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A RECONNAISSANCE STUDY OF PLATINUM-GROUP-ELEMENT (PGE) CONTENTS FROM MAGMATIC SULPHIDE MINERALIZATION IN LABRADOR

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ABSTRACT

Following the Voisey's Bay discovery, exploration in Labrador resulted in recognition of widespread and varied magmatic sulphide mineralization within northern Labrador. Although available platinum-group-element (PGE) data from Voisey's Bay itself suggest low levels, PGE data reported by companies in other areas provide only sporadic coverage. Therefore, a systematic reconnaissance study was completed using samples collected between 1996 and 1998, as part of the Labrador Nickel Metallogeny Project. The results show that PGE concentrations are almost universally low, which was expected in the light of data from Voisey's Bay and theoretical considerations based on the nature of mineralization elsewhere in Labrador. There are some subtle variations in PGE contents amongst different types of magmatic sulphide mineralization, but none of these imply potentially significant enrichments.

Although the results are generally negative, two samples of mineralized, metamorphosed ultramafic rocks about 70 km west-northwest of Nain show strong PGE enrichment, containing up to 0.7 ppm Pt and 2.1 ppm Pd (i.e., 0.7 and 2.1 g/t), coupled with up to 1.4% Ni and 0.2% Cu. The samples are from float blocks, rather than outcrop, but are likely of local origin. Given the limited previous exploration in this remote area of northern Labrador, these strongly anomalous PGE results suggest that further investigation is warranted.

INTRODUCTION

Many nickel sulphide deposits also contain significant amounts of platinum-group-elements (PGE; i.e., Pt, Pd, Ir, Os, Rh and Ru), which can be important byproducts. The PGE may be dispersed within Ni-rich mineralization, or form discrete zones of PGE–Cu-enriched sulphides that result from fractionation of the sulphide liquids, or perhaps from hydrothermal redistribution. For example, at Sudbury, several PGE-rich "footwall zones" associated with larger nickel orebodies (e.g., the Strathcona Mine) contain high-value ores. These have been particularly important in the last few years because the prices of the PGEs have risen significantly, whereas prices for base metals such as Ni, Cu and Co have remained flat or declined.

Until 2000, there were no public-domain PGE data for the Voisey's Bay deposit, but it was widely assumed that PGE concentrations were low, because Diamond Fields Resources would probably have announced any grades of economic interest. The PGE data, now summarized by Naldrett *et al.* (2000), indicate that the Voisey's Bay sulphides all contain less than 1 g/t combined Pt and Pd, and less than 0.5 g/t Au. As these data are recalculated to 100 percent sulphide, it follows that the bulk of the material has significantly lower PGE contents. The massive sulphide bodies, which have the highest absolute PGE values, all contain less than 0.5 g/t combined [Pt + Pd + Au]. Thus, as stated elsewhere, (e.g., Naldrett, 2000), the PGE are unlikely to be of economic importance at Voisey's Bay.

The Labrador exploration boom led to the discovery of numerous and varied examples of magmatic sulphide mineralization elsewhere in the Nain Plutonic Suite, (e.g., Kerr and Ryan, 2000). The exploration focus was for Ni–Cu–Co, but many companies completed some PGE analyses as part of their programs. However, such analyses were rarely systematic, and in many cases data were not included in assessment reports. In view of the current interest in PGE, and the sporadic nature of company data, a reconnaissance study was completed using samples collected between 1996 and 1998, as part of the Labrador Nickel Metallogeny Project. The objectives were to verify existing data, where available, and to test for previously undetected PGE enrichments. Theoretical considerations (*see below*) predict that most Labrador sulphide mineralization should be PGE-depleted, and this indeed proved to be the case. However, there are two strongly anomalous results, and a few scattered low-level anomalies; the data are clearly of sufficient interest to merit discussion.

THE GEOCHEMICAL BEHAVIOUR OF PGE IN MAGMATIC SULPHIDE SYSTEMS

The PGEs of most economic interest are Pt, Pd and Rh. Like Ni, Cu and Co, these elements are strongly chalcophile, i.e., they are strongly concentrated into sulphide liquids rather than silicate magmas. They have a very strong affinity for the sulphide liquid; the [sulphide liquid/silicate magma] partition coefficients for Pt range from 1500 to 20 000, whereas the equivalent parameter for Ni ranges from 300 to about 1000 (Barnes and Maier, 1999). The equivalent partition coefficients for Pd and Rh are even higher than those for Pt, although the experimental data are understandably scattered (*see* Barnes and Maier, 1999, for more discussion).

These high partition coefficients aid in the concentration of PGE from a silicate magma, which typically contains only a few ppb of each, but also place inherent limits on the PGE contents of most sulphide liquids. For an individual sulphide liquid droplet to actually achieve the predicted PGE concentrations, it must interact with huge amounts of the silicate magma. The R-factor (i.e., the mass ratio of silicate magma to sulphide liquid) must be very large, likely >10 000, and values of such magnitude are hard to achieve in nature. The same considerations do affect the concentrations of Ni and Cu in sulphide liquids, but effects are small when R > 1000; the effects on Co are small when R > 100. Despite such differences, the base metals and PGE are generally correlated, i.e., sulphide liquids with high base-metal contents are more likely to contain elevated PGE, and sulphide liquids with low base-metal contents are commonly depleted in PGE.

The strong affinity of the PGE for a sulphide liquid does, however, provide a method whereby they can be decoupled from the base metals. If a silicate magma segregates a small amount of sulphide under the right R-factor conditions, it will be depleted in PGE but will retain most of its Ni, Cu and Co. Any sulphide liquid that forms later will inherit this early PGE depletion. This provides a method whereby a relatively Ni–Cu-rich sulphide liquid can remain PGE-poor, and it may apply at Voisey's Bay. However, it is important to note that there is no analogous mechanism that can produce a Ni–Cu-poor, PGE-rich sulphide liquid.

The PGE can also be enriched by fractionation of a sulphide liquid following its development and collection. Sulphide liquids behave like silicate magmas; they crystallize gradually, initially forming a single high-T sulphide phase, and a residual liquid phase. Nickel behaves almost neutrally during this fractionation process, but Cu and the PGE are concentrated in the residual sulphide liquid. If this residual liquid can then escape and solidify elsewhere, it will show very significant PGE enrichment. This process is likely responsible for the development of many such zones associated with large Ni deposits such as Sudbury and Noril'sk (Naldrett, 1989).

Magmatic sulphide mineralization in Labrador, excluding Voisey's Bay, is generally characterized by low sulphide metal contents* (Kerr and Ryan, 2000). Pyroxenite-, anorthosite- and ferrodiorite-hosted mineralization generally have sulphide Ni contents below 1 percent, although sulphide Cu contents are more variable. Mineralization associated with gabbroic and troctolitic rocks, such as the Pants Lake Intrusion (Kerr, 1999; Kerr *et al.*, 2001) has higher sulphide Ni contents, but these remain below typical Voisey's Bay levels (about 4 percent Ni). Generally, most Labrador sulphide mineralization outside Voisey's Bay exhibits low Ni/Co ratios, which is commonly an indication of low R-factors during sulphide segregation.

Based on the available data, the PGE concentrations of most magmatic sulphide mineralization in Labrador would be predicted to be low. However, as the above discussion indicates, the behaviour of the PGE can be influenced by several processes, and they are also known to be mobile in hydrothermal fluids. The old prospectors' saying "*gold is where you find it*" may apply equally well to the PGE, and undue reliance on theoretical arguments is never a good idea in the exploration business.

METHODS AND ANALYSIS

During the Labrador Nickel Metallogeny Project (1996-2000), numerous field and drill-core samples of sulphide mineralization and its host rocks were analyzed for major and trace elements. A subset of 150 samples was selected for PGE analysis; these cover all areas where mineral exploration was active from 1995 to 1999, including the Harp Lake Complex (Kerr and Smith, 2000). Most of these samples are mineralized, and were selected on the basis of their Ni and Cu contents to provide a range of both sulphide metal

* The sulphide metal content, as defined here, is the concentration of the element in the sulphide component of a sample, rather than in the whole-rock sample. It is calculated by a simple procedure based on the amount of sulphur in the sample. *See* Kerr (1999) for an explanation of the procedure.

Table 1. Location information for anomalous samples (> 100 ppb Pt and/or > 100 ppb Pd)

Sample and Lab Number	Details	NTS Sheet	UTM East	UTM North	UTM Zone
AK96-315A (6340165)	Staghorn Lake (Massive Sulphide)	14E/01	531400	6319560	21
AK98-104 (6341387)	Harp Lake - Collette I (anorthosite w/ sulphide)	13K/13	576310	6089191	21
AK97-031 (6340319)	West Margin, Tasisuak L. (pyroxenite w/ sulphide)	14D/15	505360	6302115	21
AK97-032 (6340321)	West Margin, Tasisuak L. (pyroxenite w/ sulphide)	14D/15	505390	6302155	21

Note: UTM coordinates are recorded from Global Positioning System (GPS) receivers, and have an accuracy of approximately ± 50 m.

contents and Ni/Cu ratios. A few unmineralized (sulphide-free) host rocks were also analyzed to provide background information. The general locations of the areas from which samples came are indicated in Figure 1; the UTM coordinates for the most significant anomalous results are listed in Table 1.

Samples were analyzed for Pt, Pd and Au using Fire Assay extraction followed by inductively-coupled plasma (ICP) analysis at Bondar-Clegg Ltd. The standard WMG-1 was employed to monitor accuracy. Six determinations of this sample gave mean values of 123 ppb Au, 778 ppb Pt and 398 ppb Pd compared to recommended values of 110 ppb Au, 731 ppb Pt and 382 ppb Pd. A sample of the mineralized “basal breccia” from Voisey’s Bay was also used as an internal standard to check consistency of analyses, and several internal duplicates were also analyzed to monitor precision. The detection limit for Pt is quoted at 5 ppb, and detection limits for Au and Pd are quoted at 1 ppb. Data from duplicate analyses imply that analytical precision between detection limits and about 100 ppb is at best ± 10 percent, and degrades significantly approaching detection limits. This must be borne in mind when interpreting results, particularly if recalculated to higher sulphide contents (*see below*). Cobalt, Cu and Ni were analyzed by ICP methods at the Department of Mines and Energy Laboratory, and have detection limits of 1 ppm, and analytical precision of ± 2 percent or better. Sulphur was analyzed by Leco furnace method, with a detection limit of 0.01 percent, and analytical precision of ± 4 percent or better.

RESULTS

GENERAL SUMMARY

The analytical results for Co, Ni, Cu, Au, Pt, Pd and S are listed in Table 2. The elemental sulphur analyses provide an indication of the sulphide content of some samples; those with more than 30 percent S are thus essentially massive sulphides. Gold, Pt and Pd display very low values in almost all the samples, and many Pt results are below the 5 ppb detection limit. Given the precision constraints noted above, differences between samples of 10 ppb or less are probably not statistically significant.

Two samples have strongly anomalous Pt and Pd concentrations of up to 661 ppb Pt and 2147 ppb Pd, coupled with up to 216 ppb Au, as reported previously in a data release (Kerr, 2002). These are from angular float blocks of sulphide-bearing pyroxenite collected north of Tasisuak Lake (Figure 1). The Pd analyses of approximately 2 ppm (i.e., 2 g/t) are of considerable interest. These samples, and the area from which they come, are described in more detail below. Several other samples show mildly anomalous values ranging up to 300 ppb Au, 100 ppb Pt and 200 ppb Pd. These values are well below any economic thresholds, but they do require some limited discussion.

With a knowledge of elemental sulphur abundance, Au, Pt and Pd values can be recalculated to predict sulphide metal contents, as for Ni and Cu. However, it is important to

Table 2. Base-metal and platinum-group-element contents of Labrador magmatic sulphide mineralization

Sample	Lab #	Details	Co (ppm)	Ni (ppm)	Cu (ppm)	Au (ppb)	Pt (ppb)	Pd (ppb)	S (%)
NAIN PLUTONIC SUITE: Anorthosite-hosted Mineralization									
Alliger Lake Area – License 1506 Prospects									
AKC205	6340457	DDH: 1506-96-7	221	1017	1607	2	<5	10	27.70
AKC213	6340465	DDH: 1506-96-6	235	502	931	9	<5	<1	nd
AKC216	6340467	DDH: 1506-96-6	1297	5597	2269	26	16	5	33.70
AKC225	6340474	DDH: 1506-96-5	1120	9262	4154	6	31	18	27.90
AKC234	6340479	DDH: 1506-96-3	2760	9183	4772	27	<5	21	36.90
Alliger Lake Area – Krinor (OKR) Area									
AKC302	6340522	DDH: OKR-96-3	2584	8771	1125	3	<5	7	33.70
AKC304	6340523	DDH: OKR-96-3	1045	6291	3457	4	<5	12	23.30
AKC305	6340524	DDH: OKR-96-3	639	3592	6607	16	36	5	13.50
AKC324	6340532	DDH: OKR-96-5	1083	5977	4401	5	11	4	23.60
Alliger Lake Area – Cirque Area									
AKC627	6340633	DDH: LBN-96-1	664	1078	4146	15	<5	3	19.30
AKC630	6340636	DDH: LBN-96-3	1199	3350	832	4	<5	8	38.40
AKC967	6341208	DDH: LBN-97-11	1675	2821	3181	5	11	4	16.80
Alliger Lake Area – License 1514									
AK96-239	6340103	"G-zone" showing	2170	13126	4089	8	16	8	33.60
AKC443	6340698	DDH: 1514-96-21C	2797	6038	3131	14	33	12	34.00
AKC449	6340702	DDH: 1514-96-21C	1227	3965	3379	16	23	18	29.70
AKC472A	6340718	DDH: 1514-96-25B	1484	4948	4355	6	20	16	37.20
AKC482	6340726	DDH: 1514-96-25	3087	5808	20603	88	19	25	34.50
Alliger Lake Area – License 1558									
AKC454	6340705	DDH: 1558-96-18	376	941	1499	11	<5	2	nd
AKC541	6340752	DDH: 1558-96-13B	2069	5698	730	3	7	5	36.50
AKC543	6340754	DDH: 1558-96-13B	2085	5766	1233	4	6	7	37.20
AKC573	6340777	DDH: 1558-96-12	551	2118	4830	19	36	<1	18.30
AKC585	6340787	DDH: 1558-96-17	1912	5614	955	5	31	8	36.20
AKC609	6340808	DDH: 1558-96-14	1895	5172	644	5	6	9	34.20
Alliger Lake Area – Hilltop Project									
AK96-196	6340074	Hilltop showing	820	4032	2124	13	17	6	14.60
GBC1109	6341453	DDH: HT-96-03	1800	4959	4030	15	<5	19	35.44
GBC1121	6341465	DDH: HT-96-02	219	639	4044	19	<5	<1	5.67
Staghorn Lake Area									
AK96-315A	6340165	"15-1" showing	1984	11783	5660	6	117	210	33.30
AKC1043	6341286	DDH: NDT-96-13-10	516	2082	7482	12	<5	<1	13.30

Table 2. Continued

Sample	Lab #	Details	Co (ppm)	Ni (ppm)	Cu (ppm)	Au (ppb)	Pt (ppb)	Pd (ppb)	S (%)
AKC1044	6341287	DDH: NDT-96-13-10	1461	4554	4211	1	72	8	30.71
AKC1056	6341298	DDH: NDT-97-23A-11	421	847	1543	37	<5	5	nd
AKC1065	6341306	DDH: NDT-97-26-11	285	876	5637	9	<5	<1	nd
NBK Showing									
AK96-265B	6340128	Main showing	140	657	2099	15	<5	6	nd
AK96-265C	6340129	Main showing	145	678	1280	15	7	4	nd
Nain Hill Area – Project 44									
AK97-012	6340434	Valley Zone	334	1282	3108	10	16	32	4.54
AK97-015A	6340435	Kauk Harbour Zone	647	5133	5540	3	22	16	20.20
Nain Area – Sachem Bay									
AK97-073A	6340445	Surface showing	153	523	634	27	<5	6	nd
AK97-073B	6340446	Surface showing	132	2587	16	9	5	7	nd
Nain Area - Mount Sophie									
AK97-002	6340433	Surface showing	2442	12676	1201	4	30	6	30.70
Voisey's Bay Area – VBE-1 Project									
AKC955	6341197	DDH : VBE1-97-7	527	2886	3672	14	35	5	14.10
AKC957	6341199	DDH : VBE1-97-7	281	1057	1551	9	40	4	6.29
NAIN PLUTONIC SUITE: Pyroxenite-hosted Mineralization									
Umiakovarusek Lake Area – OKG Project									
AKC340	6340542	DDH: OKG-95-3	452	4777	2438	7	73	10	10.20
AKC344	6340545	DDH: OKG-95-3	154	620	2512	16	<5	<1	nd
AKC364	6340556	DDH: OKG-95-5	489	4700	3590	19	8	7	11.00
AKC373	6340561	DDH: OKG-96-9	260	1033	4817	21	<5	<1	nd
AKC376	6340892	DDH: OKG-96-9	2158	10032	468	3	6	3	35.90
Umiakovarusek Lake Area – Golden Trump Area									
GBC1089	6341436	DDH: GTN-96-2	1887	18281	13699	3	<5	30	nd
GBC1094	6341439	DDH: GTN-96-4	2077	17612	12456	9	<5	20	35.44
GBC1104	6341447	DDH: GTN-96-1	163	714	761	9	<5	<1	1.90
GBC1105	6341448	DDH: GTN-96-1	1337	10916	1793	52	<5	24	nd
JHC233	6341473	DDH: GTN-96-6	359	3244	2430	17	<5	<1	nd
JHC235	6341475	DDH: GTN-96-6	2014	16965	676	5	25	6	nd
Iglusuataliksuak Lake Area									
AKC419	6340593	DDH: ABS-96-1	111	1117	7	2	<5	<1	nd

Table 2. Continued

Sample	Lab #	Details	Co (ppm)	Ni (ppm)	Cu (ppm)	Au (ppb)	Pt (ppb)	Pd (ppb)	S (%)
AKC422	6340595	DDH: ABS-96-3	99	1056	2	1	5	1	nd
AKC423	6340596	DDH: ABS-96-3	122	1006	954	16	<5	9	1.23
AKC424	6340597	DDH: ABS-96-3	183	757	1457	8	<5	5	nd
AKC429	6340603	DDH: ABS-96-3	191	802	1608	37	45	78	2.72
Kiglapait Area – Dudley and Nanuk Projects									
AK96-247A	6340107	Topaz Point Showing	445	3126	1545	3	<5	15	9.52
AKC985	6341226	DDH: NG-96-1	414	1306	2621	7	<5	4	8.95
AKC986	6341227	DDH: NG-96-1	271	544	1001	3	<5	1	4.73
AKC991	6341233	DDH: DG-95-1	456	2128	2204	2	<5	12	12.02
AKC1000	6341238	DDH: DG-95-1	1535	5737	3205	33	<5	10	30.42
Jonathon Island Area									
AK96-306D	6340155	Jonathon I. Showing	301	1187	662	5	<5	4	4.52
AK96-306E	6340156	Jonathon I. Showing	343	1849	735	3	<5	7	6.96
NAIN PLUTONIC SUITE: Ferrodiorite-hosted Mineralization									
Umiakovik Lake Area									
AKC925	6341171	DDH: OK-M1	194	552	1194	25	<5	<1	4.34
AKC926	6341172	DDH: OK-M1	162	551	2582	108	6	<1	4.19
AKC931	6341176	DDH: OK-M1	130	597	4044	298	<5	<1	4.36
NAIN PLUTONIC SUITE: Gabbro and Troctolite-hosted Mineralization									
Kiglapait Area – Franco Project									
AKC1003	6341242	DDH: FG-96-01	544	3507	2238	6	<5	4	nd
Voisey's Bay – Luk Area – Project 61									
AK96-147B	6340035	Main showing	222	4634	1933	42	13	22	2.46
AKC111	6340644	DDH: NDT-61-2	552	6577	2515	11	6	11	16.80
AKC118	6340647	DDH: NDT-61-3	116	3549	941	85	<5	34	4.87
AKC126	6340652	DDH: NDT-61-3	936	12313	3772	9	<5	35	27.60
AKC142	6340662	DDH: NDT-61-8	356	10740	3447	130	20	49	5.02
Nain Area – Paul Island – Project 43									
AK97-041A	6340438	Main showing	3834	21875	2783	4	5	62	33.70
AKC155	6340669	DDH: NDT-43-20	599	10428	3877	43	<5	47	12.70
AKC156	6340671	DDH: NDT-43-20	693	8292	2419	29	<5	20	13.70
AKC161	6340672	DDH: NDT-43-20	2816	19880	4424	17	25	29	34.50
Nain Area – Palungitak Island – Project 42									
AK96-089A	6340017	Main showing	122	864	3710	9	10	7	

Table 2. Continued

Sample	Lab #	Details	Co (ppm)	Ni (ppm)	Cu (ppm)	Au (ppb)	Pt (ppb)	Pd (ppb)	S (%)
AKC170	6340678	DDH: NDT-46-22	93	537	1150	9	9	10	nd
AKC174	6340682	DDH: NDT-46-21	130	664	1759	6	9	7	1.52
AKC178	6340686	DDH: NDT-46-21	140	1292	4198	11	10	19	2.12
AKC180	6340687	DDH: NDT-46-21	131	1942	2096	26	75	96	1.67
Voisey's Bay Area									
AK97-136	6340416	Troctolite - E. Deeps	238	556	3	5	<5	<1	nd
AK97-138	6340418	Troctolite - E. Deeps	256	614	2	4	<5	<1	nd
AK97-146	6340427	Troctolite - E. Deeps	181	545	12	3	<5	<1	nd
VB-1	6340440	Basal Breccia - Ovoid	nd	nd	nd	89	105	95	8.45
Pants Lake Intrusion									
AKC640	6340819	DDH: SVB-96-02	342	2601	1932	28	11	11	4.56
AKC668	6340843	DDH: SVB-96-03	519	3967	2328	29	<5	10	7.30
AKC724	6340899	DDH: SVB-97-67	748	5810	6351	174	55	87	10.40
AKC830	6340935	DDH: SVB-98-102	1885	6652	2638	63	<5	45	26.00
AKC839	6340945	DDH: SVB-98-103	1285	5089	2911	20	<5	11	14.30
AKC842	6340947	DDH: SVB-97-89	409	4168	2305	33	18	23	6.20
AKC853	6340959	DDH: SVB-97-70	597	4966	5057	124	15	62	7.95
AKC861	6340968	DDH: SVB-98-104	114	518	599	8	<5	7	1.23
AKC877B	6340987	DDH: SVB-97-86	112	564	34	1	<5	<1	0.20
AKC1130	6341064	DDH: SVB-98-113	443	7279	4622	67	32	96	9.35
AKC1158	6341035	DDH: SVB-97-80	812	4441	2990	29	<5	23	6.10
AKC1166	6341073	DDH: SVB-97-88	143	2432	2906	57	22	44	4.91
AKC1194	6341098	DDH: SVB-97-63	264	2328	2125	12	8	17	4.40
AKC1207	6341109	DDH: SVB-97-93	569	1582	1225	7	5	6	11.00
HARP LAKE INTRUSIVE SUITE: Massive and Semimassive Sulphide Mineralization									
AK98-090B	6341374	Gossan 99 showing	1492	3944	2668	4	<5	7	29.20
AK98-090C	6341375	Gossan 99 showing	261	694	10948	14	<5	<1	7.20
AK98-091	6341376	Gossan 99 showing	1792	4768	5621	10	17	8	34.62
AK98-141A	6341489	Dart showing	1826	5259	2044	4	<5	<1	31.07
AK98-143	6341409	Dart NE showing	301	661	812	2	<5	<1	4.46
AK98-179B	6341429	Adlatok Gorge area	183	606	721	24	<5	2	3.68
HARP LAKE INTRUSIVE SUITE: Disseminated Sulphide Mineralization in Anorthosites									
AK98-087	6341371	A-1 showing	138	854	1214	18	5	13	0.87
AK98-088	6341372	A-1 showing	100	974	1324	23	5	13	1.14
AK98-099	6341383	Colette II showing	48	1232	946	43	33	80	0.89
AK98-100	6341384	Colette II showing	73	1435	1602	37	17	56	1.30
AK98-101	6341385	Colette II showing	48	1562	972	23	13	49	0.92
AK98-103	6341386	Colette II showing	89	2871	1345	43	17	66	1.68
AK98-104	6341387	Colette I showing	90	2516	1488	100	93	174	1.81
AK98-106	6341388	Ed showing	70	1641	1236	20	14	34	1.31
AK98-109	6341391	Bax I showing	95	2634	1279	15	<5	30	1.34
AKC1197	6341329	DDH: HL2-97-4	96	895	879	16	7	21	1.30

Table 2. Continued

Sample	Lab #	Details	Co (ppm)	Ni (ppm)	Cu (ppm)	Au (ppb)	Pt (ppb)	Pd (ppb)	S (%)
OTHER MINERALIZATION TYPES: West Margin Area Pyroxenites									
Original Analyses									
AK97-031	6340319	Mineralized Pxenite	224	9323	1851	148	661	1791	2.28
AK97-032	6340321	Mineralized Pxenite	302	14505	1691	216	356	2147	2.75
Duplicate PGE Analayses (separate split; different laboratory)									
AK97-031	6340319	Mineralized Pxenite				131	1076	1390	
AK97-032	6340321	Mineralized Pxenite				174	721	1640	

note that the correction is inherently less reliable at low sulphide contents, because the large extrapolation tends to magnify analytical errors. As noted above, these error sources are significant at the 10 to 200 ppb level typical of the samples. Also, disseminated sulphides commonly exhibit higher sulphide metal contents than the related semimassive and massive sulphides, probably due to geological factors, (e.g., Barnes et al., 1997). Thus, in the following discussions, recalculated sulphide PGE contents must be interpreted with caution, because they are far less reliable than the equivalent values for Ni and Cu.

Nain Plutonic Suite

Pyroxenite-hosted Mineralization

Pyroxenite-hosted mineralization, generally comprising disseminated sulphides, is represented in the database by the Umiakovarusek Lake area, the border zone of the Kiglapait Intrusion, and an occurrence near Iglusuataliksuak Lake (Figure 1). Gold, Pt and Pd concentrations are generally low, and the PGE contents are very low in massive sulphide samples. The highest values are 73 ppb Pt in a sample from the OKG prospect, and 78 ppb Pd in a Cu-rich sample from Iglusuataliksuak Lake.

Anorthosite-hosted Mineralization

Anorthosite-hosted mineralization is probably the most abundant within the Nain Plutonic Suite, and is represented in the database by numerous occurrences, mostly located north of Nain (Figure 1). Although the sulphides are commonly hosted by anorthosites, semimassive to massive sulphide mineralization appears to be genetically related to small-scale mafic intrusive bodies of pyroxenitic to gabbronoritic composition that locally contain disseminated sulphides (Kerr, 1998; Kerr and Ryan, 2000).

Gold, Pt and Pd contents of these samples are almost all low, and most contain less than 100 ppb combined [Au + Pt + Pd]. Many samples have high sulphide contents, indicating that they are essentially massive sulphides, but their PGE contents remain close to detection limits. Some minor Pd–Au enrichments appear to be associated with high Cu/Ni ratios, suggesting that these might represent fractionated sulphide liquids. The only value of significance is a massive sulphide sample collected near Staghorn Lake, which contains 117 ppb Pt and 210 ppb Pd. These values are moderately anomalous, but well below economic thresholds.

Ferrodiorite-hosted Mineralization

Ferrodiorite-hosted mineralization is represented in the database only by the Umiakovik Lake project (Figure 1), where widespread disseminated sulphides occur in iron-rich quartz–gabbro and diorite (Kerr and Ryan, 2000; Wilton and French, 2001). These samples contain virtually no Pt and Pd but they do contain elevated Au (up to 298 ppb). The weakly anomalous gold has also been reported by the exploration company in their press releases and by Wilton and French (2001). Recalculation of data to 100 percent sulphides implies sulphide metal contents of about 2 ppm Au (i.e., 2 g/t), but there is no indication of any significant sulphide accumulation, and this large extrapolation may be unreliable. Moreover, there is no guarantee that Au is directly associated with the sulphides.

Gabbro and Troctolite-hosted Mineralization

Gabbro and troctolite-hosted mineralization is represented by the Voisey's Bay deposit (e.g., Naldrett *et al.*, 1996), by the mineralization of the Pants Lake Intrusion (Kerr, 1998, 1999), and by several other occurrences. Sulphides occur in disseminated or massive form, and are closely associated with the host mafic rocks. This type of

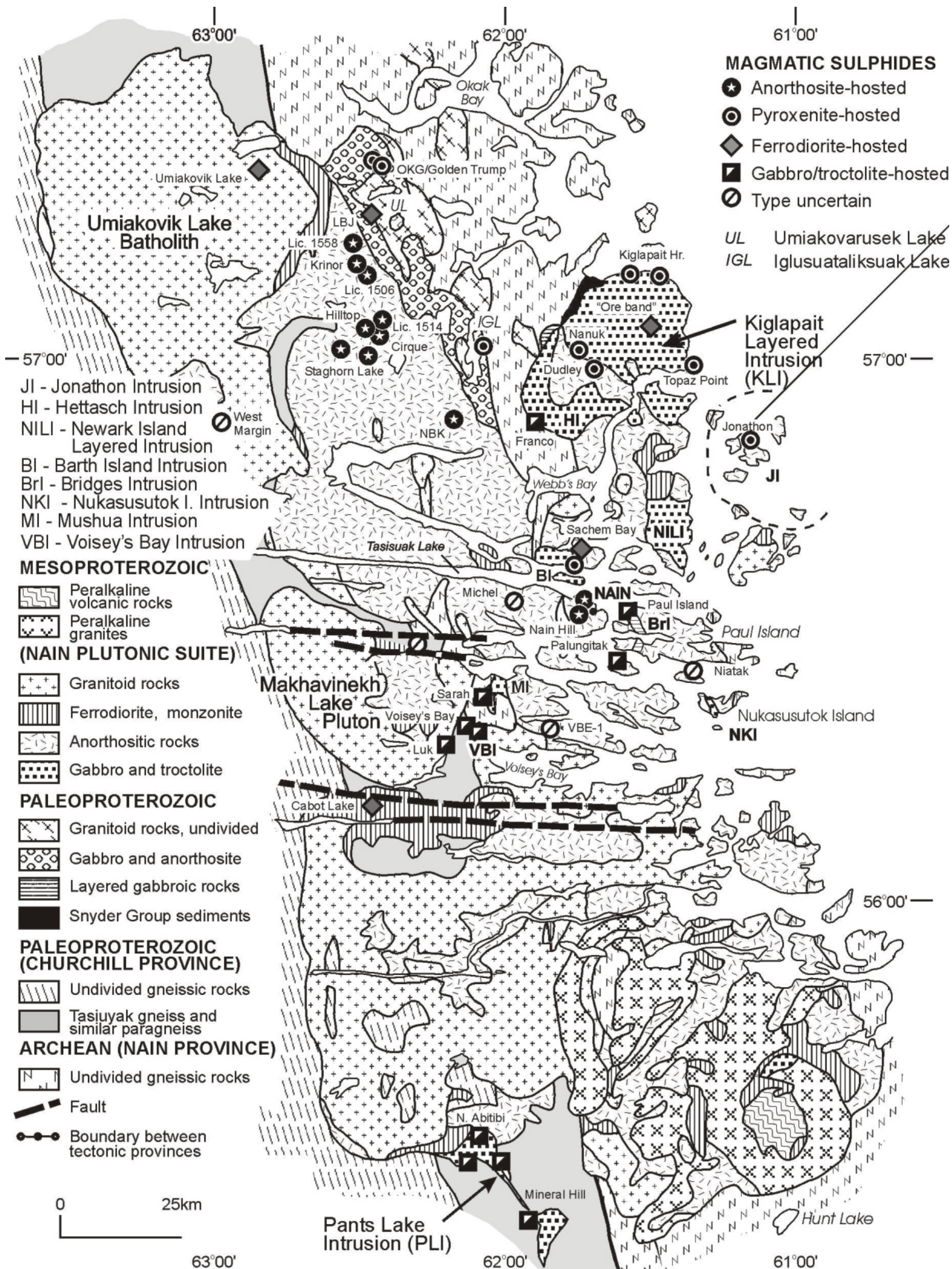

Figure 1. *General locations of magmatic sulphide mineralization discussed in this report from the Nain Plutonic Suite and surrounding areas (after Kerr and Ryan, 2000). The Harp Lake Complex mineralization is not indicated, but showing locations can be found in a previous report by Kerr and Smith (2000).*

mineralization generally has higher Ni and Cu contents in sulphides than the other types described above (Kerr and Ryan, 2000). The absolute Au and PGE contents of this mineralization are low, but they appear to be higher on average than those for other mineralization types described above.

Three unmineralized troctolite samples from the Voisey's Bay intrusion all contain <5 ppb Pt and <1 ppb Pd. Sulphide mineralization from the "basal breccia sequence" associated with the Ovoid deposit contains 89 ppb Au, 105 ppb Pt and 95 ppb Pd. Although this sample contains only about 25 percent sulphides, its PGE values are higher than virtually all samples described above from other mineralization types, including the massive sulphides. Samples from the nearby "Luk" project area, believed to represent part of the wider Voisey's Bay magma chamber, have a similar range of Au values, but are poorer in Pt and Pd. Recalculation of all these data to 100 percent sulphide yields a range of sulphide metal contents similar to that reported from Voisey's Bay by Naldrett *et al*. (2000).

Mineralized gabbros from the Pants Lake Intrusion contain 20 to 174 ppb Au, 5 to 32 ppb Pt and 10 to 96 ppb Pd. These samples all represent disseminated sulphides, and recalculation of the data to 100 percent sulphide implies that sulphides may have higher PGE abundances, possibly up to 500 ppb combined Pt + Pd, i.e., similar to results from Voisey's Bay (Naldrett *et al.,* 2000). The general range of Au, Pt and Pd contents obtained from this study is similar to that reported by Fitzpatrick *et al.* (1998) from the exploration program. The best result from the Pants Lake Intrusion came from a 1.1-m-thick, high-grade massive sulphide intersection that contained 11.9% Ni, 9.6% Cu, 54 ppm Ag, 170 ppb Au, 109 ppb Pt and 794 ppb Pd (Fitzpatrick *et al.,* 1998). However, other massive sulphide intersections from the Pants Lake Intrusion were only weakly anomalous in PGE (Fitzpatrick *et al.,* 1998).

Gabbro- and troctolite-hosted mineralization from the Nain area has modest Au, Pt and Pd contents, but one sample from Palungitak Island contains 75 ppb Pt and 96 ppb Pd. These values are only weakly anomalous in absolute terms, but the sulphide content is low. Recalculation to 100 percent sulphide implies that sulphides could contain up to 1.6 ppm Pt and 2 ppm Pd (i.e., 1.6 g/t and 2 g/t). However, as in other areas, there is no indication of significant sulphide accumulation, and the low sulphide content and poor PGE precision may render this extrapolation unreliable. Drilling at this site in 1996 intersected 1.1 m of 1.64% Ni, 3.5% Cu and 0.09% Co, which also contained 146 ppb Au, 44 ppb Pt and 175 ppb Pd (Miller *et al.,* 1997). This mineralization was unavailable for sampling.

Harp Lake Intrusive Suite

Anorthosite-hosted Mineralization

Anorthosite-hosted mineralization is represented in the database by the Dart and Gossan 99 showings, which resemble the anorthosite-hosted sulphide mineralization of the Nain Plutonic Suite (Kerr and Smith, 2000). The sulphides typically form semimassive to massive zones hosted by anorthosites. They exhibit very low Au, Pt and Pd contents, similar to their counterparts in the Nain Plutonic Suite.

Disseminated Sulphide Mineralization in Anorthosites

The Harp Lake Intrusive Suite also contains disseminated sulphide mineralization in anorthosites, which in many cases appears to be broadly stratiform (Kerr and Smith, 2000). The Harp Lake area was previously investigated for PGE as part of a regional exploration program, with generally negative results (Reusch, 1986). Data from this study are similarly discouraging, as most samples contain less than 150 ppb combined Au + Pt + Pd. However, considering that most contain only small amounts of sulphides, the results do suggest that these sulphides are more PGE-enriched than those in the Nain Plutonic Suite. Disseminated sulphide mineralization in the Harp Lake Intrusive Suite also shows relatively high Ni and Cu at 100 percent sulphide (Kerr and Smith, 2000).

The best result is from the Collette I showing, which contains 100 ppb Au, 93 ppb Pt and 174 ppb Pd. Recalculation to 100 percent sulphide implies that sulphide metal contents could exceed 1 ppm Pt and 2 ppm Pd. Samples from the nearby Collette II showing also have calculated Pt and Pd concentrations above 1 ppm at 100 percent sulphide. However, there is no evidence of significant sulphide accumulation, and the extrapolation may be inherently unreliable. Reusch (1986) also found that the sulphide showings in this area had higher PGE contents than those elsewhere in the Harp Lake Intrusive Suite.

"West Margin" Area

Metapyroxenite-hosted Mineralization

The most significant results come from a remote area located within the Churchill Province, about 40 km northwest of Tasisuak Lake, and 70 km west-northwest of Nain (Figure 1), where two samples of mineralized metapyroxenite float containing disseminated sulphides show strong PGE enrichment and high Ni contents (Table 2). Specifically, sample AK97-031 contains 0.93% Ni, 0.18% Cu, 661 ppb Pt and 1781 ppb Pd, and sample AK97-032 contains 1.4% Ni, 0.17% Cu, 356 ppb Pt and 2147 ppb Pd. These values are particularly noteworthy because the samples contain less than 10 percent sulphides. Recalculation of these data to higher sulphide contents suggests Ni and PGE grades that would clearly be of economic interest. To verify the results, separate sample aliquots were sent to another laboratory. The reanalysis confirmed the high PGE values, but indicated higher Pt and lower Pd than initial results (Table 2). This may indicate a "nugget effect" caused by the occurrence of PGE in (a) discrete mineral phase(s). The “West Margin” property, as it was known, has not been previously described outside company assessment reports, and is summarized below.

Exploration History

The West Margin property (formerly license 775M) was one of many claim blocks staked by Noranda Mining and Exploration following the Voisey’s Bay discovery. Prospecting and geophysics during 1995 and 1996 resulted in the discovery of mineralized outcrops and float, and several conductive zones (Squires *et al.*, 1996, 1997). The property was inactive during 1997, and was later optioned to a private company (North Atlantic Nickel Corporation), who conducted further ground exploration and a short drilling program in 1998 (North, 1998). Drilling in the extreme eastern part of the area encountered essentially barren sulphides in mafic intrusive rocks, but samples were not analyzed for PGE (North, 1998). No further work was recommended, and the property reverted to the crown early in 2001, and retained that status when the PGE data were first assessed. The area was subsequently staked by Hudson's Bay Exploration and Development (HBED) in late summer 2001 (License 8180M), with further acquisition of some adjacent ground in the fall of 2001 (Licenses 8244M and 8245M). A reconnaissance exploration program was conducted in 2001. The anomalous PGE data was released early this year (Kerr, 2002) and some areas adjacent to the HBED licenses were staked in response.

Geology and Mineralization

The West Margin area was visited only briefly by the author in 1997, at which time there was approximately 60% snow cover. The most detailed account of the geology is by Squires *et al.* (1996, 1997). Outcrop is locally abundant, but large areas are covered by till and/or boulder fields. The area is dominated by high-grade gneisses of the Churchill Province, which include quartzofeldspathic orthogneisses, and also garnet–biotite-bearing paragneisses that resemble the Tasiuyak gneiss (Figures 1 and 2). These give way to mafic, anorthositic and granitic rocks of the Nain Plutonic Suite in the east. Mapping in the east of the area (North, 1998) identified anorthosite and "troctolite" outcrops, suggesting the presence of a larger mafic intrusion adjacent to the gneisses. Contrary to published geological maps for the area (Ryan, 1990, based on unpublished work by E.P. Wheeler), granite is rare. Concordant mafic granulite and pyroxenite units, up to 10 m thick, occur within the gneisses, and likely represent pre- or syn-metamorphic intrusions that have been rotated into general parallelism with the gneisses. Some of these mafic rocks were later suggested to be discordant by North (1998), although this was not clearly documented by Squires *et al*. (1997).

Sulphides occur in concordant paragneiss units, where they are associated with graphite, and also in some pyroxenitic and mafic granulite units. One of these, reported to be present in outcrop and frost heave, contained 0.66% Ni, 0.5% Cu and 0.06% Co (Squires *et al.,* 1996). The outcrop locality was resampled by the author, but gave only weakly anomalous Ni and Cu values. Further prospecting by Noranda located a northeast-trending train of large, angular blocks of friable metaperidotite and metapyroxenite, some of which contained sulphides (Figure 2). Two of these returned assays of 1.43% and 1.17% Ni, coupled with about 0.2% Cu (Squires *et al.,* 1997). As far as can be ascertained, no PGE analyses were ever completed. Later work (North, 1998) showed the presence of disseminated sulphides in the mafic intrusive rocks to the east. Two short drillholes were completed in this area, and intersected rock types described as peridotite, pyroxenite and norite. Thin sulphide-bearing intervals returned generally low Co, Ni and Cu assays (<1000 ppm), but the sulphide metal contents are not known, because sulphur was not analyzed. The best results were 3090 ppm Ni and 3600 ppm Cu (North, 1998). No PGE analyses were conducted. The boulder train was briefly examined and sampled by the author, and the closely similar Ni values (Table 2) imply that the NDME samples represent exactly the same material. Squires *et al*. (1997) imply that similar metapyroxenite and metaperidotite float was observed elsewhere in the area, but it is not clear if all such occurrences were analyzed.

Ground geophysical surveys indicated numerous coincident conductivity and magnetic anomalies parallel to the regional foliation, and more subtle anomalies that do not appear to represent formational conductors (Squires *et al.*, 1997). North Atlantic Nickel completed a short (76 m) drill hole beneath the site of the mineralized float blocks, but this mostly intersected quartzofeldspathic gneiss and paragneiss, containing minor sulphides. Ni and Cu contents were low, generally < 500 ppm (North, 1998).

Petrology and Mineralogy

Several mineralized and unmineralized samples were examined by CANMET as part of a consultant study (included in Squires *et al.*, 1997). They were described as

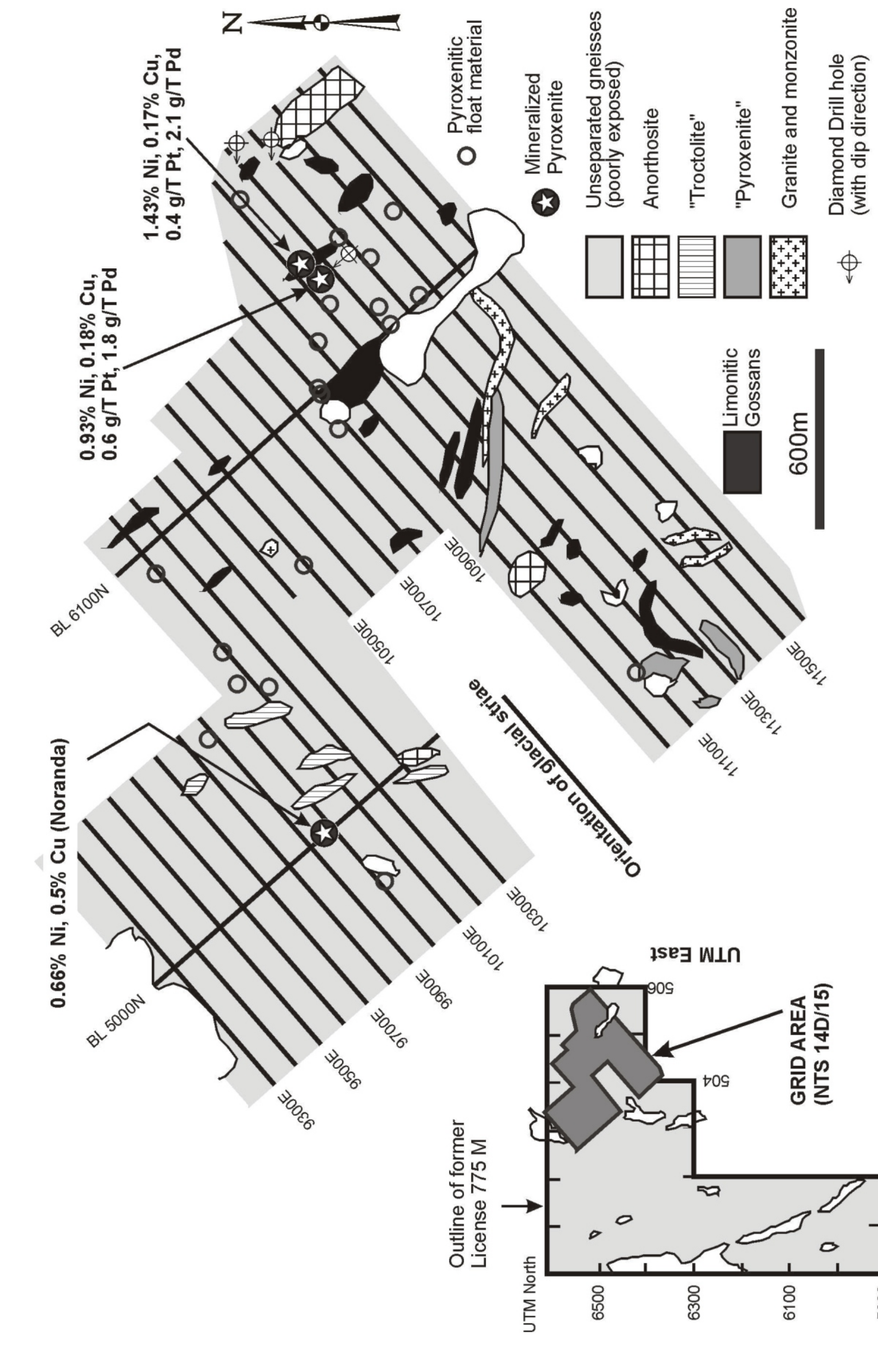

Figure 2. *Generalized geological map of the West Margin property (formerly license 775M), showing locations of mineralized outcrops, float blocks and the exploration grid (after Squires et* al.*, 1997). Locations of drill holes completed by North Atlantic nickel are from North (1998), and are approximate.*

metamorphosed orthopyroxenites, websterites and peridotites. The sulphide phases include pyrrhotite, chalcopyrite and pentlandite; the latter mineral (Fe–Ni sulphide) was described as "abundant".

Samples collected by the author fit this general description. Sample AK97-031 is essentially an orthopyroxenite having minor interstitial clinopyroxene and plagioclase, and variable amounts of phlogopite. Its texture is granoblastic to granular, but it is not obviously foliated. The sulphides form patches located at grain interstices, and are locally observed to be intergrown with plagioclase and clinopyroxene. Although the texture was described as "adcumulate" by CANMET, it appears thoroughly recrystallized to the author. Sample AK97-032 is an olivine-orthopyroxenite, containing about 25 percent forsteritic olivine, and it is mildly serpentinized. Compared to sample AK97-031, it is poorer in clinopyroxene, phlogopite and plagioclase. It has a granoblastic, recrystallized texture, but is not obviously foliated, although some pyroxenes are visibly strained. The habit of the sulphides appears to be very similar to that observed in AK97-031. A sample collected at the site of the mineralized "pyroxenite" outcrop is actually a fresh mafic granulite of approximately noritic composition, containing 50 to 60 percent plagioclase. It contains minor interstitial sulphides, but it may not be the "pyroxenite" assayed by Noranda.

Mineral analyses from the CANMET study show that olivines are highly magnesian (> Fo_{80}), but not nickel-depleted, as they contain up to 0.3% Ni (=3000 ppm). The orthopyroxenes are Mg-rich enstatites and bronzites, rather than the more common hypersthene variety (Squires *et al.*, 1996). Geochemical data for the NDME samples (Table 3) show low SiO_2, CaO and Al_2O_3, coupled with high MgO and modest Fe_2O_3. These compositions are consistent with interpretation of the samples as metamorphosed ultramafic rocks.

DISCUSSION AND CONCLUSIONS

Platinum-group-element and Au analyses of magmatic sulphide mineralization in northern Labrador, with the exception of the results from the former West Margin property, are not encouraging for exploration. Most of the samples have Pt and Pd concentrations from <5 ppb to about 30 ppb, and almost all contain less than 100 ppb combined Au + Pt + Pd. These results were expected given that most of the magmatic sulphide mineralization in Labrador exhibits low sulphide Ni and Cu contents.

Table 3. Compositions of metamorphosed mafic and ultramafic rocks from the former West Margin property, Labrador

Sample		AK97-030A	AK97-031	AK97-032
Lab #		6340317	6340319	6340321
Rock type		Meta-norite	Meta-pyroxenite	Meta-peridotite
SiO_2	%	51.01	48.77	45.21
TiO_2	%	0.73	0.21	0.17
Al_2O_3	%	11.63	5.27	3.99
Fe_2O_3	%	16.02	13.10	13.15
MnO	%	0.40	0.13	0.11
MgO	%	7.07	25.57	28.22
CaO	%	9.44	2.88	4.41
Na_2O	%	0.43	0.11	0.31
K_2O	%	0.25	0.33	0.21
P_2O_5	%	0.10	0.06	0.04
LOI	%	3.05	1.77	2.11
Total		100.13	98.20	97.93
Li	ppm	10.6	6.3	1.4
Be	ppm	1.7	0.5	0.4
Sc	ppm	37.9	15.8	11.5
Ti	ppm	4109	1368	1122
V	ppm	306	116	97
Cr	ppm	442	1887	2173
Mn	ppm	3127	1118	949
Co	ppm	29	224	302
Ni	ppm	134	9323	14505
Cu	ppm	224	1851	1691
Zn	ppm	635	163	142
Ga	ppm	21	12	7
Sr	ppm	184	45	56
Y	ppm	28	6	7
Zr	ppm	41	34	28
Nb	ppm	3	1	1
Mo	ppm	5	2	1
Ba	ppm	110	85	55
La	ppm	9	9	7
Ce	ppm	27	22	17
Dy	ppm	3.7	0.6	0.8
Pb	ppm	4	7	7

Notes:
1. Co, Ni and Cu data are repeated in Table 2.
2. Low major element totals for samples 031 and 032 reflect the high Ni, Cu and Cr contents in these rocks.

There is some subtle variation amongst the different types of mineralization outlined by Kerr and Ryan (2000). For example, gabbro- and troctolite-hosted mineralization, including the Voisey’s Bay and the Pants Lake areas, tends to show higher PGE abundances at lower sulphide contents than anorthosite- or ferrodiorite-hosted mineralization. The calculated sulphide PGE abundances for the Pants Lake Intrusion are generally similar to those reported by Naldrett *et al.* (2000) from Voisey’s Bay. However, there is still no indication that PGE could be present at economic levels in either area. Ferrodiorite-hosted sulphide mineralization in the Umiakovik Lake area shows weak Au enrichment. Disseminated sulphide mineralization from the Harp Lake Intrusive Suite also shows relatively high PGE contents at low sulphide contents, and calculated sulphide PGE contents are locally in the 1 to 3 ppm range (i.e., 1 to 3 g/t). However, there is no evidence for sulphide accumulation here, and the recalculation may be unreliable. Kerr and Smith (2000) suggested that these sulphides may have equilibrated with late-stage trapped residual liquids in which Ni (and the PGE) were incompatible elements. If this is the case, significant accumulation of sulphides is unlikely.

High PGE contents (up to 0.7 ppm Pt and 2.1 ppm Pd) obtained from metamorphosed ultramafic rocks at the former West Margin property stand out from the low regional background values. Given that these samples are not very sulphide-rich, these results are highly significant. Although the results come from float blocks, rather than outcrops, the angular shape and the friable nature of this material strongly suggests a local origin, as also suspected by Squires *et al.* (1997). Exploration in this area has to date been limited and, as far as can be ascertained, there have been no previous PGE analyses. Furthermore, the wider area surrounding the former West Margin property was not intensely explored following the Voisey’s Bay discovery, because it is largely underlain by gneisses, rather than intrusive rocks. The area clearly now merits further exploration on both local and regional scales. The available information suggests that the target rock types should be mafic and ultramafic units within the Churchill Province gneisses, but a connection to the mafic rocks of the Nain Plutonic Suite cannot yet be ruled out.

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