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STUDIES IN THE SEAL LAKE GROUP, CENTRAL LABRADOR, PART II: GEOCHEMISTRY OF DIABASE SILLS

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ABSTRACT

The intermixed basaltic flow and continental sedimentary rocks of the Middle Proterozoic Seal Lake Group in central Labrador are intruded by the numerous diabasic to gabbroic sills of the Naskaupi sills unit. The major and trace-element geochemistries of thirty-five samples of these sills were analyzed to define, 1) the petrogenesis of the sills, 2) the geochemical signatures of copper-bearing ore fluids that flowed through the contact zones of some sills, and 3) the Platinum-Group Element (PGE) potential of the sills. The sills are transitional tholeiitic to alkalic in composition and resemble typical continental flood or plateau basalts. Those sills affected by the copper-bearing hydrothermal fluids have extreme depletions in K, Rb and Ba and slight enrichments in Sr. The sills do not appear to be a good prospect for PGE mineralization.

INTRODUCTION

As described in part I (Wilton, *this volume*), the Seal Lake Group consists of six mixed igneous and sedimentary formations (Brummer and Mann, 1961; Gandhi and Brown, 1975), the middle members of which (the Wuchusk Lake, Whiskey–Salmon Lake, and Adeline Island formations) are intruded by diabasic to gabbroic sills (Figure 1). These sills are so numerous in the Wuchusk Lake Formation, south of Adeline Lake that they constitute > 70 percent of the interval between the underlying Bessie Lake Formation and the overlying Whiskey–Salmon Lake Formation.

Baragar (1969, 1974, 1981) completed detailed petrographical and geochemical studies of the sills, north of Seal Lake on the northern limb of the Seal Lake syncline. In this present study, the sills south of Seal and Adeline lakes (i.e., in the southern limb of the syncline) were examined. The stratigraphy in the southern limb is compressed compared to that of the northern limb because of thrust faulting (Brummer and Mann, 1961), and the sills south of Seal Lake also contain numerous copper occurrences. Detailed prospecting (Brummer and Mann, 1961; Gandhi and Brown, 1975) has failed to reveal any significant occurrences north of the lake. Thus, the aim of this study was to compare the sills south of the lake and syncline, with those described by Baragar (1981) to the north.

PREVIOUS WORK

Evans (1952) described diabase sills as being intrusive into all formations of the Seal Lake Group. He also mentioned the very coarse grained nature of the sills near Adeline Lake.

Fahrig (1957) suggested that the diabasic to gabbroic sills are concentrated between the mafic volcanic rocks of the Bessie Lake Formation and the mixed red slate and basaltic volcanic members of the Salmon Lake Formation. He described the sills as being up to hundreds of feet thick, and associated with coarse plagioclase and pyroxene crystals (up to 2.5 cm in diameter), in the central parts of the sills. He also noted the presence of olivine during microscope studies.

Brummer and Mann (1961) subdivided the diabase sills into two different formations, *viz.*, those within the Wuchusk Lake Formation and those within the Salmon Lake Formation. The Wuchusk sills, along the southern limb of the syncline, are metadiabase due to saussuritization of plagioclase, serpentization of the olivine, and chloritization and epidotization of augite. The Salmon Lake sills are also described (*ibid.*) as metadiabase, but more closely resemble the basalt flows within their host unit, than the diabase sills in the Wuchusk Lake Formation.

Roy and Fahrig (1973) suggested a five-fold subdivision of the Seal Lake Group in which Unit 2, a volcanic and sandstone unit (the Majoqua Formation), and Unit 4, a volcanic and shale unit (the Salmon Lake Formation), were seperated by Unit 3, a diabase with sandstone and shale unit (i.e., the Wuchusk Lake Formation). To these authors, diabase intrusion between the two periods of volcanism represented the continuation of the igneous activity. They supported this supposition with geochemical data, which 'suggested a common magma source' (Roy and Fahrig, 1973, p. 1291) and they defined the volcanics and diabase as undersaturated tholeiites.

Gandhi and Brown (1975) stated that the diabase sills intrusive into the Adeline Island, Salmon Lake and Wuschusk formations were related to Salmon Lake Formation magmatic activity. They suggested that the diabase unit, intrusive into the Adeline Island Formation sedimentary rocks north of Brandy Lake, was actually posttectonic (post-Grenville), and

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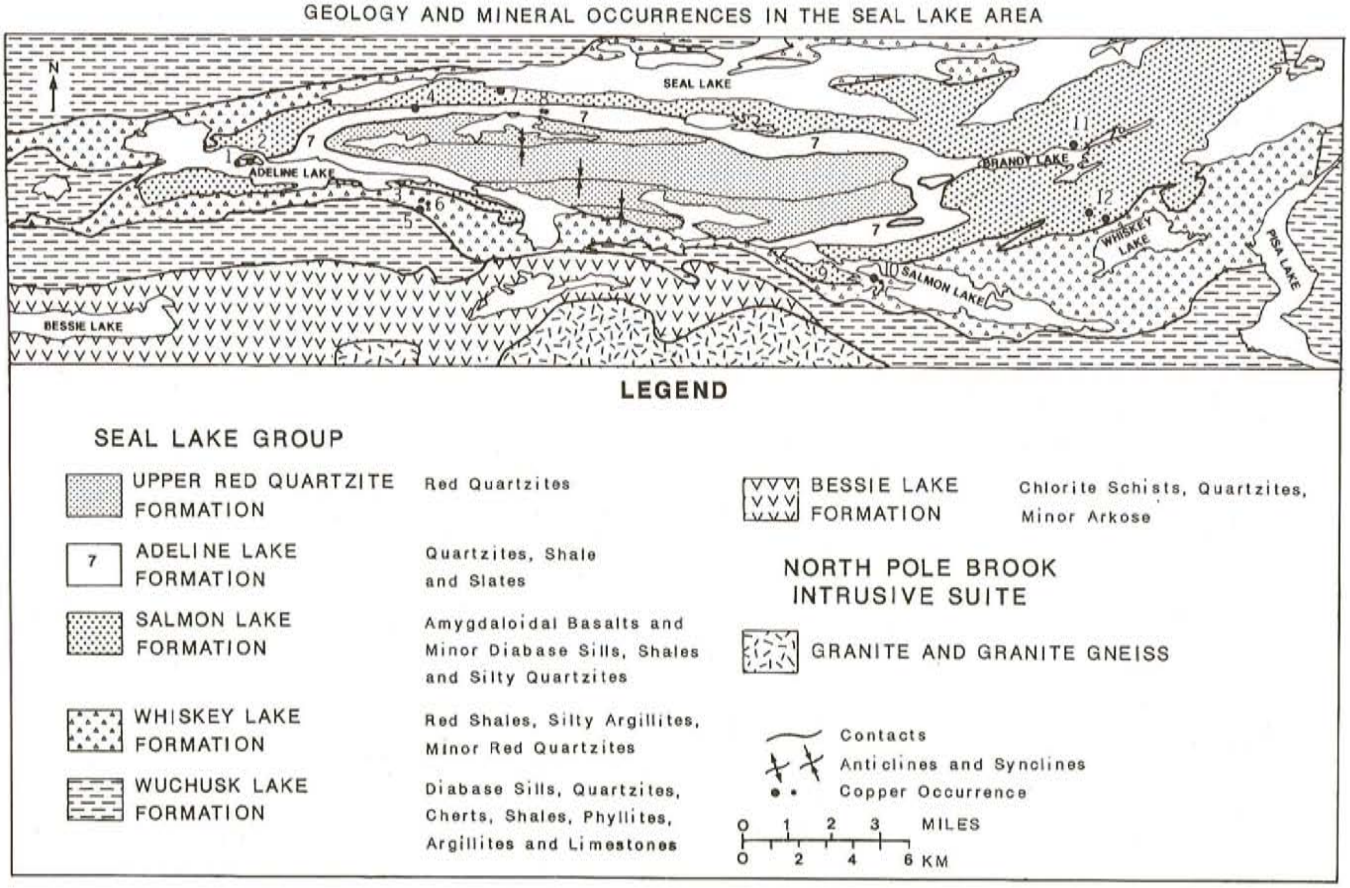

Figure 1. *Geology of the Seal Lake Group (after Brummer and Mann, 1961). Key to deposit numbers and copper occurrences have been described and discussed. Most of the area underlain by the Wuchusk Lake Formation consists of diabasic Naskaupi sills (> 70 percent south of Adeline Lake). There are also numerous diabase sills in the Salmon Lake Formation and a few in the Adeline Island and Whiskey Lake formations.*

therefore unrelated to the 'deformed' diabase sills stratigraphically lower inthe Seal Lake Group.

Baragar (1981), mainly describing the Seal Lake Group north of Seal Lake, grouped all the sills into a new unit that he called the Naskaupi sills. He termed the sills, dolerite, and described them as intrusive into the Wuchusk Lake, Salmon Lake and Adeline Island formations. Baragar (1981) suggested that the sills intruded the thick accumulation of sedimentary rocks in the Seal Lake basin just prior to renewed volcanism, represented by the Salmon Lake Formation. He further defined the sills as being somewhat transitional between alkaline and subalkaline tholeiitic in composition, and that they could be termed the products of potassic or K-rich basalt magmas.

Meyers and Emslie (1977) and Emslie (1980) directly correlated the Naskaupi sills with the regionally extensive Harp dykes. These latter dykes were defined by these authors as having a chemical composition transitional between tholeiitic and alkalic. Emslie *et al.* (1984) similarly correlated the Mealy dyke swarms of the Grenville Province with the Seal Lake (Naskaupi sill) diabases. Wiebe (1985) suggested that dykes cutting the Nain Anorthosite Complex were compositionally and temporally similar to the Harp dykes and, hence, the Naskaupi sills.

Description of the sills

The diabase sills are best exposed in two sets of steep cliffs that trend east–west through the area as a ridge along the southern shoreline of Seal Lake, and as a prominant ridge extending from the southern shore of Adeline Lake to the southern shore of Salmon Lake (Figure 1); the former ridge rises up to 200 m above Seal Lake and the latter up to 300 m above Adeline Lake (at Adeline Mountain). In both cases, the ridges are capped by diabase sills, and there are thinner sills present in the Seal Lake cliff face below the cap. Adeline Mountain (or Wuchoo Mountain, Brummer and Mann, 1961), at > 540 m above sea level is the highest hill in the area, and is a perfect example of the typical diabase profile (Plate 1), wherein Whiskey Lake Group slates are 'capped' by 120 m of diabase dipping gently to the north.

Exposed contacts are often difficult to find due to vegetation cover, but locally, very fine grained phases are

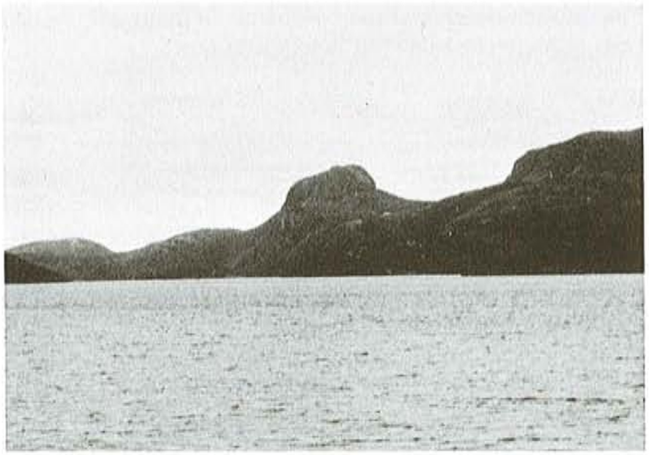

Plate 1. *View to the east along Adeline Lake with Adeline (Wuchoo) Mountain in the centre. This monadnock is capped by a diabase sill (shown by the change in slope) and underlain by hornfelsed shale; the ridge along the right is also capped by diabase.*

found within coarse layers implying the intrusion of sills within sills. Sedimentary lithologies (especially slates) are extensively hornfelsed in contact regions (in places, red slate is hornfelsed into black slate). Well developed columar jointing is evident in some of the thicker sills (Plate 2).

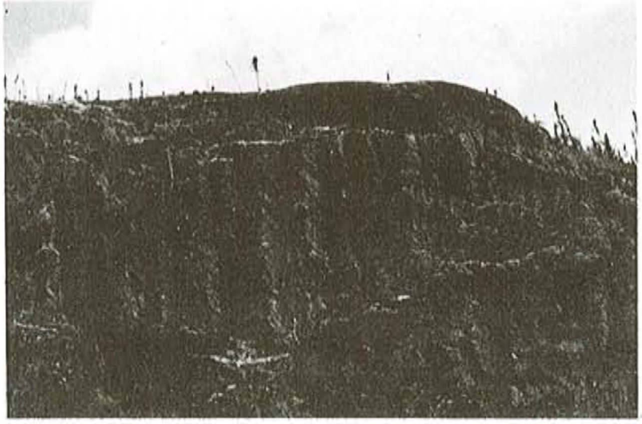

Plate 2. *Columnar jointing in diabase sill intrusive into the Salmon Lake Formation south of Seal Lake.*

The coarsest grained diabase, which occurs south of Adeline Lake, contains pyroxene crystals up to 2 by 2 cm, plagioclase laths up to 0.5 by 2.5 cm, together with magnetite blades (up to 2 cm by 3 mm) and rare, disseminated pyrite. Diabase, which is intrusive into the Salmon and Adeline Lake formations, is finer grained, more equigranular, and displays visible epidote alteration. As described in Wilton (*this volume*), the contact zones of the sills are the loci for quartz–carbonate veins containing copper sulphide mineralization.

Geochemistry

Geochemical analyses have been completed on thirty-five diabase–gabbro samples of the Seal Lake Group (Table 1) from the southern limb of the syncline (south of Seal Lake). Major-element analyses were done by atomic absorption techniques, and the trace-element determinations by XRF analysis of pressed powder pellets (Longerich and Veinott, 1986) at Memorial University.

One of the reasons for sampling the diabase sills was to define their PGE potential. Analysis for these elements has yet to be performed. However, other geochemical data from the Naskaupi sills tend to downplay their potential for significant primary (or orthomagmatic) concentrations of these elements. In all known examples of PGE concentrations within undeformed mafic to ultramafic rocks (the Naskaupi sills sampled are undeformed), platinoid minerals are associated with either chromite-bearing horizons and/or nickeliferous sulphides (e.g., Dillon-Leitch *et al.*, 1986; Irvine *et al.*, 1983; Macdonald, 1987). However, Ni and Cr concentrations within the Naskaupi sills are quite low, with Cr contents generally < 200 ppm (one sample had 317 ppm) and Ni also mostly < 200 ppm, implying that Cr and Ni-bearing phases are substantially lacking. The spinel present within the sills is obviously magnetite to titanomagnetite (as shown by the elevated TiO_2 contents of up to 3.8 wt percent).

In terms of some classic variation diagrams, the Naskaupi sills have a transitional subalkaline to alkaline (Figure 2) tholeiitic (Figure 3) composition. On Pearce and Cann's (1973) Ti *versus* Zr discrimination diagram (Figure 4a), the sills plot partly in the ocean-floor basalt (OFB) field, but are also so enriched in Zr and Ti that half of the samples plot outside the defining fields. However, on the Zr–Ti–Y discrimination diagram (Figure 4b) from Pearce and Cann (1973), the sills plot as transitional between calc-alkali and within plate basalts.

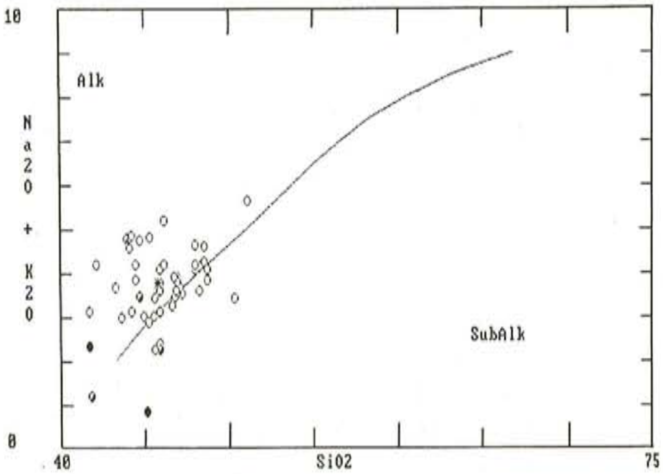

Figure 2. *Total alkalies vs. silica diagram for Naskaupi sill samples. Fields for alkaline (Alk) and subalkaline (SubAlk) magmas are from Irvine and Baragar (1971). Open circles are normal diabase, half-filled circles are of diabase having visible copper mineralization, filled circles are of diabase from near copper occurrences but are not actually copper or vein-bearing, the * symbol represents Baragar's (1981) average Nasakupi sill composition.*

Table 1. Geochemical data for Naskaupi sills; major oxide data reported in weight %; trace elements in ppm; n.d. = not detected; – = not analysed; Bar-avdol = Baragar's (1981) average Naskaupi sill composition.

	W87-105	W87-16	W87-46B	W87-71A	W87-31A	W87-93D	W87-46A	W87-81I	W87-81D
SiO_2	47.20	35.70	45.10	45.90	46.10	46.90	41.80	43.90	45.90
TiO_2	1.88	2.24	1.80	1	1.52	3.60	2.04	1.68	1.24
Al_2O_3	14.60	18.50	16	18.30	15.20	11.80	17.20	17.40	16.50
FeO	13.28	16.50	13.15	10.55	12.58	17.66	13.60	13.64	12.12
MnO	0.19	0.19	0.19	0.14	0.22	0.24	0.20	0.18	0.17
MgO	5.28	6.69	6.28	10.06	6.64	4.71	6.82	7.51	6.66
CaO	8.82	11.08	9.28	9.68	6.96	9.16	9.28	4.24	9.22
Na_2O	2.63	1.29	0.84	1.95	2.16	2.68	1.18	3.93	2.24
K_2O	0.90	n.d.	n.d.	0.43	3.04	0.84	n.d.	0.85	0.02
P_2O_5	0.25	0.22	0.22	0.11	0.21	0.24	0.22	0.24	0.20
Total	98.03	92.78	92.78	98.12	94.63	97.83	92.34	93.57	94.27
H_2O	-	-	-	-	-	-	-	-	-
CO_2	-	-	-	-	-	-	-	-	-
LOI	2.35	4.66	4.09	0.72	2.77	0.76	4.57	4.17	3.50
Mg #	41	42	46	63	48	32	47	50	49
Cr	65	148	108	144	101	n.d.	122	95	73
Ni	38	98	124	224	67	n.d.	138	122	156
Co	-	-	-	-	-	-	-	-	-
Sc	-	-	-	-	-	-	-	-	-
V	256	336	267	106	237	588	289	197	203
Cu	102	100	177	40	68	219	8345	71	72
Pb	n.d.	26	n.d.	n.d.	n.d.	2	n.d.	1	n.d.
Zn	103	122	108	54	103	128	127	128	102
Sn	-	-	-	-	-	-	-	-	-
K	7471	n.d.	n.d.	3569	25235	6973	n.d.	7056	166
Rb	17	n.d.	n.d.	9	81	17	n.d.	20	n.d.
Ba	364	1	66	106	517	354	n.d.	311	n.d.
Sr	264	723	023	273	193	215	1036	110	558
Ga	18	25	20	17	22	23	18	18	16
Nb	11	10	8	6	7	11	10	8	8
Zr	168	175	157	65	128	157	173	130	133
Ti	11271	13429	10791	5995	9112	21582	12230	10072	7434
Y	35	34.8	27	10	33	41	29	28	25
Th	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
U	3	5	n.d.	n.d.	3	3	n.d.	5	6
La	14	6	13	1	8	8	7	9	4

According to Condie *et al.'s* (1987) TiO_2 *versus* Zr discrimination diagram (Figure 5), the Naskaupi sill samples all plot in the combined midocean ridge–continental rift–oceanic-island basalt field similar to their Superior Province dyke data. The Naskaupi sills more closely resemble Condie *et al.'s* (1987) Archean and Early Proterozoic dykes than their Middle Proterozoic dykes, which are more enriched in incompatible elements. This later (Middle Proterozoic) enrichment was modelled (*ibid.*) as the result of assimilation of more evolved continental crust.

All the diabase samples collected for this study have similar compositions and generally exhibit coherent groupings on trace-element variation diagrams (e.g., Figures 2 to 5). The compositions are the same as those defined by Baragar (1981). Samples of diabase associated with epigenetic copper occurrences, however, have distinctive variations from the main group, for example Sr is increased (Figure 6) and SiO_2 decreased (Figure 7).

The [Mg] (where [Mg] = $(Mg/(Mg+Fe^{+2})$ and Fe^{+3}/Fe^{+2} = 0.15) values for the samples range from 0.19 to 0.62, but are generally less than 0.5 (Figure 7). Such low [Mg] values (< 0.68) coupled with the low Ni and Cr contents are typical of evolved lavas that have undergone extensive fractionation prior to intrusion (e.g., Goldberg *et al.*, 1986; Wiebe, 1985).

Table 1. *(Continued)*

W87-106	W87-74	W87-117	W87-88C	W87-71B	W87-80	W87-88A	W87-78A	W87-78B	W87-77B
48.20	45.90	48.70	46.90	46.80	45.90	48	45.90	48	51.10
1.72	1.20	2.32	3.80	1.72	3.04	2	3.80	2.92	2.80
14.70	17.50	13.50	11.20	15.90	10.60	12.90	10.60	11.20	12.60
11.10	11.60	14.28	18.45	12.65	14.88	16.57	18.74	16.77	15.21
0.17	0.16	0.20	0.26	0.21	0.22	0.23	0.28	0.26	0.26
6.17	8.41	5.19	4.12	6.82	6.30	3.71	3.54	3.80	2.02
9.54	9.04	7.44	8.58	9.58	11.16	8.08	8.08	8.80	7.06
2.80	2.54	2.99	2.61	3.02	2.39	2.74	2.75	3.64	4.24
1.36	0.58	0.86	1.18	0.45	1.20	1.44	1.34	0.98	1.40
0.02	0.17	0.27	0.35	0.22	0.30	0.33	0.68	0.63	0.88
95.78	97.10	95.75	97.45	97.37	95.99	96	95.71	97	97.57
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
2.07	0.10	2.88	0.55	1.95	0.90	1.13	1.92	1.29	1.12
50	56	39	28	49	43	29	25	29	19
76	47	53	n.d.	216	67	70	n.d.	29	19
69	132	25	n.d.	61	16	n.d.	n.d.	n.d.	n.d.
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
234	136	259	511	213	45	194	154	259	65
72	53	104	216	n.d.	253	32	170	178	55
n.d.	n.d.	2	n.d.	n.d.	1	4	n.d.	n.d.	1
81	68	112	143	75	93	133	194	164	169
-	-	-	-	-	-	-	-	-	-
11289	4815	7139	9795	3735	9961	11953	11123	8135	11621
27	13	21	33	8	26	43	47	31	36
677	266	350	443	224	333	473	521	389	494
244	311	204	220	285	186	239	228	302	243
19	20	20	25	19	19	21	24	22	27
8	5	11	13	9	11	12	20	18	28
129	86.8	212	197	111	153	194	259	259	418
10311	7194	13908	22781	10311	18225	11990	22781	17505	16786
30	18	42	47	22	37	45	56	58	78
n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
n.d.	n.d.	4	n.d.	4	3	6	2	5	1
3	5	16	16	5	11	27	24	24	43

Spidergrams

A rapid method for evaluating overall geochemical distributions and heterogeneity of a group of rocks is acheived with construction of extended trace-element variation diagrams (or 'spidergrams' after Thompson *et al.*, 1984). Figure 8 (a to h) consists of a number of these diagrams for all the Naskaupi sill samples analyzed (they are ratioed to Primitive Mantle values of Taylor and McLennan (1981) and Jenner *et al.* (1987)). There is a significant chemical coherence between all the samples from this study, and Baragar's (1981) average dolerite plots within this grouping. The high K (and Rb) nature of these sills as defined by Baragar (1981) is also borne out.

The overall patterns for the Naskaupi sills are, not surprisingly, quite similar to those for continental flood basalts (Figure 8g and h) from Thompson *et al.* (1983, 1984). Figure 8g shows typical patterns for continental flood basalts that resemble ocean-island basalts; Thompson *et al. (op. cit.)* suggest these magmas represent uncontaminated melts from ocean-island basalt mantle. Figure 8h illustrates Thompson *et al. (op. cit.)* patterns for continental flood basalts that have been variably contaminated by assimilation of continental crust upon magma ascent through the crust.

In general, the Naskaupi sills are intermediate between these two types of continental flood basalts. Compared to the ocean-island basalts and the continental flood basalts, the

Table 1. *(Continued)*

	W87-81E	W87-63	W87-72B	W87-42	W87-88B	W87-36	W87-16A	W87-77A	W87-31B
SiO_2	44.70	46.60	44.20	43.60	48.20	74.70	41.70	46.90	45.90
TiO_2	1.44	1.72	1.84	1.36	2.44	0.12	2.24	2.32	1.44
Al_2O^a	16.50	15.60	16.90	16.20	12.10	13.60	16.20	15.60	15.30
FeO	12.65	12.27	11.90	12.10	15.02	0.06	15.15	11.01	12.65
MnO	0.20	0.17	0.16	0.16	0.22	n.d.	0.21	0.19	0.17
MgO	6.89	6.35	7.98	10.08	5.04	0.02	5.75	5.57	7.02
CaO	8.56	9.32	9.54	8.28	9.54	0.18	9.28	9.68	7.86
Na_2O	2.90	2.51	2.44	2.42	2.58	3.22	2.19	2.89	1.79
K_2O	0.56	0.75	0.68	0.54	1.02	6.98	0.14	1.03	1.98
P_2O_5	0.19	0.21	0.24	0.16	0.29	0.02	0.27	0.40	0.16
Total	94.59	95.50	95.88	94.90	96.45	98.90	93.13	95.59	94.27
H_2O	-	-	-	-	-	-	-	-	-
CO_2	-	-	-	-	-	-	-	-	-
LOI	3.19	2.73	1.26	3.33	0.99	0.10	3.95	1.30	2.88
Mg #	49	48	54	60	37	37	40	47	50
Cr	66	76	80	53	196	n.d.	94	120	77
Ni	124	106	159	214	4	n.d.	41	50	93
Co	-	-	-	-	-	-	-	-	-
Sc	-	-	-	-	-	-	-	-	-
V	231	234	192	164	417	239	293	270	233
Cu	73	84	70	4	133	n.d.	118	97	72
Pb	5	n.d.	1	n.d.	n.d.	9	18	n.d.	1
Zn	101	94	73	76	119	139	142	84	97
Sn	-	-	-	-	-	-	-	-	-
K	4649	6226	5645	4483	8467	57934	1162	8550	16435
Rb	14	17	14	20	28	75	3	25	51
Ba	183	282	215	89	363	549	393	312	469
Sr	330	306	295	234	231	638	508	271	205
Ga	17	22	19	16	23	26	21	20	18
Nb	8	7	8	7	10	23	11	13	7
Zr	133	125	115	88	166	465	194	162	114
Ti	8633	10311	11031	8153	14628	719	13429	13908	8633
Y	26	26	23	22	39	91	36	36	26
Th	n.d.	n.d.	n.d.	n.d.	n.d.	6 0	n.d.	n.d.	n.d.
U	n.d.	n.d.	6	n.d.	n.d.	8	n.d.	n.d.	4
La	5	11	4	n.d.	12	48	16	11	6

Naskaupi sills have variably lower contents of K, La, Nb and Sr (the Sr differences may reflect different degrees of plagioclase fractionation). The La/Nb ratios of the Naskaupi sills lie between 0.5 and 2, which according to Thompson *et al.* (1983, 1984) is the general field of continental flood basalts. Continental flood basalts that resemble ocean-island basalts would normally have La/Nb ratios of about 1. According to Thompson *et al.* (1983, 1984) addition of normal crustal material to an ocean-island basalt–continental flood basalt melt, should provide a relative increase of K and La and decrease of Nb in the magma. Therefore, it would appear that if the parental magmas of the Naskaupi sills were contaminated, then the contaminant material would have to have been depleted (e.g., granulite) crust (i.e., something from which these typical mobile (fusible) components had been already removed).

Such a conclusion is supported by the isotopic data of Ashwal *et al.* (1987), which demonstrated only minor upper sialic crust contamination of the Harp dykes parental magma (i.e., correlatives of the Naskaupi sills). According to Ashwal *et al.* (1987) the actual contaminants to the mantle-derived parental magma would have been depleted in Rb, U–Pb and Th–U, and as such, probably represent Archean gneiss (by inference, this crust was probably granulitized–hence assimilation by the mafic magma would provide minimal addition of the typical upper crustal elements).

Table 1. *(Concluded)*

W87-72C	W87-65	W87-60C	W87-71E	W87-92	W87-71C/D	W87-71F	Bar-avdol
45.60	48	45.60	48.50	48.70	47.10	48.50	45.77
1.64	2.24	1.68	2.28	2.32	1.80	2.72	2.03
18.20	15.20	15.10	14.40	12.90	16	14.10	17.05
10.73	14.01	12.74	11.82	14.32	11.05	12.59	12.26
0.16	0.20	0.18	0.18	0.22	0.18	0.18	0.18
6.91	4.40	6.68	4.62	4.77	6.33	4.81	7.08
9.84	8.20	9.76	10.48	9.50	10.40	10.40	9.02
2.69	2.84	1.91	3.48	3.11	2.92	3.28	2.96
0.75	1.24	0.33	1.11	0.99	0.75	0.96	0.82
0.24	0.25	0.22	0.51	0.32	0.21	0.28	0.25
96.76	96.58	94.20	97.38	97.15	96.24	97.82	97.42
-	-	-	-	-	-	-	3.26
-	-	-	-	-	-	-	0.13
1.29	2.47	2.98	1.08	1.16	1.29	1.04	-
53	36	48	41	37	51	41	51
69	150	79	244	311	190	119	109
124	17	120	4	5	52	9	117
-	-	-	-	-	-	-	53
-	-	-	-	-	-	-	28
164	264	228	287	350	223	415	287
61	95	75	80	170	80	127	156
4	n.d.	1	n.d.	2	n.d.	6	5
69	111	100	69	128	62	78	185
-	-	-	-	-	-	-	1.61
6226	10293	2739	9214	8218	6226	7969	6807
13	26	6	23	25	15	21	n.d.
233	321	126	3471	452	221	287	223
300	271	338	263	272	270	240	271
20	21	18	21	23	18	21	32
9	10	7	13	10	9	12	-
122	162	132	170	170	113	174	155
9832	13429	10072	13669	13908	10791	16306	12170
23	35	24	38	37	25	36	31
n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-
5	n.d.	1	n.d.	1	n.d.	2	-
10	9	13	22	16	60	9	-

As a final note, samples W87-60C and W87-63 were collected from the diabase ridge north of Brandy Lake. As shown on Figure 8b and e, these samples are exactly the same geochemically as the other sill samples. Thus, Gandhi and Brown's (1975) supposition that the sill north of Brandy Lake is post-Grenville, and therefore unlike the other sills, is probably incorrect.

Figure 9a and b are spidergrams of diabase samples that were mineralized with copper sulphide, or are from the vicinity of mineralization (the values for Baragar's (1981) average dolerite are also plotted on this diagram for comparison). This diagram illustrates the great changes in geochemistry brought about by reaction of the ore-forming fluids with the host diabase.

The unusual geochemical composition (and hence pattern) for sample W87-36 (Figure 8) is not as readily apparent. This sample was collected from a small island in Salmon Lake, wherein a diabase unit contained abundant disseminated pyrite and some minor quartz veining. It may actually reflect an earlier mineralizing event more closely related to magmatism (or a later event). Its main features are increased La and Zr and decreased Ti contents.

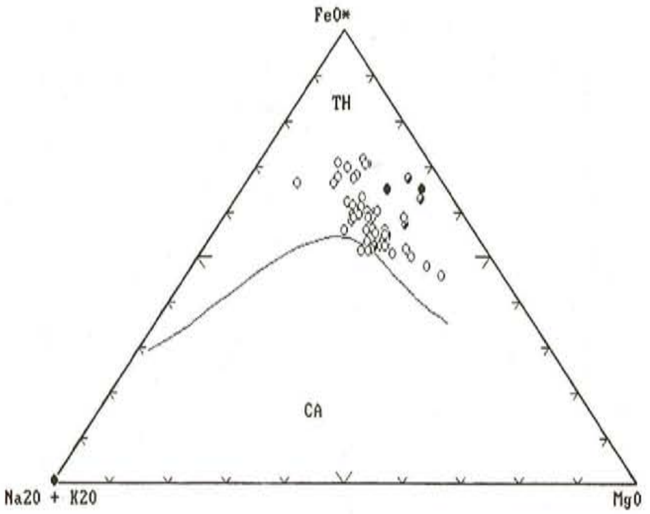

Figure 3. *AFM diagram for Naskaupi sill sample fields for tholeiitic (TH) and calc-alkaline (CA) magmas from Irvine and Baragar (1971) (the symbols are described in Figure 2).*

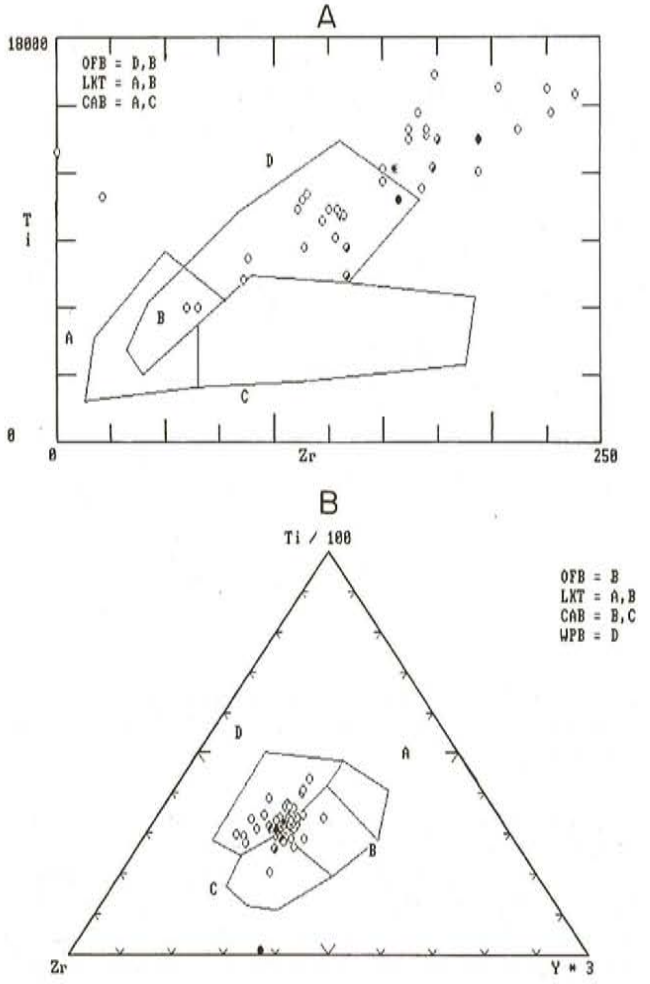

Figure 4a and b: *Trace-element discrimination diagrams (from Pearce and Cann, 1973) for Naskaupi sill samples. OFB = ocean floor basalts; LKT = low K tholeiites; CAB = calcalkaline basalts; and WPB = within plate basalts (symbols as in Figure 2).*

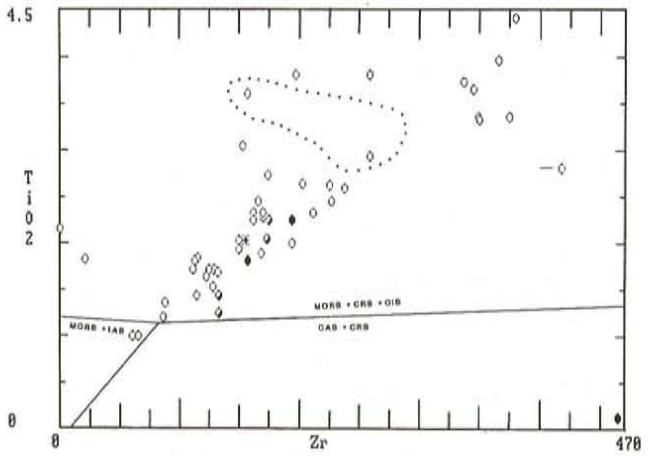

Figure 5. *TiO_2 vs. Zr plot for Naskaupi sill samples (symbols as in Figure 2). Subdivisions from Condie et al. (1987). MORB = mid-ocean ridge basalt, IAB = island-arc basalt, CRB = continental rift basalt, and OIB = ocean-island basalt. The dotted area represents Condie et al.'s field of Middle Proterozoic diabase dykes.*

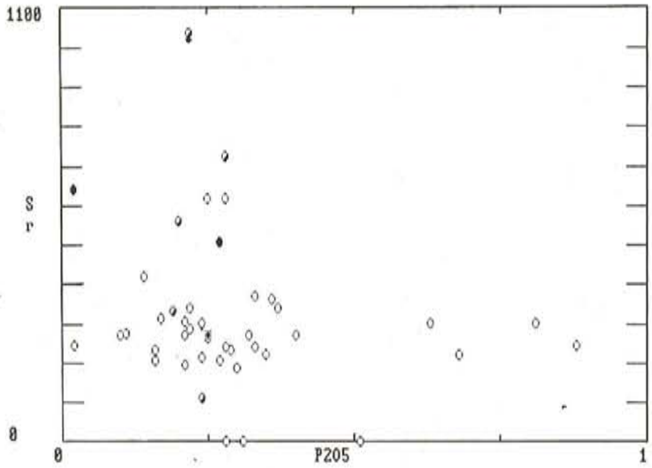

Figure 6. *Sr vs. P_2O_5 variation diagram for Naskaupi sills; the sills associated with copper mineralization have enriched Sr contents.*

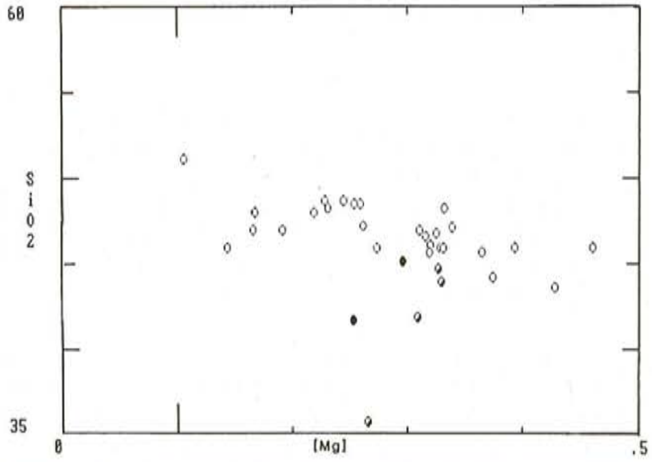

Figure 7. *SiO_2 vs. [Mg] for the Naskaupi sills; all samples have [Mg] of less than 0.6 (i.e., have undergone significant fractionation) and diabase samples associated with copper mineralization have decreased SiO_2 contents.*

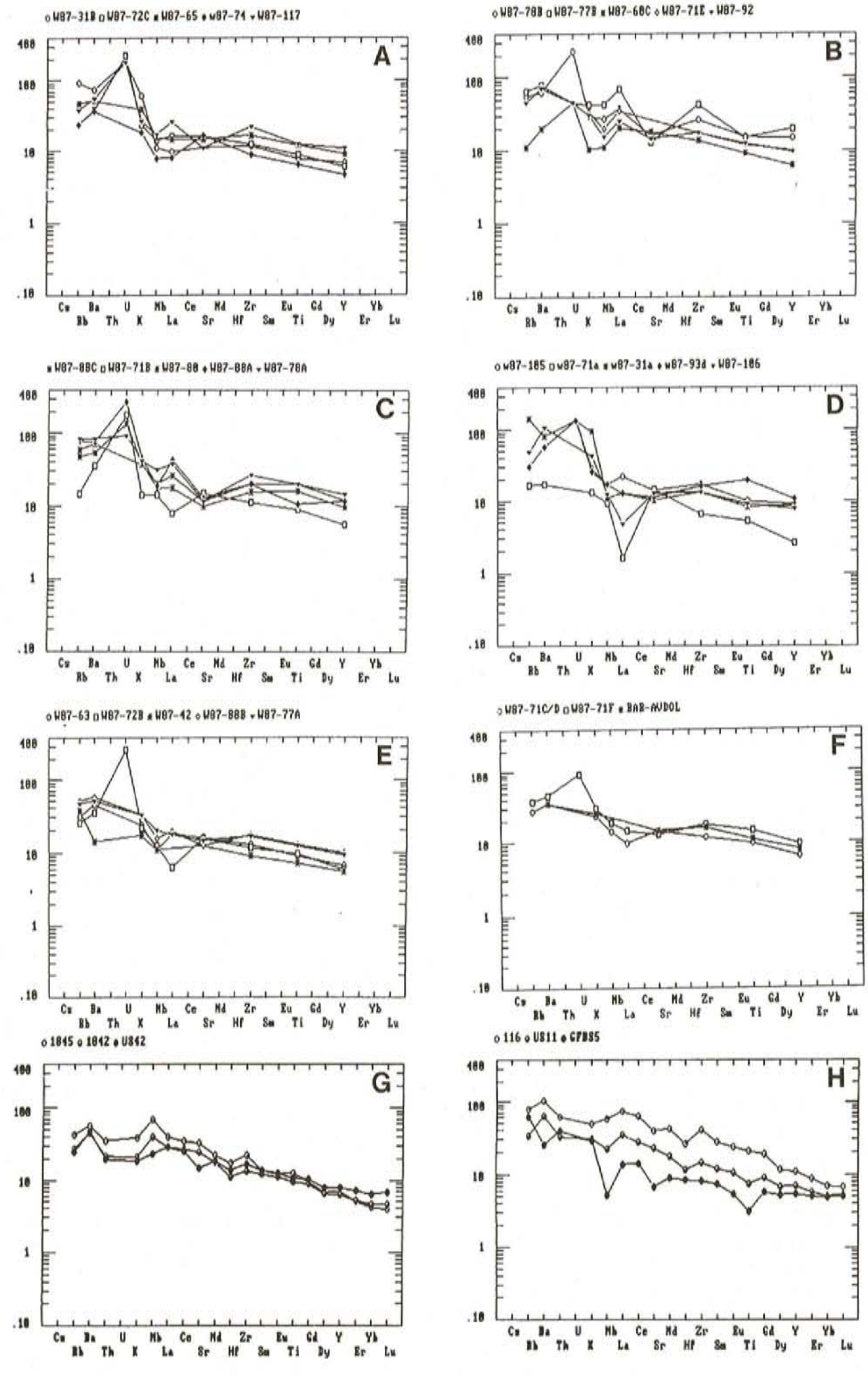

Figure 8. *A to h are spidergrams for Naskaupi sill diabase samples. The elemental concentrations are ratioed to the primitive mantle values of Taylor and McLennan (1981) and Jenner et al. (1987). Baragar's (1981) average value for the Naskaupi sills is sample bar-avdol. G and h are spidergrams of Thompson et al. (1983; 1984) continental flood basalts; g only resembles ocean-island basalts (note: the Thompson et al. (1983, 1984) data sets do not contain U concentrations).*

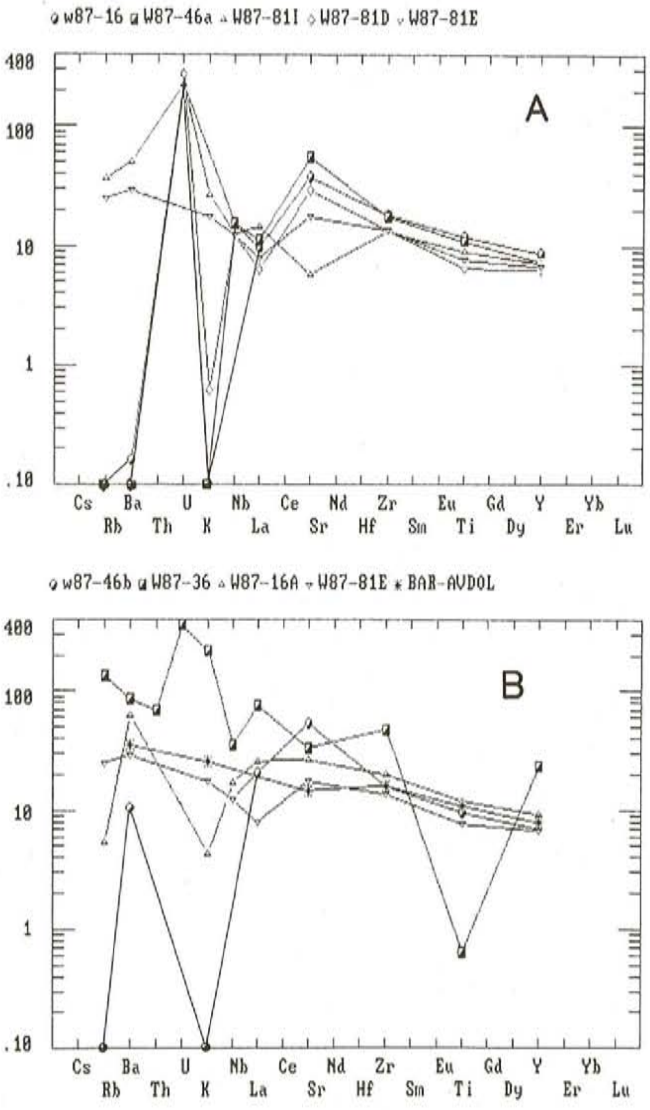

Figure 9a and b. *Spidergrams for mineralized diabase samples from the Naskaupi sills. The elemental concentrations are ratioed to the primitive mantle values of Taylor and McLennan (1981) and Jenner et al. (1987). Sample bar-avdol is Baragar's (1981) average value for the Naskaupi sills. A, represents those sill samples from copper occurrences and B, those from sills in proximity to copper occurrences.*

Sample W87-16 (Figure 8) is from a small island northwest of Adeline Island, wherein the host diabase is cut by quartz−carbonate veins and minor bornite and malachite (± chalcocite). Sample W87-46A is from the Seal Lake Main Showing, and sample W87-81D is from the most thoroughly mineralized trench at the Whiskey Lake (Mineral Occurrence 64) Showing. All three samples show extreme depletion in Rb, Ba and K and enrichment in Sr (i.e., the carbonate-rich ore fluids leached Rb, Ba and K from the diabase and added Sr).

Aside from the graphic depiction of ore fluid reaction, these common patterns are very significant because they show that the mineralizing processes were the same throughout the Seal Lake Group (i.e., W87-46A is from a showing generally agreed to be in the Salmon Lake Formation, whereas, W87-81D is definitely from stratigraphically higher mineralization). It has been suggested by Gandhi and Brown (1975) and Baragar (1981) that there were two periods, or styles, of copper mineralization in the Seal Lake Group *viz.*; a stratigraphically lower, epigenetic native copper style and a stratigraphically higher, syngenetic copper sulphide one. The geochemical data described here further support Wilton's (*this volume*) supposition that copper mineralization in the Seal Lake Group was probably the product of epigenetic ore fluids that were emplaced along structural weaknesses during a period of deformation

CONCLUSIONS

Based on these preliminary results, the Naskaupi sills do not appear to have significant potential for PGE concentrations. The geochemistry of the sills indicate that the parental magmas fractionated prior to intrusion and assimilated minor amounts of granulitic, or depleted, crustal material. Overall, the sills have geochemical signatures that are typical of continental flood basalts. Epigenetic copper-bearing hydrothermal fluids produced local, distinctive geochemical changes marked by depletion of Ba, K, and Rb.

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