

FIRST REPORT OF PLATINUM-GROUP MINERALS AT BLUE LAKE, LABRADOR TROUGH, QUEBEC¹

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ABSTRACT

We describe here the first known occurrence of platinum-group minerals (*PGM*) from the Labrador Trough, Quebec: sudburyite PdSb, temagamite Pd₃HgTe₃ associated with bismuthian kotulskite Pd(Te, Bi), kotulskite PdTe, and michenerite PdBiTe intergrown with altaite PbTe and an unnamed mineral Pd(Sb, Te, Bi) close in chemical composition to UN1976-4 from Sudbury. The *PGM* have been found in the Center and Pogo Lake zones of the Blue Lake Cu-Ni-*PGE* massive sulfide deposit. The massive sulfides are hosted by a peridotitic and gabbroic sill. The *PGM* are closely associated with Cu-rich sheared margins of massive sulfide lenses and their adjacent chloritized host-rock. Occurrences and textures of the *PGM* suggest that the *PGE* and Cu were remobilized from the primary magmatic sulfides by hydrothermal solutions and preferentially precipitated in shear zones at the margins of massive sulfide lenses. This episode of alteration and deformation is most likely related to the Hudsonian Orogeny (1.8 Ga).

Keywords: platinum-group minerals, massive sulfide, peridotite, hydrothermal, metamorphism, deformation, Labrador Trough, Quebec.

SOMMAIRE

Nous décrivons ici le premier exemple d'une suite de minéraux du groupe du platine (*MGP*) dans la Fosse du Labrador: sudburyite PdSb, temagamite Pd₃HgTe₃ associée à une kotulskite bismuthifère Pd(Te, Bi), kotulskite PdTe, et michenerite PdBiTe associée à de l'altaïte PbTe et un minéral sans nom, Pd(Sb, Te, Bi) comparable en composition chimique au minéral UN1976-4 de Sudbury. Ces minéraux ont été découverts dans les zones Center et Pogo Lake du gisement de sulfures massifs à Cu-Ni-*EGP* du lac Bleu, Fosse du Labrador, Québec. Les sulfures massifs sont encaissés dans un filon-couche de roches péridotitique et gabbroïque. Les *MGP* sont étroitement associés à la bordure cisailée riche en Cu des lentilles de sulfures massifs et aux épontes chloritisées de la roche encaissante. D'après la distribution et les textures des *MGP*, les *EGP* et le Cu

proviendraient de la remobilisation des sulfures magmatiques primaires par des fluides hydrothermaux qui les ont précipités préférentiellement dans les zones de cisaillement aux contacts entre les sulfures massifs et l'encaissant. Cet épisode d'altération et de déformation pourrait être lié à l'orogénèse hudsonienne (1.8 Ga).

Mots-clés: minéraux du groupe du platine, péridotite, sulfures massifs, hydrothermal, métamorphisme, déformation, Fosse du Labrador, Québec.

INTRODUCTION

In this paper, we present the first account of platinum-group minerals (*PGM*) from the Labrador Trough, Quebec. Our report is preliminary, as it covers only certain zones of the Blue Lake deposit, the main occurrence of platinum-group elements (*PGE*) known in the Labrador Trough (Fig. 1). The *PGM* were found by petrographic examination of polished thin sections of the various facies of massive sulfide from the Center and Pogo Lake zones.

The Labrador Trough consists of Archean clastic and chemical sedimentary rocks and basalts intruded by sills of ultramafic and gabbroic rocks. The intrusive rocks have been dated at 1.9 Ga by Pb-Pb and Sm-Nd geochronology (Rohon *et al.*, in prep.). This assemblage unconformably overlies an Archean gneissic basement. The belt was folded, faulted and regionally metamorphosed during the Hudsonian Orogeny (*ca.* 1.8 Ga) (Dimroth 1978). The Blue Lake deposit is estimated to contain about 2.9 Mt of ore at an average grade of 0.84 % Cu, 0.55 % Ni, 0.69 g/t Pd and 0.14 g/t Pt (Clark *et al.* 1989).

GEOLOGICAL SETTING

The Blue Lake deposit consists of three zones of outcropping Cu-Ni-*PGE* massive sulfides, named Pogo Lake, Center, and Blue Lake, hosted in a composite sill. Several buried zones have been discovered by drilling. The sill was emplaced at the contact between pelites of the Thompson Lake Formation, which form the floor of the sill, and basalts of the Willbob Formation, which occur at its roof. In the

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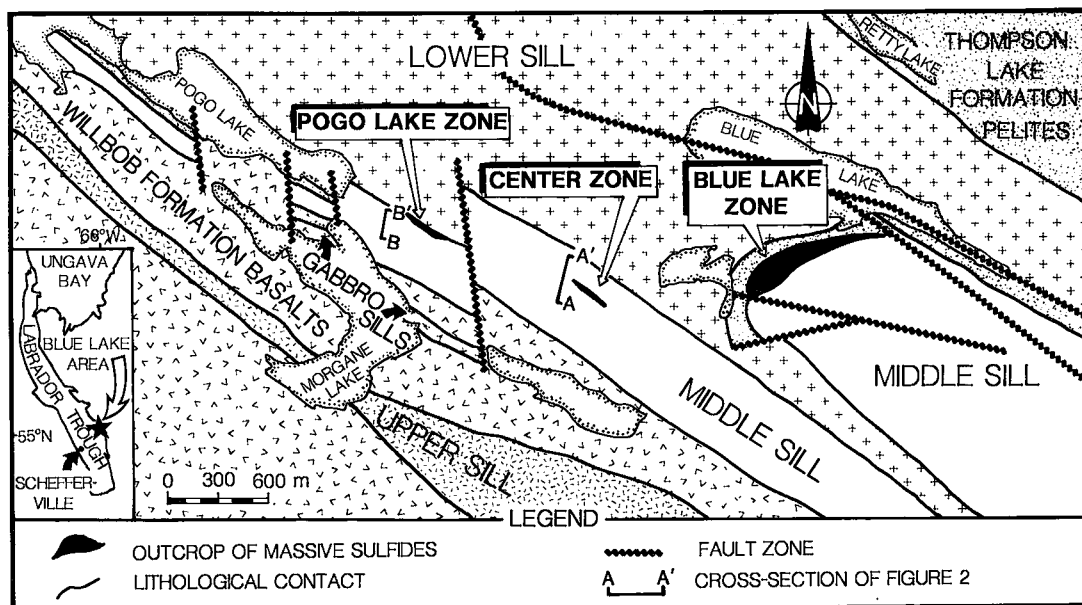


Fig. 1. Geological map of the Blue Lake deposit area, Labrador Trough, Quebec, with outcrops of Blue Lake, Center and Pogo Lake mineralized zones indicated.

Blue Lake area there are three sills, but only the middle one is mineralized (Fig. 1; Rohon *et al.* 1988, Beaudoin & Laurent 1989, Rohon 1989). The sills are composed of a lower unit of wehrlitic dunite, wehrlite, and olivine websterite in transitional contact with an upper unit of gabbro with a granophyric zone and a chilled margin (Fig. 2). Massive sulfides form lenses of variable thickness (up to 6.7 m) located at the base of (Blue Lake and Pogo Lake zones) or within (Blue Lake and Center zones) the middle sill (Fig. 2). Margins of massive sulfide lenses are commonly sheared, with a foliated chalcopyrite-rich band in contact with the chloritized host-rock. The chloritized zone extends up to 50 cm from the massive sulfides (Clark *et al.* 1989).

Sulfide minerals in the massive sulfide lenses are coarse to fine grained and locally foliated parallel to lens contacts. They are composed mainly of pyrrhotite (over 80%), with up to 10% chalcopyrite, up to 3% pentlandite and up to 6% magnetite. Pyrrhotite is fine to coarse grained (up to 1 cm), locally elongate parallel to the plane of foliation, and shows lenticular and lamellar twins and kink bands. Chalcopyrite is irregularly distributed in roundish aggregates, in elongate lenses in the foliation plane, or occurs as irregular grains interstitial to pyrrhotite. Pentlandite forms euhedral to anhedral grains (up to 1 mm) commonly located at the boundary of pyrrhotite or chalcopyrite grains. It also occurs as ubiquitous "flames" and irregular inclusions in pyrrhotite. Pentlandite is almost completely replaced by

violarite in the Center zone, but only in part in the Pogo Lake zone. Magnetite occurs as subhedral to roundish anhedral grains, up to 1.5 mm, irregularly disseminated in massive sulfides.

MICROPROBE ANALYTICAL TECHNIQUES

Analyses were made with CAMECA CAMEBAX automated wavelength-dispersion electron-microprobes at McGill University and the Centre National de la Recherche Scientifique (CNRS, Orléans, France). Calibration for the analyses performed at McGill was done using synthetic PGM standards provided by J.H.G. Laflamme (CANMET), with the exception of Ni, for which a synthetic nickeliferous pyrrhotite was used. Analyses done at the CNRS were calibrated using pure metals, with the exception of Fe and S, Sb, and Hg, for which pyrite, stibnite, and cinnabar were used, respectively. Precision for analyses performed at McGill University is better than 2% for major elements and 12% for Ni. Comparable precision was obtained at the CNRS, although some discrepancy exists for Ni, due probably to the Ni content (0.2 wt. %) of the pyrrhotite used as a standard at McGill compared to a pure metal at CNRS.

OCCURRENCES OF PLATINUM-GROUP MINERALS

Despite detailed examination of numerous polished thin sections, we found only two occur-

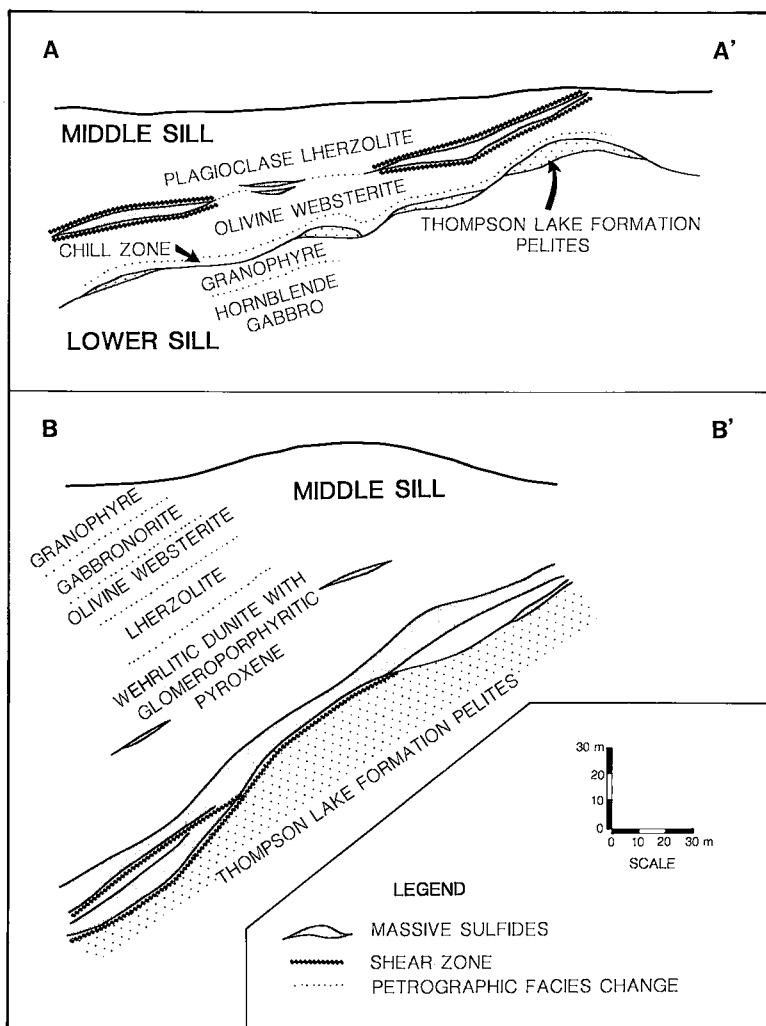


FIG. 2. A. Typical cross-section of the middle sill in the Center zone. Massive sulfides occur as elongate, discontinuous lenses within the sill. B. Typical cross-section of the middle sill in the Pogo Lake zone. Note that the massive sulfides occur at the base of the sill in contact with metapelites. The massive sulfides are repeated by a thrust fault.

rences of PGM in the massive sulfides. One is a triangular composite grain (25 μm) located beside a fracture, interstitial to pyrrhotite grains; it consists of temagamite Pd_3HgTe_3 with bismuthian kotulskite $\text{Pd}(\text{Te}, \text{Bi})$ at one of the apices of the grain (Figs. 3A, 4A). The second occurrence is a half-moon-shaped inclusion (25 μm) in pyrrhotite (Figs. 3B, 4B). The inclusion comprises a complex intergrowth of tellurides: michenerite, altaite, and an unnamed $\text{Pd}(\text{Sb}, \text{Te}, \text{Bi})$ mineral labeled PGM-1 in this paper. Kotulskite with a lower Bi content and associated with a grain of galena was described from a massive

pyrrhotite occurrence at Retty Lake (Rohon *et al.*, in prep.).

Within a laminated chalcopyrite-rich band, at the margin of a massive sulfide lens, a rounded grain of sudburyite PdSb was found accompanied by pyrrhotite and partly surrounded by a porous Ag telluride (Fig. 3C). The grain is at the contact between pyrrhotite and laminated lenses of chalcopyrite. The Ag telluride (hessite?) was identified by SEM, but microprobe analyses proved to be unreliable, probably because of the porous state of this mineral.

The contact between massive sulfide lenses and the

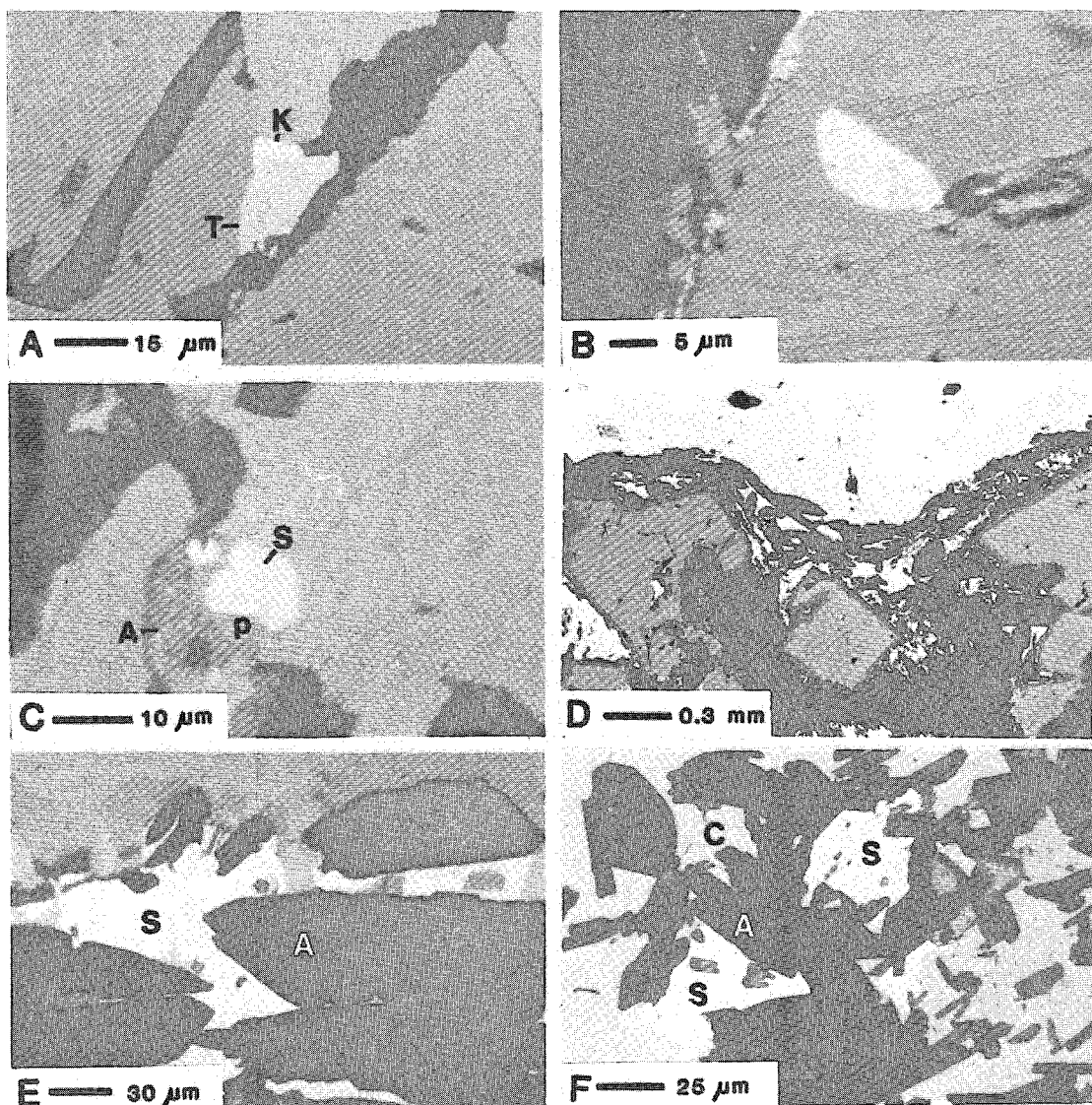


FIG. 3. A. Triangular grain of temagamite (T) along a fracture in massive sulfides. Bismuthian kotulskite (K) forms one of the apices of the triangle. B. Complex intergrowth of altaite - michenerite - PGM-1 in massive pyrrhotite. C. Sudburyite (S) and pyrrhotite (P) partly surrounded by a round grain of porous Ag-telluride (A) at the contact between a lenticular aggregate of chalcopyrite and a pyrrhotite grain. D. Seam of euhedral magnetite molded by a band of prismatic amphibole at the contact between massive sulfides and chloritized peridotitic wallrock. E. Sudburyite (S) interstitial to amphibole (A) in the band molding euhedral magnetite in Fig. 3D. F. Anhedral grains of sudburyite (S) interstitial to prismatic inclusions of amphibole (A), in contact with disseminated chalcopyrite (C) in a chloritized peridotitic wallrock.

host rock is sheared and was recovered in only one drill core in the Center zone. It consists of a seam of euhedral grains (0.5 mm) of magnetite molded by an undulating band of prismatic amphibole (Fig. 3D). Numerous grains of sudburyite, up to 0.1 mm

across, were found within this interval; they occur interstitially to and molding the amphibole, pyrrhotite and chalcopyrite (Fig. 3E). The peridotite at the contact with the massive sulfides is chloritized and contains up to 30% chalcopyrite. Sudburyite occurs

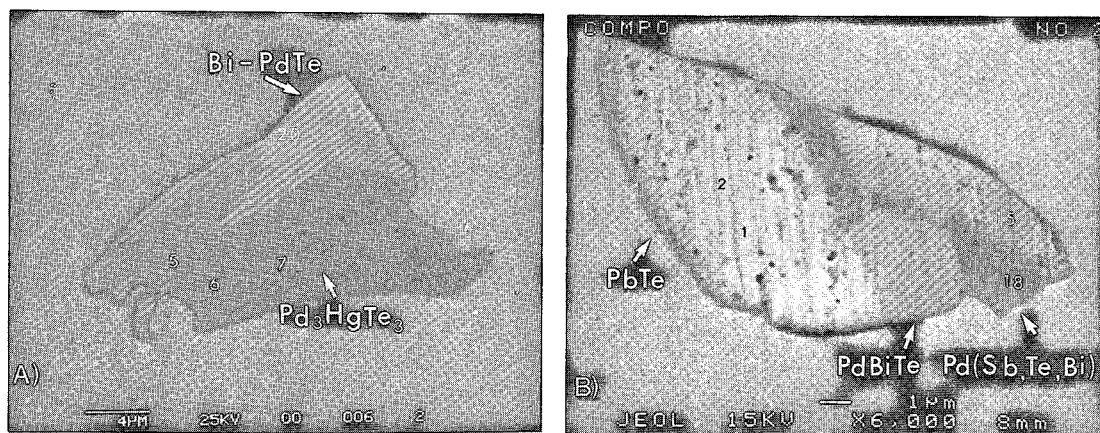


FIG. 4. A. Back-scattered electron image of temagamite (black) overgrown by bismuthian kotulskite (white). Numbers refer to some of the analyses in Tables 2 and 3. B. Back-scattered electron image of the complex inclusion, consisting of altaite (white) replaced by michenerite (light grey), both cross-cut by *PGM-1* (dark grey). Numbers refer to some of the analyses reported in Tables 4 to 6.

TABLE 1. CHEMICAL COMPOSITION OF SUDBURYITE

Grain	I ¹	II	III	1a ²	1b	1c	1d	1e	2a	2b	2c	2e	Mean
n	2	1	2	7	2	7	1	1	3	7	1	2	
Pd	39.30	42.94	43.26	41.03	41.67	40.67	41.63	39.38	40.83	41.89	40.34	40.56	41.17
Pt	—	—	—	0.31	0.24	0.98	0.16	0.27	0.41	0.43	n.d.	0.63	0.51
Ir	—	—	—	0.56	0.11	0.35	n.d.	0.12	0.23	0.47	0.51	0.65	0.42
Ni	6.39	5.39	5.33	2.69	2.61	2.74	2.39	2.65	2.62	2.14	2.99	2.48	3.00
Fe	—	—	—	0.35	0.08	0.55	1.62	1.20	0.61	0.72	0.57	0.14	0.55
Cu	—	—	—	0.11	0.17	0.17	0.67	0.89	0.20	0.18	n.d.	0.09	0.20
Hg	1.23	1.77	1.94	n.d.	0.10	0.11	n.d.	n.d.	0.31	n.d.	0.31	1.28	0.50
Sb	46.24	50.37	50.28	54.06	52.83	53.24	52.97	54.16	52.74	53.57	53.51	52.27	52.74
Bi	3.17	1.17	1.03	0.75	1.56	0.91	0.76	0.35	1.01	0.89	1.01	1.17	1.06
Te	3.17	n.d.	n.d.	0.04	0.14	n.d.	n.d.	n.d.	0.92	0.04	1.18	1.31	0.51
As	—	—	—	0.33	0.42	0.14	0.21	n.d.	0.55	0.13	0.25	n.d.	0.24
Total	99.50	101.64	101.84	100.23	99.93	99.86	100.63	99.58	100.43	100.46	100.67	100.58	

¹ Roman numerals stand for analyses obtained with the McGill microprobe. ² Arabic numerals stand for analyses obtained with the CNRS microprobe. n: number of analyses per grain; n.d.: not detected. At McGill, the analyses were performed at an acceleration voltage of 25 kV and a beam intensity of 30 nA for periods of 30 seconds. The following detection limits (wt.%) were computed according to Ziebold (1967) from repeated measurements of the standards over the period of analyses: Pd, 0.04; Ni, 0.03; Hg, 0.08; Sb, 0.04; Te, 0.03; Bi, 0.06. Analytical techniques used at CNRS are reported in Ohnenstetter et al. (1986). Fe, Cu, S, and possibly As are probably due to fluorescence from matrix sulfides. Precision and accuracy of trace concentrations of Pt and Ir are unknown, and the values reported should be taken as estimates only. Concentrations are expressed in wt.%.

as anhedral grains (up to 0.04 mm) that mold prismatic amphibole grains and chlorite mats, enclosed within disseminated chalcopyrite (Fig. 3F).

MINERALOGY AND CHEMICAL COMPOSITION

Sudburyite

Sudburyite PdSb occurs as anhedral grains (25–100 μ m) that may contain inclusions of prismatic amphi-

bole. Sudburyite is whitish cream in air, with weak but distinct anisotropism in brownish grey to dark greenish to bluish grey tints; no reflection pleochroism was observed. The sudburyite (Table 1) is comparable chemically to other occurrences elsewhere. Major-element concentrations of Pd and Sb are within the range of values reported by Cabri & Laflamme (1974, 1981). The average Ni content is lower than the average sudburyite from Sudbury, but within the range of variation reported by Cabri &

TABLE 2. CHEMICAL COMPOSITION OF TEMAGAMITE

Analysis	I	II	IV	1	4	5	6	7	13	16	32	36	Mean
Pd wt. %	33.93	33.77	34.02	33.93	33.28	33.03	33.92	33.19	32.75	32.94	32.42	33.32	33.38
Ni	1.77	1.96	1.89	1.77	0.94	0.96	0.76	0.82	0.90	0.86	0.89	0.82	1.20
Hg	21.51	21.51	21.14	21.51	20.13	20.95	19.40	18.50	20.51	21.18	20.56	21.29	20.68
Te	41.80	41.80	41.73	41.80	42.89	42.55	41.49	41.45	42.81	43.36	43.47	42.68	42.32
Sb	0.39	0.30	0.28	0.39	0.23	0.15	0.45	0.40	0.34	0.13	0.32	0.22	0.30
Bi	0.68	0.63	0.61	0.68	0.98	0.66	3.59	4.83	0.71	0.58	0.34	0.25	1.21
Pt	—	—	—	0.06	0.39	0.37	0.12	0.35	0.38	0.11	0.07	0.30	0.24
Ir	—	—	—	n.d.	0.23	0.07	0.25	0.29	0.32	0.13	0.15	n.d.	0.21
Cu	—	—	n.d.	0.39	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	0.34	0.21	—
Fe	—	—	—	n.d.	1.08	1.20	0.40	0.86	1.47	1.01	1.19	1.08	1.04
Total	100.08	99.97	99.67	100.13	100.54	99.93	100.37	100.69	100.18	100.40	100.43	100.39	—

See Table 1 for analytical conditions and comments.

Laflamme (1981). Values for Bi, Hg and Te are variable. The Bi concentration is higher than the Sudbury average (1.06 versus 0.77 wt. %); Hg and Te concentrations were not reported by Cabri & Laflamme (1981).

Temagamite

Temagamite Pd_3HgTe_3 , of medium grey color in air, occurs next to pyrrhotite and bismuthian kotulskite. Neither reflection pleochroism nor

anisotropism is observed, but Cabri (1981a) reported weak anisotropism in air. Temagamite has a homogeneous chemical composition (Table 2), with major elements Pd and Hg at the lower limit, and Bi and Sb at the upper limit of the range of compositions reported by Cabri & Laflamme (1981), whereas Bi and Sb are more abundant. Ni was not reported by Cabri & Laflamme (1981), but our analyses indicate that Ni can be a minor constituent of temagamite.

Kotulskite

At Blue Lake, kotulskite $\text{Pd}(\text{Te}, \text{Bi})$ is bright creamy white in air next to temagamite and pyrrhotite. Variable reflection pleochroism and anisotropism were reported for kotulskite by Cabri (1981a), but neither was recognized in this specimen. The kotulskite has a chemical composition at the bismuth-rich end of the range of compositions reported by Cabri & Laflamme (1981) and relative to the composition of Retty Lake kotulskite (Table 3). Pt and Ni are at low levels, similar to other occurrences elsewhere. Sb, however, is more abundant than in most localities where it has been measured, with the exception of the New Rambler deposit, Wyoming (Cabri & Laflamme 1981).

Michenerite and PGM-1

The complex telluride inclusion in pyrrhotite (Figs. 3B, 4B) consists of pale bluish grey altaite (Table 4), pinkish michenerite and creamy to yellow PGM-1; all three are neither pleochroic nor anisotropic in air. Back-scattered electron imagery suggests that altaite is replaced by michenerite, and both are cross-cut by PGM-1. The crystallization of altaite (924°C, Cabri & Laflamme 1976) and its replacement by michenerite (490–500°C, Cabri & Laflamme 1976) indicate that the system evolves from Te to TeBi and later to Sb (PGM-1) with decreasing temperature.

TABLE 3. CHEMICAL COMPOSITION OF KOTULSKITE

	Retty Lake				Blue Lake			
	53	55	57	Mean	I	18	20	Mean
Pd ^a	40.65	41.01	39.46	40.37	37.31	36.32	32.17	35.27
Pt	0.33	0.49	0.46	0.43	—	1.07	0.49	0.78
Ir	0.18	0.58	n.d.	0.38	—	n.d.	n.d.	—
Ni	n.d.	0.09	0.07	0.08	0.17	n.d.	n.d.	—
Hg	n.d.	n.d.	—	—	1.59	n.d.	n.d.	—
Te	44.36	44.46	43.52	44.11	26.07	24.67	21.42	24.05
Bi	10.19	9.56	9.46	9.74	31.05	31.64	27.87	30.19
Sb	2.55	2.62	2.42	2.53	2.58	2.08	1.76	2.14
Fe	2.33	2.00	3.45	2.59	—	3.49	9.64	6.57
S	0.22	0.16	1.79	0.72	—	1.63	6.55	4.09
Total	100.81	100.98	100.64	100.84	98.79	100.90	99.91	—

See Table 1 for analytical conditions and comments.
Concentrations expressed in wt. %.

TABLE 4. CHEMICAL COMPOSITION OF ALTAITE

	1	2	3	8	Mean
Pd wt. %	0.06	0.08	0.23	0.09	0.12
Pt	n.d.	0.66	0.38	0.16	0.40
Bi	n.d.	n.d.	0.39	n.d.	—
Te	36.31	36.37	35.60	36.21	36.12
Sb	0.25	0.36	0.37	0.57	0.39
Pb	60.57	59.93	60.51	61.47	60.62
S	0.84	1.01	0.94	0.39	0.80
Total	98.02	98.41	98.42	98.89	—

See Table 1 for analytical conditions.

The unnamed *PGM*-1 has a chemical composition similar to an unnamed mineral (UN1976-4) described and analyzed by Cabri *et al.* (1973), Cabri & Laflamme (1976), and Cabri (1981b) (Table 5). As is the case with UN1976-4 from the Vermillion and Creighton deposits, Sudbury area, *PGM*-1 is associated with michenerite (Cabri & Laflamme 1976). The chemical composition of michenerite (Table 6) is similar to that of other occurrences, except for Bi, which is at the lower limit of the range of compositions reported.

SOLID SOLUTION IN THE SYSTEM Pd-Te-Bi-Sb SYSTEM

The extent of solid solution and the end members in the system Pd-Te-Bi-Sb are still poorly known. The average chemical composition of the Blue Lake *PGMs* is shown in Figure 5 in relation to the field of variation of known minerals in the system Pd-Te-Bi-Sb. A complete solid-solution between sobolevskite and kotulskite is indicated by the wide variation in Bi content of kotulskite, coupled with the occurrence of a series of unnamed minerals along the kotulskite-sobolevskite join. A kotulskite-sobolevskite join is favored relative to a polarite-kotulskite join with an immiscibility gap close to the polarite pole, as suggested earlier by Cabri & Laflamme (1976). Polarite is orthorhombic and reported to contain between 20 to 40 wt.% Pb (Cabri 1981a, Cabri & Laflamme 1981). Both sobolevskite and kotulskite are hexagonal (Cabri 1981a), and preliminary data indicate hexagonal symmetry with similar cell-parameters to those of sobolevskite for UN1973-18 (Cabri 1981b).

The chemical compositions of a series of unnamed *PGMs*, including *PGM*-1, fall in the space above the sudburyite-sobolevskite-kotulskite plane in the system Pd-Te-Bi-Sb (Fig. 5). These unnamed *PGMs* display considerable scatter in a projection onto the sudburyite-sobolevskite-kotulskite plane. Present data preclude identification of fields of solid solution or immiscibility and the end members.

DISCUSSION

Although the mineral suite reported here is preliminary and probably not exhaustive, it points to a Pd-dominated mineralogy of the *PGM* at Blue Lake. An important feature of the distribution of *PGM* is their scarcity in carefully investigated massive sulfides and, on the other hand, their relatively high abundance in the contact zones of the massive sulfides and their adjacent chloritized rock. The abundance of *PGM* at the border of the massive sulfides and in adjacent chloritized rock is corroborated

TABLE 5. CHEMICAL COMPOSITION OF *PGM*-1 AND UN1976-4

	5	6	18	21	22	Mean	UN1976-4 ¹		
Pd*	36.10	35.11	32.69	34.22	35.27	34.68	42.3	40.3	37.4
Pt	0.46	0.19	0.25	0.71	0.64	0.45	-	-	-
Ir	0.20	n.d.	0.22	0.43	n.d.	0.28	-	-	-
Fe	3.32	4.87	6.36	4.01	3.01	4.31	-	-	-
Ni	3.27	3.01	2.68	2.50	2.53	2.80	-	-	-
Pb	1.78	1.14	0.60	0.90	2.15	1.30	-	-	-
Sn	2.00	1.93	1.83	1.86	2.04	1.92	-	-	-
Hg	0.17	0.19	0.11	0.10	n.d.	0.14	-	-	-
Bi	11.89	12.09	13.96	14.39	15.43	13.55	17.8	32.3	45.9
Te	15.40	15.52	17.23	16.96	16.77	16.38	18.8	11.1	10.4
Sb	24.51	23.71	20.12	21.99	21.00	22.27	22.0	16.2	6.1
As	0.75	1.79	0.79	0.99	n.d.	1.08	-	-	-
S	0.52	1.40	2.30	0.98	0.32	1.10	-	-	-
Total	100.37	100.93	99.12	100.14	99.15		100.9	99.9	99.8

¹ Cabri (1981b). See Table 1 for analytical conditions and comments. Pb values are probably due to fluorescence from nearby altaite. Concentrations are expressed in wt.%.

TABLE 6. CHEMICAL COMPOSITION OF MICHENERITE

	4	14	15	31	Mean
Pd*	23.61	21.73	20.65	24.05	22.51
Pt	1.65	1.03	0.80	0.85	1.08
Ni	n.d.	0.35	0.51	0.11	0.32
Cu	n.d.	0.21	0.30	0.32	0.28
Pb	0.14	6.08	9.46	n.d.	-
Sn	n.d.	0.26	0.21	n.d.	0.24
Bi	41.13	35.03	31.23	39.95	36.84
Te	31.83	31.26	31.77	32.55	31.85
Sb	1.50	3.37	3.91	1.86	2.66
S	0.47	0.38	0.59	n.d.	0.48
Total	100.33	99.70	99.46	99.72	

See Table 1 for analytical conditions and comments. Erratic high Pb values probably caused by fluorescence from nearby altaite. Concentrations are expressed in wt.%.

by whole-rock assays that reveal a characteristic enrichment in Pd at the base or top of the lenses of massive sulfides (Fig. 6) (Beaudoin & Laurent 1989).

The textural relationship of sudburyite to the metamorphic and hydrothermal minerals in the margins of massive sulfides and in adjacent chloritized rock (Figs. 3D, E, F) indicates that sudburyite post-dates the dynamothermal event that overprinted the massive sulfides. Temporal relations are documented by the development of a tectonic foliation in the massive sulfides, shearing at the contacts of the massive sulfide lenses, and precipitation of amphibole and chlorite replacing the host rock. Concentration of Pd at the margins of massive sulfide lenses and within the chloritized wall-rocks most likely resulted from the remobilization, by hydrothermal solutions, of Pd originally contained in the primary massive sulfides. This event also induced remobilization of Cu and the concentration of massive chalcopyrite at the margins of the massive sulfide lenses. These margins, which were strongly sheared owing to competency contrasts between massive sulfides and enclosing peridotite, served as channelways for hydrothermal fluids

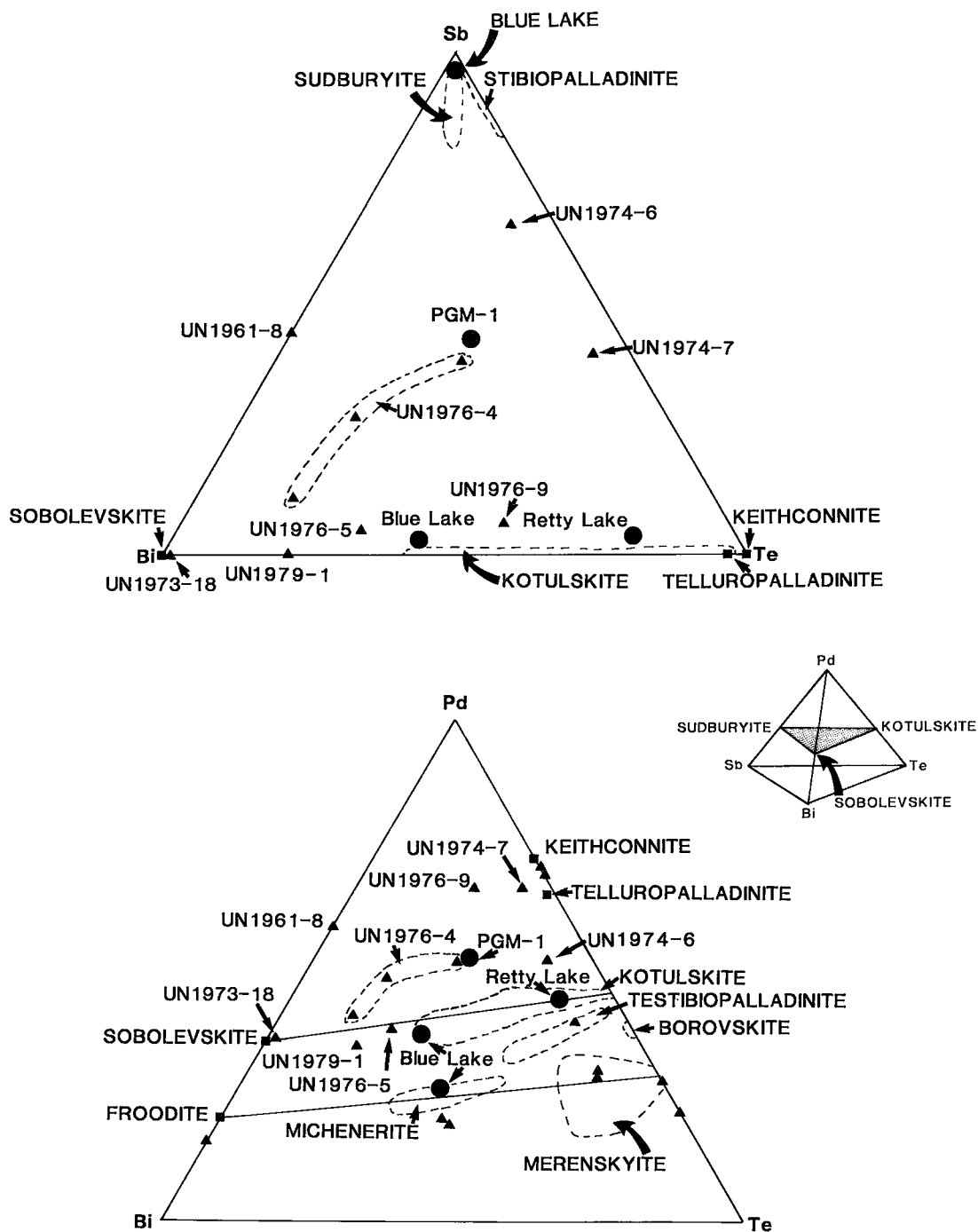


FIG. 5. Chemical composition of *PGMs* in the system Pd-Te-Bi-Sb. Average composition of *PGM* from this study represented by large dots. Minerals with little compositional variation are represented by squares, whereas the field of variation of the others is outlined with a broken line (Cabri & Laflamme 1981). Average composition of unnamed minerals is represented by triangles (Cabri 1981b); only those above the sudburyite – sobolevskite – kotulskite plane are identified and discussed in the text. Unnamed minerals plotting at the Bi or Te poles are not shown for the sake of clarity.

precipitating disseminated sudburyite and chalcopyrite. The occurrence of sudburyite at sulfide-silicate grain boundaries in dynamically metamorphosed rocks at the Donaldson West deposit, Cape Smith fold belt, also has been interpreted to indicate direct precipitation from hydrothermal fluids (Dillon-Leitch *et al.* 1986). The association of sudburyite and kotulskite with hessite or galena suggests a rather low temperature for the hydrothermal fluids.

We propose that the hydrothermal fluids responsible for the secondary Cu-Pd enrichment were generated during a major dynamothermal event because the mineralization is clearly associated with deformation. Furthermore, no other distinct hydrothermal overprint has been documented. The Hudsonian Orogeny (1.8 Ga) is the major dynamothermal episode known in this area of the

Labrador Trough. Our present hypothesis, which needs to be tested further, implies that *PGE* concentration and *PGM* precipitation are secondary and tectonically controlled, resulting from the remobilization of primary massive sulfides of magmatic origin.

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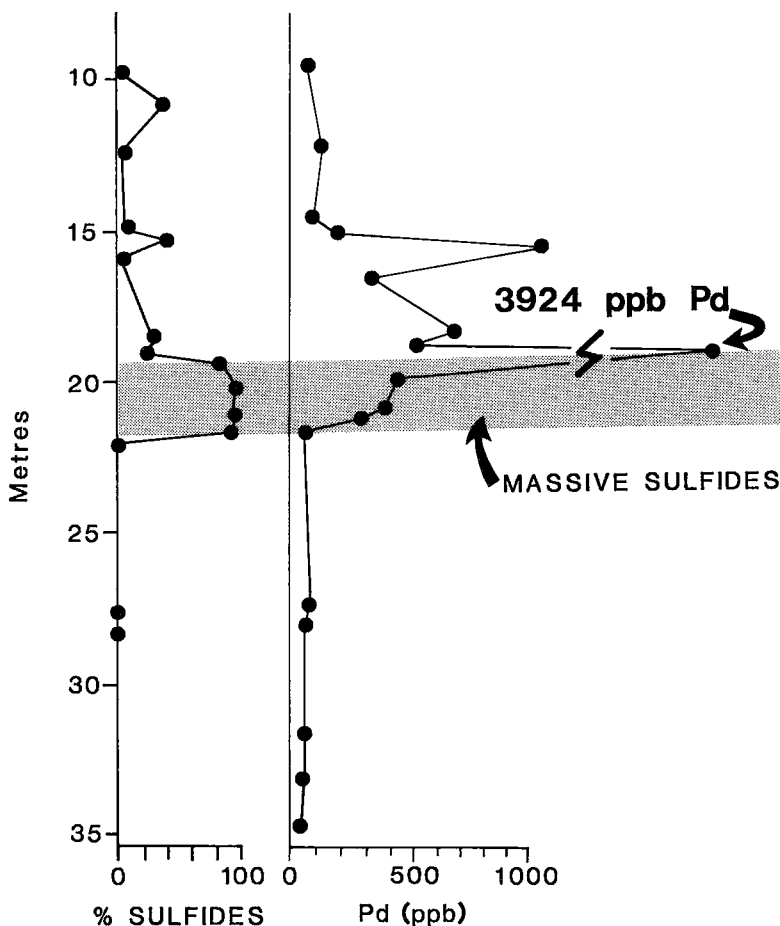


FIG. 6. Profile of Pd and sulfide abundances in the middle sill, Center zone. The most prominent Pd enrichment occurs at the top of the massive sulfide lens in this drill hole, whereas in others it occurs either at both, or at the top or bottom of the massive sulfide lenses (data from Beaudoin & Laurent 1989).

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