518	55	3000
Aphyric Ash-Flow Tuff–Average (6)	283	4663	79	419	249	803	14	938
Aphyric Ash-Flow Tuff (non-compacted)	338	4912	79	492	392	1081	20	1000
Aphyric Ash-Flow Tuff (non-compacted)	350	5185	82	499	359	1006	19	760
Aphyric Ash-Flow Breccia–Average (7)	383	6099	115	582	348	2059	17	1189
Quartz-poor Ash-Flow Tuff–Average (12)	321	5505	100	563	509	1200	17	895
Quartz-poor Ash-Flow Breccia	184	3736	35	228	75	403	4	520
Quartz-poor Ash-Flow Breccia	137	2030	36	197	33	154	7	420
Feldspar + Quartz-poor Ignimbrite–Average (17)	214	3657	58	326	276	805	19	669
Aphyric Flow–Average (22)	87	1729	15	130	191	438	7	334
Lower Crystal-rich Ash-Flow Unit (#3)								
Quartz Porphyry–Average (5)	46	803	14	72	147	303	5	320
Quartz Porphyry Breccia	42	974	18	90	114	284	6	400
Quartz Porphyry Breccia	72	1378	21	94	118	317	5	250
Quartz-Mafic Porphyry–Average (11)	44	759	7	75	112	252	5	314
Feldspar-Quartz Porphyry–Average (10)	74	1156	12	103	162	360	7	327
Amphibole-bearing Porphyritic Unit (#2)								
Amphibole-bearing Ignimbrite–Average (13)	291	3568	47	318	225	642	29	545
Amphibole-Feldspar-Quartz Porphyry–Average (22)	117	1604	12	136	262	572	11	358
Feldspar-Quartz ± Amphibole Porphyry–Average (28)	47	850	8	78	159	321	7	315
Basal Tuff Unit (#1)								
Bedded & Massive Tuffs–Average (6)	13	232	8	31	27	71	5	298
Carbonate Unit	1	3	0	3	6	9	0	150
Gabbro Sill	3	182	0	31	23	53	1	200
Gabbro Sill	4	157	0	31	25	54	3	185
Flowers River Granites								
Granite Aplite	289	5599	92	432	315	838	33	940
Microgranite–Average (13)	80	1210	17	96	184	407	10	341
Coarse Granite–Average (7)	55	692	6	50	135	300	5	254

Average (6) = 6 samples used to calculate average
Rare-metal analyses by I.C.P. analysis

to 506 ppm for the amphibole ignimbrite. The amphibole ignimbrite subunit in the Amphibole-bearing porphyritic Unit (Unit 2) has average Y values which are 200 ppm less than the amphibolite ignimbrite subunit of the Upper ash-flow Unit (Unit 5). Also, one of the amphibole ignimbrite samples has a highly anomalous Y value (546 ppm) and is the only highly anomalous sample outside of Unit 4.

The relative relationships observed for Y between the various subunits and units of the Nuiklavik felsic volcanic rocks are also observed for the other rare-metals listed in Table 1. Zirconium values, in particular, mirror the relationships outlined above and they also reflect the highly anomalous, economically very interesting, absolute values of Y.

Nb	Zr	Th	Y	Unit
122	1885	27	175	Upper Ash-Flow Tuff (Unit 5)
521	8094	164	792	Quartz Ash-Flow Tuff (Unit 4)
375	6277	118	553	Aphyric Lithic Ash-Flow Breccia (Unit 4)
646	11162	222	1024	Quartz-poor Ash-Flow Tuff (Unit 4)
				Ash-Flow Breccia (Unit 4)
112	1941	20	240	Aphyric Ash-Flow Tuff (Unit 4)
118	211	22	176	Quartz-poor Flow (Unit 4)

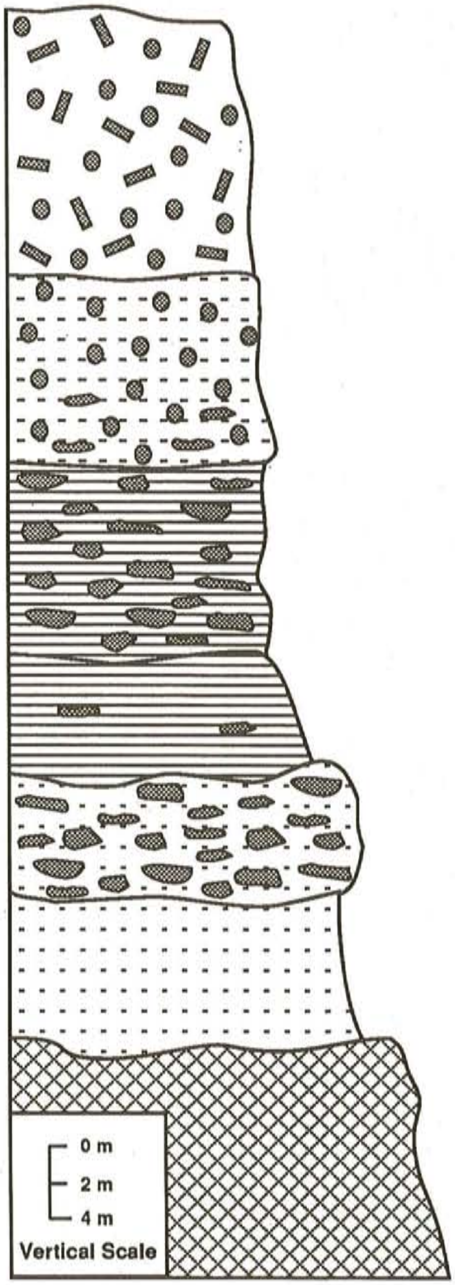

Figure 5. *A complete detailed section through the Crystal-poor and quartz-phyric ash-flow Unit of the Nuiklavik felsic volcanic rocks; this unit contains the most anomalous Y and other rare-metal values.*

For the purposes of this study, highly anomalous Y values are any values above 490 ppm. A total of 21 samples (see Figure 4 for sample locations) occur in the highly anomalous range of values. Most of these samples occur in the Crystal-poor and quartz-phyric ash-flow Unit (Unit 4), particularly the quartz-poor ash-flow, the aphyric ash-flow and the quartz ash-flow subunits. Almost all of the aphyric ash-flow samples are highly anomalous (11 out of 15), whereas the quartz-poor ash-flow and quartz ash-flow subunits have an anomalous population, which is approximately one-third of the total (6 out of 17 and 3 out of 10 respectively); samples with Y values over 900 ppm are evenly distributed between these three subunits.

Figure 5 is a complete detailed section of an exposure of the rare-metal-enriched Crystal-poor and quartz-phyric ash-flow Unit (Unit 4; see Figure 4 for location). The mineralized samples are found in quartz-poor ash-flow tuff and breccia, and quartz ash-flow tuff and breccia. Fragment types are dominantly aphyric flow and quartz-poor ash-flow tuff; many if not all fragments are also mineralized. This section contains

32 m of mineralized ash-flow units that have Y values in the range between 550 and 1020 ppm. Other mineralized partial sections of this unit range from 4 to 10 m thick with comparable or higher Y values. Figure 4 illustrates the distribution of the Crystal-poor and quartz-phyric ash-flow Unit (Unit 4) and the location of the highly mineralized samples in it.

Petrographic studies of the mineralization are ongoing. The aphanitic to very fine-grained nature of the mineralized units has made it very difficult to identify rare-metal minerals. Preliminary results suggest that the rare-metal mineralization occurs as sub-microscopic grains in the groundmass of the ash-flow tuff and in the groundmass of breccia fragments.

CONCLUSIONS

Highly anomalous Y and other rare-metal mineralization occur in felsic ash-flow tuffs and breccias of the Crystal-poor and quartz-phyric ash-flow Unit (Unit 4) of the Nuiklavik felsic volcanic rocks. This mineralization has been observed to be 32 m thick in one occurrence and at least 4 m thick over an area of 14 km^2; Y values range from 300 to 1900 ppm in this unit and Zr values are commonly greater than 4000 ppm.

The Nuiklavik felsic volcanic rocks are an excellent target for rare-metal mineralization. This preliminary work has established the stratigraphy of the volcanic rocks and has outlined the location of the stratigraphically controlled rare-metal mineralization. More detailed exploration work, including drilling and metallurgical work, is needed to further evaluate this mineralization. These rare-metal showings, located in the Flowers River area, are presently open for claim staking.

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